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COMMUNITY SOLAR ENERGY PROGRAMS: A BRIGHT SPOT FOR JUST ENERGY POLICY?

By

Emily W. Prehoda

A DISSERTATION

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DOCTOR OF PHILOSOPHY

In Environmental and Energy Policy

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This dissertation has been approved in partial fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY in Environmental and Energy Policy.

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Preface

The research included in this dissertation was conducted under the supervision of Dr. Chelsea Schelly and Dr. Richelle Winkler in the Environmental and Energy Policy Program, Department of Social Sciences, Michigan Technological University, between January 2016-April 2019. The work in this dissertation is the product of collaborative research.

The Michigan Department of Agriculture and Rural Development (MDARD), the American Public Power Association's (APPA) Demonstration of Energy & Efficiency Developments (DEED) program, and the Department of Energy Solar in Your Community Challenge Technical Assistance Grant funded the research conducted in this dissertation. The Upper Peninsula Solar Technical Assistance and Research Team (UPSTART) formed in March 2017 in response to the Solar in Your Community Challenge. I joined this team as one of several Michigan Technological University researchers. UPSTART wanted to bridge together knowledge, resources, and skills to help design and develop a community solar program in the Villages of L'Anse and Baraga. The team began as a partnership between both village administrators, WPPI Energy, and the Western Upper Peninsula Planning and Development Region (WUPPDR). The project evolved and expanded UPSTART membership and resources to include marketing and contract development with Michigan Energy Options, energy efficiency studies with LOTUS Sustainability & Engineering, the University of Michigan Dow Sustainability Fellows Program, and media development with a team of Michigan Tech students learning documentary production (CinOptics). My role was to help development and coordinate the social feasibility study conducted in each village. I collected and analyzed data from key stakeholder interviews, focus group discussions, and survey instruments. Each chapter in this dissertation has multiple co-authors; their contributions are described below.

Chapter 2: Research for this manuscript was collected from Michigan energy laws and policies, utility case filings, and personal communications. As lead author, I was responsible for conducting all research and preparing the manuscript with oversight from my co-authors; one co-author is also a part of the APPA DEED team. Both co-authors were involved in idea-sharing and editing the manuscript for final submission. This chapter is published in the *Energies Special Issue: Energy Policy*.

Chapter 3: This chapter describes the social and technical feasibility methodology that was conducted by the Upper Peninsula Solar Technical Assistance and Resource Team (UPSTART) from 2017-2018. I participated in collecting interview and focus group data collection, survey design, and analysis of the data. I am the lead author and responsible for preparing this manuscript with oversight and guidance from the co-authors and UPSTART members. Both co-authors helped develop the structure and content for this chapter, along with editing for the manuscript for final submission. This paper is published in a *Social Sciences Special Issue: Engaged Scholarship for Resilient Communities.*

Chapter 4: This chapter uses qualitative and quantitative data from interviews, focus group discussions, and community surveys conducted in 2017-2018. With guidance from UPSTART, I created interview and focus group protocols. I helped create the survey instrument used. I was responsible for collecting data in the field, transcribing, coding, and analyzing qualitative and quantitative data. As lead author on this manuscript, I identified the themes within the paper and prepared the manuscript with guidance from my advisor and other committee members. This paper will be submitted to the journal *Renewable Energy Focus*. Expected date of submission is May 2019.

Appendix A and Appendix B includes two of my co-authored works that are relevant to the research background and findings for this project. The first paper is published in *AIMS Energy*. The second paper is guidebook completed for the APPA DEED project.

Emily Prehoda, April 2019

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I want to thank my family for their presence throughout this journey. Their continued love and support were constant reminders to keep moving forward to achieve my goals. I especially want to thank my mother, Maggie Wilkins. Your hard work and tenacious, fiery spirit serve as the model I turn to in all aspects of my life. Finally, thank you Dean Johnson for your unwavering love and encouragement while I completed my dissertation.

Abstract

Energy systems are complex, and this complexity requires diverse regulatory forms and strategies of management. Michigan's energy system is situated within a multi-scalar governance structure reaching from national to local levels. As a result, the process of energy system decision-making can leave out smaller, remote communities and those without the economic, political, and knowledge capital necessary to engage in complex bureaucratic processes. These communities can become subject to high electricity prices and unreliable electrical service from long transmission and distribution lines, raising energy justice concerns. Additionally, resulting from utility regulatory practices, small remote communities are often not afforded the opportunity to explore alternative, local, and environmentally friendly energy generation sources. This dissertation utilizes data collected from two case study sites in Michigan to examine how decisions are made regarding energy system management, who participates in what forms of decision-making, what implications community solar can have for improving energy justice, and the role of energy policy. Specifically, the research attempts to examine how community solar may create more just energy systems and the particular policy and governance dimensions that shape the use of community solar for the pursuit of energy justice. Chapter 2 explores how Michigan investor-owned utilities interpret and implement energy laws to hinder distributed generation proliferation in Michigan. Chapter 3 reflects on the community engaged research process used to determine the viability of a community solar program. It argues for incorporating collaborative governance principles to further improve the community engaged research process to help insert local control and affordability into energy systems. Finally, chapter 4 utilizes and analyzes interview, focus group discussion, and survey data to understand from a community perspective what factors are important for community solar viability. It situates this data within the community social context as it recognizes that perceptions alone do not explain program viability. Energy justice does not apply to just one level of policy making. The subsequent implementation and decision-making process of these existing policies can be determined through collaborative governance strategies, such as community solar, that align with energy justice values.

1 Introduction

This dissertation includes chapters that explore aspects of community solar and its impacts on energy policy and energy justice. I seek to understand the opportunities and challenges of community solar for contributing to a more just energy system in the state of Michigan. This theme is based on previous work demonstrating that the level at which energy decisions are made (i.e. size and type) matters for distributing benefits and burdens to society, determining who participates in decision-making, and determining affordability and accessibility of energy systems (Banerjee et al. 2017). On the surface, community solar may present a solution or alternative to improving social injustices associated with the current U.S. energy system; however, its successful implementation is dependent on structural, contextual, and community factors.

Injustices within the U.S. energy system can include different populations' experiences with decreased access to affordable, clean, reliable, and safe energy technologies and decision-making surrounding these energy technologies (Lovins 1976). Many energy decisions rest in the hands of government and corporate decision-makers, including electric utilities. The electric utility model centers on recouping investment from large scale, centralized systems or plants that the utility can build, own, and operate.(Tomain and Cudahy 2011). While some residential consumers can own and operate their solar PV systems, many either cannot afford the upfront cost of these systems or do not have the physical household characteristics to accommodate these systems. Community solar programs provide a solution that involves both utility interconnection and residential system ownership or leasing. Community solar is a relatively new solar PV application that includes different program definitions and designs (SEPA, 2018). While some of the chapters below will describe these different programs, this dissertation employs the following community solar description: a voluntary program where community subscribers pay for a portion of a locally-sited solar photovoltaic (PV) array and receive credit on their electricity bill proportional to the power produced (SEPA, 2018, Wanderscheid et al 2013).

1.1 An overview of energy governance in the United States

A complex network of centralized power plants and vast transmission and distribution infrastructure comprises the current U.S. electrical system. Regulatory bodies govern this network at the national, regional, and state levels. The Federal Energy Regulatory Commission (FERC) regulates the interstate transmission of electricity, natural gas, and oil at the national level (FERC, 2018)). Specifically, FERC regulates rates and services for interstate electric transmission and electric wholesale power sales by public utilities, transmission companies, and independent power producers. In efforts to increase competition in the wholesale electric marketplace and provide better management of multiple independent power supply companies, FERC issued two Orders (888 and 889)[1]

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[1] Orders and Public Acts can be found at ferc.gov and legislature.mi.gov, respectively

to introduce Regional Transmission Authorities (RTO) and Independent System Operators (ISO). These regional authorities are responsible for controlling, coordinating, and monitoring operations across multiple states or within a single state. A key task of RTOs and ISOs is to operate wholesale electricity markets allowing participant utilities to buy and sell power. Ideally, this system allows for reliable long- and short-term electricity supply for participants and their consumers at the lowest possible cost. However, electricity in remote communities is more costly as there are fewer consumers to share the costs of long transmission and distribution lines necessary to provide access to these areas (Davis and Caldeira, 2010, Day et al, 2016, Cust et al, 2007). A majority of Michigan's electricity market is currently under the purview of the Midwest Independent System Operator (MISO), (FERC, 2017), with a small portion of Southwest Michigan participating in the Pennsylvania, Jersey, Maryland Power Pool (PJM) (PJM, 2018).

There are three utility types in Michigan: (1) investor-owned, (2) electric cooperatives, and (3) municipal utilities. The Michigan Public Service Commission (MPSC) regulates electric utility interconnection as well as all investor-owned utilities. The 2008 energy law package allowed a pathway for Michigan's electric cooperatives to become member-regulated. Currently, Michigan electric cooperatives (P.A. 167, 2008) and municipal utilities regulate their electric rates. Investor-owned utilities (IOU) in the U.S. operate as a natural monopoly. In the early days of electricity, multiple companies would build multiple sets of power lines in the same cities attempting to capture electricity consumer business. The regulatory compact was created to reduce this mass waste of resources. Under the regulatory compact provides IOU's exclusive service territories, and in exchange, state public service/utility commissions regulate electricity rates for consumers at fair and reasonable rates (Tomain and Cudahy, 2011). Regulators require utilities to satisfy performance standards for customers at the lowest feasible cost, to explore and use all cost saving opportunities, and function to the benefit of the consumer rather than internal business objectives. In return, regulators must establish a rate of return that is consistent with the utility's performance.

Ratemaking is a significant portion of the regulatory compact and is inherently political as it is concerned with a valuing a product that is deemed a social necessity (Tomain and Cudahy, 2011). The formula used to determine customer's electricity rates in Michigan is (MPSC, 2014):

$$RR = r(RB) + E + D + T - \text{Other revenue}$$

RR, the utility revenue requirement, is defined as the appropriate revenue provided to a utility to ensure service to customers and a fair return for utility shareholders. "r" is the overall rate of return provided to the utility. The MPSC determines the utility's "r" or return on equity through a series of financial analyses that compares attributes from a group of utilities nationwide that are similar to the utility in question. Attributes such as generation capacity, equipment values and property plans, credit ratings, among others are factored into different financial analyses (Eubanks, 2018). These include discounted cash flow, capital asset pricing, or risk premium (Eubanks, 2018). The MPSC then develops a range of return on equity figures to choose from. The decision for selecting an appropriate return on equity attempts to balance a fair and reasonable rate for both ratepayers and utility shareholders. Michigan's current return on equity is roughly 10% (MPSC, 2018).

Next, the rate base (RB) includes the net cost of the plant plus the working capital. The rate base is a portion of the ratemaking equation where utilities can earn a profit from their investment in energy infrastructure. E, D, and T represent the utility's operating expenses, depreciation and amortization, and taxes, respectively. In Michigan, IOU's submit a rate case to the MPSC that includes requests for cost recovery of assets to be included in the rate base; more often than not, the MPSC has agreed to provide an increase in IOU electricity rates (MPSC, 2018). While ratemaking can function to serve as a balance between the public's interest, electricity consumers, the IOU's, and their shareholders, regulatory ratemaking goals conflict which can result in increased rates that negatively impact consumers. Exploring alternative utility models, such as municipal utilities, can function to circumvent hurdles to renewable DG generated by IOUs.

A state grants power to municipal governments to develop and implement policies, laws, regulations, incentives and other programs to provide benefits from public services to its citizens. This level of control applies to energy governance as some municipalities own and operate their electric utility infrastructure. Municipal electric utilities allow municipalities to generate a large portion of income for use in local government matters, such as creating renewable energy initiatives, goals, or targets (Homsy and Warner, 2012, Lubell et la, 2009). Municipal governments that more sensitive and responsive to community needs (Homsy, 2015) and are simultaneously in control of the local electric grid can look to shift energy governance at the local level and beyond to benefit their communities.

While state and local governments regulated most of the generation, transmission, distribution, and sales of electricity in the early 1900's (Yergin, 2011), their attempts to regulate interstate electricity sales in the 1920's resulted in the creation of the Federal Power Act (Tomain and Cudahy, 2011). The Federal Power Act serves to clearly define and preserve the division of authority between federal and state regulation of public utilities (U.S. Congress, 1920). However, as the U.S. looks to more renewable powered distributed generation sources, this defined line between federal and state regulatory authority becomes hazy. Three constitutional provisions exist to give energy regulatory authority over to the federal government to either facilitate or limit regulatory power. The first is the Commerce Clause which gives Congress authority to use a federal agency, FERC for example, to regulate interstate commerce (U.S. Constitution, Article I, Section 8, Clause 3). The Supremacy Clause speaks to the inability of a state to pass a law that conflicts with federal law, an act of Congress, or more broadly the U.S. Constitution (U.S. Constitution, Article VI, Clause 2). The Supremacy Clause binds all judges, including at the state level, to adhere to constitutional principles over state law. The Takings Clause applies to actions by both the federal (U.S. Constitution, Fifth Amendment) and state governments (U.S. Constitution, Fourteenth Amendment).

Governments that wish to acquire private property, for both direct or indirect public use, can do so but with just compensation provided to the property owner.

These jurisdictional boundaries are important for renewable energy development, but more broadly energy policy in that regulations cannot be enforced without first adhering to the Commerce, Supremacy, or Takings Clauses. As technology changes, these jurisdictional boundaries become blurry (Dennis et al, 2016). The Commerce Clause can be significant to federal regulation of renewable energy sources anytime they negatively impact interstate commerce. Most state energy laws or policy that look to benefit in-state economies at the burden of out-of-state economic competitors will result in a limitation of state regulatory authority by the federal government, or specifically Congress. The Supremacy Clause serves as a reminder that any state law that conflicts with federal law becomes subordinate to federal law. An example can be found with growing state deregulation of energy. As more states look to separate energy supply and delivery, competition emerges for different energy types from different energy suppliers across state boundaries. Federal jurisdiction and regulation over transmission across state lines may become more prominent and could impact the role of renewable powered distributed regulation. The Takings Clause is an important weapon in a utility's arsenal, particularly when used as an argument for obtaining a fair return on investment for its assets. With the existing utility rate structure, utilities can place cost recovery into customers electricity rates. Utilities can cite the Takings Clause and engage state or federal regulators to address an impediment to the utility's right to obtain a fair return on investment; such as distributed renewable generation.

In 2008, Michigan enacted Public Act 295, also known as Michigan's Renewable Energy Standard. P.A. 295 is a renewable portfolio standard (RPS) that required utilities to obtain 10% of energy generation from renewables by 2015 (recently increased to 15% by 2021). Under P.A. 295, Michigan's municipal utilities must file a renewable energy plan with the MPSC. The RPS was amended in December 2016 by Public Acts 341 and 342. The amendment includes requiring the MPSC to create a distributed generation program to replace net metering. Utilities must create and submit an integrated resource plan (IRP) - a utility roadmap to providing least cost service - to the MPSC.[2] Michigan is also considered a restructured state that allows for 100% electric choice. This concept of 100% electric choice in Michigan is misleading, though, as only 10% of a utility's generation load can engage in electric choice (P.A. 286). Michigan's regulatory climate supports the adoption of renewable energy technologies through its Renewable Energy Standard. However, in terms of net metering and its upcoming replacement, the distributed generation tariff, utilities can cap distributed generation adoption to 1% of the utility's peak load, ultimately excluding customers from participating after meeting the legislative minimum.

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[2] Other brief amendment descriptions can be found at https://www.michigan.gov/mpsc/0,4639,7-159-80741---,00.html

As Michigan is currently in the final stages of implementing P.A. 341 and 342, the community solar research in this dissertation can be used to help inform policymaking at the state level and implementation of these policies at other, local levels. Michigan's energy structure is situated within a multi-scalar governance structure. As a result, the process of energy system decision-making can leave out smaller, remote communities. These communities can be subject to high electricity prices and unreliable electrical service from long transmission and distribution lines, raising energy injustice concerns (Chaurey et al, 2004, Sovacool et al, 2013). Additionally, resulting from utility practices, smaller remote communities are often not allowed to explore alternative, local, and environmentally friendly energy generation sources without utility approval or participation. Community solar is one form of an alternative energy system that has a just nature as it attempts to increase affordability, reliability, and environmental quality with more distributed ownership. Community solar arrays are smaller in scale and more localized. The design of a community solar array can closely align with energy justice forms. Locally owned and operated systems allow costs and benefits to be absorbed by participants rather than placing undue cost burdens on non-participants; additionally, as community solar is a renewable technology, it does not negatively impact environmental quality experienced by non-participants. Community solar program ownership is typically voluntary, allowing community members power over the decision to participate, contribute, or be impacted by the energy system. These characteristics contribute to the equitable allocation of benefits and burdens found in distributive energy justice and fair process and participation found in procedural energy justice.

Federal energy laws currently lack coherent, enabling policies to support community solar. California, Colorado, Connecticut, Illinois, Maryland, Massachusetts, Minnesota, Oregon, Rhode Island, and Washington, D.C. represent a handful of states with community solar enabling policies (NREL, 2018). While Michigan is one state without a community solar enabling policy, the MPSC is currently conducting stakeholder workgroups to develop such a policy. This lack of institutional and policy support leaves decision making regarding community solar program design and development at the discretion of utilities. Continuing to support utility level decision-making reinforces a system of inequitable wealth generation and distribution that locks out community level participation and benefit sharing from energy systems.

1.2 Exploring community solar to reconcile decision making scales

At the close of the 19th century, Samuel Insull developed tiered demand metering into the electrical utility model to lower prices and sell electricity to as many people as possible, to democratize electricity access (Yergin, 2011).

In the current system, most people have very little influence on the technical experts who control production (Lovins 1976; Winner 1980). The development of the U.S. electrical grid involved processes rooted in political and economic power (Winner, 1980). Individuals with less wealth and access to information have little power in energy system decision-making (Downey 2015; Lerch 2017). Development of renewable energy technologies at the utility scale allows those with political and economic power to continue influencing decision-making at the state level to benefit and further their agenda, while perpetuating injustices at the smaller, local levels. This idea reiterates the main theme of this dissertation: the level at which energy decisions (i.e. size and type) are made matters for distributing benefits and burdens to society, determining who participates in decision-making, and determining affordability and accessibility of energy systems (Banerjee et al. 2017). Additionally, these decisions can negatively impact the reliability and environmental quality obtained from the existing electrical systems. Taking this further, the scale at which energy possibilities are imagined matters. IOU's may support integrating renewable energy technologies but only at scales that further support existing rate structures and the utility model (Yergin 2011; Lerch 2017).

This dissertation utilizes data collected from two case study sites in Michigan to explore community solar innovation as an alternative level for energy decision making. These case studies provide context for who, what, and how energy decisions are made and what implications community solar can have for improving energy policy decision-making. The Villages of L'Anse and Baraga are rural and remote communities; a qualification that can result in the need for more infrastructure and higher costs to provide power to these communities. However, Village of Baraga and L'Anse utility customers (residents and businesses) pay lower electricity prices compared to investor-owned utilities in the region as they receive power from municipal electric grid. L'Anse and Baraga are both comprised of households (43% and 66%, respectively) that qualify as low-to-moderate income (MSHDA, 2017). These numbers are significant as LMI populations typically lack access to solar energy systems as well as community solar programs. There is relatively low solar radiation in the Upper Peninsula of Michigan compared to other U.S. states. The Villages of L'Anse and Baraga are exploring community solar projects as a potential application to increase solar PV adoption in their area. Focusing on these case studies can provide useful information regarding the lived experiences and challenges faced by communities to inform and develop future research. These cases are important because they represent two communities that encounter barriers and challenges that suggest it will be difficult to develop solar PV capacity successfully. Taking this further, decision makers may overlook developing supportive solar PV policies for communities with similar characteristics. Non-action is still a decision that can ultimately fail to serve the public interest. Learning from these cases can highlight the need for decision making beyond cost-effectiveness or economic reasoning; energy decision making can begin to lean on justification from broader social benefits communities can experience if allowed to explore community solar programs. In a broader context, exploring community solar in these two case studies seeks to provide an example to improve Michigan energy policy towards more just ideals through a collaborative governance approach.

1.3 The scholarship: energy justice, collaborative governance, how they relate, why they matter

This dissertation relies on energy justice scholarship to consider how community solar applications represent a potential opportunity to reconcile with the social injustices that result from energy policy decisions implemented at certain levels. While renewable energy technologies promise to mitigate environmental injustices experienced by the scale of the contemporary energy system (Ottinger 2013), building them into the existing utility model may further the social injustices experienced by some populations. The following paragraphs provide a brief review of procedural and distributive energy justice and scale politics to establish the theories and framework used to explore community solar application's potential to mitigate these injustices. A brief review of collaborative governance is included to describe an approach to the type of decision-making explored in this research.

1.3.1 Energy Justice

Energy justice is a field of scholarship that seeks to bridge justice theories and principles with energy systems, including policy, infrastructure, production, consumption, and other energy-related activities. As with most justice scholarship (theories and principles), energy justice is difficult to pin down to one particular definition. This proposal will lean on Sovacool and Heffron's (2016) definition: "an energy just world [i]s one that equitably shares both the benefits and burdens involved in the production and consumption of energy services, as well as one that is fair in how it treats people and communities in energy decision-making" (pg 5).

Energy systems are inescapable within society. Daily life and activities are dependent upon energy systems, from obtaining basic needs to facilitating financial transactions to powering water infrastructures. Energy justice scholarship places distributive justice theory at its focal point (Forman 2017; Fuller and McCauley 2016; Deutsch 1975; Grunewald 2017). Distributive justice, considered is one of two primary forms of energy justice, (McCauley et al. 2013) articulates how "social goods are allocated across society" (Sovacool et al 2013). This form includes a spatial and temporal component - where and who receives these goods, how goods are distributed, and through what approach are these goods distributed? Specifically, goods can be distributed based on need, entitlement, cost effectiveness, benefit of least advantaged, utility, and/or equality (Dobson, 1998). Currently, energy systems distribute electricity one centralized grid to consumer. As rural, remote populations spread farther away from generation sources, they can be subject to higher transmission and distribution costs, with decreased reliability. These various impacts speak to distributive energy justice scholarship that is concerned with the benefits and burdens of energy experienced by different social groups.

Additionally, the distribution of energy systems can impact the distribution of power in social relations (Deutsch, 1975). As energy affords opportunities for access to education, health services, and clean air and water, etc., inequitable distribution of energy can impact the ability of society to maintain and foster power in social, economic, and political relations. Equitable distribution of energy thereby has the potential to equitably distribute economic and politic power.

Procedural justice describes an adherence to due process and fair treatment of individuals and communities. It comprises the consideration of how decision makers engage with their communities (Jenkins et al. 2016). The main question here is: how are decisions made? Does the decision-making process involve full participation, allow full expression of opinions, provide sufficient and transparent information, and involve impartiality of decision-makers? In the context of energy, procedural justice considerations include governance of energy systems that is imbalanced (Goldthau and Sovacool, 2012). Due to our energy system's complexity and participation by many actors with differing resources and power, governance strategies can be biased towards certain groups. Different energy policies, laws, and regulations reflect this bias by perpetuating inequitable wealth generation and distribution for a select few, while locking out populations from participating in benefits from these systems. Procedural energy justice also points social power, like distributive energy justice. However, it explores the inequitable social power manifestations in decision making. The complexities within energy systems leaves decision-making and control of these systems to technical and economic elites. Organizations with greater power mobilize and expand their political network to garner support, demobilize antagonistic organizations, and utilize monetary and other resources to bring adherents closer and push opponents out of decision making processes (Fuller and McCauley, 2016). Typically, rural, remote, and low-to-moderate income communities have the potential to be excluded from participation and decision-making regarding energy systems. A simple example points to energy system development in communities without free and fair informed consent or community participation (Sovacool and Dworkin, 2015). Broader community involvement (Forman, 2017) and participation can alleviate some of these ills.

Each chapter provides specific case study examples that ultimately seek to shift Michigan towards more just energy policy through distributive and procedural energy justice considerations. The dissertation chapters each explores cases of community solar applications with energy justice considerations. The goal here is two-fold: (1) utilize energy justice forms to improve the just nature of community solar program design and (2) illustrate how more just community solar applications can influence more just Michigan energy policy.

1.3.2 Collaborative Governance

This dissertation is based on an approach to decision-making known as collaborative governance. Specifically, it marries energy justice forms to collaborative governance, an arguably more just form of decision-making. Energy systems are complex and may require different forms of management strategies to deal with these complexities. A relatively new governance approach, collaborative governance, attempts to include multiple stakeholders to "engage in consensus-oriented decision making" (Ansell and Gash 2008; pg 543). For this dissertation, politics of scale informs the collaborative governance decision making process. Decision makers establish policies utilizing a particular rhetoric of scale to advance agendas (Tsing 2011). The level at which energy policies are created shapes the implementation and application of the existing policies. This approach becomes problematic if policies and an exclusive decision making process produce narrow access to practices in energy systems; for example, applying existing policies in a way that decreases affordability of community solar, which by nature attempts to improve affordability for consumers.

Dietz et al (2008) argue that global and national environmental decision makers frequently ignore the advantages of tools within community-based governance, yet these tools can have a significant impact on success of mitigating negative impacts on environment and society. Collaborative governance can be an approach used to mitigate negative impacts on communities. Ansell and Gash (2008) describe six criteria that must be present in collaborative governance efforts: 1) Public agencies or institutions must be responsible for initiating decision-making, 2) the process must include non-state actors, 3) these participants are directly engaged in the process, 4) collaboration between participants occurs in a formal setting, (5) the collaboration attempts to make decisions through consensus whenever possible and 6) efforts are focused on creating public policy. Benefits of collaborative governance can include improved effectiveness of decision-making by expanding an organization's capacity and utilizing a shared network to improve the ability to solve complex problems (E. Rogers and Weber 2010).

Community solar programs can be designed to align with energy justice, yet concerns have emerged about the potential negative impacts of community solar programs developed by actors external to the community. So, while community solar programs have a just nature, they can be designed in a way that perpetuates injustices experienced by the existing energy system. As collaborative governance works to enhance decision making with regards to policy, it presents an opportunity to improve or aid the just nature of community solar programs. Collaborative governance aims to involve all potentially impacted stakeholders in decision making. It refocuses decisions regarding community solar program design around community members, emphasizing the need to include all impacted voices. Providing this sense of control aligns with energy justice considerations that point to the importance of community member control in outcomes. Collaborative governance maintains balance with the sense of local control in that it does not artificially give final decision making power to all stakeholders. While collaborative governance seeks to improve power relations between multiple levels of decision makers, it reminds the process that ultimately one or a select few have decision making power. The emphasis lies in incorporating community members concerns and viewpoints into final decision making. Collaborative governance reconciles with this and energy justice by looking to full transparency throughout the process. Effectively communicating participation roles in community solar development can mitigate misconceptions about decision making process expectations. Overall, collaborative governance can shift community solar program design and decision making efforts to better align with energy justice forms. Energy policy in Michigan can begin to transform to consider and incorporate voices from the local communities impacted by energy decision making.

This dissertation uses a collaborative governance framework to assess community solar program design processes. Specifically, it illustrates a social feasibility study that incorporates formal and non-formal actors and direct engagement with potentially impacted community members. Local level decision-makers utilize community feedback to come to a consensus regarding the community solar design and implementation. Part of the community solar design is to create a project that can be replicable and inform Michigan energy policy.

1.3.3 The link between justice and scales of collaborative governance

Energy justice can help to improve the level at which policies are formulated and adopted. Energy justice is a field that attempts to place a renewed emphasis on the human dimension of energy systems, which is often missing or marginalized in contemporary energy studies (Forman 2017). Conventional energy systems are centralized and operated by top-down authorities (Sovacool et al, 2013) that generally inequitably distributes power and marginalizes those without political power, resulting in less democratic participation. Energy justice does not discount the capability of top-down changes, but rather calls for a transformation in how planners and policymakers make decisions at all levels. For example, shifting policy goals and leadership to focus on human rights at the top can begin to transform our energy systems at the bottom. Collaborative governance strategies can support implementing bottom-up policies and practices can be at local levels, such as local energy efficiency programs, community energy projects, and volunteer or civil society efforts to increase energy education access.

Energy justice first intersects with collaborative governance strategies through the distribution of benefits, burdens, and power that can adversely impact those connected to energy systems. The current U.S. energy system operates on an imbalanced system of wealth generation that locks out different population from participating or receiving a portion of these benefits. Additionally, while distributive energy justice speaks to the allocation of benefits and burdens from energy systems across different populations, collaborative governance scholarship forwards a method to improve the impacts by energy system distribution choices. Distributive energy justice recognizes both spatial and temporal distributions of energy systems. As collaborative governance strategies can be iterative and constantly evolve throughout the process, it allows decision makers to think about and evaluate changes in energy system distributions over time. Because collaborative governance places emphasis on involving stakeholders who are impacted by energy systems, it speaks to a shift in motivations behind the distribution of energy systems. Specifically, it can work to shape energy systems that produce benefits for less advantaged populations based on need. Ultimately, collaborative governance can contribute to creating a more equitable system of wealth generation that more equitably shares benefits across all populations.

Secondly, energy justice intersects with collaborative governance through the process of decision-making and an equitable balance of who participates in decision making. Both energy justice and collaborative governance function at multiple levels of policy making, which is significant with regards to the complexities and multiple level actors of the U.S. energy system. Collaborative governance necessitates participation by affected stakeholders in decision-making. It begins with an assessment of power dynamics and imbalances that exist within a community and seeks to improve this by including stakeholder groups. This exploratory nature connects to procedural energy justice that looks to differing levels of social power and fairness in decision-making that allows full participation and expression of opinions. Both collaborative governance and energy justice forms attempt to improve the overall practice, effectiveness, and decision making with regards energy policy.

Each chapter has implications for energy justice and collaborative governance, both in scholarship and non-academic applications. The second chapter describes the nuanced in the process of rulemaking and implementation of existing Michigan energy laws and regulations by utilities that deliberately limits the equitable distribution of benefits and burdens by energy systems. Michigan utility customers located in rural regions can be subject to uneven accessibility, affordability, and reliability issues. Current decision making perpetuates wealth generation for IOUs through preventing these customers from accessing distributed generation sources, such as community solar, that could improve affordability and reliability. Additionally, while utilities sometimes offer public forums for commentary regarding new energy policy and practice development, ultimate decision making is left at either state-level (MPSC) or utility level. This is just one example of exclusionary practices in decision making that can leave out relevant or affected stakeholders (i.e. ratepayers). This chapter forwards energy justice and collaborative governance scholarship by providing an in-depth exploration into how energy actors at multiple levels navigate energy laws to maintain the status quo of power relations and inequitable distribution of energy system benefits and burdens. It provides suggestions based on energy justice and collaborative governance theories and principles for real-world policy applications to improve energy policy development that goes beyond economic motivations.

The third chapter advances a novel collaboration between community engaged research and consensus-oriented governance strategies to improve just decision making surrounding community solar program design. Michigan's lack of enabling community solar policies and programs leaves decision making to develop community solar to IOUs. In this IOU ownership model, the utility retains benefits from the community solar while the burdens from participating, such as increased energy costs, are left in the communities. This chapter forwards a research process that can be replicated by utilities and other community solar developers to help include these communities in decision making; however, this process can retain injustices experienced by communities (e.g. distribution of power to make final decisions). More broadly, this chapter describes a research methodology that can be incorporated into energy justice scholarship. In practice, energy justice considerations and collaborative governance strategies can guide community engaged research to improve how researchers work with communities to develop more just community solar programs. Ultimately, improving this research process can inform Michigan energy policy decision makers to incorporate community level participation from affected stakeholders; balancing out social power and equitably distributing benefits and burdens experienced by energy systems.

The fourth chapter builds upon Michigan's lack of community solar enabling policies and ownership models that are external to communities. It highlights a disconnect between the conceptualizations regarding viability of community solar development and the local community perspectives. Typically, energy industry decision making regarding community solar development centers around viability as a function of cost effectiveness. This conceptualization is arguably an unjust method to decide whether or not to develop community solar programs as it does not take into account the ways communities perceive multiple dimensions of program viability. This chapter advocates an unconventional approach to enhance the viability of community solar programs: to incorporate community perspectives that highlight community solar viability dimensions beyond economics. This chapter contributes to energy justice and collaborative governance scholarship by providing community level analysis and findings from a practical application of allowing full participation in a decision making process. The findings have implications for the industry to further strengthen the viability of community solar program design and development by incorporating community level perspectives. It improves the just nature of community solar program design by giving communities more equitably distributed power over program design; rather than leaving power with utilities and external third-party developers. This chapter also contributes to more just Michigan energy policy by emphasizing a need to move beyond energy decision making based upon positive economics for a select few.

Energy justice serves to guide decision-making towards a just process that examines which populations are impacted by our energy choices and understands who makes these energy choices. Additionally, the intersection of energy justice and collaborative governance's goal of consensus-oriented decision-making aligns with community needs and shifting priorities to achieve equitable allocation of energy system benefits and burdens. Collaborative governance strategies, aligned with energy justice values, can ultimately determine the subsequent implementation and actual decision-making process of these existing policies. Utilizing a collaborative governance approach with these characteristics in mind can provide a process that results in equitable and equal distribution of benefits and burdens, full participation, and transparency.

1.4 Structure of the Dissertation

The overarching goal of this dissertation is to explore community solar as an approach to creating more just energy systems and the particular policy and governance dimensions that shape the use of community solar for the pursuit of energy justice. This dissertation utilizes a case study of community solar program development that is informed by values of distributive and procedural energy justice. The research illustrates injustices resulting from decision-making regarding the application and implementation of Michigan energy policies. It then considers collaborative governance as an approach to reconcile these injustices and forwards community solar as the specific application to achieve this. Each chapter explores the potential for community solar to lead to more just energy policy in the state of Michigan.

The studies in this dissertation explore Michigan utilities operating within existing state and federal level energy regimes as well as provide case study analyses of community solar. Energy justice scholarship acknowledges that context matters (Sovacool et al, 2013). This work utilizes the case study analyses to build a better understanding of what contextual factors matter for community solar adoption and participation in aligning with principles of energy justice. This methodology used can function to improve just processes and outcomes in energy decision-making practices.

Chapter 2 provides a review of the existing policies and regulations of utilities within Michigan. This chapter considers how utilities exercise their power within and outside existing regulatory, policy, and legal regimes to hinder DG proliferation. Recent case study examples from Michigan utility strategies highlight the need to think about how utilities interpret and implement rules when designing energy legislation and policy to maximize the benefits for consumers and society. Policy recommendations and alternate strategies are provided to help enhance the role of energy policy to improve rather than limit the utilization of RE DG. This chapter is published in *Energies Special Issue: Energy Policy* (Prehoda et al, 2019).

Chapter 3 describes the community engaged research process utilized to consider the viability of developing a community solar program in two Michigan Upper Peninsula communities. This chapter reflects on the obstacles the team encountered throughout the process rather than presenting the empirical findings from the research. It points to the importance of incorporating collaborative governance strategies to improve the community engaged research process for community energy projects. This chapter takes lessons learned to forward the conceptual argument that collaborative governance strategies can help to address challenges experienced throughout the community engaged research process. This chapter is published in *Social Sciences Special Issue: Engaged Scholarship for Resilient Communities* (Prehoda et al, 2019).

Chapter 4 describes and analyzes findings from a social feasibility study conducted in two low-to-moderate income communities in Michigan's Upper Peninsula. Data was collected and analyzed from qualitative interviews, focus group discussions, and community surveys for factors that correlate that are important to community solar viability. Additionally, it considers the community social context of each community to help understand what contextual factors can influence program viability.

These chapters acknowledge that there are opportunities and issues to consider when implementing community solar programs. Community solar is mainly accessible by more affluent communities, which continues to lock out populations from equitably experiencing economic and social benefits of our energy system. This dissertation seeks to shift decision making to better reflect added social benefits that community solar can provide. Chapter 2 provides policy recommendations for more and enhanced distributed generation proliferation in Michigan. Chapter 3 forwards contributes to the community engaged research field by incorporating community engagement in community energy projects. Additionally, it describes a methodology to improve decision making regarding energy systems. Chapter 4 looks to close the gap between solar industry and solar developer community solar decision making centered around economic viability without considering community perspectives. More broadly, this dissertation attempts to forward collaborative governance and community engaged research as tools to promoting community solar programs that are more aligned towards more procedurally just decision making regarding Michigan energy policy. The guidebook located in the appendix provides an applied tool for pursuing this aim.

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2 Policies to Overcome Barriers for Renewable Energy Distributed Generation: A Case Study of Utility Structure and Regulatory Regimes in Michigan

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Abstract: Because of its environmental damage and now often being the most expensive source for electricity production, coal use is declining throughout the United States. Michigan has no active coal mining and seemingly supportive legislation for distributed generation (DG) and renewable energy (RE) technologies. However, Michigan still derives approximately half of its power production from large centralized coal plants, despite the availability of much lower cost RE DG technologies. To understand this conundrum, this study reviews how Michigan investor owned utilities utilize their political power to perpetuate utility structures that work toward the financial interests of the utilities rather than the best interests of the state's electricity consumers, including other firms and residents. Background is provided covering the concept of DG, the cost savings associated with DG, and utility regulatory regimes at the national, regional, state, and local levels. Recent case studies from specific utility strategies are provided in order to illustrate how Michigan utilities manipulate regulatory regimes via policy misinterpretation to deter or hinder the proliferation of DG in favor of maintaining the existing interests in centralized, fossil fuel-based electrical energy production. The results of this study demonstrate how DG proliferation is hindered by Michigan regulated utilities via the exercise of political power within existing legal and regulatory regimes. This highlights the need to think about how utilities may interpret and implement rules when designing energy legislation and policy to maximize the benefits for consumers and society. Policy recommendations and alternate strategies are provided to help enhance the role of energy policy to improve rather than limit the utilization of RE DG.

Keywords distributed generation; energy policy; renewable energy; electric utilities; utility regulation

1. Introduction

Nearly half of electrical generation in Michigan is provided by coal-fired electrical power plants that are concentrated in the Lower Peninsula [1]. Although there are some coal resources underground in Michigan, the state has no active coal mines [2]. This requires Michigan to import all of its fuel for these coal-fired power plants, moving money out of the state [3]. Yet, Michigan has substantial renewable energy (RE) resource potential in the form of biomass from an abundance of forestland area [4], hydroelectric power along many rivers [5], as well as ample wind [6] and solar energy [7,8]. Modern solar photovoltaic (PV) [9] and wind energy [10] technologies provide a lower levelized cost of electricity [11–13] than coal-fired electricity [14,15]. In addition, they can be inherently distributed (e.g. each electricity consumer produces some or all of their electricity on site). Distributed generation (DG) has several technical advantages, including improved reliability and reduced transmission losses [16,17]. RE resources in general and DG RE in particular increase access to more affordable and locally (or even individually) owned energy systems, arguably a more socially just technological application for the provision of electrical energy services [18–22]. Despite these benefits, Michigan's RE profile remains low [1] and some of Michigan's residential electricity consumers are paying approximately 20% more for electricity than the United States (U.S.) averages [9]. To understand why Michigan continues to use more expensive and less environmentally benign electricity generation technologies, this study investigates the utility structures and regulatory regimes in Michigan. It explores how existing utility entities in the state navigate the implementation of existing energy policy, finding that policy interpretation and implementation serve to perpetuate the existing, fossil fuel dependent energy regime.

As with other U.S. states, electrical energy is provided to Michigan's customers by various utility entities organized in three utility structures: (i) municipally owned entities, (ii) cooperative electric associations, and (iii) investor owned utilities (IOUs). Municipal utilities and rural electric cooperatives or rural electric associations are organized as public entities. IOUs, on the other hand, are private and for-profit firms that provide electricity to 67% [23] of U.S. and 84% of Michigan customers [24]. As privately owned utility companies, IOUs must comply with regulatory measures that are set by the state.

However, the implementation of regulatory measures involves interpretation. In the past, Michigan utilities' interpretation and implementation of existing federal and state energy laws functioned to disincentivize DG proliferation, which limited the growth of RE deployment. For example, Michigan maintains a Renewable Energy Standard (RES) that requires regulated utilities to obtain 15% of electrical generation from renewables by 2021 [25]. A net metering program that provides DG customers with credit for excess generation is within the RES; Michigan legislation states that "An electric utility or alternative electric supplier is not required to allow for a distributed generation program that is greater than 1% of its average in-state peak load for the preceding five calendar years" [26]. Some IOUs operating in the state interpret this as a maximum and cap net metering capacity to 1% of the peak generation load [27]. Michigan legislation also provides choice of electric supplier to consumers, yet the legislation limits participation to 10% of the generation load [28]. These are just two examples of how utility interpretation and implementation of energy legislation function to limit DG within the state of Michigan. As a result, the DG capacity of Michigan at the end of 2017 was roughly 30 MW [29], totaling 10% of Michigan total energy usage [30].

The purpose of this study is to investigate how IOUs in Michigan utilize their political power to perpetuate utility structures that work in the financial interests of the utilities rather than the best interests of the state's electricity consumers, including other firms and residents. Background is provided covering the concept of DG, the cost savings associated with DG, and utility regulatory regimes at the national, regional, state, and local levels. Recent case studies of specific utility strategies are provided to illustrate how Michigan utilities use policy interpretation and implementation to deter or hinder the proliferation of DG in favor of the maintenance of existing interests in centralized, fossil fuel-based electrical energy production. Finally, policy recommendations and alternate strategies are provided to help in enhancing the role of energy policy to improve rather than limit RE DG.

2. Background

This section begins with a brief description of DG including the cost savings associated with DG for Michigan utility customers before turning to the Michigan Public Service Commission (MPSC) compliance requirements to the Michigan legislature regarding DG reporting. It then describes the multilevel governance structures within which U.S. utilities operate. The Federal Energy Regulatory Commission (FERC) oversees the wholesale electricity market along with the interstate transmission of electricity. Public Service Commissions (PSC), which are also known as Public Utility Commissions (PUC), regulate the retail rates of utilities within each state. Different utility types are regulated differently in each state; this section describes utility regulation only as specifically applicable in Michigan.

2.1. What is Distributed Generation?

Distributed generation refers to technology that generates electricity at or near where it will be used [31–33]. DG has different scales and applications, including a residence [34,35], a business [31], or a larger system [36] operating as a microgrid for resilience or security [37]. Utility scale energy generation, by contrast, and regardless of energy source, involves much larger systems, which are often located further away from the site of use, which are owned and operated by or for utility needs first. DG can be powered with RE sources, such as solar [31], wind [32], and hydro [38], as well as other conventional fuels, such as diesel-powered [39] generators and various hybrid arrangements of multiple sources [34,40]. This paper specifically focuses on DG from RE sources for their ability to promote locally owned and operated energy systems as well as the improvement of electrical grid operations by decreasing load and stress on transmission and distribution lines [41–45]. The environmental benefits of RE production as an alternative to conventional fossil fuels are also well established [19–21], such as reduced pollution [46], lower rates of morbidity and mortality from air pollution [47], and lessened environmental degradation [48].

On average, Michigan residential consumers pay \$0.1512/kWh for electricity [9]. In order to show that DG technologies, particularly solar PV, can provide electricity savings to residential customers in almost all Michigan counties, the following analysis was conducted. A state of Michigan county shapefile was obtained from the GIS Open Data database [49]. The electricity rates for each IOU were obtained from the Michigan Public Service Commission bank of electric rate books [50]. Potential savings for each county were calculated using the levelized cost of energy following the method outlined by Branker et al. [11] from the electric rates using the following assumptions: inputting average sun hours/county, an average 5 kW solar residential system capacity, and average \$/W cost of \$2.50/W (The PV \$/W cost was obtained through personal communication with solar development firms in Michigan, including Chart House Energy, LLC, Quality Solar, and Strawberry Solar. The value used is the average of PV suppliers and it does not include any tax credit). In addition, the LCOE is based on average annual sun hours between 3.4 and 4.4 kWh/m^2/day in each county, the capacity factor calculated from sun hours, inverter replacement period of 10 years, PV system warranty of 30 years, solar PV system degradation rate of 0.5% per year, and 3.0% annual discount rate for present-value calculations. Subsequently, the savings were calculated by subtracting the solar LCOE from the IOU rates then geolocated onto each Michigan county utilizing ArcMap version 10.6.1. Table 1 breaks down each county by IOU residential rates, LCOE, sun hours [51], and the PV savings per kWh. The average monthly savings of a residential consumer that utilizes 600 kWh/month is shown in Figure 1. It is important to note that most counties contain municipal, electric cooperative, and IOUs. As this paper specifically focuses on IOU strategies to hinder DG proliferation, that is the utility type reflected in both Table 1 and Figure 1. It should also be pointed out that no incentives of any kind were assumed (e.g. current 30% federal investment tax credit), so the PV savings are an extremely conservative estimate.

Table 1. Michigan County solar photovoltaic (PV) savings for residential systems breakdown per kWh.

County	Utility	Solar Flux (kW/m^2/day)	PV LCOE \$/kWh	Residential Rates \$/kWh	PV Savings \$/kWh
Alcona	Consumers Energy	3.75	\$0.109	\$0.162	\$0.052

Alger	Upper Peninsula Power Co (UPPCo)	3.57	$0.115	$0.185	$0.070
Allegan	Consumers Energy	3.80	$0.108	$0.162	$0.054
Alpena	Alpena Power Co.	3.71	$0.110	$0.133	$0.023
Antrim	Consumers Energy	3.65	$0.112	$0.162	$0.049
Arenac	Consumers Energy	3.79	$0.108	$0.162	$0.054
Baraga	UPPCo	3.62	$0.113	$0.185	$0.072
Barry	Consumers Energy	3.79	$0.108	$0.162	$0.054
Bay	Consumers Energy	3.78	$0.108	$0.162	$0.054
Benzie	Consumers Energy	3.74	$0.109	$0.162	$0.052
Berrien	Indiana Michigan Power (IMP)	3.79	$0.108	$0.125	$0.017
Branch	Consumers Energy	3.81	$0.107	$0.162	$0.054
Calhoun	Consumers Energy	3.81	$0.107	$0.162	$0.054
Cass	IMP	3.82	$0.107	$0.125	$0.018
Charlevoix	Consumers Energy	3.68	$0.111	$0.162	$0.051
Cheboygan	Consumers Energy	3.68	$0.111	$0.162	$0.051
Chippewa	non-IOU	3.66	$0.000	$0.000	$0.000
Clare	Consumers Energy	3.73	$0.110	$0.162	$0.052

Clinton	Consumers Energy	3.79	$0.108	$0.162	$0.054
Crawford	Consumers Energy	3.70	$0.111	$0.162	$0.051
Delta	UPPCo	3.70	$0.111	$0.185	$0.074
Dickinson	UMERC	3.69	$0.111	$0.138	$0.027
Eaton	Consumers Energy	3.80	$0.108	$0.162	$0.054
Emmet	Consumers Energy	3.66	$0.112	$0.162	$0.049
Genesee	Consumers Energy	3.79	$0.108	$0.162	$0.054
Gladwin	Consumers Energy	3.76	$0.109	$0.162	$0.052
Gogebic	Xcel	3.65	$0.112	$0.115	$0.003
Grand Traverse	Consumers Energy	3.69	$0.111	$0.162	$0.051
Gratiot	Consumers Energy	3.78	$0.108	$0.162	$0.054
Hillsdale	Consumers Energy	3.82	$0.107	$0.162	$0.054
Houghton	UPPCo	3.64	$0.112	$0.185	$0.073
Huron	DTE	3.73	$0.110	$0.133	$0.023
Ingham	Consumers Energy	3.80	$0.108	$0.162	$0.054
Ionia	Consumers Energy	3.78	$0.108	$0.162	$0.054
Iosco	Consumers Energy	3.77	$0.109	$0.162	$0.052
Iron	UMERC	3.67	$0.112	$0.138	$0.026
Isabella	Consumers Energy	3.76	$0.109	$0.162	$0.052

Jackson	Consumers Energy	3.81	$0.107	$0.162	$0.054
Kalamazoo	Consumers Energy	3.81	$0.107	$0.162	$0.054
Kalkaska	Consumers Energy	3.67	$0.112	$0.162	$0.049
Kent	Consumers Energy	3.78	$0.108	$0.162	$0.054
Keweenaw	UPPCo	3.63	$0.113	$0.185	$0.072
Lake	Consumers Energy	3.73	$0.110	$0.162	$0.052
Lapeer	DTE	3.77	$0.109	$0.133	$0.024
Leelanau	Consumers Energy	3.66	$0.112	$0.162	$0.049
Lenawee	Consumers Energy	3.84	$0.107	$0.162	$0.054
Livingston	DTE	3.81	$0.107	$0.133	$0.026
Luce	non-IOU	3.63	$0.000	$0.000	$0.000
Mackinac	non-IOU	3.70	$0.000	$0.000	$0.000
Macomb	DTE	3.81	$0.107	$0.133	$0.026
Manistee	Consumers Energy	3.73	$0.110	$0.162	$0.052
Marquette	UPPCo	3.63	$0.113	$0.185	$0.072
Mason	Consumers Energy	3.76	$0.109	$0.162	$0.052
Mecosta	Consumers Energy	3.74	$0.109	$0.162	$0.052
Menominee	UMERC	3.75	$0.109	$0.138	$0.029
Midland	Consumers Energy	3.77	$0.109	$0.162	$0.052
Missaukee	Consumers Energy	3.69	$0.111	$0.162	$0.051

Monroe	DTE	3.85	$0.106	$0.133	$0.027
Montcalm	Consumers Energy	3.76	$0.109	$0.162	$0.052
Montmorency	Consumers Energy	3.70	$0.111	$0.162	$0.051
Muskegon	Consumers Energy	3.78	$0.108	$0.162	$0.054
Newaygo	Consumers Energy	3.76	$0.109	$0.162	$0.052
Oakland	DTE	3.80	$0.108	$0.133	$0.025
Oceana	Consumers Energy	3.77	$0.109	$0.162	$0.052
Ogemaw	Consumers Energy	3.75	$0.109	$0.162	$0.052
Ontonagon	UPPCo	3.61	$0.113	$0.185	$0.072
Osceola	Consumers Energy	3.72	$0.110	$0.162	$0.052
Oscoda	Consumers Energy	3.72	$0.110	$0.162	$0.052
Otsego	Consumers Energy	3.68	$0.111	$0.162	$0.051
Ottawa	Consumers Energy	3.80	$0.108	$0.162	$0.054
Presque Isle	Consumers Energy	3.68	$0.111	$0.162	$0.051
Roscommon	Consumers Energy	3.73	$0.110	$0.162	$0.052
Saginaw	Consumers Energy	3.78	$0.108	$0.162	$0.054
St. Clair	DTE	3.66	$0.112	$0.133	$0.021
St. Joseph	Consumers Energy	3.80	$0.108	$0.162	$0.054
Sanilac	DTE	3.78	$0.108	$0.133	$0.025

Schoolcraft	UPPCo	3.82	$0.107	$0.185	$0.078
Shiawassee	Consumers Energy	3.74	$0.109	$0.162	$0.052
Tuscola	DTE	3.77	$0.109	$0.133	$0.024
Van Buren	Consumers Energy	3.81	$0.107	$0.162	$0.054
Washtenaw	DTE	3.83	$0.107	$0.133	$0.026
Wayne	DTE	3.84	$0.107	$0.133	$0.026
Wexford	Consumers Energy	3.70	$0.111	$0.162	$0.051

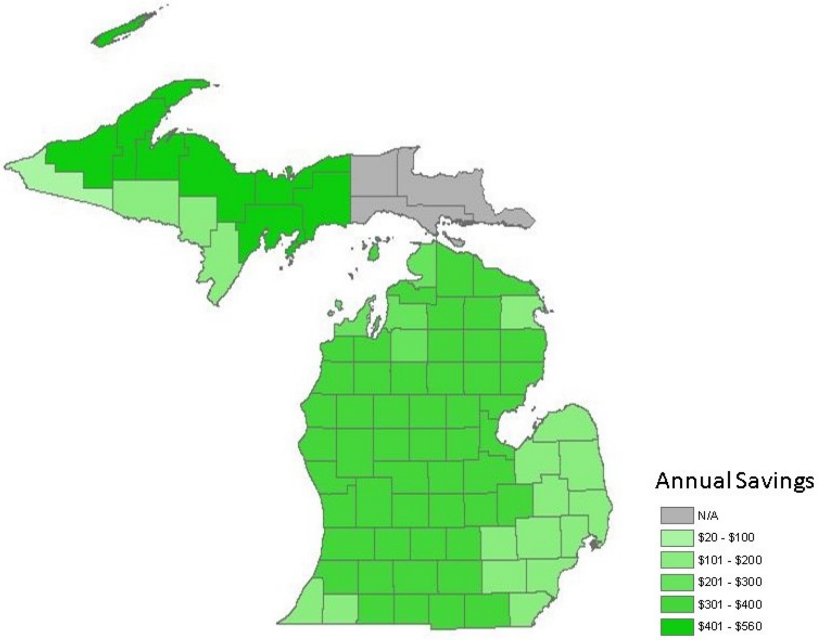

Figure 1. Savings ($/kWh) provided to each Michigan county from residential solar PV.

2.2. Utility Regulatory Regimes: National, Regional, State, and Local

The current U.S. electrical system is largely comprised of a complex network of centralized power plants, transmission and distribution infrastructure. Regulatory bodies at the national, regional, and state levels govern this network. At the national level, the Federal Energy Regulatory Commission (FERC) regulates electricity markets. Broadly, FERC regulates interstate transmission of electricity, natural gas, and oil [52]. Specifically related to electricity, FERC regulates the rates and services for interstate electric transmission and electric wholesale power sales by public utilities, transmission companies, and independent power producers. FERC maintains its legal authority from the Federal Power Act, which allows the commission to “prescribe, issue, make, amend, and rescind orders, rules, and regulations” regarding public utility activity [53]. FERC does not have authority over the local distribution of electric energy, sales of energy to customers, or determining what generation and transmission is built.

In efforts to increase competition in the wholesale electric marketplace and to provide better management of multiple independent power supply companies, FERC issued two Orders in 1998 [54], to introduce Regional Transmission Authorities (RTOs) and Independent System Operators (ISOs). These regional authorities are responsible for controlling, coordinating, and monitoring operations across multiple states or within a single state. A key task of RTOs and ISOs is to operate wholesale electricity markets, allowing for participant utilities to buy and sell electrical power. Ideally, this system allows for reliable long- and short-term electricity supply for participants and their consumers at the lowest possible cost. However, electricity in remote communities becomes costly for consumers based on a centralized model of distribution, as long transmission and distribution lines are necessary to provide access to these areas. A majority of Michigan’s electricity market is currently under the purview of the Midwest Independent System Operator (MISO), with a small portion participating in the Pennsylvania, Jersey, Maryland Power Pool (PJM) [55].

State legislatures consider energy matters that are brought forth by the governor or other state congressional and committee members. They create energy legislation and subsequent laws that PSCs must comply with and enforce. For example, the Michigan Public Service Commission (MPSC) is required to produce a report [27] to summarize the previous year’s electric utility RE growth. The report serves two purposes: to ensure that electric utilities comply with RE standards in existing Michigan energy laws as well as ensure that the MPSC is properly monitoring electric utilities’ utilization of RE resources. The MPSC compiles data from each electric utility’s reports and presents it to the senate and house committees on an annual basis.

The MPSC regulates electric utility interconnection, reviews rate cases, and regulates the state’s renewable energy mandates. Currently, Michigan electric cooperatives [56] and municipal utilities are allowed to regulate their own electric rates. The 2008 energy law package allowed a pathway for Michigan’s electric cooperatives to become member regulated [56]. While electric cooperatives can still choose to be rate regulated by the MPSC, all of them remain unregulated in terms of electric rates. This allows electric cooperatives to be accountable to their members rather than a governmental agency [57,58]. The MPSC still regulates electric cooperative interconnection as well as cooperative and municipal adherence to renewable portfolio standard and energy waste reduction standards.

3. Policy Review

This paper reviews the existing regulations and laws that address DG proliferation at both the national and state levels. First, Public Utility Regulatory Policy Act (PURPA), the Clean Renewable and Efficient Energy Act and its amendments, and the Customer Choice and Reliability Act of 2000, are discussed [25,26,28]. Examples from utility legal and rate cases, in addition to direct firsthand experiences working with utilities, are provided to illustrate how IOUs in Michigan manipulate regulation through practices of interpretation and implementation and how these practices limit the growth of DG.

Michigan is currently undergoing deliberations regarding net metering, electricity provider choice, integrated resource planning (IRP) rulemaking, along with annual rate cases [59]. Therefore, this section provides a timely review of Michigan IOUs’ interpretation and implementation of existing legislation. Federal and Michigan energy laws are reviewed to provide a foundational understanding of the environment within which Michigan utilities must operate. The PURPA review provides the federal legal context through which regulated utilities must buy power from independent power producers. P.A. 295 [26] describes

Michigan’s 2008 energy law that implemented the renewable energy standard and subsequent net metering program. P.A. 341 [25] and 342 [60] are the recent 2016 amendments to P.A. 295. P.A. 141, 142, and 286 [28] are the energy laws regarding customer choice in Michigan. This section only reviews the portions of the above laws that are related to DG.

3.1. Public Utilities Regulatory Policies Act (PURPA), 1978

The Public Utility Regulatory Policy Act (PURPA) was passed in 1978 in response to the 1973 oil shocks. Legislatures hoped to promote generation from alternative energy sources and energy efficiency, and to diversify the electric industry [61–63]. PURPA requires utilities to buy power from independent companies or qualified facilities (QF) that can produce power for less than what it would have cost for the utility to generate the power, called “the avoided cost”. While FERC and state Public Utility Commissions (PUC) share the enforcement of PURPA, FERC designates the QF, as well as setting the general regulatory framework. PUCs calculate and set the avoided cost and determine PURPA contract terms. In order to compromise with contestations against PURPA’s mandatory purchase obligation, Congress amended PURPA through EPAct 2005. Legislatures found that, as QF have nondiscriminatory access to wholesale power markets, utilities are no longer obligated to purchase power from QF with 20+MW. FERC’s final order keeps the purchase obligation in place, but allows for utilities to apply for relief from the obligation; QF’s can rebut the application if they are not receiving nondiscriminatory access. The purchase obligation remains wholly in place with QFs of less than 20MW. FERC can respond to petitions for action by choosing to intervene in state utility operations during interstate electricity commerce issues or if a ruling is needed during PURPA contestations [64].

PURPA has been instrumental in creating a market for power from non-utility power producers. This is especially true with DG, as current PURPA avoided cost rates are based on natural gas generation and the RE costs continue to drop below this [14]. This is due to the interpretation of FERC orders that utility avoided cost should be based on the cheapest available marginal power (natural gas combined cycle) [65], whereby DG is competing against a lower avoided cost than the relatively high cost of coal-fired electricity in antiquated power plants that make up the majority of Michigan’s power plants [13]. Before PURPA, only utilities could own and operate electric generating plants. However, recent contestations to PURPA include cuts to contract terms [66], reductions in avoided cost rates [67], and issues with providing open access to interconnection [68].

The MPSC recently issued a new framework for PURPA contracts in the state. Despite PURPA’s significance in driving RE development, Michigan utilities met the new framework with strong resistance. The MPSC recently ordered 20-year contracts at a standard rate for projects that are up to 2MW and a PURPA avoided the cost rate of ~\$0.10/kWh [62]; PURPA avoided cost rates had not been updated in 30 years, which are not reflected in the cost of electricity to consumers, which has increased by over 50%% in 30 years in Michigan [69]. As the new avoided cost rate is favorable (\$0.10/kWh), independent power producers can now secure financing more easily with a 20-year contract term [70]. Michigan utilities simply object to being forced to buy power from PURPA projects, despite the fact that RE systems provide power at lower costs than the utilities can produce from their less-efficient power plants [71].

3.2. Clean Renewable and Efficient Energy Act Public Act (P.A.) 295, 2008

In 2008, Michigan enacted Public Act 295, which is also known as Michigan’s Renewable Energy Standard. P.A. 295 is a renewable portfolio standard (RPS) that required utilities to obtain 10% of energy generation from renewables by 2015 (recently increased to 15% by 2021) [26]. Under P.A. 295, Michigan’s municipal utilities must file a renewable energy plan with the MPSC. Every year following P.A. 295 enactment, the MPSC is required to submit a report to the Michigan Senate and the House of Representatives detailing the implementation of P.A. 295.

Under P.A. 295, Michigan regulated utilities are required to provide a net metering program to DG prosumers [72,73]. This is different from the required interconnection service that was established under the Energy Policy Act of 2005, as EPAct 2005 amended net metering and interconnection standards with regards to PURPA [74]. Although this is the law, a recent study has found widespread inconsistencies in the net metering policies throughout the U.S., within states, and even within individual companies, with a tiny percentage offering retail rate compensation [75]. P.A. 295 language states that a minimum of 1% of the utility's peak generation load could apply and participate in the net metering program.

The net metering program separated and defined credits for excess energy from DG systems into three different levels. The first level represented systems up to 20 kW. These systems received "dollar for dollar" compensation, which is otherwise known as retail credit. The second level included consumers considering installations between 20 KW and 150 KW. These customers receive less than retail credit. Finally, the third level comprises DG systems with grid-tied generation of 150 KW or more [76]. These generators receive zero credit for excess generation under current legislation. The 2016 amendment, however, allows for 150+kW methane digesters to receive partial credit (amount subject to each utility's discretion) in a modified net metering program. The act also included capacity requirements for utilities in Michigan that served between 1–2 million retail customers and two million customers or more. The first designation required these utilities to install 500 MW of renewable energy capacity by 2015; 600 MW for the second designation. Only two utilities, Consumers Energy (1.9 million customers) and DTE (1.2 million customers), qualify under these designations.

3.3. P.A. 341

P.A. 341 updated legislation regarding utility rate cases, electric choice, and capacity, and established an integrated resource planning process. For utility rate cases, P.A. 341 no longer allows for utilities to institute rate increases if the MPSC has not issued a final order six months after receiving the rate case. P.A. 341 updates provisions to electric choice, specifically with regards to the reliability and capacity of alternative suppliers. The alternative suppliers must show that they can meet the energy needs of their customers. The MPSC is now required to determine the rate that the utility must pay qualifying facilities for energy generation under PURPA. P.A. 341 creates a process to review avoided cost rates, which had not been conducted in Michigan since August 27, 1982 [77].

P.A. 341 also requires utilities to create and submit an integrated resource plan (IRP) to the MPSC, which is a utility roadmap to the provision of least cost service. The roadmap is supposed to assess the full range of options regarding energy generation and savings to a utility. The IRP must include 5-, 10-, and 15-year projections regarding utility load obligations as well as plans to meet each obligation. Projections also include utility sales, generation type to satisfy proposed capacity needs, RE purchases, and eliminated energy waste, among other considerations. Utilities must provide projected rate impacts that are based on the proposed plan. Once a utility submits an IRP, the MPSC reviews and can approve, deny, or request revisions from the utility. At the close of 2018, Consumers Energy Company was the only regulated Michigan utility to have filed an IRP, which has not been approved. The MPSC and Consumers Energy are currently in settlement negotiations regarding the IRP. Utilities have varying filing dates and requirements as determined by the MPSC [78].

3.4. Clean and Renewable Energy and Energy Waste Reduction Act, P.A. 342

P.A. 342, passed in 2016, updated RE, energy waste reduction, DG, and on-bill financing laws. This section focuses on the amendments that are related to RE and DG. First, P.A. 342 increased the RE requirement for Michigan utilities from 10% by 2015 to 15% by 2025. Utilities are now required to offer green pricing programs to retail customers. Language remained from P.A. 295, whereby utilities must allow a minimum of 1% of peak generation load to participate in the net metering program, yet the wording allows for an interpretation whereby they can continue to treat this as a limit.

P.A. 342 required the MPSC to create a new DG program; part of this legislation required the MPSC to conduct a cost of service study to determine an appropriate tariff for DG customers. The DG program calculates credit for excess energy based on an inflow/outflow methodology. DG customers will pay for all inflow of electricity delivered by the utility that is based on their regular cost of service (or retail rate), while the outflow from the solar PV system back to the electrical grid will receive a credit that is yet to be determined. Two utilities (UPPCo and Detroit Edison) have already submitted the proposed DG tariffs for MPSC review. Both utilities that have submitted their rate case proposals to value DG at a wholesale cost [79,80].

3.5. Customer Choice and Reliability Act of 2000; P.A. 141, 142, 286

Until the 1990's, most U.S. utilities were vertically integrated monopolies that maintained control over generation, transmission, and distribution of energy. However, states with high electricity rates reconsidered this structure and then sought ways to lower prices and provide more efficient utility operations [81]. Broadly, restructuring essentially establishes new legal ground rules for electricity, generation, and transmission; the exact definition is specific to each aspect of the electricity industry. In Michigan, restructuring introduced provisions to allow customers to purchase energy from alternative suppliers, to require regulated utilities to either join a RTO or divest transmission facilities, to lower residential rates, and to freeze rate increases.

High energy costs and aging electricity infrastructure in the late 1990's catalyzed the Michigan legislature to act. The Customer Choice and Reliability Act of 2000 (P.A. 141) amended Public Act 3, 1939, the legislation that directed the regulation of public utilities by the MPSC. The amendment served to shift Michigan's electricity industry towards deregulation or restructuring. The legislature intended to bring competition into electric supply as well as to encourage investment in more efficient generating capacity. The main component of Michigan's restructuring involves functional unbundling. Rather than having generation, transmission, and distribution as one package deal, the services have been separated into discrete, separately priced components. The Michigan power supply is available to competitive suppliers, while the transmission and distribution remain under the regulated utilities. Public Act 142 allowed for incumbent utilities to secure compensation for their costs that are incurred pre-restructuring that are higher than the costs during competition and in the overall transition to the competitive market.

Michigan is considered to be a restructured state in that it allows for 100% electric choice in energy supply. This is misleading, though, as, in 2008, an amendment stipulated that only 10% of a regulated utility's retail sales can engage in electric choice (P.A. 286, amendment to P.A. 141). While Michigan's choice model states that it allows all consumers the option for electric and gas choice of suppliers, utilities cap the number of customers that can participate in retail choice opportunities. Even though the legislative language sets choice at 100%, the reality is that some services are mandatory (transmission and distribution), while some are subject to choice (supply). Additionally, alternative suppliers cannot directly provide electricity to each customer contract. This may be due to the regulatory compact guiding utility and regulator engagement; the MPSC regulates utility rates, while the utility is guaranteed a service territory [82]. This means that customers do not directly receive power from an alternative supplier. Some areas where other non-incumbent utilities do not provide service, the incumbent serves as the default service provider. For example, the Village of L'Anse in the Upper Peninsula of Michigan is a municipal utility that is located adjacent to territory served by UPPCo, an IOU. The Village utility electric rates are roughly \$0.07–\$0.14 lower when compared to UPPCo, motivating consumers in UPPCo territory to seek out lower rates. For example, an industrial park that is entirely located within the Village limits contracted services from UPPCo for a limited timeframe; after this contract closed, the industrial park sought power directly from the Village because of the cost savings [83]. UPPCo is now currently pursuing litigation against the Village of L'Anse.

4. Policy Interpretation and Implementation as Utility Driven Manipulation

The history of the electricity industry credits Samuel Insull with the consolidation of utilities into larger, investor owned, centralized electrical generation stations [84]. Since this time, utilities have increasingly operated according to the main goal of maximizing profits. Decisions surrounding how to maximize profits do not usually occur without a precedent or prior experience of the firm or regulators [85]. Profits and previous experience shaped and explained utility companies' behaviors during the first half of the 20th century [86]. However, contemporary IOUs, as examined here in the case study of Michigan utilities, continue to rely on these considerations to manipulate the interpretation and implementation of laws in ways that align with business as usual utility operations and cost recovery goals.

4.1. Rate Cases and the New Inflow/Outflow Methodology

The first way that a public utility can manipulate the law is through proposed rate cases. IOUs are subject to state regulation by PSCs [82], and the PSCs set prices for different customer types as well as determining the rate of return on investment for a utility. This is a measure of profitability for the utility and therefore it is constantly updated with each rate case that a utility proposes. Prior to Michigan's 2016 legislation, regulated utilities could self-implement rate increases if the MPSC had not issued a final order within six months of receiving the rate case.

As stated above, the MPSC recently accepted an inflow/outflow methodology of crediting DG customers for their excess generation. This means that utilities will use instantaneous metering to read any electricity that flows into the customer's home, business, or building as well as excess generation from the DG system. As per the 2016 energy legislation (section 460.1177), "the credit per kilowatt hour for kilowatt hours delivered into the utility's distribution system shall be either of the following:

(a) The monthly average real-time locational marginal price for energy at the commercial pricing node within the electric utility's distribution service territory, or for the distributed generation customers on a time-based rate schedule, the monthly average real-time locational marginal price for energy at the commercial pricing node within the electric utility's distribution service territory during the time-of-use pricing period.

(b) The electric utility's or alternative electric supplier's power supply component, excluding transmission charges, of the full retail rate during the billing period or the time-of-use pricing period."

Utilities can choose to select one of these two options to credit DG customers. Option (a) utilizes locational marginal pricing from the MISO Michigan Hub. Utilities that select this option would essentially credit DG customer outflow at a wholesale rate, or \$0.03/kWh (2017 average MISO Michigan Hub price) [87]. MPSC staff was not aware of any utility selecting this option to credit DG customers under the current net metering program (Personal communication with MPSC staff on October 31st, 2018.). However, DTE recently submitted their proposed DG tariff [79], in which they propose to credit customers with the locational marginal pricing, in which power from DG sources is less valued and it does not reflect DG's contribution to reducing overall DTE operations costs, capacity, and other factors that would be considered in a Cost of Service Study, such as avoided transmission, distribution and voltage control costs [88]. Several studies have shown that DG actually lowers the electric grid operational costs that are incurred by the utility and they should be valued higher than the proposed LMP [88]. Accepting an outflow credit at this rate would create a great deterrent in the development of grid-connected DG systems. Under this model, utilities would be the only grid-connected entity that is able to take advantage of the economics and benefits from DG. Given the economics of DG solar in Michigan, this could catalyze grid defection [89] with utility customers choosing to produce their own power with a hybrid system that is made of up solar, batteries, and gas cogeneration units [11]. This risks creating a utility death spiral [90].

4.2. Legal maneuvers

Utilities can use litigation strategies, such as maneuvering or stalling, to delay legal proceedings to change public perception. One specific example is the use of the narrative that DG customers that are enrolled in net metering place extra cost burdens on traditional and lower income customers; put another way, some claim that traditional customers subsidize DG customers [91,92]. For example, DTE states that DG "customers are not supporting the costs of the infrastructure required for their service" [93]. However, as shown above, DG can actually reduce the costs for the utility and its customers [88], yet DTE appears to make the above claim without conducting its own study assessing the benefits of DG. In response to a cross-examination question regarding analyses on beneficial impacts of DG on the electrical grid, a DTE witness stated, "we have not performed those studies" [94]. DTE's proposed DG tariff seeks to reflect the discrepancy between DG and non-DG customers costs. However, in response to including DG cost assessments in historical or projected figures to justify the proposed higher costs for DG customers, another DTE employee and witness stated that such evidence was "not in mine [testimony]" [94].

A second example of IOU tactics to hinder DG is to use lobbying as a way to influence new legislation or amend existing legislation. Electric utilities fund organizations and committees to elect governors, state legislators, and attorneys general, who can enact laws and implement rules to support utility positions. The electric utility industry has the third largest lobbying contribution, spending roughly $2.4 billion [95]. Utilities have contributed some of the highest amounts of campaign money this current election cycle [96] as compared to the election cycles from 2010 onward. While utilities contributions typically lean towards the Republican Party [96], they generally support candidates in the lead, evenly contributing when elections are competitive [97].

Utilities can also use stalling tactics to buy more time during negotiation periods. This can come in the form of requesting new information [98], establishing arbitrary timelines [99], or advocating for the need for additional research before a decision can be made [30]. Utilities can slow legal proceedings to support a traditional cost recovery model where they own and operate generation [100].

In many states, the prices of utility scale DG have decreased dramatically, matching a utility's avoided costs. There has been recent pushback regarding PURPA's contract lengths, rates, and other changes, such as the need for capacity. The MPSC recently underwent a process to revise and redefine the avoided costs of qualifying facilities under PURPA, which had not been done in roughly 30 years. The MPSC revised the PURPA contract length to 20 years and increased the capacity to 2 MW; the previous contract project size was capped at 100 kW [101]. They halted implementations to work out challenges with utilities. Specifically, the Consumers Energy Company argues that they should not be required to purchase power from PURPA qualified facilities because they do not need any new generation in the next 10 years, yet they plan to close two coal fired power plants and ramp up RE energy generation to 40% and utilize clean energy, meaning both RE systems and energy efficiency projects [102]. This could be in response to the number of PURPA projects Consumers is facing (Per personal communication with MPSC staff, Consumers Energy has 2700 MW of potential contracts in the PURPA queue.). Even if regulators rule against Consumers Energy, this legal maneuver has the potential to halt any progress or implementation of PURPA projects, as it could take several months for the MPSC to successfully argue whether Consumers Energy needs capacity.

4.3. Shifting Control

Diversification activity is another response by utilities to maneuver around regulations. Specifically, utilities can expand their business dealings into loosely regulated arenas [94]. Put another way, utilities can attempt to shift control away from PSCs. They can do this through implementing various forms of demand charges, over which PSCs can have little control. They also have discretion with treating minimum legislative targets as caps and with shifting to fixed charges for energy use. All of these can function to increase the costs for customers that are interested in installing DG systems [94], but they can also be detrimental if they do not accurately reflect the costs that are imposed by DG systems [42]. Instituting arbitrary net metering caps without fully factoring in DG impacts to cost recovery can lead to further issues and ultimately "under-deployment of distributed generation" [94, page I0721]. Shifting control using these price signals inaccurately assigns and misrepresents the costs and benefits that are associated with DG, resulting in lower adoption levels. Michigan already lags in DG installations as compared to the neighboring states of Minnesota (~750MW [103]) and Illinois (400MW by 2030 [104]), both of which employ supportive DG policies [105,106]. Shifting control away from regulators in this way could function to halt DG development in Michigan.

4.3.1. Demand Charges

Michigan utilities are shifting costs over to demand charges [79,80,107]. This portion of their rate of return has traditionally only been implemented on large industrial users with high demand. However, utilities are now moving to implementing various demand equivalent charges on commercial consumers as well as all types of DG customers (residential, commercial, and industrial). A utility must maintain enough capacity to satisfy all customers and demand charges cover the cost of supplying energy at peak times. Typically, commercial and industrial consumers with a large energy demand at certain times of day face demand charges. Currently, Michigan utilities impose charges on systems that are above 150kW, which is known as standby service [31]. Utilities contract standby service to provide energy supply to DG customers when their system experiences outages. Michigan utilities charge DG customers when this occurs. DTE included a "System Access Contribution (SAC)" for residential and commercial DG consumers in its most recent proposed Distributed Generation Tariff [79]. Specifically, "customers attaching to this rider to residential secondary rate schedules, or to commercial secondary rate schedules that do not have delivery demand charges, shall be subject to the SAC charge." This is essentially a demand charge that is imposed onto residential and commercial consumers who do not typically require the same amount of demand when compared to larger industrial consumers.

4.3.2. Utility Discretion with Net Metering "Caps"

The original P.A. 295 legislation included a minimum peak load percentage who could participate in net metering. "An electric utility or alternative electric supplier is not required to allow for net metering greater than 1% of its in-state peak load for the preceding calendar year." In 2016, the legislature amended this to include a five-year average: "An electric utility or alternative electric supplier is not required to allow for a distributed generation program that is greater than 1% of its average in-state peak load for the preceding 5 calendar years."

First, the limit that is discussed in this legislation is at the discretion of the utility. UPPCo was the first Michigan utility to reach the 1% minimum [108], as the peak generation load is much smaller when compared to other Michigan utilities. The UPPCo service area struggles economically and consumers pay some of the highest base electricity rates in the nation, sometimes amounting to >$0.25/kWh [109]. According to UPPCo's CEO, rates are high due to the rural nature and sparse population of UPPCo's service territory [109]. This can contribute to reliability and vulnerability issues during harsh winter months in the UP. UPPCo is also the incumbent utility in the Western Upper Peninsula region. Because of the 10% cap on choice that is used by large institutions, no alternative power suppliers are available to allow for residents to seek alternative power supply at lower rates. Alongside this, IOUs are for profit entities that must bring money back to their shareholders. Municipalities, such as the Village of L'Anse discussed above, have lower electricity rate prices due to their non-profit designation. Additionally, they participate in member ownership of a power supply company with many different municipalities to offer more competitive pricing to their customers.

In P.A. 295, the 1% was calculated based on a one-year average, whereas the 2016 amendment is calculated based on a five-year average. A second amendment to P.A. 295 limits which technology can participate in the new DG program. Specifically, only methane digesters that are above 150kW can participate in the DG program. The MPSC conducted a cost of service study to determine a fair and reasonable rate for DG customers; however, a full study is still needed, as this study only analyzed the inflow pricing effects. In this cost of service study, MPSC staff found that DG customers were overcharged roughly $106/year [29]. Once the MPSC conducts a full study, and the fair and reasonable rate is determined, it will arguably no longer make sense to set a limit on the number of customers or the type of technology that can participate in the DG program.

4.3.3. Utility Shifting from Rate to Monthly Charges

Typically, utilities charge customers in two ways: a fixed charge ($/month) and an electric rate based on electric consumption ($/kWh). The fixed charge usually comes in the form of a "system access" fee (or equivalent) for monthly connection to the utility's electricity infrastructure. This allows for the utility to recover some of the costs that come with serving a customer, regardless of whether they use electricity or not. However, electricity demand has been plateauing, requiring utilities to seek alternative ways to continue profiting from cost recovery mechanisms [110–112]. Some examples across the U.S. include transferring distribution charges to fixed charges and including equipment costs in the time of use rate schedules [113]. A Michigan example can be found in DTE's most recent rate case [79]. DTE proposed two pilot programs, the Weekend Flex Pilot and the Fixed Bill Pilot. These pilots propose two different types of fixed charges on a weekend and monthly basis for electricity consumption. Customers pay a fixed charge, regardless of their actual electricity consumption. This can provide incentive for customers to use more electricity [114], as well as discouraging the use of customer-owned DG and allowing DTE opportunities to maximize profits without providing a direct benefit to consumers.

4.4. Modeling in Cost of Service Studies

Finally, utilities can alter the regulatory process through choice of modeling scenarios. Michigan energy legislation requires utilities to forecast and issue a plan for generation and capacity needs several years into the future. Utilities use cost benefit analysis (CBA), risk analysis, and scenario comparisons to determine their trajectory. Utilities also use CBA to assess the impacts that are associated with infrastructure investments. These analyses can help to determine which projects a utility should pursue, how to recover costs, what technologies to invest in, etc. Utilities manipulate modeling scenarios by choosing which factors to include in an assessment.

Specifically, many Michigan utilities create scenarios to maintain their control of generation. Consumers Energy Company used modeling with assumptions such as market prices, future energy demand, and varying levels of clean energy resources to determine the best strategy to meet customer's needs [102]. As a result of the declining costs of RE, Consumers Energy plans to focus on RE generation through Power Purchase Agreements (PPAs), alongside energy efficiency measures and demand response strategies. These strategies allow Consumers Energy to maintain all control over generation resources. With regard to utility scale RE generation, Consumers Energy proposed a financial compensation mechanism that would allow them to continue profiting from generation in the PPA as if they owned the asset [102].

Additionally, Detroit Edison (DTE) conducted a CBA and risk analysis in preparation for their proposed IRP. The CBA includes assumptions that heavily weight generation without time of generation being considered (Information obtained from personal attendance at DTE IRP workshop on November 12th 2018). DTE chose to include factors and assumptions in their methodology that resulted in increased costs associated with more RE generation [114]. This allows for them to implement demand response programs, conservation voltage reduction, and additional demand charges without considering options to help in demand reduction that actually decrease the total or peak load.

5. Policy Implications and Recommendations

This review of existing regulations and laws regarding DG installations in Michigan finds that utilities interpret and implement legislation in ways that can be detrimental to DG proliferation. This section will use specific examples regarding how utilities interpret these laws to inform policy recommendations to assist decision makers to support an energy transition with DG. Specific recommendations include the removal of net metering caps, support for time of use rates, electric choice, annual avoided cost calculations, transparent bookkeeping, and municipalization.

5.1. Net Metering Cap Removal

The December 2016 energy laws P.A. 341 and 342 maintain language that allows utilities to keep the net metering capacity at 1%. Utilities rely on the narrative that traditional utility customers subsidize net metering customers to prevent any further net metering DG proliferation. The 2016 legislation required the MPSC to conduct a cost of service study to place a value on distributed generation for the inflow/outflow model [25]. The MPSC cost of service report concluded the opposite—that DG customers subsidize all other utility customers [29]. This is consistent with other studies [41,42,115,116] that DG customers provide a net benefit not only to non-DG customers but also to the overall electrical grid [42]. If the MPSC value is considered to be a fair and reasonable value, per utility ratemaking, there should be no need to place a cap on net metering. Additionally, most values of solar studies conclude that net metering programs undervalue solar [42], which also provides support for the removal of a net metering cap. State legislation such as in Massachusetts [117] and South Carolina [118] recently failed to lift caps on net metering capacity, arguably to the utility's benefits to halt DG growth. A policy change could lift the cap, allowing for increased DG proliferation in Michigan for the benefit of all electricity customers.

5.2. Support for Time-of-Use Rates

Both DTE and UPPCo's recently submitted DG Tariff Rate Case proposed charging residential DG customers demand charges, a charge that usually falls upon heavy end users such as industrial or commercial consumers. This demand charge is reflective of the traditional utility goal: cost recovery. However, cost recovery does not provide any information regarding the real cost of electricity. Regulators and policymakers could turn to a commonly used rate design that attends to other objectives, such as transparency, peak and overall load reduction, and customer awareness. Time-of-use rates can be used to properly compensate for DG, as they more accurately reflect the electricity cost variations [119]. Additionally, time-of-use rates can help to change customer's behavior to actually reduce demand and overall usage [120]. Pennsylvania's time-of-use rate pilot saw success in reducing peak load demand along with saving customer's money, especially in senior and low-income populations [121]. After the tweaking and massaging of their time-of-use program, a south Mississippi utility's customers began to see significant savings, both on an individual level and a consumer type level [122]. While Michigan utilities do offer time-of-use rates, utilities such as Consumers Energy place a focus on strategies such as demand response and conservation voltage reduction to maintain control over energy supply and demand. Utilizing a time-of-use rate can help reduce utility costs by preventing the ramp up of additional generation and satisfying legislation to support energy efficiency and decrease use while allowing for continued support and proliferation of DG.

5.3. Electric Choice

Michigan's electric choice legislation caps the capacity to participate in choice at 10%. This excludes residential and commercial consumers from participating, as the larger industrial consumers demand more power that is more favorable to the utility, as they sell larger amounts of power to one customer in addition to implementing demand charges to the large users. Stating that individuals, for example, in the Upper

Peninsula, have the freedom to choose their electric suppliers, however, does not mean that they will actually be able to voluntarily choose an alternative electric supplier. This is because they do not have an alternative to choose from. While these customers are "free to choose," they are unable to due to the lack of alternatives [123] unless they actually opt to grid defect. Ultimately, utility consumer choices will be considered to be voluntary when they make these choices on the basis that there are viable alternatives; not having an alternative choice preempts an ability to choose from multiple electric suppliers. As larger industrial and commercial consumers are able to choose their alternative supplier, the 10% cap is swiftly used, leaving no electric choice options for smaller residential consumers or small and medium sized enterprises (SMEs). Policy recommendation to fix this oversight include considering incremental increases to the electric choice structure in Michigan. Michigan schools' energy usage come to roughly 1% of Michigan's energy load. Legislation could be changed to target different sectors, providing them with an opportunity for choice. This steady increase would come at greater ease when compared to a drastic increase in choice, which proved disastrous in other states [124–126].

5.4. Annual Avoided Cost Calculations

PURPA-based contracts remain critically important in diversifying electrical generation while decreasing generation costs. Non-utility power producers also provide more jobs in more diverse locations than utility projects [127,128]. Utilities argue that long stable contracts for power increase power rates, but that is simply not true, especially if the MPSC conducts more frequent cost of service studies to accurately reflect the avoided costs. Utility companies such as Consumers Energy argue that they do not need capacity from PURPA contracts, yet Consumers Energy plans to close two coal-fired power plants [102].

The PURPA rate was established by the MPSC using a "cost of service" study that results in a lower cost for the utilities to operate and, though conditions might change in the future, those stable contracts will, by nature, produce capacity and energy at a lower cost than the utility themselves would have created them. Alongside this, the cost of service studies should be annually conducted for each type to accurately reflect fuel costs and appropriately assign avoided rate costs.

5.5. Transparent Bookkeeping

The regulatory compact that exists between a government and utility guarantees a service territory to the utility. This ensures that the utility does not have competition with other energy providers. Increasingly, utilities view DG customers as another form of competition [129,130]. If regulators and utilities want to maintain an energy system by continuing this monopoly, transparency should be in place for regulators to assist utilities in making better decisions regarding energy generation, transmission, and distribution. Regulated utilities are guaranteed a 10% rate of return [50] on energy infrastructure investments. This is guaranteed on top of electric utility executive compensation that reaches into the millions of dollars per year and it is currently not structured to maximize benefit for customers or the greater society [131]. Utilities that wish to operate in a minimally competitive environment should provide full transparency of their bookkeeping. This would allow the state to see exactly how money is being spent and where it is allocated. This could translate into more informed financial models to better serve the utility customer base.

5.6. Municipalization

In Michigan, IOUs must comply with policies and laws regarding DG proliferation. Electric cooperatives and municipalities have an obligation to their customers rather than strictly to shareholders. As a result, they have flexibility in offering DG programs to satisfy their customers. One route for cities that currently receive power from a regulated utility is to municipalize. With respect to electricity, municipalization is a transfer of electric service from an IOU to municipal ownership and service [132]. This can allow the municipality to lower the electricity rates [133] through member ownership of energy supply (e.g.). Additionally, they can explore DG programs and opportunities that are currently unexplored in existing IOU territories. In 2010, Boulder, Colorado began the process of exploring municipalization as an option to reach their clean energy goals. The process of municipalization typically involves an initial feasibility study and subsequent decision-making. Every state varies in the regulatory and legal channels that are required to municipalize. Michigan law allows cities to municipalize to provide electricity [134,135], among other services; however, the price of facility infrastructure is typically determined through an agreement with the IOU [82]. The municipalization process can take time (10+ years for Boulder, Colorado [136]), but can also allow cities more control over what DG programs they offer to customers.

6. Conclusions

A recent study has noted that 42% of the world's coal plants are currently operating at a loss and that the proportion is estimated to rise to ~ 75% by 2040 [137]. In the U.S., 70% of coal plants run at a higher cost than new RE and by 2030 all of them will [137]. Thus there is a clear need, not only in Michigan but throughout the rest of the U.S. and the world, to move away from coal technology as rapidly as possible on economic grounds alone. While RE DG has the potential to provide reliable electricity that benefits consumers and electrical grid, Michigan's DG proliferation remains low in favor of antiquated coal pants. This study reviewed existing energy policies and laws with respect to DG to obtain a sense of institutional support surrounding the continued use of coal or RE DG. PURPA contestations have placed a hold on the release of several hundred to thousand MW contracts of DG. Recent legislation has sparked deliberations in Michigan's RE rulemaking. Similarly, net metering and electric choice caps prevent customers from seeking energy from renewable sources. The results of this study clearly show that DG proliferation is hindered by Michigan regulated utilities exercising political power within the existing legal and regulatory regimes.

This review highlights the need to think about how utilities interpret and implement rules for developing legislation and policies to better suit the needs of consumers. Specifically, Michigan utilities hinder DG proliferation through rate cases, legal maneuvers, shifting control from regulators, and selective modeling in the cost of service studies. Utilities can propose little compensation as well as added fees on DG customers, making DG customers' investment in RE technologies unattractive. To prevent headway in building systems under PURPA contracts, utilities utilize legal maneuvers to slow or even halt the process. Utilities can attempt to shift control away from regulators by implementing demand equivalent charges on DG customers, instituting caps on program participation, and shifting to fixed charges for a customer's energy use. Finally, utilities can conduct biased cost of service studies by including factors that provide little support for DG system adoption.

There are several policy recommendations that can support higher DG proliferation in Michigan that are relevant to other states and regions in the rest of the world. If an appropriate cost of service study finds fair and reasonable compensation for net metering customers, then the Michigan legislature should increase the minimum requirement in net metering programs. Michigan utilities can place increased emphasis on time of use rates to accurately reflect electricity cost variations and help to determine appropriate DG compensation. The cap on electric choice should be increased to allow for more participation from non-industrial consumers. Annual avoided cost calculations can help in reflecting fuel costs to appropriately compensate for PURPA contracts. More broadly, regulated utilities that wish to remain a natural monopoly should utilize transparent bookkeeping to allow for state legislatures and regulators to monitor spending to determine the best way to serve a utility customer base. Finally, cities that set clean energy goals can explore municipalization if the incumbent utility is reluctant to support satisfying these goals through DG proliferation. Just as there are several strategies that Michigan utilities use to prevent the large proliferation of DG systems, this study has shown there are several strategies to explore shifting existing legal and regulatory regimes towards the support of DG proliferation.

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3 Putting Research to Action: Integrating Collaborative Governance and Community-Engaged Research for Community Solar

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Abstract: Community solar involves the installation of a solar electricity system that is built in one central location with the costs and benefits distributed across voluntary investors who choose to subscribe and receive credits based on the generated energy. Community solar is gaining attention because of its potential to increase access to renewable energy and to democratize energy governance. This paper reflects on community-engaged research experiences in two rural community case studies in Michigan, USA, focusing on obstacles that were experienced during the research process rather than empirical findings from the research. We highlight difficulties we experienced to help advance a conceptual argument about incorporating collaborative governance strategies to improve community-engaged research for community energy projects. Our reflections illustrate challenges in community-engaged research that are associated with identifying who should be included in the decision-making process, sustaining participation and avoiding exploitation, establishing and communicating final decision-making power, and giving attention to outputs and outcomes of the research. We argue that collaborative governance strategies can help to address these challenges, as we experienced firsthand in our project.

Keywords: community solar; community engaged research; collaborative governance; disadvantaged

1. Introduction

The U.S. energy system is currently undergoing a transition to include increasing amounts of renewable energy that distributed generation powers. Energy transitions are characterized by a significant set of long-term structural changes to the patterns of energy use in society, which can have a significant impact on quality of life, economic organization, and the activities and practices of individuals (Sovacool et al. 2016). Community members have an important stake in how energy transitions occur; however, they do not often have much say in when, where, or how renewable energy projects are built (Catney et al. 2014). Engaging communities in these processes has several potential benefits (Kim 2017). It can reflect local interests and priorities (Petersen 2016), keep economic gains from energy savings local (Magnani and Osti 2016), build community pride and cohesion (Burchell et al. 2016), and help to create awareness and transparency on energy issues that may be unclear or confusing (Rogers et al. 2012).

One increasingly popular way that communities can be directly involved in energy transitions is through community solar. Community solar involves a solar electricity system being built in one central location, while the costs and benefits are distributed across voluntary investors who choose to subscribe and receive credits based on the generated energy. Community solar is gaining attention because it aims to democratize energy by bringing ownership and control of energy generation to a large number of people (NREL 2018;

Hoffman and High-Pippert 2015). Local community members can then become personally invested through a common interest in local energy generation. Community solar provides a forum for awareness, education, and discussion regarding how energy systems can work on a local scale (Klocke et al. 2017). Finally, community solar attempts but ultimately struggles to promote social responsibility through access and affordability to energy systems (Brummer 2018). For these reasons, agencies and organizations, such as the Department of Energy, the National Renewable Energy Lab, the Solar Energy Industries Association, and the Smart Electric Power Alliance (to name a few), increasingly promote community solar. The number of community solar projects in the U.S. has grown from only 36 kW in 2006 to 1226 MW through Q2 2018 (SEIA 2018).

Still, community solar projects tend to be accessible only to relatively wealthy people (NREL 2018; SEPA 2015; LOTUS 2015), and they are often designed (and ultimately controlled) by the same energy-providing utilities that control our other energy systems (Lerch 2017; Catney et al. 2014). Given these problematics, our project team implemented a community-engaged research project to explore the potential costs, benefits, and local contexts of starting community solar. The research project aimed to give local communities control over the process of deciding whether or not to build a community solar system, and, if so, how to design a program that would elicit broad interest and be affordable and accessible to low-to-moderate income households.

The purpose of this paper is twofold. First, we critically reflect on the community-engaged research process that we employed in two case communities in the Upper Peninsula of Michigan to illustrate how community-engaged research (CER) can insert more local control and affordability into community energy systems. Second, we use these reflections to advance a conceptual argument about some of the challenges that community-engaged research faces and how incorporating principles of collaborative governance may help to address those limitations. We contend that CER can incorporate principles of collaborative governance to become better equipped for community solar program development.

2. Background and Literature Review

2.1. Community Energy

Community energy projects are increasingly being promoted as a path toward renewable and decentralized energy structures that will help to promote a more sustainable and resilient society while offering communities legitimacy, consensus, and voice (Barr and Devine-Wright 2012). Community energy projects aim to pay specific attention to 'community' or, in other words, who develops and controls the project, who is impacted by the project, and how they are impacted (Walker and Devine-Wright 2008). The community energy literature stresses keeping local control and operation when developing community energy projects as well as keeping benefits local (Catney et al. 2014). Some community energy projects are conceptualized as grassroots initiatives that utilize local leaders and stakeholders to represent the local situation, interests, and values of the involved community (Seyfang and Smith 2007). In reality, however, community energy projects are often subject to external motivations, management, and control, meaning that they are not always community engaged or driven (Catney et al. 2014).

Martiskainen (2018) argues that community-engaged energy projects are inherently political. National community energy initiatives use the tactic of emphasizing the benefits of local energy generation; however, control of these energy systems still remains in federal governance structures or powerful decision-makers, rather than the communities within which they operate (Smith 2005; Walker et al 2007). Community energy projects tend to lack a unifying vision as there can be tensions between who spearheads the project versus who participates in designing and implementing the project (Catney et al. 2014). Some community energy projects rely on centralized government funding from initiatives that articulate local energy in national energy policy (Walker and Devine-Wright 2008; Catney et al. 2014; Walker et al. 2010). People are viewed as objects rather than subjects of change in the energy infrastructures of these communities. These community energy projects continue to support individual rather than collective strategies for project success (Cameron 2010; Catney et al. 2014). This means that there is an emphasis on individual behavior change towards some predetermined goal, which can be defined without or with minimal community input (Martiskainen 2018; Batel et al. 2013; Maniates 2001). Many local communities have difficulty accessing decisions regarding energy systems that can adversely impact their communities (Martiskainen 2018; Rau et al. 2012). For example, in our project, participants repeatedly described a wind project that was initiated by a larger energy development firm that ignored community input and values.

Substantial resources (e.g., human, financial, political, social, and built capital) are required for communities to really control the process of deciding on, developing, and implementing a community energy project. Rural (or otherwise structurally disadvantaged) communities may either lack these resources or not be in a position to devote limited resources to investigating community energy potential. There may be internal barriers, such as a lack of knowledge regarding energy systems, skills to navigate governance and political structures, or monetary resources that can affect community energy project success (McKenzie-Mohr 2000; Dóci and Vasileiadou 2015). Moreover, communities may struggle to engage and maintain the role of civil society in the decision-making process (Batel et al. 2013).

Our research focused specifically on community solar as a community energy project. However, community solar is not limited to one specific model, as three community solar types dominate the growing field: utility-scale, non-profit, and special purpose entity. In the utility-sponsored model, utilities build, own, and operate the system. Ratepayers can voluntarily participate by contributing a payment (upfront or ongoing) to support the system (NREL 2010). In the second model, non-profit organizations partner with the surrounding community or businesses who can provide donations to finance the project. Donors in this type do not receive direct benefits from the system, but do share in indirect benefits through tax deductions and social benefits (NREL 2010). In the final model, individuals, groups, or organizations come together to form a small business to take advantage of commercial tax benefits that accompany solar photovoltaic (PV). Benefits from this model can be realized by the organizers themselves or in a partnership between a community and special-purpose entity (NREL 2010).

How to develop and design a community solar project ultimately depends on the enabling policy context, which varies by state in the U.S. For example, some states (i.e., California, Minnesota, and Maryland) have formal laws that allow community solar program implementation directed by various different actors. Michigan does not, which leaves community solar program development to the utility's discretion. In Michigan, most community solar programs are spearheaded by members of an electric cooperative (e.g., Cherryland Electric) or by municipal utilities (e.g., the Traverse City Board of Power and Light, and the Marquette Board of Light and Power) (GLREA 2013). The Consumers Energy Company, an investor-owned utility, owns and operates a community solar program in the lower peninsula. The key takeaway here is that, in Michigan, a community solar program relies on and requires the ability to partner with a utility to install panels, establish leases, sell PV power, and/or ensure sound investments. More innovative solutions may be necessary to encourage change in community solar policies, laws, and adoption (Klein and Coffey 2016); however, this project focuses on community solar development within the context of the existing electrical energy policy regime.

Regardless of the policy context, we believe that community-engaged research (CER) could help to improve the process of community energy project development. Collaborative partnerships between communities, research institutions, and utilities designed around the principles of CER can arguably bring the necessary resources while preserving community control and decision-making in the community energy process. The process could empower community members to speak out about potential impacts of a local energy project and begin to take ownership by participating in the program's design. Ultimately, CER projects could help decision-makers to develop community energy projects that reflect community beliefs, goals, and values.

2.2. Community-Engaged Research

Community-engaged research improves the meaningful participation of community members by creating collaborative spaces between community members, community organizations, and academic researchers to address community issues or problems (Bhattacharjee 2005; Learned et al. 2017; Duran et al. 2013; Kantamneni et al. 2019; Klocke et al. 2017). We use the term “community-engaged research” or (CER) as synonymous with “community-based participatory research (CBPR)”, “participatory action research (PAR)”, and other similar concepts. Following CER principles, community members play an important role in determining the trajectory of the research questions, project design, and data collection and analysis. Action research in particular emphasizes the goal of improving community practices and empowering community members in addition to increasing knowledge (Stoecker 2012; Huang 2010; Ferrance 2000).

CER processes can improve the relevance of research, ensuring that projects are important to communities and benefit communities (Israel et al. 2017; Hacker 2013; Strand et al. 2003; Wallerstein and Duran 2010). Still, CER is a relatively new practice in most fields (outside of public health) and particularly for community energy projects. Our team has not been able to find any other published work that explicitly uses community-engaged research principles for community energy projects. As a relatively new (and different!) endeavor, several articles, chapters, and briefs offer protocols and principles for conducting CER (e.g., Burns et al. 2011; Israel et al. 2017; Strand et al. 2003). Yet, in practice, CER still faces some important challenges for teams to grapple with that are not easily answered with a clear principle or protocol.

One common CER challenge is defining the scope of the community with whom researchers collaborate (Long et al. 2016; Kantamneni et al. 2019). Contentions lie in whether to define communities based upon geography, different demographics, common interests, or community identity (Agrawal and Gibson 2001; Long et al. 2016). Who are the partners? Who is represented and how? What are their various roles? (Goold et al. 2016). Ultimately, who is included, and to what degree, drives the direction of the research, representation in the data, and likely outcomes (Hibbard and Madsen 2003, 2004). While CER scholarship recognizes this complication, it has not been fully resolved. CER principles suggest that all stakeholders should be included as partners at the table; however, including every affected individual is not feasible. Projects that seek community representatives (Goold et al. 2016) to serve as the voice of a broader community (Stoecker 2012) may function to empower those who are already relatively powerful, leaving out the most disenfranchised voices (Tumiel-Berhalter et al. 2005). CER principles note the importance of forming a collaborative, equitable partnership, but they fall short on providing clear indications of who should be involved in the partnership, under what conditions, and how.

A second challenge to community-engaged research is sustaining participation as a result of a history of exploitation within the community (Morris 2017). This is particularly difficult to overcome in disadvantaged and low-to-moderate income communities (Ansari 2005). Many disadvantaged communities, and particularly tribal communities, have experienced a history of research abuse and projects that have done little to benefit their communities (Israel et al. 2017; Hacker 2013). CER is specifically designed to combat community exploitation by offering community members the opportunity to participate and collaborate in research that will empower participants and be directly used for the community’s benefit. The Department of Energy’s SunShot Initiative and Solar in Your Community Challenge attempts to expand access to, and the affordability of, solar PV in these communities. Still, the time and effort required of community members to participate as full collaborators in research projects is immense (Baker et al. 1999; Koné et al. 2000). This can be especially troublesome in disadvantaged and low-to-moderate income communities (Ansari 2005; Flicker et al. 2007; Adhikari et al. 2014; Tosun 2000). Requesting this effort may inadvertently result in another form of community exploitation: taking people’s time without being able to guarantee results. This creates an ethical dilemma (Long et al. 2016), and also can create challenges in recruiting and maintaining sustained participation among community members who often have many other competing time demands.

CER, and especially Action research, comes from the perspective of undertaking research with the purpose of facilitating social change (Carr and Kemmis 2003). Yet, CER scholarship focuses almost entirely on the process of conducting research, with little attention to how teams use the research results to make decisions or facilitate change. Action research aims to disrupt existing power relations by specifically shifting the role of research participants to active contributors helping to shape knowledge about their community and its problems, and then using this knowledge to push for change (Cawston et al. 2007; Kimura and Kinchy 2016). Scholars provide valuable roadmaps for partnering with community members to collect and analyze data, interpret results, and report out (Hacker 2013; Balazs and Morello-Frosch 2013; Israel et al. 2017); yet it provides little direction regarding what to do with this information to ultimately improve community conditions. The process of engaging in research can be empowering, but even engaged research is not always easily translated into action and may not lead to changes in programs, services, or access.

2.3. Collaborative Governance

Collaborative governance (CG) is a decision-making and management approach whereby multiple stakeholders at various levels or scales "engage in consensus-oriented decision-making" (Ansell and Gash 2008, p. 543). CG is generally used to enhance decision-making in policy areas, such as economic development, public health, environmental protection, and land use (Rogers and Weber 2010). It is increasingly being regarded as a strategy to build shared meaning, to learn, and to incorporate change (Innes and Booher 1999). The management of energy systems in the United States is complex and involves actors at the federal (i.e., the Federal Energy Regulatory Commission), regional (i.e., independent system operators), state (i.e., public utility/service commissions), and some local (i.e., municipal utilities) levels. Often, local communities are removed from decision-making regarding energy systems and can be adversely impacted by decisions made at other, higher levels (Lerch 2017). CG approaches in community energy systems could help to shift towards more inclusive decision-making and more successful projects. Two similar approaches that also have merit are participatory design and collective impact, which tend to focus on non-formal actors designing the systems they use (Muller and Kuhn 1993; Schuler and Namioka 1993) and collective decision making for behavior change (Kania and Kramer 2011, 2013), respectively. CG specifically focuses on governance strategies to facilitate collective decision-making in policy arenas, which makes it a more appropriate approach in the context of both CER and community solar program design.

CG scholarship has paid some attention to applications in energy systems and transition decisions. Studies focusing on the U.S. show that, while collaborative planning was a strategy used to improve and advance energy systems, they fell short of participant representation and inclusion due to power imbalances (Purdy 2012). Additionally, U.S. collaborative planning strategies typically slow after the planning stage, with a lack of action following the collaborative stage (Pitt and Congreve 2017). Margerum (2002) argues that CG commits participants to implementation. Yet previous employment of CG strategies in energy systems struggled to successfully implement energy system changes. Despite this, we believe that collaborative governance approaches show good potential for planning and decision-making on community energy projects. It is especially helpful for addressing some of the challenges (summarized above) that are associated with community-engaged research, including defining the scope of community collaborators, sustaining project participation, and decision-making to move research into action.

Chrislip and Larson (1994) argue that the inclusion of all affected and/or interested stakeholders is necessary for successful collaboration. This is important for propelling the collaboration towards a more democratic process. Not including impacted members can impact the legitimacy (Johnston et al. 2010) of the project, ultimately influencing its viability. A best practice strategy emphasizes a deliberative planning process, which involves an extended group discussion to ensure the inclusion of all affected stakeholders prior to moving out of the planning stage (Hicks et al. 2008; Roussos and Fawcett 2000; Johnston et al. 2010).

In order for CG collaborations to be successful, issues must have salience for participants (Selin and Chevez 1995). Generating and maintaining participation can be difficult due to the time and effort involved (Emerson et al. 2011). CG's solution to this problem is appropriately compensating collaborative participants for their efforts in the decision-making process (Bingham 2009). This mechanism was employed in the city of Seattle to support citizen engagement during a neighborhood planning initiative in the 1990s (Page 2010).

CG scholarship provides a helpful and practical reminder that some collaboration members will be more responsible for final decision-making than others (Ansell and Gash 2008; Stoker 2004). In some cases, multiple levels of decision-making (where stakeholders at different scales collaborate) allow the process to become more adaptable to change (Newig and Fritsch 2009). Still, there is an ultimate decision-maker(s) of the collaborative deliberation process (Newig and Fritsch 2009). A key step here is to lay out process transparency from the beginning (Ansell and Gash 2008), including which and how these decisions will be made, by whom, and with what input from whom else (Ansell and Gash 2008).

CG emphasizes the outputs of successful collaborations. Outputs might be a report detailing analyses and recommendations from the collaboration team to the final decision-makers (Thomas 2008; Page 2010), a guide book for management strategies (Herrick et al. 2009), or a management program (Kallis et al. 2009). Clearly defining outputs at the start of the CG process is important for effective decision-making (Thomson and Perry 2006; Ansell and Gash 2008), yet collaborative governance strategies tend to overemphasize outputs and ignore outcomes (Koontz and Thomas 2006; Thomas 2008).

3. Purpose

This paper critically reflects on a case study experience employing CER principles to inform community solar projects in two rural communities. It is a reflective essay meant to illustrate how applying principles from collaborative governance might improve community-engaged research. Ultimately, we argue that community-engaged researchers can integrate principles from collaborative governance to enhance decision-making for action outcomes. Reflecting on our team's experiences, we recognize challenges we experienced and consider how insights from CER and CG can be combined to ultimately improve community energy projects.

4. The Case Study

Academic researchers at Michigan Technological University partnered with community leaders from the villages of L'Anse and Baraga (MI, USA), WPPI Energy (a local energy-supply cooperative utility), and planners at the Western Upper Peninsula Planning and Development Region to explore the social feasibility of starting a community solar project in each community. Each of these actors participated as equitable partners in the research endeavor. In both cases, village administrators were interested in the possibility of starting a community solar project but did not want to move forward without engaging directly with the broader community and learning more about whether local people were interested in such a program and how it might be designed so that it would be accessible and attractive to a broad range of community members. The research team generally followed the principles of community-engaged scholarship (the methods are described in more detail below) to evaluate this social feasibility. The research project idea and specific research questions originated from leaders in the community. Decisions about methods and specific details about how, when, and where to engage in research were made collaboratively. Academic researchers and a class of students at Michigan Technological University did the majority of the data collection and analysis. Interpretations were vetted and discussed collaboratively among the full team. Results were shared at public meetings where all local area residents were invited to to share their own insights and ideas.

4.1. The Communities

The case study sites are the neighboring villages of L'Anse and Baraga, Michigan (Figure 1). We defined our case study community by geographic boundaries. Both villages operate their own municipal electric utilities, both of which are adjacent to the service territory of an investor-owned utility. While some customers in each village receive power from the investor-owned utility, participation in the potential community solar programs can only be offered to the village utility customers. Each village has a population of about 2000 residents, and they are located approximately 3 miles from one another along the Keweenaw Bay on the southern shore of Lake Superior in Baraga County. These are rural and remote communities, located more than three hours away (by car) from the nearest metropolitan area (Green Bay, WI, USA). The cases represent places where community solar projects might be especially challenging. Low-to-moderate income households make up a large proportion of the population in both villages (43% and, 66%, respectively) (MSHDA 2017), which could present a hurdle to participation in community solar given that upfront subscription costs are often substantial and more affluent people are generally more likely to subscribe (LOTUS 2015; SEPA 2015; NREL 2015). These two communities have a large tribal presence, with almost 50% of Baraga's population identifying as American Indian (alone or in conjunction with another race, U.S. Census, ACS 2016). Also, in comparison to very sunny places and to places with high electricity costs, the potential financial return on investment in solar is low here, because there is relatively low solar radiation (3.4–4.4 kWh/m^2/day, NREL 2017) in this northern region and because electric rates are near the state and national average ($0.10–0.13/kWh, Village of L'Anse and Village of Baraga Utility[3]). Selling a fairly small amount of solar-produced electricity at moderate rates yields only moderate returns on the investment.

Figure 1. The location of the L'Anse and Baraga villages in the Upper Peninsula.

4.2. Methods

Data for the social feasibility study included semi-structured interviews with key informants, "world cafe"-style community meetings (Jorgenson and Steier 2013; Brown 2010), a full sample survey in each community, and financial analyses. Each of these steps is described in more detail below. This multifaceted research approach allowed the team to get a sense of the complexities behind support or lack thereof for the

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[3] These numbers were obtained from personal communication with Village Utility operators.

proposed community solar program (gleaned from qualitative data) while also making an informed estimate of general program support and projected participation levels (based on quantitative estimates). The semi-structured interviews provided a first glance into potential opportunities and challenges associated with community solar in the local community context, as well as raised awareness about the project idea among community leaders, and helped the team to advertise the first community meeting. Community meetings provided in-depth insights from a broad cross-section of community members, offered people a public chance to express concerns, and offered a unique opportunity to hear how community members talk to one another about the project idea. Because we assume that residents of a small town will discuss the program with one another and that it would be most successful if spread by word-of-mouth, understanding how community members converse with one another was important. The community meeting structure also allowed for data interpretation from community participants responding and reacting to points raised by one another and in the survey results and talking through ideas and themes to ultimately interpret what points are most important locally. The results from the interviews and community meetings both informed the survey design. The primary functions of the surveys were to obtain a basic understanding from a broad representation of community members on support for local community solar, key factors that impact that support, and to estimate the likelihood of participation under different scenarios. Survey results were imperative to demonstrate broad interest to key project leaders. Altogether, this multifaceted approach allowed the team to expand community participation by involving a large number of diverse community members in every research step.

The team started by conducting a critical review of existing community solar programs to draw lessons for successes and failures that we could learn from. We conducted 15 interviews (5 in L'Anse and 10 in Baraga) with community and tribal leaders and social service providers to gain initial insight regarding potential barriers to, or motivations for, local participation in a community solar program. Interviews were audio-recorded for later analysis. We worked with the Keweenaw Bay Indian Community (KBIC) Committee for Alternative and Renewable Energy to determine what initiatives would spark interest in the tribal community and to design data collection strategies that would engage tribal members.

Community meetings offered the general population (beyond the specific research partners) an opportunity for meaningful participation. We held an initial public community meeting in L'Anse to share information about community solar and to facilitate discussion among community members. A total of 49 people attended. The meeting followed a "world cafe" format (Jorgenson and Steier 2013; Schieffer et al. 2004; Brown 2010), where participants were asked to sit at round tables of approximately five people each and to respond in small groups to questions, then to report out to the broader group for general discussion and interpretation. Questions included: (1) what do you like about the idea of L'Anse doing a community solar project? (2) what concerns you most about this idea or makes you think it might not work? (3) would you purchase shares? And why or why not? (4) What are some things that the team needs to consider in designing the program? (5) Do you think that L'Anse should move forward with this? Why or why not? A second community meeting was held three months later where the research team shared survey results (see below), and participants were again asked to discuss community solar possibilities in small groups and report out in a similar format. Notes from each of the small tables as well as the full group discussion were recorded and analyzed for key themes (see Appendix A).

A community survey (designed collaboratively among project partners) was distributed in two separately to all Village of L'Anse and Village of Baraga utility customers to determine community members' interest in participating in a community solar program as well as to provide additional feedback regarding community solar program design. Survey respondents were provided a $5 community currency upon submitting and requesting the $5 as an incentive. Researchers administered community solar surveys through each Village's utility bill. Community members were provided a stamped envelope to return surveys through mail to WUPPDR, or surveys could also be returned to each Village office. Students canvassed door-to-door (convenience sampling) in densely populated neighborhoods to drop off additional surveys face-to-face, answer questions, listen to community feedback on the project idea, and collect completed surveys as available. We geolocated neighborhoods in the Village of Baraga with low initial response rates and then specifically targeted canvassing efforts there to provide further information about the project as well as give residences additional opportunities to respond to the survey. A total of 174 and 158 Village of L'Anse and Baraga (respectively) utility customers responded to the survey. The response rate was 14% of all residential customers in L'Anse and 24% in Baraga. Survey data were cleaned, coded, and analyzed using the Stata statistical software to estimate support for, and knowledge of, community solar, and to consider variation in these variables by age, income, length of residence, gender, education, and tribal affiliation. This information was then used to help the team (a) estimate who might be likely to participate in the community solar program and (b) understand different demographic needs to improve our community solar program. Additionally, we calculated the predicted number of solar panels that respondents said they would purchase under various program designs in order to understand what kinds of program design were most popular, how they would work for low-to-moderate income residents, and whether a community solar program would likely sell enough shares to be feasible. Survey results were important for demonstrating broad public support for moving forward with a community solar program to research partners, additional village leaders, the electric utility, and the broader community. They also offered a means of participation in decision-making that was (while minimal) accessible to all utility customers (stakeholders).

Finally, the project team integrated results from the interviews, the first community meeting, surveys, and the existing program review to generate program design options that might work for local communities. Research partners reviewed the financial costs associated with building, maintaining, and administering a community solar project of the appropriate size to meet community interest and developed initial models for investment options that both reflected community interests and covered the required costs. The team's goal was to design program options that were both financially sound and affordable and accessible to community members. The team presented initial program options and solicited feedback in the second community meeting, and then adjusted the program design options accordingly. At this writing, L'Anse has decided to start a community project and has started to pre-sell shares following a program design that was generally (with some exceptions) what the project team recommended. The project team in Baraga is still in the process of reviewing and interpreting results.

5. Discussion and Reflection

Overall, the project team felt that employing a community-engaged research approach that took participation from a diverse set of community members seriously improved the viability of starting community solar and designing program options that reflect the community's unique interests and needs. A diverse set of local people provided feedback about a community energy project that would be located in their community. This was something that they had not experienced with previous community energy projects. Moreover, the entire project idea was driven by local actors, and the research process helped to build knowledge of community solar, support for the project, and trust in the project development process. Ultimately, the program design incorporated voices from the community that expressed concerns over how people limited by geography or money could participate and what happens to a community solar subscription if you move or no longer want your subscription. The L'Anse program was designed with three different payment/credit options, which together met the interest and needs of the broader community, and it includes ideas from the community, such as collaboration with local non-profit community organizations to facilitate donating solar panels. Overall, the team believes that CER helped to improve the process of designing a community energy program. The community is generally supportive, and the utility is starting to use the process we employed as a model for other communities.

Still, the team encountered challenges that could be addressed by incorporating principles of collaborative governance to inform the community-engaged research process for community solar. We failed at inclusively defining "the community" who participated as core members in our CER process, and we struggled to sustain broader community engagement. We did not clearly communicate who the final decision-makers were, which created some confusion and tension for team members. Finally, we focused on the process of the CER while giving less attention to how our report and program may ultimately impact the environment, people's lives, and the energy mix. These challenges are described below with a discussion of how principles from collaborative governance (CG) can help to address and improve these common challenges associated with community-engaged research. While these challenges are not novel among CER projects, we show how they play out in a new context (community solar program development), and we believe that drawing on principles from collaborative governance can help to address them for various CER projects ranging from socio-ecological to socio-technical systems.

5.1. Identifying Community Participants

A key issue in community engaged research is dealing with the complexities of defining communities and subsequently identifying which members to include in the research and decision-making process. Collaborative governance reconciles this complication by suggesting that inclusion should be based upon impact, such that all parties affected by a decision should have a say in decision-making. This usually takes the form of a representative to speak for themselves, an agency, a business, a community, or a large group of public stakeholders (Emerson et al. 2009). The key piece is to ensure that not only do the impacted parties have a voice, but the relative power of collaborators does not outweigh or become railroaded by the other in agreements or collective decisions.

Drawing on CG's principles for defining community partners, CER might first consider who is impacted and then strive to incorporate representatives of all impacted groups into the partnership team. This is important for propelling the collaboration towards a more democratic process. Leaving out impacted community members can affect the legitimacy (Johnston et al. 2010) of the project, ultimately influencing its viability. CER is good at collaborating with well-organized community groups, but often falls short of incorporating others who may be most vulnerable (Tumiel-Berhalter et al. 2005). In CG, this vulnerability is viewed as a disparity of resources, such as funding, time, expertise, and even power (Bryson et al. 2006; Huxham and Vangen 2005). CG utilizes facilitated leadership to (a) prevent any one party from exercising power over the others (Chrislip and Larson 1994; Bryson and Crosby 1993; Huxham et al. 2000) and (b) push the collaboration to redistribute and share the resources for the common vision or goal of the group (Emerson et al. 2011; Milward and Provan 2000).

Previous studies grapple with defining the community by shared geography, demographics, or sense of identity (Agrawal and Gibson 2001; Long et al. 2016). Geographic communities can be defined by physical boundaries, such as streets or landmarks (Burns et al. 2011). In our community solar study, we defined the community based on electric utility area geographic boundaries, which were superficially inclusive of all impacted parties (utility customers of the utility considering the community solar project). Still, the core research team only included village managers (who also control the municipal utility), a regional planner, academic scientists, and a representative of the energy provider. The general public (customers) were not key participants in the full research or implementation process, but rather were invited to participate at key stages in the research (answering questions, sharing attitudes/feelings, and interpreting results). Even then, the public's voice was heard and considered, but they were not well-represented in decision-making, other than by the village managers, who also had other concerns (managing the utility). In this sense, our community-engaged research fell short in its inclusiveness of community members. Our community participant definition was skewed towards authority figures that may make decisions based on a different set goals, values, priorities, and perspectives (Israel et al. 2005) compared to all impacted community members. Following CG principles would have offered the team a clearer framework and reasoning for including additional community voices as members of the core CER team and better allowed all impacted community members a voice, thus improving the democratic nature of the decision-making process and bolstering the legitimacy of our research findings.

5.2. Sustaining Participation and Avoiding Exploitation

Some research projects have difficulties sustaining inclusive engagement. This is especially true in disadvantaged communities with a history of exploitation, including tribal communities (Morris 2017; Bullard 2008). Tribal communities have a long history of exploitation by state-based and academic authority figures, which can complicate establishing collaborative research projects (Doherty 2007; Smith 2013; LaVeaux and Christopher 2009). CER aims to avoid exploitation, and is specifically designed to incorporate community members into the research process rather than taking the knowledge gained elsewhere. Still, CER projects may inadvertently exploit community members by requiring considerable time and energy, often without corresponding compensation.

Drawing lessons from collaborative governance, CER projects should explicitly incorporate compensation for community members into project design and budgeting. Some CER projects already do this (i.e., Black et al. 2013); however, it is not well-established in CER practice. Incentives, such as proper compensation for time invested, must exist for impacted members to participate and collaborate in the process. A CG approach would suggest creating a fully compensated position to facilitate dialogue between the represented group and collaborators, as well as provide expertise and guidance to the represented group (Page 2010; Bingham 2009).

Following CG strategies with regards to power dynamics might also prove useful for helping to sustain community participation in CER projects and avoid exploitation. CG recommends understanding the system context, such as power dynamics (Ansell and Gash 2008) and/or historical trust and conflict issues (Radin and Romzek 1996; Thomson and Perry 2006). Understanding the system context can help to see what dynamics might emerge and further initiate the direction of the collaboration towards decision-making based on mutual trust. Applying this to CER, the community trusts the representatives to make decisions reflecting their needs, values, and goals. The partnership remains, and the community and decision-makers continuously work together to improve those decisions.

As mentioned above, some CER projects have used compensation to sustain participation (Israel et al. 2005). Others emphasize empowering community members to develop control over the research process as a way to sustain participation (Israel et al. 2001). Members of our core project team participated, at least in part, because it was part of their job. Team activities fit well enough with formal work responsibilities that they could participate as part of their regular work day. For this reason, sustained participation and commitment were not particularly problematic. Still, village managers did, at times, struggle to find time to devote. Village managers faced multiple competing demands, which presented a challenge to participation; however, the team maintained expectations that participation was part of the community partner's role.

Soliciting broader community participation for community meetings, however, proved more difficult. The Villages of L'Anse and Baraga had differing levels of community participation regarding the community solar program design. More L'Anse community members attended the community meetings, while the Baraga survey had a larger response rate. One reason for this could be our discovery of a recent example of exploitation in these communities. Our community research was conducted while, simultaneously, community leaders and the broader community were at odds regarding a large wind development project. The community leaders supported a wind development project in the area, yet the broader community opposed the project as they expressed skepticism of the wind developer's motives and feared being exploited by the large, external development companies. Our team felt that building trust, creating an open dialogue, and otherwise providing opportunities to empower locals to speak up about the project would be enough to bring community members to table. While we did not provide adequate compensation for all the time and effort that was necessary to participate in our research project, we did incentivize participation at community meetings by bringing food, door prizes, such as LED light bulbs, and a raffle for a larger energy efficiency appliance. Due to the project's timeline, each meeting and survey occurred at different times of the year, which contributed to community members' conflicting schedules and prior commitments to community events. Our participation levels might have increased had we involved more general community members as representatives. These representatives could have been compensated for their time on this project. Additionally, the team could lean upon each representative's social network to recruit community meeting participants.

5.3. Turning Research into Action: Power to Make Decisions

While action towards social change is a goal of the research process (Stoecker 2012; Huang 2010), CER principles themselves provide little direction on how to take this research and use it to make decisions. We experienced several facets of this (discussed below) with our community solar project. Collaborative governance attempts to make the decision-making process more inclusive and more localized. We can use the CG literature to remind community-engaged scholarship that there are some people with final decision-making authority (Newig and Fritsch 2009), which requires transparency for the community to understand who that will be. Specifically, the involvement and power of these actors in decision-making may outweigh community suggestions and community energy desires.

We utilized the CER methodology in both villages to provide the opportunity for all village utility customers to give feedback about the community solar program's design. We planned to use this information to determine if the community should move forward with the program. For example, with the L'Anse community solar case study, the CER results suggested that the community wanted to move forward with a community solar project. Community members were interested in creating a community advisory board to oversee the program. Survey results indicated that multiple financing options (including a no down payment option) would function to increase community solar access to all community members, including low-to-moderate income populations. Suggestions also included a donation model either from community members outside the utility service territory or more affluent to less affluent community members. This methodology appeared to place power in community members designing the program for their community. Still, the ultimate decision-making process proved to be less democratic and transparent. Community members did not make a collective decision to move forward with the community solar program; rather, the village utilities and the energy provider had the final say. The factors, timing, and process of the post CER decision-making was not communicated to team members or the community. While the research team attempted to organize member participation across research, government, and private sectors, we mainly partnered with people in official power roles rather than the broader community. Because of this, we ultimately failed to explicitly outline decision-making as a series of iterative points and to clarify exactly who held decision-making power at each of these points.

Collaborative governance suggests that an inclusive, participatory strategy involving multi-level actors is effective for decision-making. A key component of this process is transparency (Ansell and Gash 2008). This includes communicating transparent ground rules and the shared vision with team members and all impacted community members to have the same expectations about final decision-making. Some CER findings (Israel et al. 2005; Johnson and Johnson 2003; Schulz et al. 2002) deal with transparency by including communication strategies external to community meetings (in the form of email, telephone, mailings, minutes, etc.). Utilizing CG strategies would have led us to do things differently in L'Anse and Baraga. Ideally, we would have included all affected community members in the final decision-making process. A step down from this involves transparency. While it is extremely difficult to provide information about every detail in the decision-making process, we should have been forthcoming about how and why these decisions were made. Being explicit about the incorporation of CG principles into the design of this community-engaged research project would have likely improved processes and outcomes.

5.4. Focus on Outcomes versus Outputs

Community-engaged research places great emphasis on the process portion of conducting research, with the ultimate goal of facilitating social change (an outcome). However, integrating specific outputs and outcomes (evaluating the change) into the research design is not a well-established practice in CER. CER projects often emphasize community empowerment as an outcome (whether or not the team is successful in improving conditions), but neither are commonly assessed. Focusing more explicitly on outputs and outcomes may help teams to achieve this social change. CG projects are driven by an intended output, and communicating about the intended outputs (deliverables) is critical from the planning phase. Thomas and Koontz (2011) indicate that many projects that lack agreement on a shared vision from the project's beginning result in unfocused or incomplete outputs. The CG literature speaks to finding a shared motivation as key in communicating the goals (outputs). Committing to the process, outputs, and outcomes can help keep the researchers accountable.

With the L'Anse and Baraga project, our deliverable was a report for the utility and village council to make a final decision regarding the community solar program. Team members focused on the process of ensuring that the project would keep benefits local and improve quality of life by empowering community members to participate in the project as well as producing the final report. We did not build an assessment of how well our research process achieved these aims following our report and the subsequent program implementation. We could have utilized an assessment based on factors such as improved knowledge or clarity on key issues, perceived legitimacy of the project, improved trust, and how deliberations and final decisions were perceived (Emerson et al. 2011). In the planning phase, the team could have discussed and agreed upon the best way to operationalize and measure these outcomes. Including some sort of evaluative measure of outcomes of our work could help to demonstrate the real impacts of our research and open opportunities for adaptation to improve the process and program in favor of community needs.

6. Conclusions

In this paper, we reflect on our experiences using community-engaged research practices in one particular case study examining the potential of community solar projects in two communities. We also recognize that the challenges we experienced may not be novel, but that our reflections here build others' findings while being unique due to the community solar context. This conceptual reflection indicates four possible ways of improving community-engaged research by borrowing from research on collaborative governance. First, while community-engaged research projects often grapple with the complexities of defining communities and identifying appropriate members of communities to include in collaborative research, collaborative governance suggests that inclusivity should be broadly based on impact, in that anyone who will be impacted by a decision should have a seat at the table for decision-making. This can help to circumvent some of the conceptual challenges involved in defining community while also providing a question for ground truthing community engagement to ensure that the partnerships are inclusive of everyone who will be impacted by a project.

Second, sustained inclusion and engagement can be a challenge for community-engaged research; collaborative governance suggests the imperative of structuring participation to ensure that participants are compensated for their involvement and that their voices are empowered as equitable decision-makers on the team. For collaborative governance, this may mean involving those who are paid to be stakeholder representatives or may mean only involving those who have a professional or personal stake in the decision; for community-engaged research, this may mean balancing the possibilities of stakeholder representative involvement or providing compensation when asking those who have no professional duty to be involved.

Third, community-engaged research is often focused on ensuring just and inclusive engagement with the research process, while tending to ignore ultimate decision-making and the power differentials that shape it. Collaborative governance principles are attentive to ensuring that final decision-making power is established and communicated clearly prior to deliberative activities, a lesson that community-engaged researchers may benefit from bearing in mind.

A fourth, final, and related point is that community-engaged researchers' focus on a just and inclusive process may be overshadowing the need to also have inclusive conversations about the intended outputs and outcomes of community-engaged research; collaborative governance research may also struggle with operationalizing and measuring outcomes but is more attentive to establishing shared understandings of intended outputs. Processes, outputs, and outcomes are all important, and attention to each may be improved by also paying attention to—as indicated by the lessons offered by collaborative governance—decision-making power, forms of compensation that can be offered for involvement and the diverse forms of representation that involvement can take, and the necessity of being both inclusive but also pragmatic in defining communities for research.

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4 It takes a Village: Exploring community solar program viability in the Upper Peninsula, Michigan, USA

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Abstract

Energy systems are undergoing a shift away from large utility-scale solar energy systems to a model characterized by decentralized and renewable energy powered community-based energy systems. Community solar is one such model that can be developed to emphasize local ownership of energy systems. While community solar presents a relatively new and arguably beneficial way to increase access, affordability, and reliability of energy systems, program development mainly occurs in more affluent communities. Additionally, community solar program decision making is typically based upon economic viability. This study utilizes social feasibility study data to understand community perspectives regarding program viability. It relies on semi-structured stakeholder interviews, focus group discussion, survey data collection, and community social context examined in a multi-site case study in two villages in the Upper Peninsula of Michigan, USA to answer these questions. The qualitative results show that community identity, trust, economic status, and environment are important considerations for support and project success. The community surveys point to knowledge, environment, and trust as being significant factors in influencing viability. Community social context highlights that multiple factors, including the presence of a local champion, site availability, grant funding, state assistance programs, accurately presenting results, and community history with renewable development projects can all influence the viability of a community solar program.

Keywords: Community solar, viable program design, solar energy, trust, community identity

4.1 Introduction

Community solar is an emerging solar energy application that is locally owned and operated (Lerch, 2017). While several states are beginning to adopt mandatory community solar carveouts through energy legislation (SEPA, 2018), some states are only just beginning to grapple with defining community solar, implementing supportive policies, and designing viable community solar programs. Predominantly, the solar industry couches conceptualizations of community solar programs in terms of economic viability (SEIA, 2019, SEPA, 2018, GTM, 2019). While some solar industry organizations recognize a need to increase low-to-moderate income (LMI) participation into community solar, the narrative still focuses on economics (NREL, 2018, VoteSolar, 2018). Decision makers are beginning to explore broadening motivations for policy making beyond economics. This paper describes findings from a social feasibility study to understand what makes a community solar program viable from the community's perspective. There can be a mismatch between the solar industry itself developing a community solar program at a particular site, and the desires of the communities within which such a program is ultimately located. This can impact overall program viability. The qualitative results, community surveys, and community social context evaluated in this study can inform decision making by both solar industry players and communities in the hopes of increasing proposed project viability.

While there are many ways to define community solar, this paper utilizes the traditional model where system subscribers pay for a portion of a locally-sited solar photovoltaic (PV) array and receive credit on their electricity bill proportional to the power produced (SEPA, 2018). Community solar can be hosted, owned, and/or administered by various entities including utilities, third-parties such as solar developers, municipalities, other non-profit organizations, as well as for profit entities (Feldman et al, 2015). System participants can own, lease, or subscribe to the program and receive credits on their utility bill. The local nature of community solar programs provides an opportunity for a community engagement process which aids in contributing to program viability (Prehoda et al, 2019, Barnett et al, 2019).

Solar industry experts are beginning to evaluate and develop community solar guidebooks that detail ways to improve the financial viability of community solar programs and implementation (SEPA, 2017, NREL, 2018). While community solar programs intend to increase access and affordability of solar energy systems, these reports point to growing community solar program adoption mainly in more affluent communities (NREL, 2018, LOTUS, 2015, SEPA, 2015). Therefore, a broad challenge appears to exist with regards to developing financially viable community solar programs in LMI communities.

Most studies regarding the viability of community energy projects point to a narrow dimension of project economic viability (Seyfang et al, 2013, Walker, 2008, Byrnes et al, 2016, Nigim et al, 2004). There is a need to understand what factors beyond economics can influence the viability of these projects. The results from the current study indicate that community needs and values may impact subsequent community solar program implementation in a particular community. Utilizing the current results to expand or broaden policy decision making beyond economic motivations may open new market opportunities for industry experts and solar developers. Project viability can be strengthened by combining community perspectives and community needs with existing economic viability considerations.

This study evaluated the usefulness of utilizing community perceptions and values as an additional dimension of community solar program viability. Data was collected from social feasibility studies in two Michigan Upper Peninsula communities. Data was collected and analyzed from interviews, focus group discussions, participant observations, and community surveys to understand the relationships between and among these variable factors as they potentially relate to program viability. Alongside environmental values and knowledge, various concepts of community identity (i.e. community culture, pride, and empowerment), trust, and economic status were included. Historically from a community perspective, dimensions of program viability can include both degrees of support or opposition to energy development (Devine-Wright, 2011a, Firestone et al, 2009) and/or willingness to participate in local community energy projects (Kalkbrenner and Roosen, 2016, Borchers, 2007, Rogers, 2008). Because relying on just one dimension may fail to capture potential program viability, this study analyzes both dimensions in two separate logistic regression analysis. We recognized the need to connect studies of project viability to understandings of the actual social context that can shape benefits and barriers to influence viability (Byrnes et al, 2016, Chwastyk and Sterling, 2015). Contextual factors such as the presence of a local champion, site availability, identifying funding assistance, accurately presenting feasibility results, and a community's history with renewable projects can be crucial to determining the viability of a project. This study goals are embodied in the following question:

1) What social factors should industry decision makers consider to strengthen local community solar program viability?

4.1.1 Literature review

The viability of community solar programs is dependent upon technical, economic and social factors. Programs are designed to meet optimal customer participant mix, provide multiple financial options, and lower costs through customer acquisition (NREL, 2018). Industry efforts have mainly focused on producing cost-effective community solar programs, while discounting social factors that may further contribute to program viability. The following literature review provides a brief background of the viability of existing community solar programs and various social factors to be considered for overall program viability.

4.1.2 Community solar

The definition of viable used in this paper is: capable of working or functioning (Smith, 2010; pg. 22). System and program economics have typically formed the basis of community solar program viability. However, the use of "capable" above suggests a subjective component to the definition: the project might have the capacity to work or function, but there may be additional factors that influence its overall viability. Community solar programs offer a means of increasing access to solar energy, reducing the up-front costs associated with accessing electricity generated by solar PV systems, and mitigating challenges associated with onsite solar installations. Community solar also emphasizes a model based around local system ownership. While community solar programs call attention to the above benefits, typically more affluent communities adopt community solar programs (NREL, 2018, Vote Solar, 2018, LOTUS, 2015). Federal initiatives, such as the Department of Energy Solar In Your Community Challenge, and state policies and mandates, are focusing efforts on engaging LMI households and communities (Gagne and Aznar, 2018).

Most community solar studies describe differing community solar design options (Feldman et al, 2015, Coughlin et al, 2013). While industry experts provide guides on implementation of community solar, these industry visions are primarily financially motivated: looking to provide stable and fair rates for all, scalable markets to reduce costs, and innovating products around costs and technology (Vote Solar, 2018). States with mandatory community solar provide some form of incentive (e.g. Minnesota) or solar renewable energy credit market (IPA, 2018) that appear to be the only catalyst for solar developers to build community solar. The Illinois Power Agency Adjustable Block Program created large incentives to invest in community solar, so much so that the amount of funding available did and does not meet the demand for project development (Stark, 2019). Economic viability has been the cornerstone of the bulk of evaluation community solar viability to date.

The community solar industry is experiencing massive growth (SEPA, 2018, SEIA, 2019) due to large community solar demand in states with enabling policies, while simultaneously a majority of these projects are not fully subscribed (SEPA, 2018). This lack of participation questions the suitability of current community solar program design. While it is important to look at financial viability, it is potentially only one variable encompassing the complex energy production paradigm. Community solar programs attempt to break the mold of traditional solar adoption. It includes benefits of access and affordability, along with an emphasis on other social benefits for communities and participants. Understanding community perceptions of program viability can therefore narrow the gap between industry narrative of community solar economic viability and overall project viability.

4.1.3 Environmental values and knowledge

Environmental motivation and knowledge are well documented as factors that can influence viability in energy projects (Zahran et al, 2008, Schelly 2010, and Kwan, 2012, Catney et al, 2013, Denis and Parker, 2009, Hargreaves et al, 2013, Seyfang et al, 2013).). Participants are conceptualized as those individuals who incorporate improved social and environmental performance into their perceptions and actions in energy systems (Gadenne et al, 2011). Gilg et al (2005) also discussed dimensions such as environmental values and concerns that influence participation in energy systems. Additionally, socio-demographic variables (such gender and level of education) can contribute to positive perceptions of community energy production (Batel et al, 2013, Rogers et al, 2008). Prior experience or awareness of renewable energy projects leads community members to consider community energy as desirable (Rogers et al, 2008, Catney et al, 2013, Denis and Parker, 2009). In this study, knowledge and environment are analyzed from the qualitative interviews obtained; and the quantitative survey is coincidentally evaluated to capture the relationship between factors with community solar viability.

4.1.4 Social factors influencing community solar viability

The historic dialogue on factors impacting community solar viability has mainly centered on economics. The importance of social factors that work in conjunction with economic viability are evaluated in the current study. We focused on three community factors to assess their contribution(s) to viability (in terms of community members' favoring the development of a community solar program and willingness to participate in the program) for community solar program development: (1) trust, (2) community identity, and (3) status as an LMI household.

4.1.5 Trust

Greenberg (2014) defines trust as when an individual "believes that a person(s) or organization(s) can be relied upon to accomplish objectives because they are competent and possess values and intentions that are consistent" (pg 153). Trust is fundamental to relationships, as one accepts a level of vulnerability when expecting positive intentions or behaviors from another (Kalkbrenner and Roosen, 2016). Research indicates that trust of the energy industry can facilitate community energy viability (Simpson and Clifton, 2015, Eyre et la, 2010). Walker et al (2010) place heavy emphasis on trust as necessary to the viability of a community energy project. Distrust surrounding government or associated agencies that spearhead community energy projects can create skepticism and hurdles to community energy participation and overall viability (Claudy and O'Driscoll, 2008, Simpson and Clifton, 2015). Building and maintaining trust in the project is integral to achieving successful outcomes in community energy projects (Van Der Schoor and Scholtens 2015). The type of actors involved (local versus non-local) (Devine-Wright and Wiersma 2013), community history, and execution of past community projects can all influence the level of trust surrounding community energy projects.

4.1.6 Community identity

A strong sense of community identity can influence a resident's willingness to contribute to local initiatives (Kalkbrenner and Roosen, 2016). Characteristics of community identity include instilling pride and striving for continuous improvement (Hoffman and High-Pippert, 2010). A strong sense of community can encourage cohesiveness and collaboration towards action. This is especially true if the community project involves or seeks local ownership. Community identity can facilitate solidarity in action regarding energy initiatives and can largely contribute to the viability of community energy projects (Walker et al, 2010, Warren and McFadyen, 2010). Additionally, linking community energy projects to existing local initiatives increases program viability (Klein and Coffey, 2016).

4.1.7 Income and economic status

While solar PV costs have dropped dramatically in the past ten years, high up-front costs continue to be a barrier for solar PV adoption. To reiterate from above, although community solar attempts to improve access and affordability of solar energy, it is still mainly accessible to more affluent households (NREL, 2018, SEPA, 2015, LOTUS, 2015). Program structures that require up-front investment often result in excluding LMI households from participation. In this study, LMI households are defined based on the State of Michigan's Housing and Urban Development "Low Income Limit" (HUD, 2018). Because lower income households typically do not have income tax reduction as an incentive (versus higher income wage earners), they are unable to access existing solar tax incentives available to other consumers. Additionally, those with a poor credit history could face challenges securing financing. This data suggests that many LMI households may see upfront costs as a barrier to investing in a community solar program.

4.1.8 Study background

4.1.9 Case study background

The case study villages of L'Anse and Baraga, Michigan, were selected because their village administrators were interested in exploring the possibility of community solar programs. These villages are remote, rural communities located roughly 5 miles apart in the Upper Peninsula of Michigan. They each have a population of ~2,000 permanent residents with a large LMI population (43% in L'Anse and 66% in Baraga). Each Village administrator controls the municipal utility operations. As a result, they can seek opportunities to increase electricity reliability as well as continue to provide lower utility costs for all of their utility customers (Prehoda et al, 2019) by generating power from local resources. While community solar is promising, program implementation can be difficult, with challenges that are not specific these villages. The results from the case studies of these two village may be significant not only for researchers community members participating in community energy development, but also industry experts and solar developers looking to improve program viability particularly in rural and LMI communities.

Both villages formed a partnership with the Upper Peninsula Solar Technical Assistance and Research Team (UPSTART) to conduct a social feasibility study. The UPSTART team is comprised of university researchers, the Western Upper Peninsula Planning and Development Region (WUPPDR), and WPPI, the energy supply company for both villages. UPSTART had two main aims in conducting the social feasibility study to satisfy a goal of increasing community solar accessibility to LMI households:

1) Is community solar something each village wants?
2) How can the villages design a program that meets community interests and needs?

4.1.10 Social feasibility study research methods

This paper utilizes a mixed methods approach that triangulates data from qualitative interviews and focus group discussions, community-wide surveys, and participant observation to help inform the community context. The interviews and focus group discussions allowed UPSTART to get a sense of the social complexities that emerged with community solar program design. It afforded community members a medium to communicate concerns and provide feedback to further inform program design. The community surveys estimated the community members participation levels and explored key factors that could impact participation levels. The qualitative and quantitative data work together to link complex social factors to estimated participation levels. UPSTART members relied on participant observation throughout the feasibility study period to gain a holistic understanding of community viability situated within the community context.

4.1.11 Key stakeholder interviews

A total of fifteen qualitative interviews (5 in L'Anse and 10 in Baraga) were conducted with key informants in both villages. Participants were determined through a snowball sampling strategy. The goal of the interviews was to develop understanding of the local context and incorporate community stakeholder viewpoints into the rest of the study. The interviews examined how residents and business owners felt about a potential community solar program and provided insight about potential drivers or barriers to participation. Additionally, researchers investigated specific community factors that could impact the success of the project.

4.1.12 Focus group discussions

Three community meetings, two in the Village of L'Anse and one in the Village of Baraga, were held throughout the feasibility study period to build upon interview data. UPSTART utilized newspaper, radio, and community organization outlets to advertise and invite all community members to attend the event. Meetings were held at local high school buildings as they could accommodate attendance from many community members. UPSTART offered attendees door prize incentives, such as LED lightbulbs and entry into a drawing for an energy efficiency appliance. In the initial L'Anse and Baraga community meetings, UPSTART members generally described community solar to the community and invited discussions and feedback about the possibility of developing a community solar program in each village. A total of fifty-nine community members participated in providing feedback based on 5 open-ended questions (Table 1) about the project. Community members were divided into groups of 5-6 participants to reflect a "World Café" style meeting (Jorgenson and Steier, 2013, Brown, 2010). This methodology includes structured conversation between groups of participants who discuss different topics at several tables for a set time period. Once time is completed, groups move to a different table to discuss a different topic. As new participants arrive, the table host reports the results of the previous discussion, allowing participants to build upon one another's knowledge sharing. The village of L'Anse and Baraga community meeting methodology was similar in that participants were split into groups. The meeting host announced one question at a time, allowing for 10-15-minute discussions of each question. At the end of the meeting, the host aggregated feedback from each table's discussions allowing for a broader group reflection on community solar concerns and considerations. Following the preliminary program design, UPSTART presented the community solar program in the second meeting in L'Anse and a smaller meeting with the Baraga County Chamber of Commerce. At these meetings, researchers asked for feedback regarding any concerns and suggested improvements to the initial program design.

Table 1. Questions asked to community participants during focus group discussions.

What do you like about the idea of your village developing a community solar project?
What concerns you about this idea or makes you think it might not work?
If this happens, do you think you will buy one or more shares for your home/business? Why or why not?
What are some things that the team really needs to consider in designing a program?
Do you think that L'Anse should move forward with this? Why or why not?

4.1.13 Community survey

A survey was distributed to all Village utility customers totaling 1,577 customers (925 residential customers in L'Anse and 652 in Baraga). These numbers represent the total population of residential electric utility accounts. In L'Anse, surveys were distributed in the mail along with the household's electricity bill. In Baraga, survey mailers were sent separately from the utility bill. An online link to the survey was provided to village of utility customers. In total, 339 residential customers responded to the survey for a 21% response rate. The survey was generally successful at achieving a reasonable demographic representation of the population of both villages. Women and men are slightly underrepresented in the L'Anse and Baraga surveys, respectively. Both surveys underrepresented respondents with ages below 45. Respondents who reported LMI status are overrepresented in both surveys.

The survey's main goal was to determine overall village utility customers' interest in participating in a community solar program. Additionally, researchers were interested in learning the perceived barriers to participation in the community solar program. As the survey asked questions regarding project participation, the survey was also used to assess the perceived economic feasibility of the community solar program. In L'Anse, researchers utilized neighborhood canvassing to boost response rates after distributing the first round of surveys. UPSTART members partnered with undergraduate students to canvas neighborhoods door to door to provide surveys and discuss the project with community members. Team members provided community participants with a stamped envelope to easily return the survey once completed. Some community members chose to complete and return the survey in the presence of UPSTART members. Canvassing afforded community members the opportunity to discuss the potential project further and raise any questions or concerns. This drop-off/pick-up methodology provides a personal interaction that is used to increase survey response rates (Trentelman et al, 2016). Another advantage of this method is to reduce non-coverage error (Steele et al, 2001). In Baraga, neighborhoods with low response rates were geolocated and targeted for neighborhood canvasing. In both surveys, respondents were provided a $5 Baraga County gift certificate for returning the survey.

4.1.14 Measures

This section describes this study's knowledge, environment, trust, community identity, and economic status constructs. Researchers analyzed qualitative interviews and focus group discussions following an inductive process. The constructs mentioned above emerged from the qualitative data as important and were then operationalized in the survey designs with the questions described below.

During the semi-structured interviews and focus group discussions researchers asked questions about the perceived advantages and disadvantages of community solar program design, opening discussions to many social and economic considerations. Qualitative data was evaluated for key wording or patterns related to social value concepts such as trust and community identity. Specifically, discussions where respondents mentioned community improvement, community culture, community pride, and/or empowering the community were consolidated into the community identity category. Discussions emphasizing each community's economic status as a whole or a large LMI presence in the community were evaluated as economic considerations.

The survey contained questions about trust, community identity, and economic status. Likert scales (e.g. Mogey,1999, Bertram, 2007, Huijts et al, 2007, Yuan et al, 2011) were developed and employed to measure these constructs. The survey also included a measure of whether or not respondents favor community solar development and reported willingness to purchase shares. These two variables were combined into a viability index that served as the dependent variable of interest.

The environmental variable was operationalized from Farhar (1994) and Gadenne et al, 2011). Respondents were asked their level of agreement with the statement "It is important that my electricity comes from renewable sources." Following Rogers et al (2013), knowledge was operationalized as direct awareness of community solar and/or experience through knowing someone with a solar energy installation. A reliability statistic was computed to measure internal consistency of these two variables. The

Cronbach's alpha for "knowing about community solar before the survey" and "knowing anyone who currently owns solar panels" was 0.9005, suggesting high internal consistency. These variables were included in a single knowledge index.

Community identity was operationalized- taking pride in the community and a goal of making the community a better place- following Hoffman and High-Pippert's model (2010). The three response items (1) a community solar program would make L'Anse or Baraga a better community to live in; (2) a community solar program would attract more residents and businesses to L'Anse; and (3) a community solar program would increase my pride in my community, were assessed using a 5-point Likert-type scale from 0 (strongly disagree) to 4 (strongly agree). These three measures were included into a single community identity index. The Cronbach's alpha for the community identity index was 0.8818, suggesting a high level of internal consistency between these variables. The community identity index is an interval variable.

To measure trust, researchers asked respondents for their reported level of trust of electricity provider. This question allowed for a measure of general trust of the community member's local administrators as opposed to specific trust of community solar program. Responses were assessed using a 5-point Likert Scale of 0 (strongly disagree) to 4 (strongly agree).

Economic status was analyzed by asking respondents to report annual household income. Income scale was replicated from U.S. Census income brackets. The responses were then recoded to a dichotomous variable such that household incomes at or above $50,000 are categorized as non-LMI and those below as LMI households.

4.1.15 Data analysis

Data from both qualitative and quantitative research methods was collected, analyzed, and triangulated to understand what community members thought was important for community solar viability. The interviews and focus group discussions informed the survey design and contributed to a portion of the overall community context regarding program viability. Data analysis involved utilizing the survey to understand interest in and perceived barriers to participating in the community solar program. A theory-informed stepwise logistic regression was used to analyze data. Each model was compared with the Akaike information criterion and Bayesian information criterion for the purpose of identifying the "best" model (Burnham and Anderson, 2004, Kuha, 2004). Researchers explored for any resonance by combining qualitative interviews and community meetings with survey analysis. The data provide insight that may help to explain factors influencing the viability of community solar programs.

Interview transcripts and focus group discussions were analyzed in a hybrid fashion following ground theory characteristics (Glaser and Strauss, 1967, Charmaz 1996) for thematic coding along with inductive analysis to discover any patterns or concepts that emerged. Stata (version 15) was used to carry out a descriptive and logistical regression of the survey data. This provided information regarding the likelihood that respondents would state they are willing to participate in the community solar program.

4.1.16 Interview and focus group findings

While there was a general lack of knowledge regarding community solar, participants in interviews and focus groups considered the community solar project to be a good idea for the community. Reasons for support included increasing or instilling pride in the community, increasing community education, and developing a more sustainable energy source. Respondents liked the possibilities for community empowerment, local control, and energy independence associated with community solar. They focused on local benefits and designing the project to increase the local returns as much as possible, including the possibility of bringing in more business that could hire local labor.

> "Well if we did have it, it would show that we are acceptable to that [renewable energy]- if a business wanted to come in and wanted to put up a big thing to run, that would be a good thing. Hey, we're friendly to it. That could be a positive thing."

Participants said community solar program could create a sense of community pride for both villages. They could be seen as regional and national leaders. For these villages (characterized by long-term job loss and historical population loss), community pride is a really important dimension, as one participant described:

> "I think that it would give them some more pride in the community. It's something I think the people really need. They really need to be proud of the community and right now it's kind of neutral."

Prioritizing sustainability in energy resource use was also cited as important. Maintaining a level of environmental concern was viewed as a motivation to invest in the community solar project. Respondents liked that community solar provides a sustainable, green energy and local energy source. Community members identified this as a reason to support the project. One interviewer described:

> "It could provide a more sustainable electric force. I can see it being a good solution for environmental challenges we may face."

Participants felt that businesses and organizations may not consider solely the economic benefits, thinking they may participate for reasons other than financial benefits. For example, investing in environmental and social stewardship for the community that could result in broader, positive recognition. One participant said that this project could help them:

> "be a steward of the community. Our company have a fairly significant investment in environmental health and safety programs so something like this would get attention."

One challenge expressed by participants is that the community's trust of outsiders is low. This is different from the survey instrument that measured trust of the electric provider. While survey respondents and interview and discussion participants indicated trust was important, they referred to different targets of trust. Building trust in the community is a process that takes time. For instance, one participant stated:

> "I can tell you with this community, from my experience of being an outsider, things are great, but I've had to slowly build my reputation up with them; which is going super, it takes time, people don't like to let go of the past. I think people are a little more cautious up here."

Dimensions of trust were also discussed with regards to economics. One participant wanted to know who would benefit economically from this project and was skeptical that community members themselves would see any benefits:

> "I am concerned about who benefits. Because here it is becoming a money-making scheme. That's what I'm saying, people need not be making money. This should not be a money-making scheme. I'm just defending the poor here. The cost should not be filtering down to the poor even though they may get a miniscule benefit. How will this benefit the residences. Who is benefitting from this? There are grants, loans, and other resources to get this system going. We are an impoverished community."

Another challenge is associated with the culture and the past experiences of the community. Participants shared their concerns about the community's culture of unwillingness or resistance to change. One participant stated:

> "You're just going to be fighting culture. People may want to go forward, but a lot of the attitude around here is: if it ain't broke don't fix it. You could do all this research and all this work and it falls flat on its face because of the culture; not because its solar. It's funny how people dig their feet in about these things."

Stakeholders also felt that cost would be a huge determining factor in the success of this project. The villages are home to a relatively large proportion of LMI households who may be unable to afford the upfront cost for participation. Economic concerns are huge, and participants felt costs should be reduced as much as possible to include LMI households. For example, participants stated:

> “There are a lot of low-income people here. It is very low. If you could find a way that they could pay for 20 years on their light bill rather than have some set at 10. Let these people under lower income, extend down the road.”
>
> “We are very low income, we got into WPPI because UPPCo was soaring. many years ago before I got on the council, they were on a 10 year plan with the Village, when they came time to renew it, the Village wouldn't do it; WPPI came around and knocked down rates. We joined up, WPPI made it easy for us to pay our membership. We've been very pleased, rates are just phenomenal. I come from a poor family and I can’t see burdening people anymore than you have to. We try to keep it as low as we can.”

Another participant linked the Village’s stagnation over time to the lack of funding to support changes:

> “So you can't make a lot of big changes because there's not a lot of funds there, so if something like this were to come in there would have to be some sort of grant format to back it, because it would never take off if it were full prices. Some people can't afford to put food on the table. So they're not going to pay thousands of dollars to put solar panels on the their home.”

Overall, respondents were encouraged by the potential pride and empowerment the project might instill in the community. They indicated the sustainable impacts of this project could make them a regional leader. Respondents expressed concern that other factors could reduce peoples’ support of the community solar project and further prevent the project from moving forward. Any project inertia that solar developers experience could be explained by community members culture of unwillingness to change, level of trust of outsiders, an economic status that will ultimately impact project viability. These findings informed and were operationalized into the survey design and statistical analysis variable selection.

4.1.17 Survey findings

4.1.18 Community Solar Viability Measures

Respondents were asked “Are you in favor of the Village developing a community solar program for Baraga/L’Anse electric utility customers?” Descriptive statistics can be found in table 2. The responses were originally coded categorically with “Yes”, “No”, and “I don’t know” responses and are reported descriptively. This variable was then recoded to a binary variable for analysis, “0” being “No” and “1” being “Yes.” This variable was explored in the first logistic regression analysis. A second logistic regression explored the dichotomous variable that asked community members if they were willing to participate in the community solar program. Responses were coded into “0” representing “No” responses and “1” reflecting “Yes” responses. Each survey provided scenarios with different dollar values to community members. In the Village of L’Anse, respondents were asked how likely they would be willing to purchase shares with different upfront and on-bill financing values. The Village of Baraga survey asked respondents how likely they would be to purchase community solar shares at incremental upfront cost increases (e.g. \$100, \$200, \$300, etc.). A follow-up question asked respondents how many shares they would purchase. This scenario was repeated with a pay-as-you-go option. As each survey asked this question differently, a dummy variable was created to be used in the logistic regression analysis. Table 2 illustrates the frequencies of responding yes, no, or no response to willingness to purchase shares. This dummy variable does not capture the original nuanced survey responses. For example, the Village of Baraga survey provided both up front or financing options. While Village of Baraga respondents generally selected one option over the other, they were aggregated into the “yes” category for willing to purchase shares.

Table 2 summarizes the descriptive statistics of factors used in the logistic regression analysis. Tables 3 and 4 report the results of the two logistic regression models utilized in this analysis. This statistical analysis utilized a theory-informed step-wise regression that allowed for examination of each variable separately, while other variables are held constant.

The first logistic regression (Table 3) was determined to be the best model with community identity and all trust factor categories predictors of support. These variables are statistically significant with p-values less than 0.05. The McFadden’s R-squared is also interpreted in conjunction with AIC/BIC values; the pseudo r-squared=0.1203 indicating that ~12% of the variation in viability results from variations in community identity and environmental values. Community identity has a positive relationship with program viability which is consistent with the literature. We find that the for each unit increase the odds of moving from the “No” to “Yes” category of willingness to purchase shares is 1.54. The logistic regression elicited a positive relationship between environmental values and willingness to purchase which is consistent with the literature (Odds ratio for categories include “disagree” =8.42, “agree” =9.54, and “strongly agree”= 12.12). Gender, knowledge, economic status and trust are not significant in this model.

The second logistic regression (Table 4) was determined to be the best model with community identity and environmental values factor categories of “disagree”, “agree”, and “strongly “agree” significant predictors of willingness to purchase shares. These variables are statistically significant with p-values less than 0.05. The McFadden’s R-squared is interpreted in conjunction with the AIC/BIC values; the pseudo r-squared=0.4362 indicating that ~44% of the variation in viability results from variations in community identity and trust. Community identity has a positive relationship with program viability which is consistent with the literature. We find that the for each unit change the odds of moving from the "No" to "Yes" category of being in favor of community solar development is 29.05. The logistic regression elicited a positive relationship between trust and support which is consistent with the literature (Odds ratio for categories include "disagree"=0.221 "neither"=0.0030, "agree"=0.0068, and "strongly agree"= 0.0012). Gender, knowledge, economic status and environmental values are not significant in this model.

Table 2. Descriptive statistics of factors.

Variable	Observations	Level	Frequency
Gender	300	Male Female	48% 52%
Favor of program	336	Yes No I do not know	61% 5% 34%
Willingness to purchase shares	336	Yes No No response	55% 43% 2%
Village location	336	Baraga L'Anse	51% 49%
Knowledge of community solar	330	Yes No I do not know	48% 50% 2%
Know someone with solar	331	Yes No I do not know	44% 53% 3%
LMI Status	307	Below $50,000 Above $50,000 Prefer not to answer	49% 47% 4%
Environment	305	Strongly Disagree Disagree Neither Agree Strongly Agree No answer	4% 4% 26% 33% 23% 10%
Better place to live*	310	Strongly Disagree Disagree Neither Agree Strongly Agree No answer	3% 4% 43% 28% 13% 9%

Attract more residents and businesses*	304	Strongly Disagree Disagree Neither Agree Strongly Agree No answer	5% 10% 49% 20% 6% 10%
Increase pride*	304	Strongly Disagree Disagree Neither Agree Strongly Agree No answer	5% 4% 44% 26% 11% 10%
Trust	303	Strongly Disagree Disagree Neither Agree Strongly Agree No answer	5% 3% 28% 41% 13% 10%

*These variables were included in the community identity index but are summarized independently here. 5-Point likert scale is measure from 1=Strongly Disagree to 5= Strongly agree

Table 3. Logistic Regression Output Summary Model 1

	Odds Ratio (AIC/BIC of Model)						
Constant	1.831	1.853	1.933	2.325	2.877	7.042	2588
Village	0.8152 (439/446)	0.8267	0.8063	0.7452	0.6914	.6385	0.5270
Gender		1.017 (393/405)	1.005	1.007	0.9548	0.7356	0.7144
Knowledge			1.242 (391/405)	1.193	1.096	1.117	0.9420
Economic status				0.8442 (375/393)	0.8566	0.8455	0.7985
Environment							

Disagree					0.7165	0.4313	0.2060
Neither					0.6336	0.3440	0.2915
Agree					1.070	0.8342	0.6628
Strongly Agree					1.160 (341/372)	0.8593	0.9502
Community Identity						13.05* (221/256)	29.05*
Trust							
Disagree							0.0221*
Neither							0.0030*
Agree							0.0068*
Strongly Agree							0.0012* (200/249)

*p-value < 0.05

Table 4. Logistic Regression Output Summary Model 2

	Odds Ratio (AIC/BIC of Model)						
Constant	1.292	1.444	1.447	1.918	0.5140	0.3729	0.4200
Village	0.9863 (457/465)	0.9220	0.9011	0.9193	0.8298	0.8752	0.9042
Gender		0.8628 (412/423)	0.8700	0.8216	0.6800	0.5824	0.5769*
Knowledge			1.091 (413/428)	1.158	1.123	1.147	1.133
Economic status				0.78	0.8821	0.8947	0.8869

				(393/411)			
Environment							
Disagree					5.803*	8.990*	8.420*
Neither					1.857	2.598	2.474
Agree					6.110*	9.953*	9.538*
Strongly Agree					9.063* (336/368)	13.57*	12.12*
Community Identity						1.546* (307/342)	1.541*
Trust							
Disagree							0.3312
Neither							0.8801
Agree							0.9914
Strongly Agree							1.090 (312/361)
McFadden's R						0.1164	0.1203

*p-value < 0.05

4.1.19 Community context discussion

This section describes data collected from participant observation throughout the social feasibility study period. The findings remind industry experts and solar developers to situate viability within the community context. The community context can be related to formal, institutional and policy support, or more specifically to community characteristics, events, and/or lived experiences that can help shape the community's perception as a whole to community solar. This section describes the importance of looking to a local champion, identifying an available site that fits with community perceptions of the energy project, identifying funding assistance that can help lower project costs, accurately presenting results so they become meaningful to community members, and understanding community history with previous development projects.

4.1.20 Presence of a local champion

Adoption of solar PV is not exclusively correlated with economic status, community trust, or supportive policies or incentives. Rather each community varies with respect to these factors that influence adoption levels. Local champions can assist the project in various ways that are dependent upon their resources, knowledge, and skills, but ultimately, they help guide the community to a shared vision of the community energy transition.

In this case, village administrators established relationships with the research team to conduct the social feasibility study. One village administrator responded to the economic concerns surrounding the project viability voiced by the community. The administrator applied for additional grant funding to further reduce project costs, making the project more financially attractive to community members. Villages aided by a local champion who is integrated into and supports the development of a community solar program are more likely to experience a viable program.

4.1.21 Community solar site

Developing a community solar program requires an available site with three considerations: technical, perceptual, and legal. Technically, the site must have the capacity to host a larger solar array and must be viable for energy production. Perceptually, both community solar subscribers and non-subscribers must deem the location acceptable. Finally, there are legal considerations as to who owns the land in terms of solar land lease agreements.

First, a technical feasibility site study determined the site viable for installing a solar array. The next portion of the feasibility study was devoted to working with the community to determine potential locations in each village. There are varying perspectives on the aesthetics of solar PV that can impact the solar array location. The villages have access to a large industrial park where a site was devoted to hosting the community solar array should the project be successful. The industrial park is located off the main road with minimal visibility to community members. Additionally, the park provides ample space to expand the solar array, should the village need increased capacity in the future. Finally, varying land ownership could impact the community solar viability by introducing additional complications such as managing lease agreements.

4.1.22 Identifying funding assistance

Grant funding can be a way to reduce renewable energy project costs. Not-profits, governmental agencies, and LMI households cannot monetize tax benefits generated from the federal renewable energy tax credit. Local governments and rural communities can access existing federal and state initiatives and grant programs to help fund and forward clean energy goals with specific LMI and non-profit carve outs. The US Department of Agriculture's Rural Development program periodically solicits applications for loan and grant funding through the Rural Energy for America Program (REAP). The Michigan Department of Agriculture and Rural Development (MDARD) awards applications for community renewable energy project research and development. The Department of Energy (DOE) SunShot initiative offers many solar grant funding opportunities and competitions to lower solar project costs for LMI communities. Additionally, the DOE offers a Tribal Energy Program Grant to promote tribal energy sufficiency, economic growth, and employment through clean energy projects in tribal communities. The State of Michigan Agency for Energy (MAE) exists to advance Michigan's energy future towards affordable, reliable, and environmentally friendly sources. The MAE also promotes community economic growth and environmental sustainability through energy efficiency and renewable energy measures. These represent just a few of the available opportunities for local governments to submit competitive applications to forward their renewable energy project goals.

MAE invested in Michigan's first community solar program developed by Cherryland Electric to fund a carveout of LMI participation. On behalf of the Village of L'Anse, UPSTART negotiated a similar funding carve out with the MAE to provide 10 panels each for 25 LMI customers. This model eliminates a portion of the upfront cost for a panel in the upfront/on-bill financing option for LMI households. MAE also requires these subscribers to participate in a no cost energy efficiency review and weatherization measures.

4.1.23 Accurately present results

Interview and focus group discussion participants cited possible economic reluctance resulting from estimated participation costs that could influence viability or future participation in a community solar program. UPSTART expressed the system economics in terms of a simple payback period (years to make participant money back) which could be responsible for economic reluctance. While simple payback period is an easier way to understand over more complex financial models, it does not include time value of money, panel degradation, inflation, changes in credit ratings, or other investment benefits. In later financial analyses, UPSTART utilized the Net Present Value (NPV) of a potential customer's investment over the subscription term.

Solar photovoltaic systems save money in the long term, however reluctance to deploy or participate in solar energy programs results from a perceived unsatisfactory or long payback time (Pearce et al, 2009). UPSTART may have found more success by looking to a return on investment (ROI) calculation to illustrate cases where participants can receive a greater return from solar energy systems compared to other investment options.

From the social feasibility study, UPSTART provided three different financing options for community solar program participants (Table 3). The first was an upfront payment plan option where participants pay a flat upfront fee of $450 and receive monthly savings over the program lifetime of 25 years. UPSTART developed two on-bill financing options for program participants. The first, a short-term payment plan combined a partial upfront payment of $250 and a monthly payment of $2.00/month for 10 years of the 25-year program lifetime. The second, a long-term payment plan requires only monthly payments of $2.50/month for the 25year program lifetime.

Table 3. Social feasibility study estimated community solar financing options

Community Solar Subscription Options and Savings Estimates					
Payment Plans (per panel)	**Upfront Payment**	**Monthly Payment**	**Monthly Savings**	**Net Lifetime Savings**	**Payback Length (Years)**
Long-term	$ --	$2.5/month for 25 years	$3	$150	21
Short-Term	$250	$2.00/month for 10 years	$3	$410	14
Upfront	$450	$ --	$3	$450	13

As this is an issue with perception by community members, UPSTART members should have reported multiple payback options. Specifically, an inclusion of the calculated ROI when reporting out the three different financing options available would have helped to provide a different perspective. Pearce et al (2009) provide a ROI calculation that was used in this study. In the upfront cost option, over the program lifetime of 25 years, participants would receive an ROI of ~6%. In the short-term payment plan over the 25-year program lifetime, participants would receive a 5% ROI. In the long-term payment plan, participants would receive a <1% ROI. In the Upfront and Short-term payment plans, participants would receive better ROI than investing in a savings account (2.5%), certificate of deposit (3%), treasury securities (2.5%), or money market accounts (2%), to name a few (Sraders, 2018). While payback length may have been daunting to community members, converting payback to ROI terms illustrates that higher ROIs can still occur given longer payback periods, allowing the results to become more meaningful and ultimately more viable to community members.

4.1.24 **Understanding community history**

Some communities have difficulties in developing and maintaining interest in community projects. This struggle could result from a history of exploitation (Morris, 2017; Bullard, 1990) that shapes perceptions of currently proposed projects. Communities that experienced a history of exploitation for natural resource extraction, industrial pollution, or large energy development projects (for example) can become communities skeptical of outsiders. Some communities experience a local project as providing benefits outside of the community (Catney et al. 2014; Devine-Wright and Wiersma 2013). It is important for community members to conceive the project as local. Communities who do not perceive benefits to stay local may become apathetic or in some cases develop extreme opposition. There may be conflicting institutional priorities that influence a project (Wirth, 2014). These community projects may be driven by goals that do not reflect community goals, values, or beliefs.

This was consistent with findings from this case study. Many community members cited opposition to this project based on experiences with previous renewable energy projects. An external community developer proposed building a large wind farm near the two villages. Community members were reluctant to support the development of this project, which was further aided by the developer's decision to remove community members from the project development process. A second example is the existing "renewable" energy facility which is located within the Village of L'Anse yet sells power to an electric utility located in the lower peninsula. The L'Anse Warden Biomass Plant claims a renewable status as it burns a percentage of its fuel as wood chips. However, the plant also utilizes old tires and treated railroad ties for fuel, resulting in air pollution to the area. Community members expressed frustration with a plant located in their community where the benefits do not stay local, but the environmental burdens do.

4.1.25 Discussion

This paper utilized data triangulated from interviews and focus group discussions, community surveys, and participant observations to explore the social factors that industry decision makers should consider to strengthen local community solar program viability. Specifically, it explored factors such as community identity and trust, in conjunction with knowledge, environmental values, and economic status. These last three factors are well cited in the broader community energy literature and so are acknowledged as important to community solar viability. While community identity (both models), trust (model 1), and environmental values (model 2) are significant predictors in the logistic regression models, it is important to remember the problems with relying on data that utilizes reported intentions rather than observed behavior. Respondents who reported a willingness to purchase shares may or may not actually buy shares when the program is developed. Leaning on qualitative data in conjunction with survey findings can help to improve the program viability in this respect.

Trust appears to have a positive relationship with support but not with willingness to purchase shares. While this is consistent with the literature, it is slightly inconsistent with findings from the qualitative data. The qualitative interviews and focus group discussions pointed to building trust as an important avenue for project viability. However, the specific dimensions of trust operationalized in the survey instrument and qualitative findings are different. The survey instrument captured only trust in the electric utility whereas the qualitative data collection highlighted trust in outsiders that may be equally relevant to the story. This may be a limitation to the study. It is important that decision makers build upon multiple dimensions of trust to strengthen program viability.

Economic status as LMI or non-LMI household is not significant in this model. Status as an LMI household was not significant with willingness to purchase shares in the regression model, which is inconsistent with both interview and focus group discussion findings, where participants felt cost and income would impact the project viability. The information surrounding these types of project is available from industry experts and reports along with solar developers who view project viability in terms of economics. Additionally, community solar is still a new application that involves a different adoption scale compared to other solar energy installations. This means there may be a challenge in looking to literature to explain solar adoption in terms of economic status.

Community identity has a significant positive relationship with both support and willingness to purchase. This is consistent with the prior literature evaluated and our findings from the qualitative data. Community solar is dramatically growing across the U.S. It is still a new and different application of solar energy technology that seeks to provide social along with economic benefits to community members. The environmental value variable was significant in the second logistic regression model. This is consistent with the literature we evaluated that pointed to environment values as important to influencing action, in the form of willingness to purchase, in energy systems (Gilg et al, 2005, Gadenne et al, 2011).

Overall, survey findings with regards to knowledge are not significant predictors is consistent with the literature. The literature and qualitative data both point to the importance of considering other social values when developing community energy projects. The survey was developed from qualitative interviews with key leaders in the community and focus group discussions from community members interested community solar. The awareness and experience with community solar, or broadly solar PV found with interview and discussion participants may not be representative of the broader target populations of L'Anse and Baraga.

The qualitative data and community context illustrate areas to improve industry and solar developer practices towards incorporating community needs and values. Qualitative study participants generally felt positively about the idea of developing a community solar project. The interviews and discussions uncovered themes that industry and solar developers should consider in designing and marketing a potential community solar program. The resistance to change culture prevalent in each village could reduce peoples' willingness to adopt community solar. This may be a culture prevalent in locations beyond L'Anse and Baraga. Clearly communicating the positive benefits and pointing to demonstration projects can be beneficial to combatting project inertia. Building trust is a process that takes time. Industry and solar developers should partner with trusted community organizations to build rapport in the community. Linking a community solar project to ideas that locals are more familiar/experienced with and feel positively about may help produce more project success.

Economic concerns remain an important component to community solar viability and implementation. Rather than basing projects solely on economic benefits for those building community solar, industry and solar developers can expand the economic focus to provide flexibility in project design. Multiple financing programs can not only improve subscriber rates overall, they can increase access to lower income residents. The possibility for bringing economic returns is also important and attractive, but this must be communicated in a way that becomes meaningful for potential community participants.

Participants pointed to several dimensions of community identity such as community empowerment, community pride, local control, and energy independence associated with community solar. These are factors industry decision makers can use when marketing these programs. The message should center on keeping benefits local, such as creation of local jobs, local energy generation, dollars circulated locally, local skills and education opportunities, and attracting new visitors and residents to the area. Finally, environmental values are important to community members. Building the components of sustainable, green energy and local energy source into the overall community solar program development message can help community members identify with and find important, convincing reasons to subscribe. Ultimately, these factors can help to enhance or improve relationships between program developers and strengthen program viability.

4.1.26 Conclusions

Village administrator approved the development of the community solar programs. This study sought to provide solar industry experts a better understanding of factors that are important for program viability from the community's perspective. It combined qualitative interviews and focus group discussion data with quantitative survey data and statistical analyses to measure viability in terms of trust, community identity, and economic status. Study findings are juxta positioned within the social context of the communities that can shape the viability of community solar projects beyond financial viability itself (Walker et al, 2010, Wirth, 2014, Ruggiero et al, 2018).

Combining interviews, focus group discussions, and working within the community context can influence program viability in terms of program support and willingness to buy shares. Industry experts and external program developers can focus on building trust in communities and linking program design to community identity to ultimately strengthen community solar viability. Additionally, the community social context presents factors including presence of a local champion, accessing available and appropriate sites, pursuing funding to reduce costs, communicating results in a way that becomes meaningful, and understanding the community history which can contribute to the likelihood that a community solar program will succeed. Refocusing efforts to advertise community solar not only as a model to increase affordability of solar energy to all populations but as a tool to bring additional community benefits beyond economics can help broaden the viability scope.

This study looked to address a perceived gap between industry experts and individual communities with respect to adoption and success of community solar programs. Community solar program viability has generally been assessed through an economic lens. However, there is desire for policy to broaden its scope to consider other benefits that a community solar program can provide. While community solar is growing in the U.S. program participation/subscription has struggled. By understanding how a community views program viability can help to connect the mismatch between industry experts and community members. This article highlights the importance of social factors such as trust and community identity, along with social context that can contribute to community solar viability. By understanding and linking the project to a sense of community identity, building trust in the community, and teasing apart community context and dynamics can help aid project viability.

4.1.27 References

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5 Conclusions

Energy is the main way we produce and obtain basic goods and needs for our existence. The current U.S. energy system is problematic as there is a mismatch between the level of decision-making regarding existing policies and the level at which those decision makers implement policies. The scale at which energy decisions (i.e. size and type) are made matters in terms of recognizing energy injustices (i.e. outcome distribution, access and affordability, procedural fairness, etc.) that occur as a result these decisions. Case studies of community solar program development suggest that engaging communities can be a more just approach to energy decision making.

This dissertation utilizes procedural and distributive energy justice and scale politics scholarship to analyze community solar case study data in two Upper Peninsula, Michigan, USA communities. The research above applies a collaborative governance approach to the type of decision making explored in this research. The dissertation examines how community solar can or cannot reconcile with issues of scale to improve energy justice outcomes of energy systems. This dissertation includes three chapters and three additional background works (Appendix A, Appendix B, and Appendix C) that each seek to understand: the opportunities and challenges of community solar to contribute to more a just energy system in Michigan. ?

5.1 Chapter review and policy suggestions

Each chapter attempts to answer the research question from a different vantage point. Chapter 2 provides a review of Michigan energy policies, legislation, and regulatory regimes. It describes how utilities exercise their power within and outside these existing regimes to hinder DG proliferation. A limitation of this chapter is that it does not address the dominant approach to ratemaking that exists for Michigan IOUs. Explaining this process is crucial to understand the main reason behind utility reluctance to compete with DG. MPSC regulation allots a fair rate of return at 10% for Michigan utility investments (MPSC, 2018). The rate base is the net of capital costs and depreciation value. The rate base is essential to each utility's profitability as it is directly multiplied by the rate of return. Continuing with this dominant and traditional utility regulatory model provides little incentive for IOUs to accept DG.

Due to ratemaking, a utility is disincentivized to promote, support, or accept DG systems. Broadly, the ratemaking formula utilizes variables to produce a revenue requirement that is key to cost of service regulation (MPSC, 2014). The revenue requirement represents the total amount that utilities can collect from all ratepayers to earn a reasonable rate of return. Michigan utilizes cost of service regulation to allocate the revenue requirement across different customer types. Each customer type, or grouping of customers (i.e. residential, commercial, industrial) share characteristics such as energy demand or usage. By doing this, the MPSC can then provide a target rate each customer type pays to the utility to ensure the fair return on investment. Utilities bill based on kilowatt per hour usage (volumetric sales) which means a portion of their return comes from customers using more electricity. Utilities justify reluctance to support DG due to its impact total usage: customers who install DG systems may use less electricity, resulting in decreased sales for utilities. However the infrastructure costs the same amount regardless of the amount of electricity flowing. Ultimately, the traditional ratemaking model disincentivizes a utility to accept DG systems because they ultimately impact the utility's profits.

This chapter left out a crucial piece when looking to policy recommendations to support DG proliferation that suggests alternative ratemaking models which are addressed here. The first is marginal cost pricing that charges customers average rates based on a utility's financial data from the prior year (Cudahy, 1976). Another option is to keep a utility's profit incentive but place the burden of producing profits on the utility rather than the ratepayer. For example, the price of power is capped or set at a level and the utility must work to lower costs below this level to continue obtaining profits (Kirsch and Morey, 2016) . Other alternatives exist, such as rate decoupling or straight fixed variable, however these function to remove a utility's incentive to sell more electricity volume and shift cost recovery to fixed monthly charges (Tomain and Cudahy, 2011). A final suggestion includes a multi-year rate plan that looks to actual utility costs outside utility control, such as fuel costs, rather than internal profits. This allows utilities to explore opportunities to cut costs for profitability (DOE, 2015). While both benefits and shortcomings accompany each of these options, they each provide opportunities to encourage the increased adoption of DG systems.

Chapter 3 reflects upon the social feasibility methodology used in a specific case study to both describe the research process used and incorporate collaborative governance principles to both inform and improve community engagement. Broadly it promotes a more just approach to improve procedural energy justice by (1) describing community engaged scholarship as a means to insert local control and affordability into energy systems and (2) utilizing collaborative governance principles to help the research approach overcome limitations to achieve local control and affordability of energy systems in Michigan.

A policy suggestion for engaging communities is to look to environmental impact statements (EIS) for guidance. An EIS is an assessment that describes potential impacts for proposed activities on the environment. The National Environmental Policy Act requires major federal actions must undergo review and analysis (NEPA, 1969). The broad statute language extends these requirements to private projects that must obtain some form of federal approval (Hayes and Hourihan, 1985). Conducting similar analyses for community level energy projects may be an answer to the energy justice call for integrating humans into our energy systems. In recent discussions, a DTE spokesperson noted the large expense of conducting community engagement. This ties into making decisions based on cost-effectiveness. A state level policy could require a community level impact assessment before building community energy projects without community approval. This requirement could allow utilities to work with communities to better understand their needs and values to determine if the project should move forward. It can also help to build better utility-community trust relations.

Chapter 4 analyzes interviews and focus group discussions, survey data, and the community context collected from a social feasibility study conducted in two villages in the Upper Peninsula of Michigan. The chapter aims to understand what community members deem important for community solar program viability.

This chapter serves to inform industry experts and solar developers that social factors and community context can be significant in determining the viability. Incorporating these factors and considerations can help strengthen community solar viability. This chapter noted the challenge with engaging LMI households into community solar systems. One major policy suggestion would be to include community solar supportive policies with specific targets for LMI customers. Several states such as California, Colorado, Oregon, Minnesota, and Illinois, among others (NREL, 2018) have existing and emerging LMI community solar carveouts. Michigan could look to these programs and develop policies that increase LMI participation in community solar systems. Additionally, understanding the broader social benefits of community solar, industry decision makers could look to recruiting local labor forces from the communities within which these projects are located.

5.2 Reconciling with energy justice

Ultimately, each chapter attempts to illustrate a different way of exploring how community solar can be used to improve Michigan's energy future. Each chapter recognizes the perceptual, social, economic, technical, leadership, governance, or institutional dimensions by which community solar development interfaces with existing policy and future policy development. Decision making can also be associated with dimensions that can vary in terms of procedural energy justice and influence the just distribution of energy system outcomes. Current U.S. energy decision making centers around the cost-effectiveness or technical viability of energy systems. Decision making power rests with the government and corporate actors who have the economic, political, and knowledge necessary to engage in decision making. Actors with political power and the ability to influence energy policy perpetuate power imbalances and shape the disconnect between who makes decisions, at what scales (local, regional, national), and the different populations impacted by those decisions (Banerjee et al, 2017, Prehoda et al, 2019). Specifically, rural, remote, and low-to-moderate populations experience inequitable distribution of the benefits and burdens of energy systems. These populations pay higher costs for energy infrastructure that is less reliable compared to other urban and more affluent communities. As an indirect result of energy distributions, these populations experience social power imbalances that lock them out of participating or sharing in wealth generating benefits of energy systems.

Community solar program development presents an opportunity to shift the decision making process. It can involve local participation and ownership in energy decision making that attempts to place control at the community level. Community solar can be designed to spread system costs and benefits equitably among program participants. Community solar also seeks to remove any potential placement of community solar burdens (e.g. cost or aesthetic concerns) on non-participant community members. While community solar presents a relatively new and arguably more beneficial way to increase access, affordability, and reliability of energy systems, one concern is that top-down or external decision making to implement community energy projects on local scale without community input perpetuate procedural energy injustices (Catney et al. 2014, Devine-Wright and Wiersma 2013, Ruggiero et al. 2018). Energy justice does not apply to just one level of decision making. A lack of institutional and policy support at the state level leaves decision making regarding community energy systems with corporate actors who center decisions around financial bottom lines. This practice shifts benefits from communities to a select few (i.e. IOUs), while the system financial, environmental, and other social costs are left behind.

Inherently, community solar is a just application of solar technology. It is an unconventional energy application that does not fit the mold of our energy generation, transmission, and distribution. While it attempts to reconcile experiences with power, benefits, and burdens imbalances through local siting and ownership, external (to the community) parties continually strive to position community solar within existing utility regulatory regimes. As a result, community solar program design can fall short of attaining its goals of increasing access, affordability, and reliability for communities, ultimately perpetuating imbalances and injustices that currently exist. Social burdens are a product of continuing to make energy decisions regarding community solar based on cost-effectiveness for profitability alone rather than looking to community input and needs. This approach does not provide full participation, is biased, and ignores the benefits and burdens that may be experienced by smaller scales, i.e. communities (Catney et al, 2014). This dissertation recognizes the opportunities and challenges for community solar to influence more just Michigan energy policy. It calls for energy decision making to move beyond economics and consider the broader social benefits available to communities that otherwise experience adverse impacts of our energy system. Social benefits can include enhanced energy education, increased community pride, increased trust and relations with community decision makers, and the potential for job creation, to name a few. Guided by procedural and distributive energy justice and collaborative governance strategies, decision makers can refocus community solar program design to emphasize its merits as a just technology. Creating and implementing community solar enabling policies can be a first step to signal the Michigan energy policy transition towards more just decision making and benefit, burden, and power distribution.

Chapter 2 addresses how current energy policies can shift towards energy systems that support DG. It explores actors operating within larger legal and regulatory regimes that do not align with procedural and distributive energy justice forms. Sharing in benefits and burdens of energy systems are skewed towards those with more economic, political, and social power who exercise their power to maintain the status quo of wealth generation. Chapter 3 looks at how involving community members at the local scale can be improved to better align with procedural and distributive energy justice. As a researcher, I experienced challenges throughout the community solar program design process that fell short of aligning with energy justice considerations. This chapter leaned on collaborative governance strategies to help improve the research process of involving community members in community solar program design. Chapter 4 investigates and reports community perspectives of community solar program viability. Traditionally, solar and the broader energy industry conceptualize program viability in terms of economics. This disconnect does not allow community solar to reach its full potential as a procedural and distributive energy just application. However, incorporating community member perspectives from a full participation research process into program development decisions can further strengthen the viability of community solar programs. The chapters combine synergistically to argue for a collaborative governance approach to community solar development as a means to improve Michigan energy policy decision making. As collaborative governance and energy justice operate at multiple levels, energy systems can begin to reflect viewpoints and needs of those previously left out of participating and benefiting from energy systems. Affected communities that are involved in decision making deem the process as fair, a dimension that matters to people (Colquitt et al, 2001). Leaning on procedural and distributive energy justice considerations can guide energy policy decision making towards a more equitable allocation of benefits, burdens, and power relations.

5.3 Future research

My research findings focused on the process of developing more just energy policy in Michigan. Future research related to Michigan energy policy could look to an evaluation of how well the community solar process reconciled with procedural energy justice. For example, this research was conducted within two communities. Future research could return to those communities after program implementation to assess if the program adequately addressed community needs. A post social feasibility study can evaluate community solar program itself for its ability to attain and retain broader social benefits. As community solar intends to increase access and affordability of energy systems an evaluation of the impact on LMI households would be helpful. For example, Michigan utilities offer the Low Income Home Energy Assistance Program (LIHEAP) funds to help LMI households manage energy bills and costs, alongside investments in weatherization repairs. Future research could explore existing programs for decreased use of LIHEAP funds. An additional evaluation would measure changes after program implementation. For example, assessing if LMI homes that participate in community solar programs experience less electricity disconnect. As chapter 4 highlights, there is a disconnect between solar industry reports that conceptualize community solar in economic viability terms and communities' perceptions of overall project viability needs. Future work would explore how solar developers conceptualize community solar and compare this to community data. Themes that emerge from solar developers' conceptualizations could function to weaken any potential program viability. The work conducted in this dissertation and future work could be integral to evaluating community solar in a way that catalyzes stronger community solar institutional support.

5.4 References

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A Renewable, ethical? Assessing the energy justice potential of renewable electricity

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Abstract: Energy justice is increasingly being used as a framework to conceptualize the impacts of energy decision making in more holistic ways and to consider the social implications in terms of existing ethical values. Similarly, renewable energy technologies are increasingly being promoted for their environmental and social benefits. However, little work has been done to systematically examine the extent to which, in what ways and in what contexts, renewable energy technologies can contribute to achieving energy justice. This paper assesses the potential of renewable electricity technologies to address energy justice in various global contexts via a systematic review of existing studies analyzed in terms of the principles and dimensions of energy justice. Based on publications including peer reviewed academic literature, books, and in some cases reports by government or international organizations, we assess renewable electricity technologies in both grid integrated and off-grid use contexts. We conduct our investigation through the rubric of the affirmative and prohibitive principles of energy justice and in terms of its temporal, geographic, socio-political, economic, and technological dimensions. Renewable electricity technology development has and continue to have different impacts in different social contexts, and by considering the different impacts explicitly across global contexts, including differences between rural and urban contexts, this paper contributes to identifying and understanding how, in what ways, and in what particular conditions and circumstances renewable electricity technologies may correspond with or work to promote energy justice.

Keywords: energy justice; renewable energy; intergenerational justice; energy poverty socioeconomic justice

1. Introduction

Whereas the global economy runs on oil, it is electricity that powers it. Electricity pervades the residential, commercial, and industrial sectors providing lighting, heating, and cooling services whilst ensuring that assembly lines are moving and metros deliver their passengers on time. As a source of energy, electricity can be easily used, accessed, and demand-adjusted [1]. Historically, hydrocarbon and nuclear resources, especially coal, were used in electricity production propelling the developed countries towards prosperity [2]. However, this prosperity came at the high environmental, social, and political costs associated with extraction, transportation, and combustion of fossil fuels [1]. Additionally, the intensive use has limited easy to access and economically competitive non-renewable fossil fuel reserves [2,3]. It is thus essential to look for alternatives to continue electricity production to meet future energy demands.

Whilst hydro has served as an affordable and reliable renewable source since the dawn of electrification, other renewable energy resources, solar and wind, in particular, have emerged as economically viable options to meet current and future energy needs with significantly lower environmental, social, and political impacts. Globally, investments in renewable resource-based electricity (RE) have been made at an unprecedented rate [4]. This has led to a momentous worldwide increase in the number of RE facilities and the overall capacity including 1064 gigawatts (GW) of hydropower, 433 GW of wind power, and 231 GW of solar power in 2015 [5]. The scale of RE operation required to significantly reduce societal dependence on fossil-fuel energy can be imagined as colossal [6,7,8].

The transition of electricity production from fossil fuel to non-fossil fuel energy sources is fundamentally changing how energy is produced around the world. The proliferation of new RE technologies not only alters supply chains and energy infrastructure – RE projects change social and political structures in the nations, regions, and communities in which they are implemented. Such new developments also open a floodgate of positive and negative externalities affecting people with the ills or benefits of RE projects. Thus, the impacts of RE externalities have been subject of research specifically to examine these effects [9-263]. In some cases, new RE projects affect the connections people have with the place where they live [9,10,11,12], leading to societal acceptance [13,14], rejection [15], or other mixed responses towards RE projects [16]. These reactions can be based on actual or perceived injustices of the negative externalities resultant from RE development that can impact social life [17]. The burdens resulting from RE development may also be unequally distributed within societal groups, affecting different groups differently [18,19]. Apart from the impact of the socio-physical realities of new RE developments, other issues may also arise related to the capability of RE in mitigating energy poverty from access and affordability constraints [20,21,22].

In order to envisage the emergent RE sector as an integral part of a sustainable future, it is critical to avoid and if not possible, minimize negative externalities that give rise to injustices associated with energy development while transitioning to a low-carbon future. Therefore, at the current juncture when traditional ways of producing energy are increasingly being replaced by new RE, there is a need to take stock of the interlinkages among RE and energy justice. Recent scholarship tends to highlight the energy justice potential of renewable sources (for example, [17,19,23,24,25]). Also, there is a line of scholarship targeting qualitative assessment and effective measurement tools for energy-related injustices (mainly fossil fuel and nuclear) [1,26,27]. However, there is perhaps no existing work where an energy-justice related framework is used to assess the justice and injustice potential of RE projects.

A sustainable energy future calls for energy systems to be guided by principles of justice. This requires inclusion of justice goals in RE planning and development and necessitates understanding how RE projects can adhere to principles of energy justice. Given this development, the goal of this paper is to assess existing research to find out to what extent the literature on RE development worldwide addresses energy justice considerations. We use the energy justice assessment framework proposed by Sovacool et al. [1]. In this work, the scholars use the framework to mainly discuss energy justice related to fossil fuels and nuclear energy. We use this framework to assess the energy justice of RE development, identifying dimensions of energy justice in RE development discussed in current literature, noting the tradeoffs and challenges ensuring energy justice and pointing out the future research needs.

This paper focuses specifically on electricity generation technologies based on the three leading forms of RE worldwide, according to recent data, i.e. wind, solar, and hydro [5]. We selected these three forms of renewable resources given their global scope of operation. Further, wind, water, and solar technologies can be scaled up or down to address electricity demands without substantial changes in technologies or to operationalizing its use. Additionally, wind, solar hydro, and hydro resources can potentially provide energy to the transportation sector with required technological and infrastructural development. We conduct our review via systematic appraisal of existing original research analyzed in terms of the dimensions and principles of energy justice. In the following sections, we first introduce the conceptual framework regarding energy justice used in our analysis. Then, taking note of RE development in both highly centralized electrically and electrically dispersed contexts, we review the literature and analyze it in terms of geographic, temporal, technological, economic, and socio-political dimensions and based on the affirmative and prohibitive principles of energy justice.

2. The Analytical Framework

Justice is a highly contested concept with diverse meanings. One definition of energy justice is “a global energy system that fairly disseminates both the benefits and costs of energy services, and one that has representative and impartial decision-making” ([27], p. 436). In the fair dissemination of benefits and costs, future generations should also be represented so that they do not bear the burdens resulting from current energy consumption [28]. However, when considering low-carbon energy transition, researchers have recognized energy poverty, fuel poverty, energy insecurity, energy deprivation, and other problems of associated with lack of access and affordability of energy [29,30]. Therefore, energy justice should also be defined to consider that all people need energy to meet necessities and thus should be able to access and afford energy. McCauley et al. [31] summarizes these aspects in their work proposing energy justice should be based on three central tenets: distributive justice (where ills and benefits are justly distributed), procedural justice (where procedures equitably allow the participation of all stakeholders), and recognition justice (inclusion of the needs of the energy poor, the people opposing power plants in their communities etc. in decision making).

Energy justice is an emerging field of study and there are many ways in which energy justice is being theorized (notably [31,32,33]). However, what lacks in most of this work is how we can use the tenets and put them in practice to evaluate research emerging on RE developments. In their work, Sovacool et al. [1] developed a framework to highlight how current and future development of energy systems (relying on traditional sources) have a tendency to interfere with populations ability to meet basic needs and obtain basic goods. Critiquing fossil fuel and nuclear resource-based energy projects in this work, Sovacool et al. [1] establish that: (i) energy justice can be explained using two principles, affirmative and prohibitive; and (ii) energy injustices can be categorized as occurring in often overlapping geographic, temporal, technological, economic, and sociopolitical dimensions.

The philosophical underpinning of understanding energy justice foundational to Sovacool et al. [1] aligns with the philosophical conceptions of justice as reviewed in Sovacool and Dworkin [33]. In this work, the authors apply six philosophical concepts found in justice theory: (1) human rights, (2) procedure, (3) welfare and happiness, (4) freedom, (5) posterity, and (6) fairness, responsibility, and capacity when studying energy developments. The prohibitive and the affirmative principles proposed by Sovacool et al. [1], by their definition, directly or indirectly encompass justice principles. The prohibitive principle states that "energy systems must be designed and constructed in such a way that they do not unduly interfere with the ability of people to acquire those basic goods to which they are justly entitled" ([1], p. 3). The affirmative principle asserts that "if any of the basic goods to which people are justly entitled can only be secured using energy services, then, in that case, there is also a derivative entitlement to the energy services" ([1], p. 3). As energy services help people attain essential access to goods and other services for human flourishing, a just energy system should ensure that everyone has access to energy sources (affirmative principle) and the ills and benefits of an energy system does not unduly affect anyone in such a way that they lose access to other goods (prohibitive principle).

We utilize this framework to consider renewable energy projects to operationalize energy justice in evaluating RE developments. As justice is a highly debated concept, we use the prohibitive and affirmative principles to frame justice simply as equity and equality of distribution of burdens and benefits and then explore how existing RE scholarship addresses these tenets via five dimensions – geographic, temporal, technological, economic, and sociopolitical. However, going beyond the anthropocentric definition of energy justice, while conducting our research we broaden the scope of energy justice by adding inter-species impacts of RE systems, proposing that a just energy system is also one that also does not endanger species critical for ecological systems to survive, which is important in itself and extremely useful in supporting human life.

The geographic dimension focuses on the spatial allocation of energy services and the costs and benefits associated with them. Uneven energy development that affects one place more than others also involves changes to the ecological and environmental conditions in the area, impacting local communities in ways that can even lead to degradation or even displacement. This section considers RE in terms of the affirmative and prohibitive energy justice principles. In which a just energy system would include characteristics that lessen the uneven geographic impacts associated with energy development projects and improve access to energy to obtain basic needs.

The temporal dimension of energy justice stresses energy systems as an intergenerational issue, where the negative externalities of energy production and use of current generation continue to impact future generations (hence capturing intergenerational ethical obligations). Therefore, this section considers how just RE systems can elicit externalities that prevent or hinder future generation's abilities to obtain their basic goods, either through the provision of fuels or access to energy to satisfy basic goods. Therefore, a just energy system should have characteristics that lead to reduced or negligible impacts on future generations and the ways and means essential for maintained quality of life. Temporal dimensions explore intergenerational and also inter-species energy justice issues, where energy injustices will affect the generations to come who will be impacted by climate change, degraded landscapes, biodiversity loss, air pollution and associated health implications in the future stemming from current energy use.

The technological dimension explores inherent ethical deficiencies of energy systems in relation to their safety, efficiency, reliability, and vulnerability to external security threats. This section considers whether the technical components of the energy system itself have the capacity to reconcile with these principles. A just technical energy system would provide non-interference, reliable, safe, and non-vulnerability with the provision of basic goods. The economic dimension of energy justice mainly concerns the social distribution of energy services and the costs and benefits associated with them. Sovacool et al. [1] point out that energy services should be distributed in such a way that people across social groups can have access to energy that is affordable enough to cover at least the basic requirements to maintain a dignified life. Often the lack of physical access or the costs of energy services prohibits people from accessing its benefits. Therefore, a just energy system addresses both principles by considering RE projects that do not elicit negative economic impacts or cause an imbalance to different economic groups. The sociopolitical dimension of the energy system is closely tied with the economic dimension. A just energy system from the sociopolitical viewpoint would uphold the principles of human rights, democracy, and political process devoid of any dysfunctional nexus between energy producers and the government. A just energy system should also ensure that no social groups are marginalized from or given access to energy based solely on their social status.

3. RE Through the Lenses of Energy Justice

We organize the results in terms of their closest relevance to the geographic, temporal, technological, economic, and sociopolitical dimensions of energy justice. Each subsection below first highlights the major trends that emerged from our review. The review was compiled based on a systematic search for peer reviewed literature, books, and in some cases reports by government or international organizations reporting empirical research findings on the impacts of RE technology. The Google Scholar database was used and articles published between 2010 and 2017 were included. Initial search terms were based on the dimensions of energy justice used to organize the analysis; additional search terms developed based on the preliminary trends resulting from this initial search. For example, to assess the geographical dimension of RE projects, we targeted articles and reports specifically related to developing nations, with special focus on the sub-Saharan Africa, Asia, and in other rural areas of the Global South. Articles were searched utilizing key terms such as “RE and developing nations,” “rural electrification,” “energy poverty,” “energy access,” “Africa,” “India,” and “developed versus developing.” To search literature for the technical dimension keywords like “water impacts of solar/wind/hydro power”, “mining impact of renewable energy” and “ecological impacts of renewable energy” was used. After identifying the trends, specific key words like “wind power impacts on bats” or “water use of Concentrated Solar Power” were used. A similar method was employed when searching for articles in the technological dimension. Keywords in this search included “RE and technology,” “fossil fuel impacts, and health.” For economic dimension, search terms were mainly like “energy poverty and renewable energy” and “renewable energy and energy poverty in developing countries.” Similarly, for sociopolitical dimensions search terms were based on the key themes like “land acquisition renewable energy”, “green lobby and renewable energy”, “public participation in renewable energy decision making” were used.

As the main purpose of this work is to develop an understanding of how RE development is conceptualized in terms of the range of energy justice impacts, the sampling frame focused on sampling for diversity, finding a range of perspectives and trends, rather than a quantitative count of content. Given that we were more interested in finding the range of emerging trends of RE related to energy justice and injustice rather than the number of papers that reported on a thematic area, use of a single database sufficed this purpose, as we could find a broad range of issues covered in the articles selected for review. Delimiting our search between 2010–2017 (even though, for example, lifecycle analysis-based articles of RE technologies have been published since the 1990s) had two purposes. This date range helped focus the review on the impacts of current technology used rather than on older technologies. Moreover, understanding of the impacts of RE have also evolved with time as prices of technologies have fallen, scale of operation has enlarged, and penetration of RE has made it more or less contested due to socio-political reasons in recent years. In some cases, when recent articles were not available, search periods were extended. Thousands of articles came up in these searches, and articles were selected that reported original research that narrowed down to 20–30 articles for each dimension and numerous articles that address multiple dimensions with a total inclusion of over 200 studies in this review. Each article was analyzed to assess whether RE development aids or attenuates the affirmative and/or prohibitive principles. Articles were also distinguished based on the types of RE systems, either centralized or distributed, where scale plays a role in aiding or attenuating energy justice. Where possible and when possible depending on the availability of literature, we also tried to separate the impacts of decentralized energy systems from the impacts of centralized energy systems. However, it was always not possible due to lack of clarity in the reported research.

3.1. Geographic dimension of justice in renewable electricity

A basic requirement of development is access to energy. As mentioned above, energy is instrumental for human flourishing. Energy influences many quality of life indicators, including access to drinking water, life expectancy, mortality, education, and poverty reduction [34]. A key for improving these indicators is electrification [35]. Currently, 1.2 billion people (about 17%) live without access to electricity whereas 2.7 billion cook by using the traditional biomass, which results in 3.5 million deaths due to indoor air pollution [36]. Lack of electricity has adverse impacts on socioeconomic conditions in developing countries and rural regions of developed countries highlighting the inequitable geographic distribution of energy services [37].

As mentioned above, energy poverty is intertwined with lack of access to energy and energy services. Populations that are said to live in energy poverty are unable to maintain daily activities that require energy use. Many rural regions and developing nations live in energy poverty due to a lack of affordable energy services, lack of energy infrastructure, or both [26]. Most populations (about 95%) experiencing energy poverty live in sub-Saharan Africa and Asia, with about 80% living in rural regions [36].

Adverse impacts of living in energy poverty include health issues. Many households in developing nations and rural regions rely on renewable energy sources (i.e. biomass) for cooking, which, as noted above, has severe health implications. Problems such as respiratory infections, lung cancer, asthma, and many others arise out the indoor biomass combustion. Many developing nations and rural regions lack access to electrification, which negatively impacts education as many children who attend primary school in these communities do not have access to electricity. Finally, energy poverty can be linked to lackluster development in these communities. Electricity is instrumental for having running water and modern sanitation, which in turn are keys to overall improved health care, high life expectancy, lower mortality, and poverty reduction. It is important to note that traditionally, overall energy consumption was directly linked to economic development. While the direct link has been refuted in relation to developed nations, there is still overwhelming evidence such a connection exists in developing nations where it further linked to reducing overall poverty level [38].

The issue of energy poverty as a function of energy access has been in the purview of several international organizations, including the United Nations, World Health Organization, and International Energy Agency. In addition, various private and public-private partnerships have been contributing to resolving the energy poverty problem. While some studies have suggested large-scale RE installations for electrification in these areas, they may not be suitable for all rural areas and developing regions hindered by lack of electricity access [39,40,41]. A more pragmatic approach suggests utilizing RE powered mini-grids to provide lighting, heating, clean cooking, and other energy needs to local communities [42,43,44]. Smaller, decentralized RE grids can provide the optimal option for increasing energy access [45,46,47], and many feasibility studies have analyzed the use of RE systems to increase energy access and subsequent well-being in developing nations and rural regions including studies projections for future energy access [48-50].

Seventy percent of India's population lives in rural areas, making up twenty-five percent of the world's poor population [51]. Therefore, India serves as a preliminary case study and major driver for energy access studies, in light of the affirmative energy justice principle [52,53]. Similar studies have been conducted in sub-Saharan African nations [54,55,56]. Additionally, several studies have been conducted assessing the progress and success of energy access initiatives in rural regions in India [57], with a majority of projects focused on solar PV RE technologies [52,58,59]. These studies provide continuing evidence in support of decentralized RE powered micro-grid systems versus large-scale RE utility projects. Specifically, rural electrification in India provides many benefits, including improved education, increased employment, improved health, and overall reduction in poverty [60]. In studies in the African context, most researchers address optimal ways to increase energy access, through international development funds, clean energy programs, and rural electrification initiatives [48,49,61]. Within the geographical dimension, common topics include addressing energy poverty in terms of health, education, drinking water, and overall poverty.

This review found a dearth of information surrounding RE projects in the context of the geographical dimension of justice through the prohibitive principle lens. Rural communities are especially impacted by conventional energy systems, and energy planning and policy must balance the inequitable distribution of impacts and access across geographical scales. Large-scale standalone RE projects may not have the capacity to solve all rural energy scarcity problems (other than basic lighting services), as appliances and methods of heating and cooking differ from urban and rural areas, especially in energy poor remote communities [62,63,64]. Therefore, large-scale RE may have limited scope in mitigating energy poverty-related justice issues in rural and remote communities. However, smaller decentralized RE powered microgrid systems maybe provide a more appropriate solution. In addition, such projects can aid in developing communication infrastructure, commerce, health, education, and mobility in rural areas [65–72]. The affirmative principle is also addressed. Most articles focus on rural regions in developing nations of sub-Saharan Africa and India. Researchers acknowledge RE technology's capacity to improve existing conditions of energy poverty in these regions, using indicators such as better drinking water, education, health, and reduced poverty levels. In terms of the global geography of poverty, RE development offers a key tool for addressing energy injustice by both providing energy access and mitigate the environmental harms associated with energy provision. There is a lack of research surrounding energy poverty issues and rural regions in developed nations. While this problem may not be as prominent compared to some least developed regions, it is still important to acknowledge access and affordability to energy in these regions as well.

3.2. Temporal dimension of justice in renewable electricity

The prohibitive principle illustrates how transitioning to RE is justified in the face of climate change from greenhouse gas emissions, resource scarcity, pollution, increasing water stress, and how the impact on other species all of which is essential for current and future generations ability to acquire basic goods. Based on the affirmative principle, our review also included articles on the scope of RE to be able to provide for essential electricity needs for the future generations. Applying the prohibitive and affirmative principles of RE justice involved reviewing existing literature and examining the designs and structures of RE systems that can unduly interfere with future generations ability to acquire essential goods and access to energy services. It is important to recognize here that conclusive results on the capabilities or restrictions of RE to provide future generations with essential goods and services cannot be determined entirely at present time as such impacts can only be evaluated at a future date; currently we can only predict some of the temporal impacts with much certainty. Elaborating further, the current dominant energy system, which utilizes fossil fuels can negatively impact future generations' ability to obtain basic goods and services, particularly under changed climate conditions as a result of GHG emissions and depleted natural resources leading to intergenerational injustices [73,74,75]. Therefore, shifting energy production to renewable resources can significantly decrease the climate-impacting GHG emissions from power generation [76], saving future generations from the increased likelihood of catastrophic climate events. Other positive externalities of RE include the positive impacts on public health from reduced atmospheric pollution levels [77,78]. As a result of this shift, future generations can benefit from clean water and air required which are two of the essential life sustaining basic good. By reducing the climate impacts of fossil fuels, RE can significantly further energy justice potential based on prohibitive principle. When compared with fossil fuels, RE systems can be comparatively low on emissions yet RE systems are structural realities that are becoming increasingly common; like any other system of production, RE development entails the use of nature as a source and a sink. Therefore, the energy justice potential of RE in its temporal dimension must thus be explored holistically. The cumulative effect of a large RE sector on some environmental goods and services critical to human welfare can limit future generations' ability to access basic goods. Like other energy technologies, the proliferation of RE to meet future energy demands will have GHG emissions in manufacturing, installation and operation and differ in terms of materials used in manufacturing and construction, technology, location, and climate conditions, yet such emissions are less when compared with fossil fuels.

Expansion of RE will likely increase the demand for mineral resources including gold, copper, aluminum, lithium and other metals used for manufacturing RE systems components [79–82]. The growth of the RE industry can stress readily available metal ore deposits, making metal extraction costly and energy intensive [80,83] potentially impacting the availability and affordability of these resources for other purposes in the future. Additionally, metal mining comes with a host of negative environmental externalities, which is likely to have negative intergenerational justice consequences. These impacts are less clearly defined by the scale of RE development (either large-scale centralized RE projects or a large number of decentralized RE projects) than by the material used in a specific technology and the source of that material [83].

Many energy projects require significant water resources [84]. Climate change will severely stress water resources in many parts of the world, leading to water scarcity for many communities [85,86]. This will also impact some forms of RE production as well, specifically HE [87,88]. Water use in RE projects is technology specific [89,90]. In the case of SE, water is used for cleaning dust from solar installations [91] and suppressing dust in the area surrounding a facility [89].

Water use is particularly high in certain technologies like concentrated solar power plants that require water for cooling. If wet cooling or hybrid cooling methods are used, the quantity of water utilized is often higher than in thermal coal and natural gas power plants [92–95]. However, results differ when dry-cooling technologies or synthetic nitrate in place of mined nitrates salts are used, and studies suggest that SE saves water [78,96]. Therefore, to assess the water needs of SE, the particular form and scale of the technology used are of critical consideration, with water impacts lessened in large-scale centralized projects with dry-cooling alternative methods or decentralized grid connected systems.

WE, on the other hand, has limited water needs and has a significant edge in water use when compared with conventional hydrocarbon-based electricity production.

Therefore, WE can mitigate water scarcity-related problems in water-stressed areas [97–100]. HE also has a high water footprint due to the water consumed or evaporated during electricity production [101,102,103]. However, the footprint differs based on local climate differences and structural specifications of the HE facilities [104] and the ecosystem benefits of reservoir water serving multiple purposes [105].

RE developments interact with other drivers of the global environment to have intergenerational effects on water resources that are critical to sustaining human life and on landscape-level impacts such as biodiversity. Preserving biodiversity for future generations is critical due to its known and as of yet unknown benefits arising out of having a healthy and diverse gene stock [106]. Research suggests that RE developments have mixed impacts on biodiversity [107–112]. Several studies report WE projects' adverse impacts on birds and bat populations as they collide with the blades of the wind turbine [107,113–120]. Bats provide critical ecosystem services [121, 122] and have a very slow rate of reproduction that limits their population recovery [123]. Some studies have suggested that offshore WE installations may be detrimental to marine ecosystems [124,125], yet further research is required for a definitive conclusion [126]. Although limited in definitive and conclusive results, some studies have also evaluated the impacts of displacement of other species from suitable habitats due to land acquisition for WE, raising concerns regarding large scale WE development [110, 111,127–130].

The biodiversity impacts of SE have not been studied rigorously enough to come to definitive conclusions [110]. Yet many researchers have pointed to the environmental impacts of solar energy like altered microclimates over SE projects and land fragmentation creating barriers for free movement of wildlife [110,131–134]. Others point to the impacts of transmission lines on biodiversity [135,136]. SE also offers opportunities for mixed land use through agrovoltaic development, where land is used for both energy and agricultural purposes [137].

In the case of HE, river flows are critical to ecosystems [138], and any alterations of the river flow can impact aquatic ecosystems [139]. Like other forms of RE, studies have identified different negative biodiversity impacts of large HE projects [140–143]. Therefore, the scale of the dams and their impacts on local ecosystems being prominent elements for consideration of the justice dimensions of HE development [144,145,146]. On the other hand, small HE projects can be operated without large dams and their subsequent negative ecological impacts, yet considerable research is required to understand the true ecological impacts of large number of small HE projects required to meet energy demands adequately [147,148].

To explore the affirmative principle of energy justice in the temporal dimension, we analyzed how RE can meet essential electricity requirements of the future generation. In 2030, the projected end-use energy demand worldwide would be 17 trillion watts (TW) [149]. Researchers project that the large-scale expansion of wind, hydro, and solar energy technologies required to meet the future energy demand worldwide is possible economically and technologically but would require social and political impetus [6,7,8].

Therefore, our review and analysis regarding whether the RE projects aid or attenuate the prohibitive principle of energy justice in the temporal dimension found RE has many positive externalities furthers the prohibitive principle., i.e. RE on in the temporal dimension has the potential to drastically reduce the negative impacts currently experienced by conventional energy systems. This will allow populations to obtain goods and services with decreased harm caused by shifting to RE systems. However, the overall beneficial effect is partially offset by a few major negative externalities. Although these negative externalities may be of less consequence when compared with the impacts of negative externalities of fossil fuels, exploring alternative options to reduce these negative externalities should be a priority for socially just RE transition. Not surprisingly, recent research has moved in this direction, aiming to find technological options that can counterbalance some of the negative impacts. For example, constructing solar PV modules on agricultural land where shade adapted crops are cultivated can maximize land use and reduce competition for land [150,151,152]. In addition, covering HE reservoirs with floating photovoltaic (PV) arrays reduces water loss from evaporation and overheating of the PV cells [153]. Through the affirmative principle lens, RE projects increase access to energy based on the nature of these systems: utilizing renewable resources. Future generations must have the ability to obtain basic goods and services. Through a continued reliance on non-renewable resources, these future generations ability to obtain goods and services may be jeopardized. Research also suggests that altering wind turbine speed with marginal annual power loss can have significant impact in reducing bat mortality in nighttime operations [154,155]. Other researchers have found that altering colors of the wind turbine [156], type of turbine used, location of the wind farm [157] matter in increasing the negative impacts of WE on ecological systems. At best, the energy justice potential of RE in temporal dimensions is work-in-progress and coming to definitive conclusions requires further research and many of negative externalities can be solved with proper planning, implementation, and management.

3.3. Technological dimension of justice in renewable electricity

The technological dimension of energy justice highlights inequities stemming from safety, reliability, security, and vulnerability shortcomings ingrained in certain energy technologies. Significant technological innovations are constantly advancing to allow for further exploration, mining, and extraction of existing energy sources to meet growing energy demands. The quest for meeting these demands resulted in creation of the largest machine, the U.S. electrical grid [158]. This is a centralized fossil fuel-powered system that aims to provide affordable and reliable energy. This system also produces many negative externalities, including but not limited to pollution, land degradation, health effects, and climate change impacts [159,160], impacting its safety and reliability. Most national economies rely on centralized fossil fuel-based electrical grid to provide essential energy services. Therefore due to its interconnected nature, an electrical grid failure has the potential to impair economic and social functions in the event of a power outage [161,162,163]. Therefore, secure and reliable electricity supply is called into question. This section focuses on how existing studies and projects utilizing RE technologies have addressed the safety, security, reliability, and vulnerability of RE technologies using the prohibitive and affirmative energy justice lens.

As mentioned above, a significant negative externality associated with traditional energy technologies comes in the form of GHG emissions. While fossil fuel power plants produce GHG emissions throughout the entire lifecycle of the technology (extraction of resource to combustion of fuel), emissions related to RE technology are limited to the manufacturing, installation, and maintenance stages [164]. Additionally, externalities differ for each RE technology. For example, HE results in habitat disruption and microclimate changes. WE includes noise pollution, land aesthetic impacts, and avian and bat mortality. SE can require a significant amount of land. However, most negative externalities associated with RE technologies can be mitigated [165]. Alternatively, RE technology benefits tend to outweigh the burdens. RE technologies generally do not produce emissions through operation and use, resulting in overall decreased GHG emissions. Global welfare and increased employment are found to correlate with increased adoption of RE technologies. Some studies have shown that the RE development has a more significant positive effect when the technology is produced locally [166].

Scholars and technical experts agree that the continued use of fossil fuel energy technologies is no longer necessary to meet society's electrical needs because of advances in renewable energy source technologies [42,167,168]. Most RE technologies produce no emissions during use and have a well-established ecological balance sheet [169–171]. The technical community also supports a direct solution to address the technical vulnerability of the electrical grid: distributed generation and microgrids [172,173,174]. Based on this, this review aims to determine how RE technology addresses emission reduction (safety), reliability and efficient energy operations, and decreased vulnerabilities to energy generation.

Many technical and feasibility studies have analyzed the use of RE technologies that can replace fossil fuels through the prohibitive justice lens. Several articles review a decentralized RE system approach [175,176,177]. These reviews consider utilizing RE technology as a cost-competitive alternative to centralized generation technologies through off-grid or micro-grid systems power by renewables yet there is often no mention of utilizing a decentralized RE technology as a security and reliability measure. Most original research articles gear towards RE technology development design and measure optimal RE technology installations that function to reduce costs along with decrease emissions as a matter of public health [178,179]. Therefore, the safety component is addressed. However, the majority of research focused on the context of core nations considers RE technologies at a centralized, the utility scale, to ultimately shift away from traditional fossil fuel based energy sources but not to change the scale of energy technology development [180,181]. Some research uses applications and models to project and understand how policies work in conjunction with advancing technologies to influence diffusion of renewables at the centralized level [41,182–185]. Few look at RE technology applications in both the centralized and decentralized designs [186,187], yet these findings conclude that decentralized RE technology designs can be integrated to the grid with optimal policies and communication systems.

While both fossil fuel based and RE technologies produce GHG emissions in their lifecycle, RE technology and infrastructure can decrease GHG emissions and consequential adverse health impacts, and some existing studies do examine the technological dimensions of RE that contribute to its energy justice contribution through the prohibitive justice lens [39,41,175,186,188,189]. These researchers acknowledge the detrimental impacts of current energy technologies on the environment and human health and that RE technologies pose a viable solution to address mitigation and reduction in harm to health from fossil fuel based energy technologies.

This analysis suggests that there is currently a narrow discussion and study of RE technologies through the prohibitive lens in existing research and policy scholarship; i.e. the ability of RE to provide safe, efficient, reliable and non-vulnerable electricity. Only a handful of articles mention RE technology through prohibitive energy justice lens, and those that do acknowledge RE technology’s capacity to provide safe power: reduced GHG emission that present harm to humans. This suggests an area for further research into other technological dimensions of RE that relate to energy justice, including the capacity of RE to change the influence of vulnerability on the existing electrical grid, the impacts on land use through the prohibitive lens, and to ultimately provide an understanding of RE technologies viability as an efficient, safe, and reliable energy source. The affirmative principle potential of current RE technological remains inconclusive. Authors address RE technological systems as they relate climate related impacts through GHG and in terms of issues of scale. However, there is much room left for discussing issues of safety, security, vulnerability, and reliability as they relate to RE technological capacity in providing access to energy.

3.4. Economic dimension of justice in renewable electricity

Cheap and abundant energy generated from fossil fuel resources is often linked to the rapid increase of economic prosperity witnessed in the last three centuries [190,191]. Energy is necessary for human beings to access goods and services to which they are justly entitled. Yet in many parts of the world including developed nations and more so globally peripheral countries, energy deprivation arising out of affordability and access inequalities challenges human flourishing [192,193,194]. Energy poverty can contribute to or aggravate income poverty, time poverty, and can curtail social progress [195,196,197]. Moreover, energy generation and distribution fall under the primary economic activities of a nation and most fossil fuel energy production systems are owned and operated by a small number of citizens in any country who disproportionately enjoy most of the profits of the sector [1]. To assess how RE projects follow the prohibitive and affirmative principle in the economic dimension, this section focuses on assessing existing scholarship regarding how RE development has addressed and can address energy poverty and deprivation issues resulting from expensive electricity prices and how diversifying energy portfolios has affected energy affordability.

Energy poverty arises when people are unable to maintain or sustain their socially and materially essential and customary daily activities due to lack of energy [30]. This can occur due to a lack of affordable energy (fuel poverty) or access to energy infrastructure (energy poverty) [30], or a combination of both [26]. One way of solving energy poverty problems is through large-scale RE projects to diversify national energy portfolios so that energy infrastructure is accessible to all. One way of doing so is to construct large-scale RE projects must be in areas that would benefit from low-cost access to the grid or low initial costs of construction, transmission, and distribution Historically, to be cost-competitive with conventional forms of electricity production, such projects were made possible by government subsidies, making them hard to implement in poor countries [39,40,62,198,199]. However, some studies have pointed out that large-scale stand-alone RE projects may not have the capacity to solve all rural energy scarcity problems (other than basic lightning services) as appliances and methods of heating and cooking differ from urban and rural communities [62–65]. This problem can be solved to a large extent by household, community-level, and other distributed RE projects in such a way that energy services are delivered to fulfill local needs [65–70,200].

Many technical and feasibility studies have analyzed cost-competitiveness (vis-à-vis centralized systems) of decentralized WE [40,200], SE [59,200,201], micro HE [59,202], and hybrid renewable energy systems [47,203,204,205]. Several studies identified numerous obstacles in enabling RE to solve energy poverty. Some suggest that the cost of RE systems is the principal impediment to adoption at the household or community-levels [206,207]. Others suggest lack of awareness, change-adverse consumer behavior, market failures, technical and institutional problems and regulatory support as the main barriers [22,207-215]. Community characteristics and the entrepreneurial abilities of community members can also slow down RE uptake where richer and more well connected communities can opt for renewable energy technologies than poorer communities [216–219]. These limiting factors may not be inherent in the technology itself, but demonstrate that considering technologies in terms of their justice impacts requires attention to the social and situational contexts in which technologies are developed.

Apart from addressing energy poverty related to physical access, RE should also be assessed in terms of its impact on electricity prices or fuel poverty, which determine the extent to which a person can access energy services. Some authors have pointed out that currently producing electricity from RE resources is not always cost effective and in some cases it raises electricity prices, making energy access unaffordable to the economically marginalized [220–225]. This, in turn, affects the rate of RE adoption [210], as well as the preferences for adopting particular RE technologies [226]. The cost of RE is often disproportionately borne by residential, commercial, and small-scale industrial consumers rather than energy-intensive industries [227] as the former are often unable to retrofit with energy efficient appliances [228]. In addition, several studies also have shown that people with higher income are willing to pay more for RE [229,230,231]. Therefore, fuel poverty arising from affordability-related issues remains a concern worldwide, as large income inequalities exist both in developed and peripheral nations [231]. Others have refuted the claim that RE development results in electricity price increases [232] or have proposed that greater policy involvement is required to align demand and supply, hence stabilizing prices [233,234]. Therefore, there is considerable debate in how switching to RE affects energy affordability issues in the short and long run and policy contexts matter in recognizing the energy needs of different segments of society.

This analysis suggests that although there are multiple opportunities in RE development to attain energy justice potential in the economic dimension, much attention is needed to develop the social, political, and economic contexts in which these technologies are embedded to develop economically just RE systems. Some authors address the prohibitive principle by considering RE system pricing impacts on adoption levels. Additionally, researchers address the potential for disproportionate RE adoption to negatively impact pricing for other consumers. However, there is still room to fully explore the negative economic impacts of RE systems. The affirmative principle is highly prevalent as many authors discuss energy and fuel poverty. While RE is seen as a solution to mitigating these issues that are currently experienced due to fossil fuel powered energy systems, there is still a need to explore how RE may function to perpetuate energy and fuel poverty issues. The potential for RE to increase access to energy services depends on the political, technological, and geographical elements involved in development, and the potential for RE to increase economic affordability of energy services is largely depended on the existing economic and policy contexts that shape the organization of energy systems and resultant energy pricing [235,236]. In other words, RE technology may not inherently cause an increase in energy prices making energy unaffordable, rather it is largely about the how the energy market operates. Therefore, without significant changes in the social and political setup within which energy markets operate, the energy justice potential of RE in facilitating energy access and affordability in the economic dimensions remains inconclusive.

3.5. Sociopolitical dimension of justice in renewable electricity

The growth of the RE sector is contingent upon the construction of associated infrastructure. RE also requires significant research and development investment. Energy infrastructure development is a high-cost enterprise, making it susceptible to a variety of risks [1]. Profit maximization motives underlining such significant investments require being protected from shocks external to the system like sociopolitical upheavals based on resistance to such developments. Such resistances can result in political suppression and persecution, as well as human rights abuses. Just energy systems can create avenues where such problems are minimized – when inclusive processes or procedural justice enable democratic participation resulting in coexistence of profit maximization and equitable distribution of benefits. Therefore, this review examines existing research to assess how RE systems are addressing or failing to address the prohibitive and affirmative principle in the sociopolitical dimension of energy justice.

Scholars have pointed out that transitioning from high energy density fossil fuels to low energy density RE technologies requires a lot of land, which may result in struggles for land rights [237,238,239]. Using case studies, some scholars point out that such property transfers to often large and foreign investors for utility scale RE development deliver no or little benefit to local communities [198,199,240]. Meanwhile, these communities have strong cultural, economic and environmental ties to their land. The distribution of benefits from RE development based solely on the socio-politics of land ownership and access can even lead to social and economic marginalization [240,241,242]. Such impacts can unjustly restrict people from acquiring goods and services falling under their rightful entitlements. Popular discourses of environmental benefits of RE can snub the voices of the rural periphery where land is cheap for constructing RE projects [241]. Several marine renewable energy projects have also limited the access rights of coastal and indigenous communities in different countries dependent on the marine resources [243]. There are also instances where renewable industry lobbies have strongly impacted energy policies [244], which may not always favor all stakeholders [245]. Therefore, these cases show that if not properly implemented, RE projects can create injustices based on the prohibitive principles at times working at the interest of large corporations.

However, some studies have found that alternative models like community-based RE projects can mitigate these concerns and, thus, help to facilitate just energy transitions. It is possible where organizational structures allow for non-constrained participation of local community members in RE projects and who can enjoy all the benefits of the projects whilst navigating the risks with the use of local knowledge [246,247]. Community scale RE projects have wider local sociopolitical support and participation. This attributed to local distribution of project benefits, more stringent protection of local natural resources, as well as elevated community spirit and community identity and stakeholder agreeing to projects that are inclusive and follow democratic decision making processes [230,248–255]. Though these results are encouraging, the existing institutional and organizational barriers continue to pose concern regarding the increase in public participation in RE projects [256–260]. These studies show that community owned and operated energy generation by default may not ensure community participation and how energy projects construction and design can prohibit people's ability to access basic goods and services may largely depend on how the projects are organized and developed.

What emerges from the above discussion is that although large-scale RE projects can lead to sociopolitical injustices especially regarding land rights, smaller-scale RE development such as community energy projects can further the prohibitive principle by virtue of inclusive participation, collective ownership, and community empowerment. In other words, the prohibitive principle is addressed to the extent that RE systems potentially cause negative sociopolitical impacts through land use disputes. The affirmative principle is not addressed in this dimension. This dimension leaves space for further exploration into how RE can either improve or decline the quality of participation, ownership, social stratification, and community empowerment. These represent only a handful of factors surrounding RE ability to impact access to basic goods and services. Therefore, the scale of development matters significantly more than the particular technology for promoting sociopolitical energy justice. The advantage of RE technology is the ability to develop projects at local scales and to shift ownership models to promote participation and community benefit sharing. These advantages are themselves based on the technological aspects of RE, which allow for such flexibility in the scales of development [261].

4. Conclusion

Ethical issues of justice are central to understanding energy choices and energy impacts. The current generation of humans living on the earth arguably has an obligation to overhaul ways and means of producing energy to alternative low-carbon emitting resources to benefit future generations who do not yet exist [28]. Further, social and economic systems are based on energy systems, and renewable electricity can create new opportunities but also jeopardizes existing stabilized systems. Yet these ethical considerations fail to provide a systematic lens for conceptualizing and evaluating the justice components of energy systems in terms of decision making, access, and impacts; these are the purview of energy justice.

Review of existing work on renewable electricity technology development illustrates that energy injustices spanning temporal, economic, sociopolitical, geographic, and technological dimensions are all apparent in the context RE development and use. However, despite the numerous studies that point to dimensions of energy justice in RE development, very few of these studies are explicitly framed in terms of energy justice. Yet studies often offer evaluative conclusions including recommendations for policy or future research. This work would arguably benefit from explicit grounding in energy justice concepts and systematic use of an energy justice framework to frame analysis and anchor recommendations. There are multiple tradeoffs to consider when ensuring justice, but in general terms, energy system planning and policies can be formulated to aid in solving persistent problems like social inequality, marginalization, and environmental damage rather than perpetuating them. This review aims to identify how the dimensions of energy justice are discussed in terms of RE; future research must grapple with the tradeoffs among impacts across dimensions.

Further, the review illustrates that some components of RE development that are arguably essential to realizing its justice potential are relatively absent in the literature. Specifically, in the technological dimension, the safety and reliability benefit of distributed RE technology is overlooked, indicating a possible avenue for a productive research agenda in the future. Utilization of an energy justice framework can help identify gaps in the literature and potential research silos in which key questions are not yet being asked and significant impacts of RE development are not yet being explored.

Review of existing scholarship RE demonstrates that, apart from the intergenerational climate change benefits, other dimensions of energy justice are not inherent to RE. Rather than being inherent in the technology itself, many of the justice implications of RE technology development are related to choices regarding the technology, including choices regarding scale, locational siting, and organization of ownership. In general, RE development that involve distributed rather than centralized technologies, are sited to avoid ecologically or culturally significant landscapes, and are designed with community involvement is more likely to have positive implications for energy justice. One specific consideration is the impact of electricity technology on water resources; water is extremely important, given the certain future of water scarcity due to climate change, so water intensive RE development is likely to create temporal injustice.

The energy justice framework used herein provides a valuable tool for assessing the justice implications of electricity choices. One potential weakness in the use of dimensions as an organizational tool is that they necessarily involve some overlap and some ambiguity in demarcation; the dimensions are not isolated in reality and thus cannot be fully isolated in conceptualization and application. However, areas of overlap can provide for fruitful consideration of intersecting impacts or social intersectionalities across dimensions that deserve particular consideration. While there are certainly other ways of conceptualizing energy justice [262, 263], the framework used here provides a concrete tool for assessing both the energy justice potentials of technology and the avenues available for future research given gaps in how these potentials are articulated in the literature. As this review demonstrates, particular technological choices do not inherently align with particular justice implications and there is still more work to be done to understand regarding the energy justice potential of renewable energy technologies.

Conflict of Interest

All of the authors declare no conflicts of interest in this paper.

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B A Guidebook to Increasing Low-to Moderate Income Households’ Access to the Benefits of Rural Public Power Community Solar Programs

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Executive Summary

This Guidebook summarizes how public power utilities can use community engagement as a tool for exploring and ultimately designing community solar programs for rural and small communities in ways that promote community support for the project and LMI household engagement. Community solar allows for the use of solar electric generation technology without requiring a single upfront source of investment, as community members can voluntarily participate and pay in to the system over time. However, community solar programs can be designed in many different ways and involve a complex set of technical, economic, legal, and social considerations. This Guidebook demonstrates how working with a team that has expertise spread across these factors and how intentional, proactive, and iterative engagement with community members can inform and ultimately improve community solar program design. Based on the experiences of the Upper Peninsula Solar Technical and Research Team (UPSTART), this Guidebook examines a case study of community solar program design that included community engagement and study of the social feasibility of the program. This work involved interviews with community leaders, a survey of community members, and community meetings that served as informational sessions and a source of data for the

project team when thinking about community interests and ways to incorporate them into program design. Based on this case study, UPSTART recommends that public power utilities considering a community solar program should build flexibility into the entire study and design process; emphasize community involvement; offer affordable and flexible payment options; select the program design components based on community input and engagement; integrate energy efficiency into program study and design; and engage in community partnerships to build capacity.

Introduction to Community Solar

The U.S. Department of Energy declares that a clean energy revolution is taking place across America. The renewable energy sector is expanding, with the solar industry growing at a record pace.[4] Dominant models for solar energy are either large utility-scale systems that feed into the grid or small residential systems that serve the owner's home. Interest is growing in a shift towards decentralized, renewable energy projects.[5] Yet, adoption of solar technology at the household level faces a number of barriers including high upfront hard costs,[6] poor sites for installation,[7] and operations/maintenance concerns.[8] Community solar is an emerging model that attempts to place control and ownership of energy generation in the hands of community members, while mitigating challenges experienced in residential adoption.

Community solar is a relatively new application in the solar PV industry,[9] and many states do not yet provide enabling policy.[10] However, states' existing regulatory structures may still allow public power utilities to facilitate access to community solar for their customers. Federal initiatives (such as the Department of Energy Sunshot Solar in

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[4] See https://www.seia.org/solar-industry-research-data

[5] Lerch, Daniel, ed. *The Community Resilience Reader: Essential Resources for an Era of Upheaval*. Island Press, 2017.

[6] Hirshberg, Alan and Richard Schoen (1974), 'Barriers to the widespread utilization of residential solar energy: the prospects for solar energy in the US Housing Industry', *Policy Sciences,* **5**(4), 453-468.

[7] Mills, Bradford F. and Joachim Schleich (2009), 'Profits or preferences? Assessing the adoption of residential solar thermal technologies', *Energy Policy,* **37**(10) 4145-4154.

[8] Rai, Varun, D. Cale Reeves and Robert Margolis (2016), 'Overcoming barriers and uncertainties in the adoption of residential solar PV', *Renewable Energy,* **89**, 498-505.

[9] The first community solar program in the U.S. was piloted in 2006 in Ellensburg, Washington.

[10] With the exception of: California, Minnesota, Maryland, etc. Available in SEPA report, 2018.

Your Community Challenge) promote community solar as a tool to assist low-to-moderate income (LMI) household solar adoption.[11]

While community solar is promising, public power utilities face challenges implementing programs in LMI and rural and small town communities. Designing a community solar program requires a series of decisions related to whether, when, where, and how a project may be built, sold, and managed. Public power utilities in LMI and rural communities may lack the resources and expertise to spearhead, organize, and design a successful program. At the same time, turning to partnerships with organizations outside the community for guidance may lead to skepticism in the community. Many existing community solar programs struggle to achieve customer participation targets, particularly for LMI households, and may require more marketing and customer acquisition costs than anticipated.[12]

Structuring a successful program can be difficult without engaging local community members to better understand their unique interests, values, and potential constraints to participation. For example, community engagement can help inform how best to size a system, to construct attractive participation/payment options, and to market to local residents. This guidebook serves as a roadmap for public power utilities to navigate community solar program design, with a special focus on community engagement in LMI and rural communities.

About this Guidebook

In this guidebook, community solar is described as a voluntary program where community subscribers pay for a portion of a locally-sited solar photovoltaic (PV) array and receive credit on their electricity bill proportional to the power produced.[13] Rural public power utilities and their partners can use this guidebook to develop community solar programs that are inclusive to LMI households. Its purpose is to describe and promote a community engaged social feasibility research model that public power utilities can use to design community solar programs that are tailored to specific community needs, emphasizing the needs of LMI households and rural and small town

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[11] Paulos, Bentham (2017), 'Bringing the benefits of solar energy to low-income consumers: A guide for states and municipalities', Clean Energy States Alliance. https://www.cesa.org/assets/2017-Files/Bringing-the-Benefits-of-Solar-to-Low-Income-Consumers.pdf, accessed on 15 March 2018;

[12] Brummer, Vasco. "Community energy–benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces." *Renewable and Sustainable Energy Reviews* 94 (2018): 187-196.

[13] See https://sepapower.org/resource/community-solar-program-designs-2018-version/

communities.[14] Many rural communities are characterized by a high proportion of LMI households in the population[15] as well as limited access to affordable and reliable electricity.[16] This guide offers a model and example case studies that communities might follow to help mitigate challenges experienced in the rural community context, including direction on income qualified programs and energy efficiency measures. The suggestions in this guidebook are based on the logic that every community is unique, that top-down or large utility-scale design models may not meet specific community needs or interests, and that residents deserve some say in how their energy systems are structured. The guidebook should first be used to assess whether to explore a community solar program, and then as a model for how teams might move forward with more detailed assessment and project development.

Community Solar Project Development Overview

The guidebook covers aspects of program design and implementation along with key recommendations. It relies on specific examples from the Upper Peninsula Solar Technical and Assistance Resource Team's (UPSTART) case study sites to highlight key steps. It also leverages experience gained from two community solar pilot projects implemented by WPPI Energy in New Richmond, WI and River Falls, WI . The Guide begins by setting expectations for a timeline for community solar project development. It then continues into the different phases of developing and designing a community solar program. Figure 1 provides a general overview of the various activities and phases that community solar project teams should consider from initially forming a team through project implementation. It is an example, meant to give teams a sense of the full scope of the project and to demonstrate how the various phases of the project are connected.

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[14] Brummer, 2018

[15] Flora, Cornelia Butler. Rural communities: Legacy+ change. Routledge, 2018.

[16] Lerch, 2017

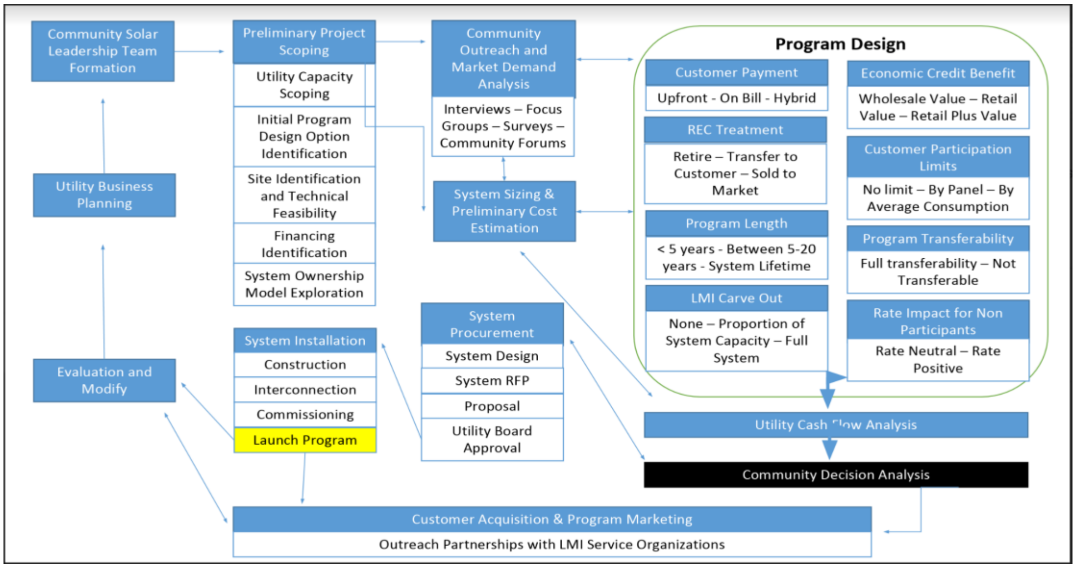


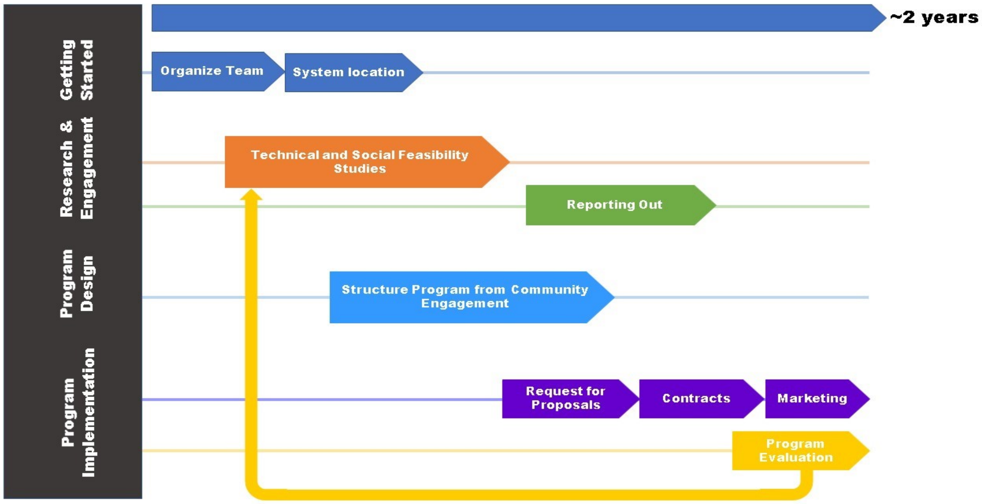
Figure 1. Community Solar Project Development Process

First, it is important to assemble a team that brings the necessary knowledge, skills, and resources for project success. Once the team is established, community engaged social feasibility research is a good way to engage the broader community in learning about and getting involved in decision making about community solar. The research process gathers data about whether the community is receptive to starting a community solar program, what kinds of pricing structures might work, who the relevant partner organizations are, and what kinds of values, beliefs, and practices might offer opportunities or pose challenges along the way. The next section summarizes various aspects of program design and structure that could be considered. A case study example illustrates how this process might look in real life along with suggestions for how to navigate challenges as they arise. The Guide concludes with general recommendations for public power utilities when considering a community solar program, specifically focused on using a community engaged approach to address community solar program design, LMI engagement, and incorporation of energy efficiency, especially in rural and small communities.

Getting Started

Timeline

The sequence of stages illustrated in Figure 2 is meant to emphasize the iterative nature of the community solar project development process. Public power utilities should plan for the process to take about two years; however every community is different and this timeframe can vary. While integrating robust research into the project development process does take time, it is an important means to understand the local context and to give communities a say in the ultimate project design.



Community Engagement & Building a Team

Unlike many utility energy programs, a successful community solar project requires the support of a wide array of community stakeholders and decision makers. In addition, a community solar program requires a combination of technical, economic, social, legal and policy considerations in order to work. The public power utility should develop a team and determine a shared understanding of the project goals, which can help shape the community solar program type as well as team needs. Once goals are established, the team can seek out and extend partnerships to others (i.e. local government, nonprofits, research institutions, etc.) who possess the knowledge, networks, resources, or skills to help achieve program goals.

Assembling a team with the right mix of skills and expertise is an important step in the project development process. Including stakeholders early in the development process can also help to achieve support for the project and identify key challenges and considerations when considering the program's design. Leadership teams can take different shapes and sizes. A helpfulful strategy to identify key team members is to consider the following:

- What community members and/or organizations have relevant skill sets?:
    - Energy, electrical engineering, and solar technology

    - Financing
    - Tax law
    - Public outreach
    - Public zoning and permitting
    - Public housing and other social programs serving LMI households
    - Marketing and communications
    - Environmental sustainability
    - Utility operations and programs
    - Other relevant skill sets
- What community members and/or organizations represent different segments or key stakeholders in our community? Examples include:
    - Local government
    - Service and philanthropic groups
    - Local businesses
    - Educational and research institutions
    - Religious and faith-based organizations
    - Environmental and conservation groups
    - Economic development organizations
    - Tribal organizations
    - Other relevant groups
- What community members and/or organizations serve in a decision making capacity that facilitates or impedes the development of the community solar program?
    - The utility administrator
    - Local elected officials
    - Community administrators
    - Appointed individuals to boards such as planning commissions, zoning boards; permitting officials, etc.
    - Other relevant departments or organizations

Once the team is in place, it is important to define partner roles. A program manager or equivalent will be helpful in keeping the team on track to meet incremental goals, satisfy deadlines, and orchestrate external meetings to help the team meet their needs. Other team member roles can include liaison between the team and broader community leaders, media outlets, or the entire community. Conducting social and technical feasibility studies will require adding experienced researcher(s) to the team. Researcher roles and goals must align with the team’s needs and interests, so that the project remains community driven. Researchers who follow a community-based participatory research model[17] will be most appropriate.

****Call out box:**

The Upper Peninsula Solar Technical Assistance and Research Team:

UPSTART formed in March 2017 to respond to a Department of Energy Solar in Your Community Challenge. The idea was to bring together knowledge, resources, and skills to help design and develop a community solar program in two rural Upper Peninsula Communities. The team began as a partnership between the Villages of L'Anse and Baraga Administrators, WPPI Energy, the Western Upper Peninsula Planning and Development Region (WUPPDR), and researchers at Michigan Technological University. As the project evolved, UPSTART membership and resources expanded to include marketing and contract development with Michigan Energy Options, energy efficiency studies with LOTUS Sustainability & Engineering, development of a cost-benefit analysis tool with the University of Michigan Dow Sustainability Fellows Program, and media development with a team of Michigan Tech students learning documentary production (CinOptics). All of these team members worked together to design and build a community solar program for L'Anse and Baraga.

Decision-making process

Discussing and defining the decision-making process and decision-making power early can improve clarity and understanding throughout the project. There will be multiple levels of decision-making within the core team, among the utility management, and extending out to the community on issues ranging from whether and when to move forward, to system design components, research design, project timeline, pricing structures, and more. Teams should start a dialogue about this process when they first form. They may choose to follow any number of decision-making models[18]. There may be one team member or a small portion of the team who ultimately decides if the project should and can move forward, or it may be a unanimous decision. Some decisions may require one type of process, while others require a different process. The key is to discuss how this will be handled and to remain transparent about how decisions are made both within the team and with the broader community. In many energy projects, the community is left out of decision-making, which can defeat one of the goals of a community solar project- to have local ownership over the energy system. Engaging the

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[17] Burns et al, 2011. A short guide to community based participatory action research. Available at: https://hc-v6-static.s3.amazonaws.com/media/resources/tmp/cbpar.pdf

[18] DEFG. 2019. Low Income Consumer Solar Working Group Final Report. Available at:http://defgllc.com/publication/low-income-consumer-solar-working-group/

community in decision-making where possible and remaining transparent throughout the process for how decisions will be made can increase trust and buy-in.

Where will the system go?

Determining potential sites for the community solar array can be tricky. The utility has to find a viable site for energy production that is acceptable to both participating and non-participating community members. The site needs to be large enough to install the system, be free of obstacles creating shade, and have access to the utility distribution system. It can be helpful to work with the community to determine potential locations. Some community members may not appreciate the aesthetics of a solar PV system in their neighborhood while others may want to see the panels in which they have subscribed. Some locations may be more susceptible to vandalism or theft. While having some site locations in mind prior to engaging with the broader public is a good idea for generating conversation, teams should keep these potential sites preliminary, and draw upon the social feasibility study to determine final system size and location.

****Call out box:**

Like any land use decision, local zoning ordinances can play a pivotal role in shaping a project's physical characteristics and even the overall performance and economics of a community solar program. Often times, large solar projects are classified as industrial projects in local zoning codes which may require screening around the project site. This requirement can add additional costs and cause shading which may decrease the systems overall efficiency. Zoning practices that allow solar projects to remain visible can help avoid this concern and help the utility more effectively market the project to attract participants. Many communities believe their zoning codes help to facilitate solar development because the codes don't specifically restrict solar projects. Unfortunately, staying "silent" on solar may actually do the opposite by leaving the community open to legal challenges from individuals who oppose solar development. Adopting zoning practices that allow for solar through conditional or special use permits proactively confirms opportunities for solar land use[19].

Who will the program serve?

One of the project team's first tasks should be to define who the target participants will be. This will help to shape which community solar model is chosen and determine availability of supporting resources and opportunities for engaging additional stakeholders. Projects might choose to target LMI households and/or other groups who are often left out of community solar participation.

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[19] For additional guidance on best practices for solar zoning visit http://www.solsmart.org.

Community solar attempts to increase access and affordability of our energy systems. Yet, a majority of community solar programs exist and operate within affluent communities[20]. Making community solar more accessible is possible and is often an important goal. While there are special considerations and challenges in designing programs for less advantaged participants, there are also opportunities for engaging different groups, expanding the stakeholder base, and accessing resources. Some possible targeted participants include:

- Low-to-moderate (LMI) income: there are many existing federal and state definitions for LMI households. A first step is to select a definition that fits program goals. UPSTART utilized the U.S. Department of Housing and Urban Development definition[21]. These populations may not have a tax liability to be able to access existing tax incentives for solar (30% Renewable Energy Tax Credit).
- Non-profits: 501c3 organizations cannot access existing tax incentives (30% Renewable Energy Tax Credit and/or 100% Bonus Modified Accelerated Cost Recovery System depreciation) for solar because of their tax benefits.
- Renters: Renting households are generally more transitory than homeowners. It doesn't make sense for them to invest in solar panels in a rental unit, so community solar may be appealing. Still, renters may require extra considerations in thinking about transferability of panel shares should they move.
- Tribal communities: Tribal communities are often leaders in renewable energy generation, and may be particularly interested in participation that meets the needs of tribal members. Tribal involvement could open access to federal funding initiatives that emphasize clean energy goals in tribal communities.

Additionally, team members need to consider other factors that can shape program participation. Some projects can be predetermined by geographic boundaries. For example, regulated utilities operate within mandated service territories and recruiting program participants from this service territory into the community solar program violates the state regulated utility service agreement. Therefore it is important to identify

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[20] National Renewable Energy Lab. Feldman, David, Anna M. Brockway, Elaine Ulrich, and Robert Margolis. 2015. Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation. National Renewable Energy Laboratory and U.S. Department of Energy. Available at: www.nrel.gov/docs/fy15osti/63892.pdf; also Lotus Engineering and Sustainability. 2015. "Analysis of the Fulfillment of the Low Income Carve-Out for Community Solar Subscriber Organizations". Available at: https://www.colorado.gov/pacific/sites/default/files/atoms/files/Low-Income%20Community%20Solar%20Report-CEO.pdf; see also Smart Electric Power Alliance. 2015. Community Solar Program Design: Working Within the Utility". Available at: https://sepapower.org/resource/community-solar-program-design-working-within-the-utility/.

[21] See https://www.huduser.gov/portal/glossary/glossary_l.html for a full understanding of the definition; see also XXX for other LMI definition options.

the geographic boundaries to structure a program that fits within these boundaries while simultaneously satisfying program goals of including LMI households.

Research Process

Before making too many decisions about whether to start a program or how to design the specifics of one, it is important to engage with the local community in a meaningful research process to evaluate both technical and social considerations. A project can struggle with program participation, support, or acceptance if it does not consider the needs or values of the community. Social considerations can include project location, program costs, and awareness and perceptions surrounding community solar systems, to name a few. The most important piece is to determine if the community even wants a project like this. Engaging the community can help teams understand local perspectives on these issues and potentially lead to improved program design.

Technical feasibility and specifications

The Solar Market is changing quickly and it is important for the utility to have a good feel for the energy output, size, and cost of a system before starting a social feasibility study. In the past few years, energy density on solar panels has increased from <250 watts per panel to >400 watts per panel at similar costs. This is likely to continue much the same as in the 1970’s when handheld calculators increased in speed, size, and functionality with no change in price. Likewise, inverters and monitoring systems have similarly improved in sophistication. Taking all these improvements into consideration can be a difficult task for a smaller public power utility that may not have staff experienced with solar PV installations. Novice utility staff should partner with a reputable and experienced installer or site assessor to help develop the initial system specifications.

This said, there are web tools readily and publicly available to facilitate this process. Two such tools are available from the National Renewable Energy Labs (NREL) in Golden, Colorado- PVWATTS and SAM[22]. PVWATTS is a simplified tool that allows homeowners and small businesses to make good estimates of the size and cost of solar installations with minimal data.

SAM (System Advisory Module) is a more sophisticated program. To use this tool, minimal information is needed, including:

1. Site Location (address or GPS coordinates)

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[22] https://www.nrel.gov/; PVWATTS tool https://pvwatts.nrel.gov/; System Advisory Model https://sam.nrel.gov/

2. Target Nameplate Power Generation (usually in Kilowatts)

3. Estimated Budget (note items 2 and 3 will require some iteration)

To use the SAM program, you simply enter the required information. The software will use weather data and the location's irradiance (energy from the sun) for the site to estimate the potential energy production. The software will also select a default solar panel from its database as well as required electronics to come up with an estimate of total system cost and annual energy production. The user can change the solar panels used and the electronics to match available equipment from local suppliers. This tool thus can be used to compare different vendor quotes when RFP's are submitted. Fine tuning of the model can be done as well to explore parameters like the altitude angle of the solar panels and the use of microinverters versus full system inverters. With this tool the team can play "What if?" games to explore larger or smaller systems.

In addition to experienced installers and site assessors, educators from local Universities might also be a good resource for assisting with making these estimates. Solar panels are an attractive area of study and make for a great student project. UPSTART worked with Michigan Technological University undergraduate students to do an initial technical feasibility analysis and cost estimate. The resulting student report is available in Appendix A.

Social feasibility study

Many projects address technical and broader economic feasibility, but fail to research social feasibility. A social feasibility study (also known as a social impact analysis) is a methodology, framework, or process that elicits and incorporates social information and feedback to design and implement a project. Public power utilities can utilize social feasibility studies to prioritize, gather, and analyze information obtained from and with their communities to best design a project for the community. Overlooking social conditions (interests and concerns) puts the success of the project at risk and limits its potential for positive impact[23].

Utilizing a social feasibility study in community solar program design can help public power utilities to better understand how to design programs that satisfy project goals and fit community needs. Existing community solar programs that included a social feasibility study felt they influenced the project's success by identifying concerns early on that could later be addressed in the project design phase[24]. Social feasibility studies

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[23] Wüstenhagen, Rolf, Maarten Wolsink and Mary Jean Bürer (2007), 'Social acceptance of renewable energy innovation: An introduction to the concept', *Energy Policy,* **35**(5), 2683-2691.

[24] see https://www.nppd.com/innovation/solar/sunwise-community-solar/

can also help identify key stakeholders, determine key community considerations, and translate project information to the community. While there are many benefits, not all public power utilities possess the skills or resources to successfully conduct social science research. Partnering with a research institution can provide access to these skills, and also ensure appropriate human subjects ethics protocols are followed.

Teams should first conceptualize social feasibility study goals. What exactly does the team want to learn? How do they plan to use that information? How will the team know if the results indicate the project is feasible or not? Is one of the goals simply sharing information with the community and increasing broad participation? And, if so, how much participation (and from who) should be expected? These are all important questions that teams should collaborate with researchers to define at the start of the project, and which will ultimately inform the research design and analysis process. Once the team decides what the aims will be, they can begin to craft the study design.

There are various tools and research approaches that teams might choose to employ, depending on the project goals. These might include: qualitative interviews with key informants, community meetings, focus groups, surveys, charettes, bus or walking tours, and/or a critical review of existing community solar projects. Each are described below. Teams might choose to combine several of these into their research design.

- **Interviews:** Qualitative interviews with key informants are a good first step to explore the local context and possible opportunities and challenges that may arise. Interviews examine how residents and business owners feel about a community solar project in their community, what hurdles might come up in if the utility pursues a community solar project, and what cultural, economic, social, or institutional factors could impact the success of a project. Researchers should collaborate with non-academic and local team members to develop interview questions and to select appropriate interviewees to ensure that the views of important community stakeholder representatives are heard. Key informants are often community leaders who know the community well, and they should come from a variety of backgrounds and be affiliated with various institutions (e.g. schools, local businesses, social service organizations, religious organizations, political organizations, sports teams, or servers/bartenders in popular gathering places). Additional contacts for interviewing can be found through snowball sampling, where interviewers ask interviewees who else they should talk to in order to hear important or different perspectives. The interviews themselves are often audio-recorded and later transcribed so that team members can review them to identify key themes. UPSTART's interview protocol and summary of interview results can be found in Appendix B.
- **Community meetings:** Community meetings allow for larger community discussions and broad information sharing. They can be structured so that the community solar team can share preliminary information about the proposed community solar project, and offer discussion time to gain insight into how community members feel about the possibility of beginning a community solar project and about potential opportunities and obstacles for designing a project that

meets community interests. They might target a specific group or be open to the public and broadly advertised, in order to garner the most participation and diversity of views possible. A World Cafe[25] format is a meeting design that is particularly well suited for both sharing and receiving information with a broad set of community members in an informal, relaxed atmosphere where participants sit and discuss specifically-posed questions in small groups, combining aspects of a community meeting with those of a focus group. Community meetings offer community members an opportunity to learn about the potential project and to expand the decision-making process widely. Opening a dialogue with the community can help to reduce local skepticism and increase community empowerment by allowing participation. UPSTART's community meeting protocol can be found in Appendix C.

- **Focus Groups:** Focus groups gather input from a small group of stakeholders on pertinent program features or topics. Focus groups are usually comprised of five to eight pre-selected stakeholders who can represent key target audiences. Generally, the group is led through a series of predetermined questions by a facilitator allowing for discussion between the participants. An important element of a focus group session is the ability to explore potentially unanticipated topics brought to light by the group's discussion. These can be challenges to participating in the program or creative program design options not yet identified by the project team. This may help identify important concerns or benefits of a project. Depending on a community's resources, multiple focus group sessions could be held with different sets of stakeholders.
- **Surveys**: A survey of public power utility customers is a good way to gather basic information from a large number of households. Surveys help to determine if the perspectives of people who participate in interviews, focus groups, or community meetings are more broadly shared and generalizable across the broader community. Survey aims might be to determine broad interest levels in participating in a community solar program, what price points are most attractive, to generate a rough estimate of how many panels a project might sell, to determine how widespread potential perceived barriers to participating in the program may be, or to provide another channel through which people can voice concerns and generally stay involved in the decision-making process with minimal time and effort committed. Survey sampling strategies and questionnaire design are critical and will require expert input in order to ensure reliable results. Getting representative response rates is another concern, and may require door-to-door canvassing or other follow-up measures. Altogether, the information gathered should help the team develop a preliminary business model that could later be presented to the community for further feedback. UPSTART's survey protocol can be found in Appendix D.

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[25] Jorgenson, Jane, and Frederick Steier. 2013. Frames, framing, and designed conversational processes: Lessons from the World Cafe. *The Journal of Applied Behavioral Science* 49: 388–405; see also Brown, Juanita. 2010. *The World Café: Shaping Our Futures through Conversations That Matter*. Surry Hills: ReadHowYouWant.

- **Charrettes:** Charrette sessions are often intense, multi-day workshops where participants help craft a vision and design for a major development project. For community solar planning, this approach can be leveraged to help design a more socially acceptable project site or location or for overall community solar program design. This process is often led by a trained facilitator and can help build consensus for the project and help community members better understand the dynamics influencing a successful project.
- **Bus or walking tours:** Walking and bus tours allow communities to collect feedback from stakeholders on key land use decisions that influence community solar projects. Tours can be used to allow stakeholders to visit existing solar projects in order to become more familiar with project development outcomes or to visit potential project sites to better understand the challenges and opportunities to site development. The process allows community members to share feedback with utility officials and project team members on proposed projects or offer new alternatives to the project's design.
- **Evaluate existing projects:** While community solar is still relatively new, several projects exist across the country. It is important to learn from the range of different projects and the challenges, successes, and failures they have experienced. Several resources exist[26] to serve as a starting point, but teams can also conduct their own evaluation of community solar; especially in regions with similar demographic characteristics and climate conditions.
- **Financial analysis**: Ultimately, at the end of a social feasibility study, both utilities and community members are going to want to know: (1) how much subscribing to a panel or share in a community solar project will cost; and (2) what will be potential returns on investment. This all comes down to the size of the system, installation costs, "soft" costs of administration, operation, and maintenance, how many people are willing to participate (estimated from the social feasibility), and how costs will be distributed. In order to determine program design options, teams will ultimately need to balance costs of implementing a program that the utility will incur with meeting the needs and designing a program that is affordable, attractive, and accessible to community investors. This is discussed in more detail in the section on *Determining Customer Costs and Payment Structures* below.

Reporting out

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[26] See https://sepapower.org/resource/community-solar-program-designs-2018-version/; See also https://www.mtu.edu/social-sciences/research/reports/lanse-cs-report2.pdf; see also https://www.nrel.gov/docs/fy11osti/49930.pdf

For broader communities to be engaged in the community solar process, they need to know the results of the feasibility research described above. A summary of study results can be shared via press releases, presentations to key stakeholder groups (e.g. school boards, city/village/town councils, chamber of commerce) or other community organizations (religious gatherings, community economic development offices, community action meetings, etc), radio conversations, social media, hosting a community meeting, or through online or print publications. It is helpful to utilize media outlets to advertise these events. Teams might use study results to design a preliminary program structure (or a set of buy-in options or scenarios). They can then share these publicly, along with the more general study results, and request additional feedback. This allows community members to generally see where the community lies in terms of community solar program support, as well as to provide additional feedback on the program design.

Program Design

Policy Context

The state and local policy context can heavily influence the success of community solar programs. Some states[27] have formal laws to support and promote community solar program implementation while others leave program development to the utility's discretion. Still, other states' energy legislation prevent non-utility owned community solar by prohibit aspects of community solar program design (i.e. virtual net metering or power purchase agreements). The policy context can influence who owns the project, how and who reaps the benefits and costs, system siting, and other program design elements. Reviewing state and local policies ensures the project is in compliance with existing laws, regulations, and rules.

Tax incentives

Solar projects may be eligible for the 30% Federal Investment Tax Credit (ITC). The ITC allows the system owner to deduct 30% of the solar project cost from Federal taxes. The 30% amount is available through 2019, after which the tax credit steps down to 26% in 2020, 22% in 2021, and 10% for commercial and industrial systems thereafter.

Additionally, systems owned by commercial businesses are eligible for the Modified Accelerated Cost Recovery System (MACRS) Depreciation. The 2017 Tax Laws allow for 5 years of 100% bonus depreciation for systems installed after September 27, 2017. This means that eligible systems can essentially expense a portion of the project cost within the first year of commissioning.

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[27] California, Minnesota, Maryland are a few examples

Other incentives, such as solar energy property tax exemptions, vary by state and locality. The Property Assessed Clean Energy (PACE) mechanism allows commercial and residential property owners to use government financing for up-front costs of eligible projects. In exchange property owners repay the up-front cost through special assessments on property taxes over a period of time. PACE programs exist at the state, regional, and local government levels and can vary in financing structures and eligibility measures[28]. Some municipalities are located in Opportunity Zones which allows investors to take additional tax deferrals when investing in LMI and rural communities. Again, these vary state to state and by location[29].

While all of these incentives can function to lower total community solar program cost, they are available only to residential, commercial, or industrial consumers that have a tax appetite. LMI communities, non profit organizations, governmental agencies, and municipalities cannot monetize these tax benefits. Seeking alternative funding options or partnership opportunities (discussed below) can reduce community solar project costs.

Program Costs

There are many factors that will influence the overall cost of a community solar program, with installed capacity being the largest contributor. PV system and construction costs increase as the capacity of the array increases, but the installed cost/capacity ratio will also gradually decrease with economies of scale as system capacity increases. Other "soft" costs that affect the overall cost of the program include operation and maintenance, marketing and administration, insurance, permitting, interconnection, financing and site development. Some of the effects of system size and soft costs on the financial model of the overall program are discussed in more detail in the remainder of this section and *Program Implementation* section.

Ownership Models

When implementing a community solar project, a public power utility doesn't necessarily have to own and operate the PV system. Although the most common model is for the utility to own the array, a developer, community organization, or other entity can build, own, and maintain the system for the utility. In this model, the utility purchases the energy output from the third party owner via a power purchase agreement (PPA), customers purchase subscriptions from the utility, and the utility credits the customer. For public power utilities, utilizing a third party ownership model can lower implementation costs with the federal ITC. Although financially attractive, managing

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[28] To find out if your project is eligible for PACE financing, please visit https://www.energy.gov/eere/slsc/state-and-local-solution-center

[29] To find out if your intended solar PV site is located in an Opportunity Zone, please visit https://esrimedia.maps.arcgis.com/apps/View/index.html?appid=77f3cad12b6c4bffb816332544f04542

additional contracts and agreements from a third party ownership model becomes complex for public power utilities. The utility must find a party willing to accept the financial liability and be dependable over the life of the project or until the assets can be transferred to the utility. It should be noted that third party financing and ownership may not be an option for public power utilities that have all-requirements wholesale power supply agreements.

Call out box

WPPI Third Party Ownership Model

In 2016 WPPI Energy implemented 250 kW community solar pilot programs with each of their member public power utilities located in River Falls, WI and New Richmond, WI. In the design phase, the goal of the project was to implement community solar in each of these communities to meet customer demand with no adverse rate impacts to non-participating utility customers. As WPPI Energy was developing the financial model for the program, it became obvious that under the utility ownership model, subscription rates would have to be set too high and would discourage customer participation. To lower costs, they successfully worked with a third party owner that could bring in the benefits of ITC and accelerated depreciation into the financial model.

Identify Program Funding

Identifying appropriate and sustainable sources of funding is key to financing up-front solar and other soft program costs. Public power utilities may be unable to take advantage of existing solar tax benefits, but they may be able to cooperate with other entities that can through creative ownership models, as described above. Many community energy projects begin with some portion of grant-funding that they ultimately turn into a revolving clean energy fund[30]. Some options to consider can include:

- **Partnerships:** These can be important sources of financing as third parties may allocate funds strictly for investment in LMI communities. Examples include: corporations, banks, and project developers. Businesses may have internal initiatives for corporate responsibility, such as engaging low-to-moderate income communities or environmental sustainability. The Community Reinvestment Act encourages commercial banks and savings to meet the needs of borrowers in all segments of their communities, including LMI households. New Markets Tax Credits help project developers lower the cost of participation for LMI customers.
- **Tax equity:** Similar to third party partnerships, a tax equity partner finances the community solar program up-front, owns the system, and monetizes and passes

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[30] See Dubuque, Iowa and Pennsylvania as examples: https://dced.pa.gov/programs/solar-energy-program-sep/.

along existing tax benefits. Depending upon the agreement, system subscribers can realize a portion of the tax benefits through decreased subscription costs. The investor also realizes a favorable return on investment and may be more likely to invest in future projects.

- **Grants:** Existing federal and state initiatives and grant programs are available help fund and forward clean energy and energy efficiency goals. Some of these can be accessed by local governments in rural communities. The US Department of Agriculture's Rural Development periodically solicits applications for loan and grant funding through the Rural Energy for America Program (REAP). The Department of Energy (DOE) SunShot initiative offers many solar grant funding opportunities and competitions to lower solar project costs for LMI communities. Additionally, the DOE offers a Tribal Energy Program Grant to promote tribal energy sufficiency, economic growth, and employment through clean energy projects in tribal communities. Some State Departments of Agriculture and Rural Development may offer funding opportunities for renewable energy and energy efficiency projects as well.
- **Low interest loans:** Community solar programs are increasingly targeting low-to-moderate income populations. To make financing more feasible to these populations, some external funding entities can provide low or no-interest loans. Additionally, some banking institutions maintain a local funding pool to help promote sustainable development initiatives in municipalities[31].

****Call out box**

Cost-Benefit Analysis:

An accurate depiction of the costs and benefits of a community solar project is an important piece of information in the decision making process. A cost-benefit analysis (CBA) attempts to monetize costs and benefits of a project or program to determine if it results in a positive net benefit for a customer, utility, or community. CBAs are a common decision making tool for policy makers and utilities since it allows for current and future project costs and benefits to be measured using today's dollars. The analysis can include direct project expenses and benefits (e.g. the cost of equipment and value of energy produced) as well as other important values that often are included in project budgets (e.g. the value of carbon emission reductions). The utility can use CBAs to determine if community solar projects financially makes sense for the utility to build the array and whether or not community members would benefit from subscribing.

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[31] See https://www.cdfifund.gov/Pages/default.aspx

The capacity to develop CBAs can vary by community and utility. UPSTART formed a relationship with the University of Michigan's Dow Fellowship program, who developed a web based cost-benefit analysis tool for this project. By simply manipulating variable cost and financing inputs, a utility can use this tool to develop a program and evaluate how different financial models will affect both the utility and its customers. The cost-benefit tool can be found under the listing for this project on the DEED project database at https://www.publicpower.org/deed-project-database

Determining Customer Costs and Payment Structures

In order to increase participation and accessibility, especially among LMI households, it is critical to keep customer buy-in costs as low as possible. At the same time, public power providers must ensure community solar projects are fiscally responsible and balance the interests of non-subscribing customers. This means that several factors and tradeoffs need to be considered when determining customer costs, payment structures, and buy-in options.

Enhancing LMI participation in the program increases the difficulty of the balancing act. Public power utilities must consider reserving a portion of the system capacity with payment options specific for LMI customers; specifically lower upfront costs and on-bill financing can be used to increase access for these customers. Without outside funding, this will typically increase non-LMI customer costs to balance lower rates offered to LMI customers. Cash flow for the utility can be an issue if on-bill financing is offered and minimal upfront payments are collected. Program costs can also increase as the utility attempts to fill reserved LMI capacity with additional marketing and customer verification efforts. Offering different subscription costs to different customer types can help to prevent or alleviate these issues.

Determining the size of the system can also affect program pricing for subscriptions. While economies of scale can reduce construction costs as system capacity is increased, the utility's liability increases if the program is oversized for customer demand and is not fully subscribed. Enlisting or pre-subscribing an "anchor tenant" to the program can help reduce the risk to the utility while helping to increase customer demand and maximize the capacity of the system. Ultimately, a successful program ensures a good investment to both the customers and the utility. Net Present Value (NPV) analysis can be used to model the value of the customer's investment over the term of the subscription. Simple payback is typically easier to calculate and understand than other financial analysis methods such as NPV or internal rate of return (IRR), but this method does not account for the time value of money, panel output degradation, customer credit rate changes, inflation, risk, financing, or the benefits of the investment after the payback is achieved.

****Call out box**

Solar Destination Ypsilanti:

Solar Destination Ypsilanti formed in early 2017 with the SunShot Solar In Your Community Challenge. This is a partnership between a private firm, Chart House Energy, a nonprofit grassroots company, Solar Ypsi, and the City of Ypsilanti to bring community solar and job training to LMI communities and nonprofit organizations. In this ownership model, Chart House Energy helps to bring the solar array cost down for non-profit organizations by owning the solar assets to monetize the tax benefits. The system owner rents the host facility roof, while the host facility receives discounted power through an equipment lease. Solar Destination Ypsilanti then uses their portion of energy savings to re-invest in additional solar projects. The team also recruits and trains individuals from LMI communities on solar installation, general construction, and safety practices in hopes these community members find employment in general construction or solar installation careers.

** **Call out box:**

Sunwise Community Solar Program:

The Nebraska Public Power District (NPPD) is a public power utility that piloted its first community solar project in 2017. NPPD held several forums to disseminate project information and use feedback to best design their community solar program. In this model, program participants can purchase shares of solar energy from the community solar system that offsets a portion of their home's electricity demand. NPPD owns the system and charges customers an enrollment fee that is returned 3 years after the enrollment date. Customers are charged a monthly rate, paying a higher premium for the solar energy vs traditional power. Although customers pay a higher rate to participate in the community solar program, NPPD locks these rates for 25 years. This means that community solar customers do not see the rate increases that a traditional customer would. NPPD is currently accepting applications for two additional community solar programs located in Venango and Kearney, NE.

** **Call out box:**

Powered by the Northern Sun:

The Marquette Board of Light and Power is a publicly owned utility company. MBLP started the first community solar garden in the Upper Peninsula of Michigan in 2017. As a municipal utility, they are unable to monetize tax benefits associated with solar PV. They use a different ownership model to help their customers access these tax benefits. Utility customers that choose to participate in the community solar program can purchase actual panels and apply for the 30% renewable energy tax credit on their own.

Transferability of Subscriptions

The operational lifetime of solar panels is 25 years or more. Paying for a long-term subscription can be a main concern of public power utility customers who choose to move within or leave the service territory during the program lifetime. While these customers may be unable or unwilling to subscribe for the entirety of the program, transferability can be an attractive program design component. The utility can consider allowing customers to do the following with their subscriptions:

- transfer to a new electric account held by the owner
- resell to another customer
- donate to a non-profit customer (e.g., church or school)
- gift to a friend or family member

Whatever option a customer decides, transferability adds flexibility to a community solar program that functions to address varying customer concerns and needs.

Partnership Opportunities

Community partnerships can play a critical role to access project capital and gain program participants, particularly LMI customers. Community organizations like schools, religious institutions, hospitals, tribal entities, and charitable organizations serve the dual role of both institutional power purchasers and also key community convenors and thought leaders. Utilities seeking a potential anchor tenant may find it helpful to start with key community organizations like these who have both large power demands and a variety of motivating factors for participating in solar programs (e.g. cost savings, environmental sustainability, social sustainability, etc.). Often times, these organizations have access to special funding resources (e.g. grants, loans, membership bases) to support investment in renewable energy and energy efficiency that businesses and residents cannot access. Membership networks like alumni, donors, tribal members, and congregations extend beyond a utility service territory. These groups can provide organizational investment in community solar programs. In addition, programs can explore the potential of developing “donor models” where panels subscriptions are purchased and donated to qualifying non-profit organizations resulting in tax deductions for individual donors. This can be an effective technique to engage businesses and philanthropic groups seeking to provide support to visible community organizations.

On the other hand, partnering with these organizations can help project teams promote the program to key target audiences. For example, human service organizations and religious institutions may already have lists for and relationships with income qualified households eligible to participate in programs targeting LMI customers. This can help reduce the soft costs of recruiting participants as well as identify potential members most likely to participate in the program. These organizations can serve as champions within the community by promoting community solar participation to their individual memberships.

Energy Efficiency

Energy efficiency programs employ measures to help maximize energy savings benefits received from community solar programs. Energy efficiency programs require initial investments that can be significant depending on the type of building or home and measures taken; this is especially true for LMI populations. The return on investment of energy efficiency measures can vary significantly based on project, building type, and energy use characteristics. This is why it may be advantageous to consider integrating energy efficiency into the program structure to increase accessibility to energy efficiency programs for LMI communities. An on-bill financing purchasing option with 0% interest can be a way around this. Under this structure, it is possible for community members to realize energy efficiency savings on a monthly basis. Reducing electricity consumption is a common focus for energy efficiency measures, but it ultimately depends on the energy use characteristics. For example, a home may have lower cost natural gas service for heating, but still rely on electricity to power heating appliances that utilize natural gas. Public power utilities can also partner with community organizations to identify opportunities to market energy efficiency to LMI households (see the above section on *Partnership Opportunities)*. Public power utilities can establish a charitable donation arm of the community solar program to facilitate tax-deductible donations towards the program at large or for the benefit of LMI households specifically. Donations can be used to offset the upfront cost of energy efficiency measures.

Program Implementation

Soliciting and Evaluating Proposals

Once the utility has identified a feasible site and the desired capacity of the solar array, it's time to solicit, evaluate, and select proposals from installers. Below are some key points to remember through this process:

- If a public power utility is unfamiliar with local or regional solar PV installers, find renewable energy networks or associations to help solicit installers and/or advertise the request for proposals (RFP).
- Provide specifications on the system requirements and details regarding the installation site in the RFP. Things to consider include: system capacity, tilt angle, azimuth, panel type, inverter type and configuration, system output voltage requirements, monitoring capabilities, installer certifications and experience, operation and maintenance training, external disconnects, security fencing, warranties, energy production estimate, system efficiency, racking design, foundation/anchor type, commissioning, and final landscaping.
- Warranties will vary for separate components. Identify warranties for PV modules, power inverters, optimizers (if used), racking systems, and workmanship.
- Be prepared to provide site maps, soil analysis, and location of adjacent trees, buildings, etc.

- The installer may require additional site prep to ensure proper grading and access roads for heavy equipment to the site. If needed, check to see if it is included in the proposal.
- Developing specifications and providing site information for the project will help return comparable proposals. This will make the evaluation and selection process easier and reduce the amount time and analysis on behalf of the installer. Be sure to allow enough time for development of the proposals depending on the information the utility can provide.
- Once the proposals are received, consider the following items in the project timeline before the unit can be commissioned: evaluation of the proposals, preparation a recommendation and presentation to the governing board for approval, site preparation, interconnection, and testing.

Program Administration, Operation and Maintenance

Alongside securing program funding, it is important to determine who will administer the community solar program. Utilities, or third parties such as solar installers/developers can fill this role. An important step is to first determine the public power utility's capacity for program administration. This is especially significant if your program utilizes different customer financing options: upfront, on-bill, or a combination of these.

Marketing and outreach is an administrative role that should be started at the genesis of and carried out throughout the lifetime of the program. Conducting a feasibility study is an effective way to start customer outreach with surveys and community meetings. Marketing efforts are needed to communicate program design information to the customers so they can decide if they want to participate. Reaching and convincing LMI customers to participate in the program can be challenging, but contact through ongoing partnerships with community action agencies or other existing LMI programs can help the utility facilitate communications and avoid skepticism about opportunities that may sound too good to be true to LMI customers[32].

Once the program is up and running, ongoing outreach and marketing may be needed to fill open subscriptions or promote renewable energy educational opportunities in the community. In addition to typical outreach channels such as bill inserts, radio & television ads, and social media, web access monitoring can be used to promote the program, keep customers engaged, and provide an educational resource for schools.

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[32] NREL. 2018. Design and Implementation of Community Solar Programs for Low and Moderate-Income Customers. https://www.nrel.gov/docs/fy19osti/71652.pdf

The utility will also have to develop and maintain customer application forms and/or contracts for the lifetime of the program. Customer contracts should contain specifics on availability, eligibility, subscription length, method of bill credit, subscription transfers, energy credit rates, and payment options. Legal review of contracts developed for a community solar program is highly encouraged before issuing them to customers.

Operation and maintenance is relatively low for solar PV systems in comparisons to other generators, but the utility needs to consider managing vegetation control, cleaning panels, angle adjustment (if capable), snow removal, component failures, and vandalism in order to keep the system operating at maximum capacity.

UPSTART Case Study Example

UPSTART established the main goal to extend community solar access to low-to-moderate income households in two small Villages in a relatively rural area located in Michigan's Upper Peninsula. In both cases, the village managers oversee operations of the public power utilities for their respective municipalities as opposed to an independent utility commission. Each village manager expressed interest in developing a community solar project but did not want to move forward without understanding whether the broader community would support such a program. Additionally, moving forward required designing a program that was accessible and attractive to all community members. Each village partnered with UPSTART to achieve explore developing and designing a community solar program.

We tasked ourselves with 1) conducting a technical site analysis and building an engineering design for a community solar array to assess the project's viability in these villages and 2) conducting a social feasibility study by engaging the community to identify both support for and sociocultural barriers to the project. By designing the program this way, we hoped to help each public power utility to design a community solar program that was accepted by the community and suited community needs first.

The case study sites are the neighboring Villages of L'Anse and Baraga, Michigan (Figure 1). The case study community was defined by existing village utility service territory. These are remote, rural communities, located about 5 miles apart. Each village has a population of roughly 2,000. At a first glance, these cases do not seem to present viable locations for community solar programs. They are characterized by low-to-moderate income households (43% and, 66% respectively)[33], presenting a hurdle to participation. Also, there is relatively low solar radiation (3.4-4.4 kWh/m^2/day[34]) and residential electric rates in comparison to neighboring electric utilities ($0.1211 and$0.1250/kWh, Village of

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[33] Please see https://www.michigan.gov/mshda/#!/ul 45866 for LMI housing information

[34] See NREL Geospatial Data Science: https://www.nrel.gov/gis/data-solar.html

L'Anse and Village of Baraga Utility respectively). All of these factors can reduce the return on investment.

Figure 1. Obtained from google maps. The Villages of L'Anse and Baraga are located 5 miles apart in the Keweenaw Bay in the Upper Peninsula of Michigan.

Policy Context

Michigan does not currently have any supportive community solar policies or programs; however Michigan legislators proposed a bill in 2018 to change this[35]. Michigan does not allow power purchase agreements that are not included in the Public Utility Regulatory Policies Act, 1978. Instead, solar equipment leases are allowed, which essentially function like a power purchase agreement. This means that community solar program design and development is typically left to the utility's discretion.

L'Anse and Baraga each operate a municipal electric utility that serves Village residents. This local ownership allows the village flexibility to design and construct a community solar program if each village supports the project. This helps to mitigate some challenges that may surface with solar project development in other Michigan regions, such as permitting requirements, interconnection, site control and zoning.

Community Solar Study Findings

UPSTART conducted a series of key interviews and forum discussions to understand how both communities felt about the possibility of community solar project in their village. The primary goals were to get a general sense of what issues could arise if each Village pursued a community solar program. UPSTART used forums as way to spread information about the potential project as well as obtain feedback about community

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[35] Please see http://www.legislature.mi.gov/(S(bqb5euxs5wamxdsi244ve301))/mileg.aspx?page=GetObject&objectname=2018-HB-5861

concerns. The team used interview and forum discussion information to design the community survey and incorporate community specific program design components.

L'Anse

Overall, the L'Anse community expressed positive feelings and support for our proposed community solar program. The community felt the program was important to help the community be forward thinking and strive for a cleaner future. They felt that this project would make the community's needs and interests a priority, something not quite experienced in the past. Finally, they felt that this project would instill community pride, maintain their young population, and overall increase education.

Many considerations emerged from this portion of the study: trust with the utility, environmental/sustainable thinking, local ownership, affordability, and leadership. Trust was a big cited factor in support for the program. Others focused on the environmental benefits from utilizing cleaner energy sources. All income levels in the community must be able to participate in this program. Local ownership with the potential to provide community training was a positive for the community. Minor concerns such as more information and transferability were outweighed by all the potential positives that could influence community member's support for community solar. We compiled these considerations into three main themes: (1) environmental benefits, (2) economics/affordability, and (3) local empowerment. Focusing program design and structure around these three themes should provide the greatest success in L'Anse.

Baraga

The community generally felt positively (beyond economic reasons) about the idea of Baraga doing a community solar project. The study uncovered several important considerations that overlap with the Village of L'Anse, as well as novel findings compared to L'Anse. Community members liked the idea for a combination of reasons, primarily combining environmental benefits with social benefits.

Economic concerns are huge and may ultimately be the deciding factor on participation. Stakeholders felt residents will want specifics on the cost to buy into the program, the payback period, whether or not the investment is guaranteed, and to clearly understand the economic risks and benefits. Many respondents associated energy efficiency projects with solar PV in general. Respondents indicated a lack of knowledge surrounding the energy efficiency programs or projects available from the village utility or other sources (state or federal funding). Baraga community members were generally seen to have an ingrained culture that is resistant to change. Respondents felt that there was not enough awareness of solar electricity, which could ultimately reduce willingness to adopt a community solar project. Inertia could be a real problem; people need to be willing to go out of their way to do something different. Also, building trust in the community is a process that takes time. Many stakeholders did not understand the dynamics between

WPPI Energy and the Village. This led to notions of distrust on who ultimately will benefit from this project. Respondents liked the possibilities for community empowerment, pride, and developing local control associated with community solar. Many felt that businesses or industries could be attracted to the village if they were aware of a community solar program availability. While respondents cited economics as the main driving factor for program adoption, they felt others might adopt beyond financial motivations.

Community survey

In order to collect information on utility customers' interest in participating in a community solar program, UPSTART partnered with the Villages of L'Anse and Baraga to conduct community surveys. The primary goals of the surveys were to develop estimates for the number of customers willing to participate in the a program, identify desirable program options, identify barriers to program participation, and generate baseline estimates for potential customers' willingness to pay to participate in the program. This information was used to select program options and to develop financial model scenarios for the project to help utilities determine if community solar program were economically feasible for their communities.

In order to deliver the survey to potential respondents, UPSTART mailed survey information to each utility's customer mail file. For L'Anse, customers received information about the survey on their monthly utility bill notice followed up by door-to-door reminders. In Baraga, paper surveys were mailed directly to the customers' billing address. Additional rounds of surveys were mailed in partnership with the local Keweenaw Bay Indian Community. Both surveys were successful at achieving reasonable demographic representation of each village.

Both villages generally supported community solar and were in favor of each Village starting a community solar program. The Village of L'Anse community members were likely to subscribe if multiple financing options were available while Baraga respondents varied on which financing option they supported; respondents who favored a high up-front cost, did not favor on bill-financing and vice versa. In L'Anse, support for community solar varied by income, age, and knowledge of renewable energy systems. In Baraga, predictors of community solar support include its potential benefits for the community, knowledge of community solar, higher income, younger community members, and status as a tribal member. In both cases, community members felt they need more information to be comfortable with moving forward with a community solar program. Finally, energy efficiency measures were included in both community surveys. Village of L'Anse community members reported taking weatherization efficiency steps but were interested in doing more such as energy audits and water heater efficiency upgrades. While the Village of Baraga community members were generally unfamiliar with energy efficiency programs, illustrating an area to provide more information and how to access particular available programs.

Partnership opportunities

Through a series of community meetings, UPSTART identified several potential community partners who expressed interest in promoting the community solar program to their respective membership bases and serve as potential anchor subscribers for the program. Representatives from local schools, churches and tribal organizations expressed an interest in connecting their members with the community solar program as well as promoting the program as a means to support investment in their own organization. During meetings with local business associations, community business leaders suggested that they saw the community solar program as an attractive option to support to local community organizations.

The Keweenaw Bay Indian Community (KBIC), a local tribal entity in the area, expressed a strong desire to help its members access solar energy in an effort to pursue environmental preservation goals. KBIC has aggressively pursued investments in solar technology on its own territory but was interested in exploring opportunities to support solar access for members not living on tribal lands. By engaging KBIC leaders during the project development process, UPSTART established a partnership to distribute surveys to tribal residents in Baraga to determine tribal members' interest in community solar. The information collected helped to demonstrate additional support for a potential utility community solar program in Baraga.

L'Anse/Baraga Program Design and Implementation

There are two significant findings in regards to financing options from this feasibility study: (1) existing community solar programs are more successful when they offer multiple financing options to participants and (2) our specific community survey respondents are in favor of a program with multiple financing options to meet the needs of all community members.

Utility Ownership Models and Funding

UPSTART explored multiple ownership models to improve project and subscription costs for Village utility customers. This included:

- Third party ownership with a tax equity partner
- WPPI ownership
- Village ownership utilizing low-interest or no interest loans
- One village owns while the other has access to panel subscriptions (this would increase program size resulting in lower program costs)
- Combined system ownership between the villages.

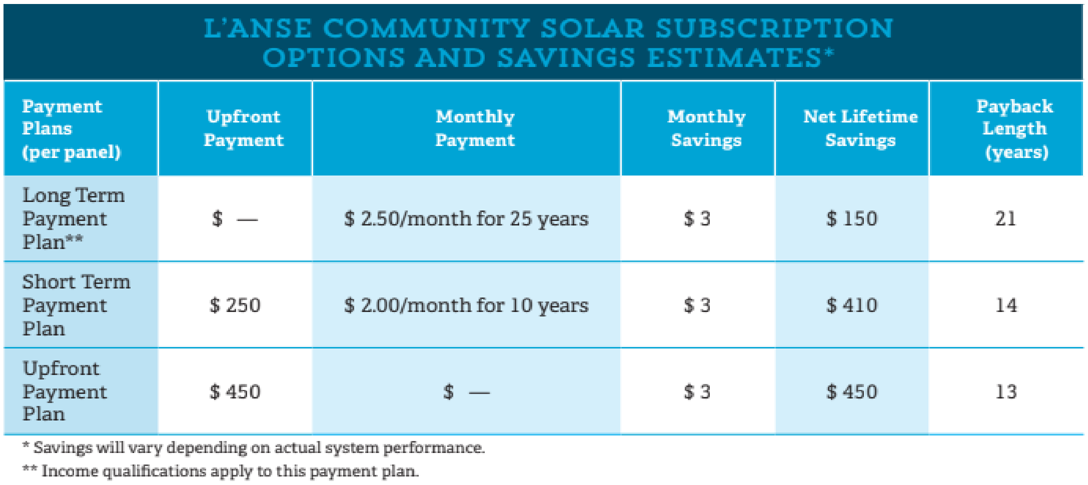
The latter four options would not allow the villages to access any tax benefits associated with owning the solar PV system, but third party ownership would provide that opportunity. Due to the relatively small size of the proposed array, the team found that it was difficult to find developers willing to take on a 100 kW system but yet be dynamic enough to be a tax equity partner.

As the project was developing, L'Anse was able to obtain (1) a grant from the Michigan Department of Agriculture and Rural Development (MDARD) to reduce system costs equivalent to the 30% renewable energy tax credit and (2) approval from WPPI Energy for 0% financing. Consequently, UPSTART moved forward assuming the system would be owned and operated by the Village utility in L'Anse.

Developing the Financial Model

For this project, conducting a feasibility study was highly beneficial towards understanding the needs of the customer base for rate design and subscription options. The study's surveys provided feedback from the customer base on how many accounts want to participate, how many panels they would subscribe to, and what price points would promote participation. Data from the study suggested that multiple subscription options would be better to meet the needs of the customer base and increase participation, but a higher number of payment plan options also increases the burden on utility billing staff and complexity of the program.

Based on the initial Community Solar Design report (Appendix A) and participation estimates from the community during the feasibility study, the team targeted a 100 kW array for the program. The Village of L'Anse issued a request for proposals to determine installation costs. The proposals were evaluated (Appendix H) and a proposal was selected to determine installation costs and capacity per subscription (watts/panel). The utilities involved in this project wanted to create a program that included an affordable LMI carve out, was profitable for all subscribers, and had a net zero profit/loss for the utility. To create this model, NPV analysis was utilized. This was also helpful to create a financial model that kept a positive cash flow for the utility for the life of the program. An example of the NPV calculations can be found in Appendix G and the table below illustrates suggested program pricing. In addition to the hard solar PV equipment installation costs, we also included other soft costs and influences into the equation: interconnection, site development, customer credit rate, maintenance, insurance, marketing and administration.



L'ANSE COMMUNITY SOLAR SUBSCRIPTION OPTIONS AND SAVINGS ESTIMATES*

Payment Plans (per panel)	Upfront Payment	Monthly Payment	Monthly Savings	Net Lifetime Savings	Payback Length (years)
Long Term Payment Plan**	$ —	$ 2.50/month for 25 years	$ 3	$ 150	21
Short Term Payment Plan	$ 250	$ 2.00/month for 10 years	$ 3	$ 410	14
Upfront Payment Plan	$ 450	$ —	$ 3	$ 450	13

* Savings will vary depending on actual system performance.
** Income qualifications apply to this payment plan.

UPSTART's community research identified a strong interest by utilities' customers to participate in a community solar program; however, responses from the survey indicated that many customers were unable or unwilling to pay for the full cost of the program. This is a common challenge in LMI communities where many customers lack the disposable income to pay for the full cost of installing solar technologies. By conducting community-based research, UPSTART was able to identify the gap between the cost of implementing local community solar program and the community's capacity to pay for the program and then make the business case for additional support from state agencies. In addition to the MDARD grant and 0% financing, a limited amount of incentive based on a rate of $0.08/kWh were available through the Village's Efficiency United program. These funds were also included in the NPV evaluation.

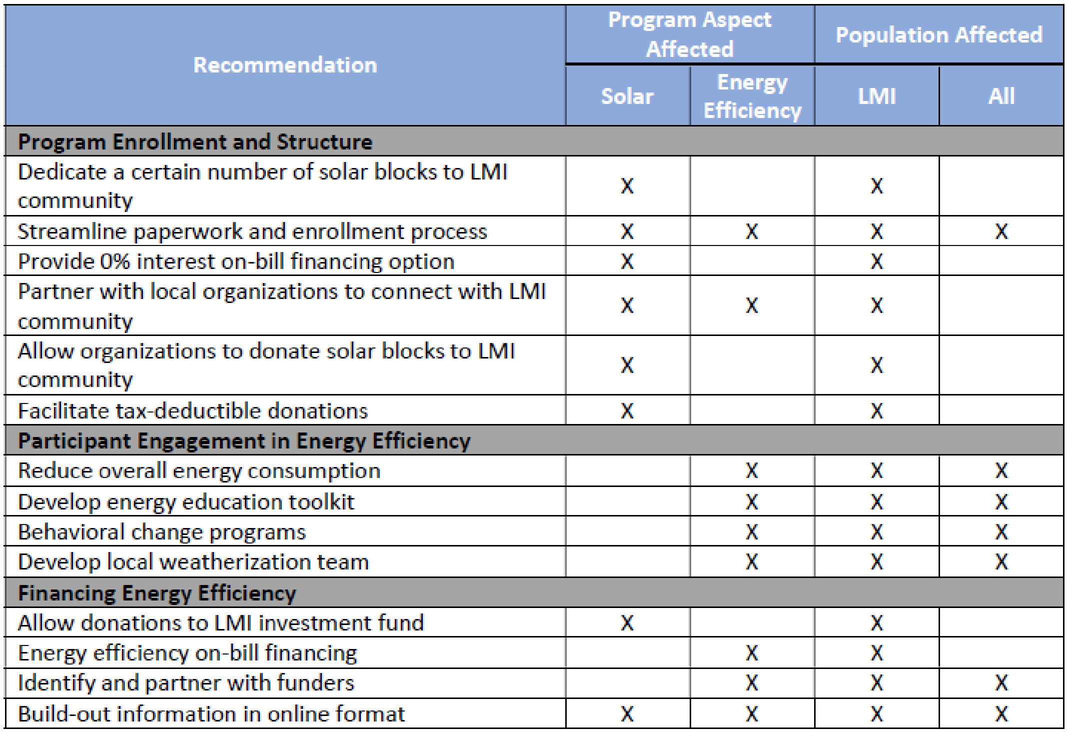
Subscription Contracts

Through a technical assistance grant obtained by UPSTART through the U.S. Department of Energy SunShot program, a third party consultant was hired to draft a contract the utility would issue to subscribing customers. Based on feedback from the feasibility study, transferability of subscriptions was a key concern to be addressed in the contract. Other items addressed in the contract include: eligibility, length of contract, capacity per subscription, subscription costs, LMI qualifications, and depreciation schedules.

Energy Efficiency

UPSTART contracted with Lotus Engineering and Sustainability, LLC to develop a roadmap for defining integration of income-qualified programs and energy efficiency elements to best serve the needs of all community members. The community surveys also gauged which energy efficiency measures residents and businesses completed. The UPSTART team and the Village of L'Anse Electric Utility identified an opportunity to utilize the community solar garden to drive reduced energy costs for low-income households and encourage investments in energy efficiency across the community. For these programs to be successful, particular attention must be given to making resources on efficiency accessible to the LMI community, whether that is through free information and outreach, volunteer teams providing donated weatherization services, or affordable financing tools to support larger efficiency investments in the home. Table 2 provides an overview of the recommendations by program aspect affected and population affected. By leveraging relationships with other local organizations supporting the LMI community or focused on reducing energy burden, such as KBIC, BHKCAA, and WPPI Energy, UPSTART can successfully develop a regional model for an energy efficiency program.

Table. 2 Recommendations by program and population affected.



Recommendation	Program Aspect Affected		Population Affected	
	Solar	Energy Efficiency	LMI	All
Program Enrollment and Structure				
Dedicate a certain number of solar blocks to LMI community	X		X	
Streamline paperwork and enrollment process	X	X	X	X
Provide 0% interest on-bill financing option	X		X	
Partner with local organizations to connect with LMI community	X	X	X	
Allow organizations to donate solar blocks to LMI community	X		X	
Facilitate tax-deductible donations	X		X	
Participant Engagement in Energy Efficiency				
Reduce overall energy consumption		X	X	X
Develop energy education toolkit		X	X	X
Behavioral change programs		X	X	X
Develop local weatherization team		X	X	X
Financing Energy Efficiency				
Allow donations to LMI investment fund	X		X	
Energy efficiency on-bill financing		X	X	
Identify and partner with funders		X	X	X
Build-out information in online format	X	X	X	X

Recommendations and Considerations for Public Power Utilities

Recommendation 1: Build flexibility into the entire process

It is important to recognize that the community solar program development process is not linear. It requires constant reflection and iteration. This begins at the team development stage, all the way through program design and implementation. Throughout the process, different needs can arise that current team members cannot fill. Community feedback may require necessary changes to the feasibility study and/or program structure. Some communities may be underrepresented in community forums and surveys. In this instance, public power utilities should consider changing strategies- a few examples include holding multiple, smaller meetings to accommodate community members schedules, attending community organization gatherings, changing survey length, or conduct neighborhood follow up survey canvassing- to elicit greater participation and community feedback. Over time, changing community needs can result in changes to the community solar program. Building flexibility into the community solar development process can bring the program more success.

Recommendation 2: Emphasize community involvement

A characteristic of community solar is to promote local ownership of energy systems for and by the community within which they operate. Therefore, it makes sense to involve community members at every stage possible. Community members can provide accurate feedback on what sort of program would work in their community. They can be used to recruit program participants through peer-to-peer marketing in a worker co-op or volunteer model. The public power utility can build into an RFP that a portion of the labor for the community solar installation must come from training community members. This can provide valuable skills for underemployed community members to seek employment in general construction jobs or specifically the solar industry. Finally, the community solar array can be a source of an educational program with the community school system- to teach students about energy use and solar energy.

Recommendation 3: Provide a program that is affordable

Many community solar programs are still only accessible in affluent communities. This can be directly linked to the affordability of the program. It is important for local governments and public utilities to design a program that capitalizes on all available options to decrease program costs. Additionally, program administrators should include a way to qualify low income participants beyond a FICO score (i.e. history with electric bills). Options to consider include:

- Partner with a developer and/or tax equity investor or seek out state, federal, and private grant opportunities to lower program costs.
- Provide multiple financing options- especially those that can be accessed by income qualified households or non-profit facilities
- Partner with community organizations or businesses to build a donation option in the model
- Consider utilizing an anchor customer: Selling a large portion of panels from the system to an individual customer can reduce the cost liability to the utility and can spur/promote subscriptions from other customers.

Recommendation 4: Program design components

Every community is different with respect to the program design considerations. It is important to listen to community feedback and incorporate these considerations into the community solar program design. The following describe some components that often surface during community solar program design for a small rural public power utility, but utilities may encounter other considerations not included in this list.

- Transferability: A common concern in many existing programs, customers want to know what will happen to their subscription if they move away, can no longer afford the subscription, or simply do not want a subscription. Public power utilities should account for the many different scenarios in the design of the program.
- Ease of participation and transparency: Complicated community solar program design and sign up can create confusion and frustration for customers. Make the participation process as easy as possible for customers. Community members can also make a more informed decision with more information about the potential project. It is important for municipalities provide as much information as possible to help community members either accept or reject a project.
- Length of program & number of subscriptions: These design components can directly influence the affordability of the system. The length of program can be varied to consider and suit different participation interests. The number of subscriptions available will determine the amount of benefits experienced by each customer, but the utility can choose to limit number of subscriptions to allow great distribution of community solar benefits.
- Financial model: Rate design and program pricing is a tricky balancing act between:
    1) creating opportunity for LMI customer participation without shifting too much cost to non-LMI subscribers
    2) offering enough pricing/financing options to the customers while keeping the program manageable for the utility
    3) installing a system big enough to capitalize on economy of scale installation costs and customer demand without incurring liability to the utility with an unsubscribed program
    4) designing a program that is a reasonable investment for both the customers and the utility for the life of the program.
- Operation and maintenance: Some utilities may not have the capacity, skills, or knowledge to operate and maintain a community solar array. The utility can consider contracting with the solar developer for these services or provide employee training (i.e. through developer). Training could also be provided to under and unemployed community members to create job opportunities within the community.

Recommendation 5: Integrate energy efficiency measures

Implementation of energy efficiency should always be the first step before considering installation of renewable energy generation. A good avenue to introduce energy efficiency into the community is through a survey on energy efficiency awareness and community outreach. The utility can supplement survey findings with a broader community toolkit to both educate community members on available opportunities as well as learn which energy efficiency measures households need to address to reduce energy costs. Taking this a step further, utilities should consider how to integrate energy efficiency programs into their community solar program design.

Recommendation 6: Engage in community partnerships to build capacity

Often times, a utility's internal capacity (limited time, financial resources and expertise) represents a significant barrier to developing community solar programs. Many utilities do not have staff equipped and/or available to conduct community-engaged research to determine the social, technical and economic feasibility of a community solar program and it can be cost prohibitive to hire third-party consultants to do the work. Establishing partnerships with local universities, planning agencies, nonprofit organizations, state agencies and other groups can help access resources to assist with evaluating and planning community solar programs. In some cases these groups may be willing to partner or lead the evaluation at little to no charge to the utility. Similar to UPSTART's work, the process can help develop a coalition capable of accessing financial resources for additional research and program implementation.

C Supplementary Statistical Appendix

Types of Variables:

The type of variable matters because different statistical analyses assume that variables have specific levels of measurement. Choosing the a statistical analysis with an inappropriate variable can result in inaccurate results.

Categorical: (Sometimes referred to as nominal variables) These variables have two or more categories without a natural or logical order. A categorical variable allows the research to assign categories rather than clearly ordering them.

Ordinal: Similar to categories, these variables have a clear and logical order. While ordinal variables can be ordered from low to high (for example) the distance between each variable is different.

Interval: These variables are assigned a numerical value and can be measured along a continuum. The distance or space between values in interval variables is equal.

Ratio-level: A subset of interval variables where zero is meaningful.

Dichotomous: These variables include only two values, generally, a 0 or a 1, where the zero again is meaningful.

Statistical Analysis Methods:

Descriptive Statistics: This method is used to summarize data. They include a measure of frequencies, central tendencies, and variability. Descriptive statistics are used to describe characteristics of research participants. This type of statistical procedure does not allow researchers to make any conclusions beyond data that is analyzed. While descriptive statistics are important to the story, they can be deceiving if interpreted incorrectly.

Inferential: This methodology utilizes the existing data set to measure relations and effects between variables. Inferential statistics can be used to test theories regarding explanations or predictions. From this analysis, the research can make generalizations about populations. Inferential statistics uses correlational statistics such as regressions.

Regression analyses:

Regression is a form of explanatory statistics that examines or explores for a relationship between two or more variables. Regression analyses allow the researcher to examine the influence of one or multiple independent variables on a dependent variable. Regression analyses can be used to determining what factors matter in impacting a topic of interest. The nuts and bolts of conducting a regression involve creating a regression line from a dataset and generating a regression equation that tells the researcher about the relationship between the independent and dependent variables (either positive or negative).

Linear: Multiple regression models are available to analyze continuous variables with infinite values. Linear regression, also known as ordinary least squares (OLS), attempts to explore the relationship between an explanatory variable and a dependent variable by fitting a linear equation to the data. The linear regression does not imply causation between variables, only that there is an association between variables. Stepwise regressions are special forms of a linear regression that allow the researcher to introduce and identify significant variables. In this model, the researcher builds the regression by adding or removing one variable at a time until it is no longer necessary to add or remove any more.

Non-linear: This approach also seeks to understand the relationship between independent and a continuous dependent variable. This approach is useful if the linear regression did not obtain a good fit. This model fits data to curves rather than lines.

Logistic: Regression models also exist to analyze categorical dependent variables. A logistic regression seeks to describe the relationship between independent variables and categorical dependent variable. A binary logistic regression seeks to understand the probability that an event will occur. This model requires a binary dependent variable, which has only two options. An ordinal logistic regression models ordinal dependent variables. A nominal logistic regression models the relationship between the predictor variables and a nominal dependent variable.

Statistical analysis used in this dissertation:

Chapter 4 of this dissertation conducts three statistical analyses. Two binary logistic regressions were conducted. The first used the dependent variable asking respondents whether or not they are in favor of the village developing a community solar program. The second analysis uses a dependent variable that measures respondent's willingness to purchase shares in a community solar program (0=No and 1= Yes). Both logistic regressions used a theory-informed stepwise regression. The following variables were included: village location, gender, knowledge, environment, economic status, community identity, and trust. The results of both analyses are below. An Akaike Information Criterion and Bayesian Information Criterion was conducted after each regression to determine the best quality model.

Logistic regression stepwise with Q4

	Odds Ratio (AIC/BIC of Model)						
Constant	27.17	32.72	30.561	14919	65033	274369	90228
Village	0.475 (142/149)	0.5349	0.5740	0.4184	0.3942	0.3559	0.3633

Gender		0.9982* (136/148)	0.9985*	0.9989	0.9988	0.9988	0.9992
Knowledge			0.7697 (137/152)	3.34e+17	1.95e+21	1.69e+25	2.75+21
Economic status				1.341 (113/132)	1.33	1.288	1.257
Environment					0.9991 (114/137)	0.9991	0.999
Community Identity						0.7639 (116/142)	1.293
Trust							0.9982 (117/147)

In this model, the last two variable additions showed significant variables- both community identity and environment variables and then just the environmental variable in the last one. This last model has the lowest AIC/BIC relative to the others. I was inclined to think about using this in the paper, because it does have significance with community identity but no other variables that we discussed that come through in the literature.

Logistic regression stepwise with Qshares

	Odds Ratio (AIC/BIC of Model)

Constant	1.347	1.350	1.34	1.551	1.705	1.743	1.313
Village	0.9558 (463/471)	0.9561	0.9572	1.060	1.0271	0.9532	0.9423
Gender		0.9999 (465/476)	1.000	0.9993	0.999	0.9993	0.9989
Knowledge			0.9800 (467/482)	1.248	1.235	1.369	2.03
Economic status				0.8699 (426/444)	0.8647	0.8363	0.8490
Environment					0.9992 (424/446)	0.9992*	0.9992*
Community Identity						0.7021* (421/447)	0.2794
Trust							1.003 (419/449)

This final stepwise regression analysis shows knowledge and environment as significant factors throughout. The strongest model appears to be the 5th iteration (if we're looking just at AIC/BIC which are the lowest here). Trust is significant when using a p-value of less than 0.10.

Linear regression with viability index as DV

	Coefficient (AIC/BIC of Model)						
Constant	0.115	0.014	0.0294	-0.202	-0.360	-0.364	-0.0161
Village	-0.230 (242/250)	-0.24	-0.315	0.0143	0.197	0.0209	0.0226
Gender		0.00002 (244/255)	-0.0001	-0.00004	-0.00003	-0.00003	-1.60e-06
Knowledge			0.1352* (221/237)	0.2793*	0.281*	0.2796*	0.2544*
Economic status				0.042 (65/84)	0.0426	0.0431	0.0420
Environment					0.0001 (61/83)	0.0001*	0.0001*
Community Identity						0.005 (62/89)	0.0685
Trust							-.00022** (61/91)