# Understanding Participation in Energy Transitions:

# Insights from the US and Mexico

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved November 2022 by the
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December 2022

ABSTRACT

Transitioning towards low-carbon energy systems requires participation from a diversity of organizations, governments, and actors. Yet it is still unclear who, when, how much, and what types of participation are needed to realize such transformations. I address this gap by analyzing the role of participation in energy transitions using interviews, participant observation, document analyses, and novel visualization approaches deployed in the USA and Mexican contexts.

I offer a framework to explore how engagement in energy transitions unfolds over time and deploy the framework to 1) investigate the role of engagement in decreasing the consumption of gas and electricity at municipal and residential levels in 12 US communities during a three-year competition (2014-2017) organized by Georgetown University; and 2) assess the acceptance and longevity of solar projects that grant electricity access to rural and dispersed Indigenous Ralámuli communities in Chihuahua, México. I found that wider and deeper participation does not always secure lower energy consumption in the US case, which highlights the need to tailor participation for specific goals. Results from Ralámuli communities suggest that the benefits of participation reach a limit; that is, when high participation surpassed the budget (in the form of cash/money and time availability) of solar users, participation became detrimental to user satisfaction and technology acceptance. Lastly, the analysis of how participation occurred in solar home systems with longer longevity (more than five years of use) showed that maintenance and operation costs (e.g. battery replacements) are the greatest barriers to longevity, while knowledge and capacity building might be elements driving longer longevity. Recommendations include: (1) offering clear information in the user’s first language about the costs and maintenance of solar systems, (2) seeking ideas from solar users at the early stages of solar programs, and (3) reducing costs through understanding electricity needs and offering collective forms of ownership.

My work expands the theoretical understanding of the role of participation in energy transitions and offers practical resources for practitioners and researchers to facilitate a critical reflection on how participation influences desirable outcomes in different contexts, including communities in the global North and South.

ACKNOWLEDGMENTS

1. As a small gesture of recognition and respect, I would like to acknowledge that this research was designed and developed from the ASU Tempe campus which sits on stolen and unceded lands. This territory has been the home of the Huhugam, ancestors of O'odham nations, and the Yavapai, and Peepash nations.

2. I also want to acknowledge that this research takes place in the territories that belong to the Tepehuanes, Odames, Pimas, Guarjios and Rarámuli nations that now live in the Sierra Madre Occidental in Chihuahua, México where I have worked in the past and from where I have collected data for this project.

3. I am aware of the colonizing practices that research institutions like universities have conducted with Indigenous communities, and I hope to actively contribute to change this problematic history. I hope this research will provide resources for Indigenous nations to make informed decisions about how they want to engage in projects that are offered in their communities. I will work to continue socializing results to inform future solar projects. I do this acknowledgment as a gesture of humility and with the intention of denouncing the injustices that colonization has caused in the past and that are still affecting Indigenous nations in the present.

4. I would also like to express gratitude to my committee for their support and guidance while designing and executing this research and throughout my doctoral studies. Their mentorship was crucial in this process.

5. I also would like to thank my friends, family, and colleagues in Mexico who made this research possible. I want to thank Aidé, Monse, Jordi, Bernardo, Crucita, Moni, Celene, Mariel, and organizations like Pies de la Tierra, CEDAIN, COEPI staff, and women in the cooperative Napawika Simabo who offered help, support, and guidance during my fieldwork. I want to thank Jordi Borja and Horacio Almanza Alcalde for their feedback on the interview protocol and methods I used during the fieldwork in this research. I also want to thank Juan Carlos, Letty, Mare, Karla, and my goddaughter Mia who offered their support during my fieldwork seasons. I want to thank Lili, Eri, Carsten, Santi, Marijo, Anika, Francisco Marline, and my husband

Mackenzie who have also supported me in this journey. Thank you, this project could not have been possible without your support and love!

6. I would also like to express gratitude to the School of Sustainability at ASU, Re-engineered, the National Council for Science and Technology (CONACYT), Team Belonging, and Earth Systems Science for the Anthropocene (ESSA) for their economic support during my studies.

7. I would like to thank and acknowledge that this research was possible thanks to all my Ralámuli friends, solar users, and solar industry colleagues, and GUEP organizers and communities who shared their experiences that made this research possible. I will keep working to socialize the findings in this research to inform future projects that intend to actively work to decolonize our practices.

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# CHAPTER 1

# INTRODUCTION

This dissertation aims to understand the role of participation in energy transitions. Researchers and practitioners agree that participation is crucial in the transition toward low-carbon energy systems, yet it is unclear when and how much participation is needed to realize such a transformation. I offer answers to this dilemma through a qualitative and systematic analysis of participation in two different settings: first, a competition that aimed to reduce gas and electricity consumption in the US, and second, several solar photovoltaic home systems (SHS) programs that granted electricity access to rural, remote Indigenous Ralámuli communities in Chihuahua, México.

Participation in decision making has been a popular term in diverse scholarly fields. In development studies participation became mainstream in the 1970s (Alvial-Palavicino et al., 2011; Cohen & Uphoff, 1980; Cornwall, 2008; Michener, 1998). In the early 2000s, Science and Technology Studies (STS) used the term "participatory turn" (Jasanoff, 2003, p. 235) to describe the rising popularity of participation of the public in co-production of scientific research and socio-technical systems. In more recent years, STS literature has continued highlighting participation as an important element in the study of energy and social sciences (Hess & Sovacool, 2020).

The utilitarian and democratic motives are two common objectives of participation in energy transitions literature. Research has portrayed participation as an instrument to achieve desired goals and has explored the drivers that sustain participation to support such transformations. For example, participation is meant to secure public support of renewable energy projects like wind farms (Devine-Wright, 2011) or rural electrification projects (Huacuz & Agredano, 1998), change electricity consumption behavior to match the hours of the day with high solar generation (Krietemeyer et al., 2021), and ultimately support a widespread energy transition (Renn et al., 2020). Other authors have argued that the participation of the public in early stages of projects will secure solar acceptance (Pasqualetti & Schwartz, 2011), while others have showed that user participation is important for solar PV adoption in California (Wolske, 2020), Wisconsin (Schelly, 2014) Australia (Sommerfeld et al., 2017) and Malaysia (Lau et al., 2020). The literature also suggests that understanding the energy culture in co-design processes (Krietemeyer et al., 2021), as well as the performance of key actors like facilitators and organizers (Ernst & Fuchs, 2022) are factors that could sustain participation. Another body of literature on energy democracy particularly highlights the need to include historically marginalized groups in the decision-making processes of the energy projects that affect them (van Veelen & van der Horst, 2018).

Despite this myriad of positive outcomes that participation creates, research has also shown the limitations of participation. Some authors have warned about the dangers of public participation in the reproduction of the inequalities that it is meant to redress (Cooke & Kothari, 2001). For example, in the case of Chile's Energía 2050, participation brought together stakeholders with diverse views to imagine the energy future of the country, yet participation was also a form of tokenism that secured the views of the most powerful stakeholders (Urquiza et al., 2018). In response to such shortcomings, literature has developed concepts like depth and breadth of participation to further describe how participation occurs (Bebbington & Farrington, 1993) examine who is included, excluded, and self-excluded across the process (Cornwall, 2008), and to highlight. The importance in bringing clarity and specificity in how we understand participation (Cohen & Uphoff, 1980).

In the same vein, authors in energy research have indicated the need of systematic analysis of participation to increase the use of renewable fuel sources in our energy systems. Social sciences could play an important role at informing future evidence-based practices of engagement through systematically monitoring and evaluating empirical participation (Devine-Wright, 2011). Other authors have used novel approaches to differentiate and map forms of participation and public engagement to understand how participation transcends individual practices and explore the links of participation to collective transformations of energy systems (Pallett et al., 2019). Authors also approach public participation in energy transition efforts as co-produced, relational, and emergent to differentiate how participatory collectives occur and unveil the potential of participation in systemic change (Chilvers & Longhurst, 2016).

Thus, important gaps in our understanding of participation and its outcomes remain. We know participation is crucial for energy transitions, yet it is unclear how much participation and influence from the public is needed for a successful energy transition (Bidwell, 2016). Additionally, authors have suggested that participatory process may require a lot of time and could be expensive (Cornwall & Jewkes, 1995). This dilemma has encouraged intergovernmental organizations to look for strategized design and evaluation of participation (OECD, 2022; Renn et al., 2020) to make the best use of time and resources of local communities and the public.

To achieve this goal, I built on the lessons and instruments already present in the literature to develop a framework of energy participation. This framework is an analytical tool that enables researchers and practitioners to track how participation occurs in different settings and explore how participation influences diverse outcomes. It was inspired by previous mapping and visualizations of participation. For example, Krütli et al. used Arnstein's ladder of participation (1969) to differentiate among three approaches of decision-making processes that use different intensities of engagement to plan radioactive waste management in Germany (2006) and Stauffacher et al. used a similar approach to map different intensities of participation across a process of landscape development in a Swiss prealpine region (2008).

I complemented these techniques to visualize and differentiate among engagement intensities across the process of participation with three concepts offered in the co-productionist framework in Chilvers et al. (2018): (1) objects of participation (also see Chilvers & Longhurst, 2016), or the activities or issues where participation takes place, (2) the subjects or actors participating, also defined as breadth of participation by Bebbington & Farrington (1993), and (3) the forms or models of engagement that describe how participation occurs, also defined as depth of participation (Bebbington & Farrington, 1993) or typologies of participation; (Arnstein, 1969; Jackson, 2001; Pretty, 1995).

Thus, these elements can be plotted in graphs that visualize the process of participation. These graphs show the forms of engagement, the actors involved, and the different events that occurred in diverse processes, which brings precision to what we mean by participation. Such visualizations could also be used to answer research questions, facilitate reflection, and test hypotheses about the possible effects of engagement efforts among different processes. Reflections on this process could help us identify what practices might be working best and when. This technique to visualize the process of participation offers the possibility to understand and keep track on how engagement unfolds across the process under analysis so that we unlock participation's full potential and avoid potential unintended consequences and inequitable outcomes.

Through empirical analyses in the three papers of this dissertation, I offer examples of how such an instrument could be used to explore the effects of participation in energy transition efforts. Ultimately, this dissertation sheds light on how to strategize participation to make the best use of our limited resources, particularly the time that participants invest in a project, and to secure desired outcomes. This work provides theoretical insights on how we conceptualize participation to advance our understanding on the role of participation in energy transition interventions.

## 1.1 Research Questions

The overarching research question in this dissertation are: How does participation enable energy transitions, and what is its role in achieving the energy transition outcomes? The specific questions that each of the papers in this dissertation answers are the following:

***Paper 1: Visualizing Energy Participation: A Method for Practitioners and Researchers***

- What tools can we use to analyze the process of participation in energy efforts?
- How did communities participate to decrease gas and electricity consumption in the Georgetown University Energy Prize (GUEP)?
- Did higher forms of engagement lead to more savings?

***Paper 2: Energy Participation and Solar Photovoltaic Technology Acceptance by Ralámuli Users in the Sierra Madre Occidental, Chihuahua, México***

- What modes of participation were deployed in solar home system programs that granted electricity access to Ralámuli communities in the Sierra Madre Occidental, Chihuahua, México?

- What is the relationship between participation in programs and higher or lower solar acceptance and user satisfaction?

***Paper 3: How Energy Participation Influences the Longevity of Off-grid Solar Home Systems in the Sierra Madre Occidental, Chihuahua, México?***

- How did participation occur in solar programs that lasted more than 5 years?
- What is the role of participation according to local narratives?
- Are free programs set to failure?

## 1.2 <u>Methods</u>

This dissertation uses qualitative methods and two sets of data to answer the previous research questions. In paper one I conducted an analysis of documents generated in the GUEP competition to understand how US urban communities participated in efforts to decrease the consumption of gas and electricity in municipal and residential buildings. In paper two and three I used participant observation during two seasons of fieldwork (January-March 2021 and November-December 2021) and conducted 63 interviews with solar users and solar developers to understand how participation occurred in electricity access programs that offer solar PV technologies to Ralámuli users in rural communities in México.

In addition, I used the same systematic data analysis to answer the research questions in each of the three papers of this dissertation. Figure 1 below illustrates the flow diagram I used to synthesize the data in this dissertation. First, I divided information into small pieces that conveyed one single idea. Then, I asked if such information was part of an activity or strategy. If the answer was yes, I specified who are the actors engaged, on what are actors participating and during which stage of the process, and the form of engagement they enacted. In the contrary, if the initial answer was no, then I simply use standard qualitative analysis methods to organize information.

I used content analysis and deductive (categories from the literature like the ladders of participation) and inductive codes (categories that emerged from data) to differentiate among objects, subjects, and forms of engagement in each of the energy projects under analysis. I create a codebook (DeCuir-Gunby et al., 2011; Mihas, 2019), with a three-level structure (Gioia et al., 2013), to define the categories and variables under analysis and clarify the inclusion/exclusion criteria. The codebook also provided examples of each category and showed the nuances among codes. I used MAXQDA as a coding software to organize all data and Excel to generate the visualizations of participation. I also followed Deterding & Waters work (2021) to divide information by index codes that grouped information by broad topics, and then I conducted a more detailed analysis of the codes that required more attention to answer the research questions in each essay.

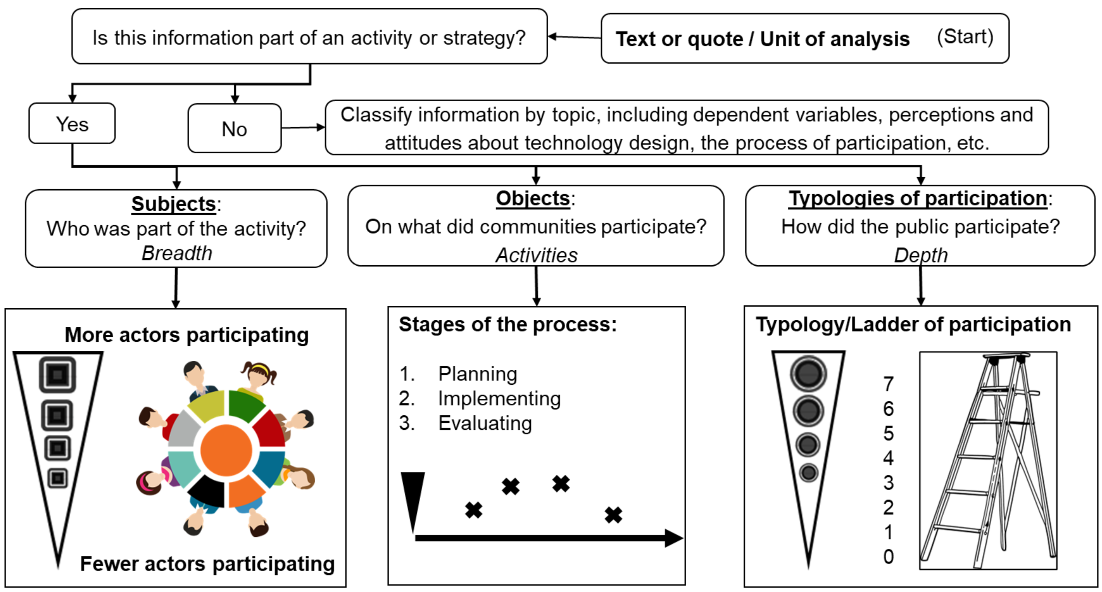

Figure 1. Systematic Qualitative Data Analysis

### 1.3. Summary of Papers and Contributions

**Paper 1** (Morales-Guerrero & Karwat, 2020) starts from the assumption that participation requires systematic and rigorous frameworks to realize its full potential. I borrowed concepts present in the literature to build energy participation as a framework. I then used this analytical instrument to understand how participation occurred in practice. I explored how communities and stakeholder groups organized to decrease consumption in the context of the Georgetown University Energy Prize (GUEP). GUEP was a three-year competition (2014-2017) where 50 US communities—small cities or towns with populations between 5,000 and 250,000—competed to win a US$5 million prize that would benefit the community as a whole.

GUEP launched in 2014 and encouraged US communities to implement energy efficiency programs, educational campaigns and organize towards one goal: to reduce the consumption of gas and electricity at municipal and residential levels (GUEP, 2017a). GUEP encouraged communities (1) to deliver standardized reports that described their practices, (2) to collaborate and create partnerships between at least three stakeholder groups: the government, utilities, and community organizations to work toward reducing energy consumption, and (3) to provide energy consumption reports from 2013-2017 to generate an Overall Energy Score (OES[1]).

The visualizations of participation helped me distill the text of hundreds of pages spread across a range of reports and documents into a few images. Through this simplification of information, I was able to tell a story of how participation occurred and hypothesize about how the diverse forms of engagement/participation across the process of 12 US communities could have influence communities decrease consumption of gas and electricity.

Results suggest that wider (that refer to more actors involved) and deeper participation (that refer to the levels in participation in the ladder or typology of participation) were not present in communities with higher energy savings. Such results suggest that instead of blindly looking for deeper and wider engagement, participation must be strategized to reach its full potential and make the best use of participants and communities' resources. For example, informing communities about the benefits of energy efficient light bulbs might be a shallow form engagement, but it might be important to encourage and realize electricity savings in households.

This paper offers empirical evidence that energy participation as a framework can be used to compare diverse efforts and hypothesize how participation might influence the outcomes of such efforts.

**Paper 2** applies the energy participation framework to explore how engagement affects acceptance and user satisfaction for residential solar energy in rural México. I conducted field

[1] The OES "quantifies their energy saving performance relative to the community's baseline as a percentage change. The OES is calculated based on the Adjusted Source Energy Use per Residential Bill (ASEU) averaged" (GUEP, 2017, p. 20) over the first 24 months constituted baseline or ASEUB and the following 24 months would be the score during the competition or ASEUC. This is the formula: OES = 100 x (ASEUC – ASEUB) / ASEUB

work in the municipalities of Bocoyna, Guachochi and Batopilas in the Sierra Madre Occidental (SMO) in Chihuahua, México and tested if energy participation was a suitable framework to understand the processes of participation outside the US. This time I use official documents, 57 semi-structured interviews with Ralámuli SHS users, 6 semi-structured interviews with solar developers, and participant observation to explore how participation occurred in five solar programs that granted electricity access to rural, remote, and disperse communities that include programs developed through (1) federal policy, (2) state and municipal initiatives, (3) a gas pipeline consultation, (4) nonprofits, and (5) privately owned solar systems. This second paper advances the framework developed in paper one by adding three analytical codes for directionality that identified if solar users led the performance of participation or if there was two-way communication as actors participated. This structure helped me identify the directionality of how participation is performed by actors across the stages of the process in each solar project.

The results suggest that the absence of user-led engagement and/or two-way communication (between final users and solar developers) during the planning stage might set high expectations from participants that could ultimately translate into lower solar technology acceptance and user satisfaction rates. For example, despite a high level of user-led participation during the implementation stage of the federal policy solar project, Ralámuli users' acceptance and satisfaction was considerably low to the rest of the solar programs in this study. Ralámuli solar users justified the low technology acceptance and user satisfaction scores in the federal program with the costly monthly payments and time invested while doing the monthly payments. Users explained how they need to decide between buying food or paying their electricity bills. Thus, large presence of user-led participation that surpasses the budget and economic means of participants in a solar program could become a detrimental factor for user satisfaction and technology acceptance. The federal program might be contributing to reproduce inequalities in the form of user debt and energy poverty by offering expensive electricity though solar technologies.

This analysis provides recommendations for future solar programs that aim to avoid unintended consequences. For example, clear and sound information about solar programs must be offered in user's first language to avoid mismatch of information about users' responsibilities and rights after singing their contract. It is important to emphasize that opening communication channels with users will not be enough, there is the need of capacity building to secure users' informed decisions about the solar technologies they will adopt, like how much solar capacity they will need to meet their electricity needs and the costs of the solar modules. Thus, solar users must be included at early stages of the programs so that solar developers understand electricity needs of users to offer enough solar capacity installed that meets the users' needs while also offer affordable electricity. Other suggestions include offering collective ownership to reduce costs. I hope these recommendations and reflections inspire future decision makers to co-design programs with both end users and experts from early stages. These recommendations are crucial to design projects that stop the reproduction of inequalities that some solar projects are currently causing to historically marginalized communities.

This paper also makes conceptual contributions by further refining the energy participation framework and showing how it can be used to understand processes in the global south. Additionally, it supports the finding from paper one that researchers and practitioners need to strategize participation. Simply proposing high participation from the public during the implementation of projects to secure solar technology acceptance is not enough, solar developers and practitioners must plan and balance the intensity of participation based on users' needs and resources, like time and income level, to avoid unintended consequences like lower user satisfaction or the generation of user's debt.

**Paper 3** focuses on one case study, the solar program offered by the state and municipalities, to explore the role of participation in the longevity of PV systems in the Sierra Madre Occidental (SMO), Chihuahua México. Literature suggests that participation is important for energy transitions in different avenues like matching electricity production of renewable sources and electricity demand (Krietemeyer et al., 2021; Sloot et al., 2022), understanding social acceptance of energy infrastructure through public engagement, ownership (Upham et al., 2022), and public's influence in decision making (van Veelen & van der Horst, 2018), or though understanding barriers for solar technology adoption (Lau et al., 2020; Scholly 2014; Sommerfeld et al., 2017). Yet the literature in the intersection of energy transitions and participation has overlooked the relationship of participation in the longevity of SHSs. I argue that it is important to understand the factors that lead to their long-term reliability of solar system because a successful transition towards low carbon energy sources needs to ensure the reliable operation of technologies over time. I fill this gap by empirically exploring the state and municipal programs that have been offered to Ralámuli communities over the last 14 years. I focused on the projects that continue to operate for five or more years. Drawing on 22 interviews, I created graphs and visualization of participation to explore the reasons of longer uses of SHS.

Results show that material participation in the form of costs are the main barrier for a prolonged use of SHS, which include replacement of batteries and other spare parts of the solar modules. Such costs can be exacerbated by bad weather and thefts. Functional participation in the form of the re-use of old truck batteries or changing and installing batteries from other solar systems are informal practices that secure longevity of solar systems. Also, participation in the form of active use of solar technologies helped users to gain knowledge about how to take care of their solar systems and avoid technical issues caused by weather. Thus, knowledge and capacity building are also drivers for longer use of SHS.

Despite the fact that the solar program offered by the state was free of charge, results showed that users needed to invest in operation and maintenance costs to secure the longevity of the program. The results also showed that free solar programs are not necessarily set to fail, yet the investments in operation and maintenance costs are necessary elements for a long and successful use of solar SHS technologies. Recommendations to prolong longevity of solar systems include (1) informing key actors like women and youth about the use and maintenance of solar systems and (2) offering solar systems with low maintenance and operation costs.

### 1.4 <u>Conclusion</u>

The common theme in all the three papers of this dissertation is participation in energy transitions. Paper one built the framework to understand energy participation and implemented it to understand participation in the US context. Paper 2 then applies the same framework to compare participation among SHS projects in rural Mexico. Paper 3 uses the same framework to focus on one solar program and offers a case study. Each paper looks at different outcomes that are needed in energy transitions that include the reduction of electricity and gas consumption in communities in the global north like the US, solar technology acceptance and user satisfaction in rural and disperse communities in global south countries like México, and the longevity of solar systems that grant electricity access to Ralámuli communities in the global south.

The three papers in this dissertation offer insights on important elements in energy transitions. The framework that I built through this research facilitated a systematic analysis of participation to synthesize information from official documents, participant observation and interviews and explore how engagement influences desired outcomes that are important for researchers and practitioners. The main takeaway in the three papers in this dissertation indicate that participation needs to be strategized based on the goal of the intervention because “high participation” does not always translate into the outcomes needed for an energy transition. Thus, participation requires a critical use to avoid unintended consequences and achieve the outcomes we need in a transition to a low-carbon energy system. This dissertation also offers practical contributions for practitioners; this analysis allowed me to create a practical step-by-step guide to plan, design, and evaluate participation in diverse contexts including the global north and south.

In the coming chapters, this dissertation presents each of the papers previously described. The concluding chapter elaborates on the contributions for practice, it also offers a reflection on the limitations of this instrument and framework, and it details some avenues to overcome such limitations. Additionally, I elaborate on the theoretical contributions of this dissertation and offer final remarks that summarize the main findings in this dissertation.

CHAPTER 2

# VISUALIZING ENERGY PARTICIPATION: A METHOD FOR PRACTITIONERS AND RESEARCHERS[2]

**Abstract**

Through our analysis of the data generated by 12 communities in the Georgetown University Energy Prize—a US-wide effort to increase energy efficiency and reduce greenhouse gas emissions—we present a widely useable method to create visual maps of participation in energy projects. These maps, which show the *breadth* (who participated), *depth* (how), and objects (issue) of participation, can summarize large amounts of information on participation in just a few visualizations. For this study, these maps describe how communities organized to decrease the consumption of gas and electricity at the municipal and residential levels during the prize. Our results show that broader and deeper participation would not always lead to greater energy savings. Thus, instead of blindly aiming for higher participation to achieve better outcomes, results suggest that *breadth, depth* and objects of participation must be strategized based on the context and possibilities of the community, as well as the goals of the project. Maps do not only add transparency in decision-making processes by disclosing the who, how and on what of participation, but also facilitate the comparison of participatory efforts across process, communities and time. While the maps visualized participation that occurred in the past, the framework and method can be customized and used by governments, planners, community stakeholders, etc. in understanding, mapping and strategizing ongoing future participatory efforts in energy projects. Our instrument offers a flexible framework to plan, implement, evaluate, and research participatory interventions past, present and future.

## 2.1 Introduction

The urgency of addressing climate change is in conflict with the time and patience it takes to undertake meaningful participatory processes in energy transitions. Recent literature

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[2] This paper was published as an article in Energy Research & Social Science 66 (2020), DOI: 10.1016/j.erss.2020.101496, © 2020 Elsevier Ltd

suggests that strong participatory processes, in which the public is included in the process of decision making, are key to promote social acceptance of wind energy projects (Baxter, 2017; Devine-Wright, 2005; Rand & Hoen, 2017), renewable energy (Liu et al., 2019), and addressing energy justice (Capaccioli et al., 2017). Therefore, in order to accelerate energy transitions, it is important that we create tools that build trust (Dwyer & Bidwell, 2019), strengthen participatory processes, allow for strategizing and evaluating citizen participation, and increase our ability to share knowledge and understanding quickly with the objective to accelerate energy transitions.

The use of the term "participation" has a long history in academic literature. In the 1960's and early 70's scholars documented how citizens participated in the decision-making process of land use (Richards & Dalbey, 2006). Since the 1970s, agencies like the World Bank and United Nations have been producing documents and narratives that promote participation as a means to success (Cornwall, 2006). Around this time, *Pedagogy of the Oppressed* (Freire, 2018) and Sherry Arnstein's famous "ladder of citizen participation" (1969) influenced the participatory research spheres and the development industry. Since the 1980's, participation has been a concept widely used in the development industry (Cohen & Uphoff, 1980; Michener, 1998). In recent years, science and technology studies (STS) has coined the term "participatory turn" (Jasanoff, 2003, p. 235) to describe the popularity of such term in multiple socio-technical and co-production practices.

Despite the popularity of participatory practices, participation has also been described as a vague buzzword or catch-all concept with unclear meanings (Cornwall & Brock, 2005). Participation could work as a boundary object which encourages heterogenous and often distant stakeholders to temporarily work together on the implementation of a project (Green, 2010), but it could also legitimize oppressive practices that "harm those who were supposed to be empowered" (Cooke & Kothari, 2001, p. 1). For example, while the case of Chile's Energía 2050 policy showed how participation aligned partially conflicting stakeholders' interests in the construction of an energy future (Urquiza et al., 2018), this study exposed how participation could have also been a form of tokenism to advance the visions of particular stakeholders (Urquiza et al., 2018).

Previous studies have offered frameworks to systematically analyze participatory processes. Chilvers et al. (2018) studied the process of participation in UK energy system transitions between 2010-2015 and coined the term ‘ecologies of participation’ as an approach in STS to understand the process of energy participation. They differentiate from the literature conceptions of participation as residual realist, relational and systemic; these ideas are useful to situate the applicability of the method and framework we propose in this paper.

Stauffacher et al. Complement Chilvers et al. (2018) work by providing an analytical approach to understand a participatory learning process with scientists and community members (2008), in a sustainable landscape development effort in the Swiss perlapine region of Appenzell Ausserrhoden. They illustrate the process of engagement through a graph that showed the activities (objects), forms of engagement (typologies) developed in one community project, and a table that show the actors (subjects) who participated. Stauffacher et al. work described a discrete participatory process.

These two examples illustrate past efforts that systematically mapped participation. However, they also suggest the need for methods of analysis that reconcile both the comparison and visualization of how and who participate in the local process of decision making in diverse discrete events, and how such processes intersect as Collective Participatory Practices[3] (CPP) that reproduce and challenge wider political, cultural and socio-technological systems (Chilvers et al., 2018).

In appreciation of this need, in this paper, we provide a method of data analysis that facilitates the systematic mapping and/or understanding of the diverse tangible aspects—practices, events or actions “which can be observed” (Coster & Khetani, 2008, p. 643), quantified or experienced—of CPP. We applied this method to understand how communities organized to successfully decrease their consumption of gas and electricity at municipal and residential levels during the Georgetown University Energy Prize (GUEP). In this case, the method summarized more than 2,000 pages of information in just a few visualizations that add clarity to the vague

[3] Concept borrowed from (Chilvers et al., 2018; Chilvers & Longhurst, 2016)

meanings of participation as it compares at once the *breadth*, *depth*, and process of participation for several communities. This analysis focuses on mapping how participation looks in practice, offers a method to keep track of participatory process, and explores if such analysis could shed light on the effects of how CPPs are performed.

This paper is arranged as follows: we first describe the framework that we built through the exploration of literature to understand the diverse aspects of participation. Second, we present a background on GUEP and why we chose to analyze data generated through this competition. Third, we present a replicable method that we used to conduct the text analysis of GUEP dataset. Fourth, we present results from our analysis of GUEP by showing maps of participation to visualize and explain how the process *breadth* and *depth* of participation unfolded during the program as gleaned from the analysis of the dataset. Finally, we discuss our reflections on the maps and results in the context of the dataset and list the benefits, limitations and recommendations for the future application of the outcome of this exercise—a bespoke instrument that could keep track of and evaluate participatory efforts.

### 2.2 Participation as a Framework

We understand participation or CPP as a set of independent and intersecting processes (Cornwall, 2008; Reed, 2008) through which organizations, stakeholders and/or community members enact an action and a form of engagement that create projects and reproduce or challenge wider systems (Chilvers et al., 2018). For example, a CPP is performed as citizens fill out a survey or as they share ideas in a brainstorming session to make decisions about a transportation project that occurs during a community meeting.

CPP is important in making decisions about energy futures (Fraune, 2015; Haarstad et al., 2018; Poncian, 2019). We believe CPP could accelerate an energy transition to a carbon free system. For this goal to be realized, it is important to take into consideration: “what exactly people are being enjoined to participate in, for what purpose, who is involved” (Cornwall, 2008, p. 281), “who is excluded and who exclude themselves” (Cornwall, 2008, p. 275); when and where are subjects participating, how are these “spaces of participation” (Gaventa, 2006, p. 26) created; and how are constituents and stakeholders participating (Arnstein, 1969; Pretty, 1995). Additionally, we understand “participation as an inherently political process rather than a technique” (Cornwall, 2008, p. 281) that must be planned based on the objectives of the participants’ development projects and/or energy systems. Based on this definition, we present a framework that incorporates the main components in CPP:

### *2.2.1 Subjective dimensions of participation.*

Subjective dimensions of participation include the perceptions and opinions of participants about the perceived quality of participatory experiences (e.g. (C. Walker & Baxter, 2017)). The literature offers diverse methods, like surveys and interviews, to analyze and evaluate such dimensions (Danielson et al., 2009; Webler & Tuler, 2001). For example, Mannarini and Taló (2013) subjectively “evaluated” participation in two steps: first, they included participant’s input to validate two evaluative tools—measurement of perceived quality and outcome of participatory procedures—second, they analyzed the perceptions of participants and found that higher scores in these evaluations predicted future engagement of citizens in similar projects (2013). While this dimension is crucial to understand and evaluate the impact and outcomes of energy and citizen participation, it is beyond the scope of research here.

### *2.2.2 Tangible dimensions of participation.*

Tangible dimensions of participation include those aspects of participation in events and practices that can be experienced, quantified or observed. We identified at least four main


Figure 2. Components of the Tangible Dimension of Participation

characteristics in this dimension (see Figure 2). We understand them as characteristics of the practice of participation under analysis, these are:

(1) The *object* of participation (O) describes the activity, issue, or the action under analysis (Chilvers et al., 2018). The object of participation could be a participatory mapping session (Chambers, 2006), the use of smart energy devises (Ryghaug et al., 2018) or the installation of a solar PV system in a household or in a community solar project. A group of objects of participation could be aligned to reach a specific objective, like the reduction of carbon emissions in an energy system.

(2) The notion of *breadth* of participation (Bebbington & Farrington, 1993) is useful to differentiate participatory processes as wide/narrow according to the intensity of who is participating. For example, “wide” participation involves a diverse and large range of people working in one activity; “such a process can remain ‘narrow’, however, if it involves a handful of people, or particular interest groups” (Cornwall, 2008, p. 276). Defining who is involved in a participatory process—the subjects of participation—shows the *breadth* of participation. In the diagram of CPP (Chilvers et al., 2018) this metric was conceptualized as the subjects (S) in Figure 2.

(3) *Depth* of participation (Bebbington & Farrington, 1993) describes how the public or/and the community are engaged. One example are the typologies of participation (e.g. (Arnstein, 1969)) that differentiate between shallow and deep according to how people are participating. *Depth* could be explained as the forms of participation. *Breadth* and *depth* are complementary metrics to systematically quantify the intensity of participation across the activities and stages of the process during a given energy or development project regardless of the scale of the project. This metric was conceptualized as the models or typologies of participation (P) in Figure 2.

(4) *Space* and *time* of participation describe the when and where participation occurs (W). Analyzing the spaces of participation describes how and who created the space where participation occurs (Cornwall, 2000). It describes if subjects participate in an online platform, at home or in the facilities of a non-profit, and pays attention to the power

dynamics that occur in such spaces (Gaventa, 2006). Time could be explained through different stages of the process.

These characteristics of CPP are present in virtually all types of participatory practices, and they are compatible with different theoretical understandings of participation. They can be used to describe participation as dynamic processes that influence and are influenced by wider social, political, cultural and technological systems (Chilvers & Kearnes, 2019; Chilvers & Longhurst, 2016). The characteristics of CPP could also be used as indicators to complement previous evaluations of participation. For example, public participation has inspired multicriteria evaluations to test the accountability efforts in energy policy in the UK (Stagl, 2006). Authors have paid attention to practical issues that facilitate the understanding on how evaluations are conducted (Rowe et al., 2005; Schroeter et al., 2016). Others investigate how participatory efforts can be cost-effective in behavior change/energy consumption projects (Romanach et al., 2014) and aim to build theories that tell which characteristics of participation works best under particular contexts (Rowe & Frewer, 2005).

## 2.3 An Overview of the Georgetown University Energy Prize

Prizes and challenges have historically been events that accelerate technology innovation (Gallo, 2018, p. i), develop new industries and encourage participants to quickly solve the contemporary problems or obstacles they are facing (Nesta, 2014). Importantly, given standardized reporting guidelines (General Services Administration, n.d.), prizes generate datasets that allow for comparison of performance of approaches in solving a problem.

The GUEP was a competition (2014-2017) launched by Georgetown University's Program for Science in the Public Interest, Global Social Enterprise Initiative and Environment Initiative that offered a $5 million prize to promote innovation, educate and encourage US communities—small cities or towns with populations between 5,000 and 250,000—to implement long term energy efficiency programs. GUEP organized communities towards one goal: to reduce the consumption of gas and electricity at municipal and residential levels. Fifty communities from across the US participated in GUEP. Communities saved 11.5 BTUs during GUEP which translate into $100 million dollars of savings and 2.76 million metric tons of avoided carbon emissions (Brandes et al., 2018).

GUEP required communities to (1) deliver standardized reports that described the activities and programs performed; (2) collaborate and create partnerships between at least three stakeholder groups—the government, utilities and community organizations—to work toward reducing energy consumption; and (3) provide energy consumption reports from 2013-2016 to generate an Overall Energy Score (OES)[4]. This ability to compare performance—a key feature of prizes—inspired us to imagine ways in which GUEP data could be used to create a systematic method to map and visualize participation. According to the GUEP Guidelines v8.5, the prize was granted to the community with the highest scores based on the following criteria:

Table 1. GUEP Indicators to Rank Community Performance

| **Indicators** | **Points** |
|---|---|
| Energy savings (first place = 10 points; 10th place = 1 point) | 10 |
| Judge evaluation | 15 |
| Innovation | 15 |
| Potential for replication | 15 |
| Likely future performance | 10 |
| Equitable access, community and stakeholder engagement | 10 |
| Education | 10 |
| Overall quality and success | 15 |

Our work provides insights on indicators that keep track of the community and stakeholder engagement and visualize how the process unfolds across an Energy Prize like GUEP.

## 2.4 <u>Method of analysis</u>

We applied the CPP framework shown in Figure 2 to analyze how participation unfolded in energy-focused projects implemented in communities across the US during GUEP. We systematically analyzed the text in the community plans and updates that communities produced

[4] The OES "quantifies their energy saving performance relative to the community's baseline as a percentage change. The OES is calculated based on the Adjusted Source Energy Use per Residential Bill (ASEU) averaged" (GUEP, 2017, p. 20) over the first 24 months (2013-2014) that constituted the baseline or ASEUB. The following 24 months (2015-2016) of energy use that were scored during the competition are represented in ASEUC. This is the formula to calculate the OES = 100 x (ASEUC – ASEUB) / ASEUB. GUEP used the number of residential utility bills issued, as a proxy for the population of the community. The EPA's Portfolio Manager was used to calculate the weather-normalized source-energy use for each fuel type.

during the competition. This method and the framework in section 3 were developed through an iterative process as we describe next.

### *2.4.1 GUEP Data*

GUEP encouraged communities to provide different data across its different phases. During 2014, GUEP required communities to apply by submitting a summary of past energy efficiency efforts and the history of the community, a plan of action and letters of commitment from municipalities, utilities and (optional) community organizations.

In November 2014, accepted communities submitted a program plan with the following eight sections: (1) *program management and partners* that described the leadership program and how the community stayed engaged; (2) *energy savings plan* with methods, technologies and high-return opportunities for affordable housing, residential rentals and historic neighborhoods; (3) *utility data reporting* of gas and electricity including residential (renters, owners and multifamily accounts) and municipal accounts (offices, infrastructure, parks, schools, etc.) with some exceptions like universities, military and hotels accounts and the energy used in the commercial and industry sectors; (4) *innovation, creativity;* (5) *potential for replication* of the community plan; (6) *likely future performance* that explains how energy-savings will be permanent; (7) *education programs* for K-12 school system and other community efforts; and (8) how the *prize* would be used. These documents were complemented with annual updates (2015-2016) that described the progress of such programs. Finally, between August and December 2017 finalists resubmitted a final report.

Given the vast amounts of documentation generated by the 50 communities (each community produced between 150 to 400 pages of documentation), we decided to focus analysis on the documentation produced by 12 communities.  Nine of the communities we chose were finalists in the competition (they had high energy savings during the competition), and the other three were chosen to diversify the geographical location and the demographics of the communities we analyzed.

***2.4.2 Step-by-step diagram of text analysis***:

We conducted deductive-inductive qualitative text analysis using the notions of *breadth* and *depth* of participation to differentiate between diverse intensities of participation across the activities and the process communities undertook in a large-scale effort like GUEP. We started our analysis with pregiven categories of *depth* or forms of community engagement. We formed these categories inspired by Arnstein's ladder of citizen participation (1969), Pretty's typology of participation (1995), Jackson's stages of public involvement (2001), intensities of involvement in (Stauffacher et al., 2008) and the IAP2 spectrum (2018) to differentiate between the "degrees and kinds of participation" (Cornwall, 2008, p. 270) that stakeholders experienced during GUEP. We also used an open coding approach to analyze the GUEP data. Through the analysis of the first five communities, new themes emerged and constituted the foundation for the code structures that explain the objects and the typologies of participation (Table 2 and 3) that we used to analyze the data of the rest of the communities.

The following four step list (illustrated in Figure 3) describes the replicable method we used to systematically analyze CPP that were described in our sample from the GUEP data. Later, in the Results section, we present an approximation of how the engagement process between the utilities, municipal government and community groups occurred in one community, and a comparison of the participatory process that we were able to capture in the analysis of the GUEP efforts in 12 communities.

**(4)** <u>Selecting the unit of analysis:</u> We divided this universe of data into small excerpts of information that we call 'codes' or 'units of analysis'. Each code would convey one single idea; normally they were shorter than four/five sentences. We determined whether each unit of analysis was describing an activity, action or program performed during GUEP. If the unit of analysis was not describing any activity, we simply grouped them by topic (e.g. community description or staff biography) with no further analysis. If the code described an activity, we proceeded to classify it by topic. Examples of such activities are audits, marketing campaigns, workshops, etc. (see

Figure 3 and Table 3). Thus, each code analyzed partially or fully described one activity and contained enough information to ask the following three questions:

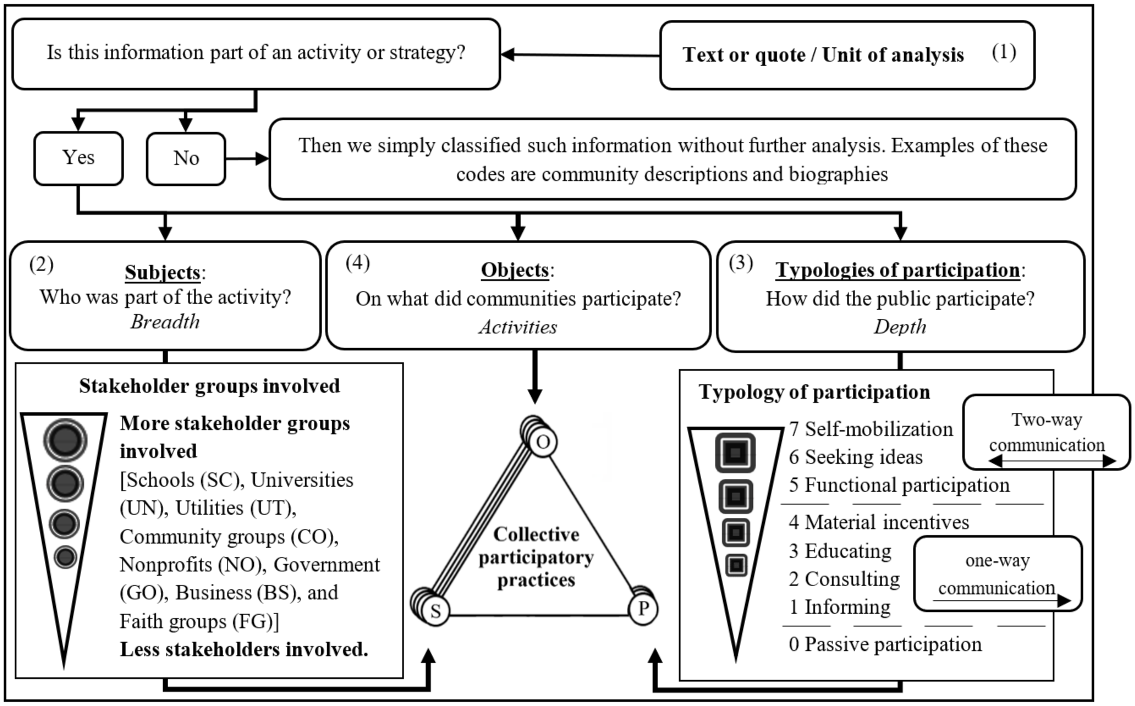


Figure 3. Data Analysis Flow Chart to Understand CPP During GUEP

(2) Subject of participation: Who was part of an activity? For our analysis, subjects of participation are defined as the individuals and/or organizations that were taking part during the activities in the time frame of GUEP (our method does not map partnerships, which is beyond the scope of our research). Due to the information provided in the data set under analysis, we decided to analyze the interactions between *stakeholder groups* and to exclude the quantification of individual participation of community members and/or organizations. For example, communities did not indicate the number of individuals that participated in each of the activities described; yet, they specified the stakeholders that were part of such initiatives. Though this deductive-inductive analysis, we identified eight participating stakeholder groups: schools (K-12), universities (UN), nonprofits (NO), utilities (UT), community groups (CO), government (GO), businesses (BS) and faith groups (FG).

Each analyzed code had a number of stakeholder groups that were part of that activity in a scale from 1-8. If we identified more than one individual or organization that belonged to the same stakeholder group type participating in this activity, then the stakeholder group *type* they represented was marked only as one. For example, if the Department of Energy and some legislators were part of the activity under analysis, then the government (GO) was marked as one, even though more than one group from the government was involved in the activity. As all communities participating in GUEP created a leadership team to plan and implement the activities during the time frame of the competition, we quantified the stakeholders that were part of the team and assigned the same number of stakeholder groups each time the team was mentioned in a code. We assumed that the same number of stakeholder groups were part of all activities in which the leadership group was mentioned. This illustrates the *breadth* of participation.

(3) Typologies of participation: How were stakeholder groups involved? Building on the typologies of participation (e.g. (Arnstein, 1969; Jackson, 2001; Pretty, 1995)) and through an inductive qualitative analysis, we created a 0-7 scale to map the *depth* of participation. This scale illustrates and explains the *depth* of participation, or *how* participation was performed during GUEP. Table 2 explains in detail each level of participation.

We divided our typology scale into three categories: (a) “no communication” contains either codes that describe activities performed and decisions made without the input of the public, and it also contains codes that did not have enough information to be ranked; (b) ‘one-way communication’ describes top-down approaches in which the public and stakeholder groups were only receivers of information and did not provide input in the development of the activities; and (c) ‘two-way communication’ describes approaches through which stakeholders and the public offered their input in the development of the activity.

The highest rung of our scale—our participatory utopia—is self-mobilization (instead of empowerment or seeking consensus as other typologies suggest (e.g (IAP2, 2018; Jackson, 2001)). We consciously used the term ‘self-mobilization’ because we understand power cannot be held, thus no one can empower anyone. Under this understanding, power is not finite, and it can only be self-exercised through our social networks (Foucault, 1980). Thus, our highest form of participation describes actions that leverage our individual and collective assets and social capital (Whiteley, 2015). If 'self-mobilization' is present, the capital and time invested by external agencies would be used more efficiently since the collective is already invested in such process or project.

**(4)** Object of participation: On what were stakeholders participating? We used inductive qualitative analysis to classify the tangible activities that stakeholders experienced during GUEP. Table 3 describes the themes that emerged through this analysis and the activities that communities performed during GUEP. We arranged these themes by the following stages of the process: 1) *Planning*: decision-making that shaped the budget, funds, goals, timeline and expected outcomes; 2) *Implementing*: planning "put into action"; and 3) *Understanding*: developing and tracking progress in GUEP.

Table 2. Typology of participation based on the analysis of 12 communities participating in GUEP

| | | |
|---|---|---|
| **No communication** | Passive Participation Ranking: 0 | Form of participation where *decisions were made without the involvement of the public*. This level also includes codes or units of analysis that did not have enough information to be classified. |
| **One-way communication** | Informing Ranking: 1 | Form of participation in which *the public received information* about the program goals and the strategies about energy and water efficiency and water conservation. Information was also available in *outreach* events and public demonstrations and used digital, traditional and social *media*, brochures, infographics and reports. Additionally, communities developed *targeted messages* for special audiences. |
| | Consulting Ranking: 2 | Form of participation where community members *agreed on* the implementation of services like energy audits, upgrades, on-bill financing programs and installation of energy-efficient furnaces. In the planning stage, for example, some GUEP leaders and *community members voted* to approve plans, funds and building certification (performance standards) policies. Additionally, *stakeholder group types*, like schools, agreed on or *gave consent* to the data collection process. |
| | Educating Ranking: 3 | Form of participation where community members, leaders and teachers *implemented educational programs, games, curriculum, workshops and campaigns* that taught students, low-income renters, government staff, business and community members in general about the basics of energy, sustainable behaviors, energy efficiency, and energy use, reduction and conservation. |
| | Material Contributions Ranking: 4 | Form of participation in which *individuals and organizations provided material contributions* like funds, grants, payments, voluntary extra fees, human resources, infrastructure and volunteer hours to implement energy efficiency and other strategies. |
| **Two-way communication** | Functional Participation Ranking: 5 | Form of participation in which stakeholders like community members, staff or utilities *worked together* with other organizations *to* plan/draft strategies, set goals, pilot programs, achieve the funds and staff requirements, promote renewable energy, etc. |
| | Seeking ideas Ranking: 6 | Form of participation where individuals *shared ideas* and joined in brainstorming sessions to *develop goals and action plans.* Some communities organized meetings and workshops to understand their communities' interests, others created working groups to recreate their plans. Additionally, communities used surveys and focus groups methods, and feedback to develop messages for intended audiences or to evaluate their plans. |

| | | |
|---|---|---|
| | Self-mobilization<br>Ranking: 7 | Our *utopia*. Form of participation where individuals are autonomous and self-organized to develop activities and projects without the need of the interventions of external agencies. For example, "people in communities […] organize to drive the development process themselves by identifying and mobilizing existing (but often unrecognized) assets, thereby responding to and creating local economic opportunity" (Mathie & Cunningham, 2003, p. 474). |

Table 3. Code book: activities (objects of participation) conducted during the GUEP.

| | | |
|---|---|---|
| **Planning** | Budget setting | *Grants* awarded and support for grant writing; fund-raising campaigns and other strategies to fund projects; paid *staff* and *volunteers* to implement the programs. |
| | Goal setting | *Creation of* energy efficiency, gas and water reduction *programs*; description of goals and programs implemented during GUEP; use of research tools such as ACEE self-scoring to *plan goals*; events where stakeholder groups sought ideas to set goals and develop activities, strategies and projects. |
| **Implementing** | Technology and financial aid | *Conducting audits and retrofits*: software to rank efficiency, infrared scans, scores for cost-effective improvements, weatherization & LED bulbs; *Providing financial incentives*: loans, on-bill financing, rebates, sliding-scale fees, off-peak incentives & no up-front cost upgrades; *Certification process***:** performance standards and energy codes; *Promoting renewable energy*: solar shares and co-ops, wind & methane. |
| | Communication | *Marketing and campaigning:* branding and logos, traditional media, printed and online materials, translations, letters and phone calls; *Online engagement:* websites, social media and online dashboards; *Public engagement*: community meetings, canvasing, forums, on-site demonstrations, public events like farmer's markets and fairs; *Education efforts:* trainings, games, curricula, university programs, pedagogical materials & campaigns. |
| | Collaboration | *Building partnerships:* leadership teams, financial and professional support, knowledge sharing, successful projects & data reporting; *competitions:* video and K-12 challenges, creation of web apps, reduction of waste, energy and water use & consumer awareness. |
| | Other | Implementation of *policies, institutionalization of activities,* promotion of guidelines, *climate change management, transportation & exception* of structural reviews for solar projects. |
| **Understanding** | Energy consumption data | *Collection and disclosure of energy consumption data* of gas and electricity: identification of residential (single/multifamily) and municipal accounts by rate class or code, online platforms and apps. |
| | Conducting research | *Track process:* quarterly evaluations, low-cost and non-intrusive evaluation tools, indicators, benchmarking & cost-benefit analysis*; data collection and analysis:* surveys and focus groups & case studies; research projects: multifamily energy conservation & target messages. |

In summary, we classified each unit of analysis that explained an activity by object (what), *breadth* (who) and *depth* (how) of participation. The objects are descriptions of activities while *breadth* and *depth* contain a number each. The former indicates the number of stakeholder groups involved and the latter indicates the form of participation. We used these three elements to produce visualizations or maps that show the diversity of levels of participation across the activities in the process of GUEP.

***2.4.3 Quantifying the breadth and depth of participation***

Our data classification scheme provided us the ability to quantify—and therefore map—how participatory processes unfolded across 12 US communities participating in GUEP. This section presents the formulas we utilized to calculate the averages of 'stakeholder groups involved', the 'typologies of participation' by activity and stage of the process and an example of our analysis. For each code, we assigned a value *B* for the *breadth* (number of subjects) of participation in that code, and a value *D* for the *depth* (based on our typology in Table 2) of participation exhibited by stakeholders in that code. We calculated the averages of *breadth* and *depth* of participation as indicators that facilitate the comparison of the intensity of participation across communities.

After finalizing our first round of coding, our results showed communities had a significant difference between *breadth* and *depth* of participation. Some communities had 100% of codes describing typologies of participation different than zero, while others had a larger number of codes equal to zero. To avoid disproportionate averages for *depth* of participation across communities, we calculated the averages of *breadth* of participation using 100% of codes, but we only included the codes that were different than zero in the ranking based on our typology of participation or *depth* of participation. The formulas we used to calculate the averages are:

1) *Breadth* of participation = $B_{sum} / B_{codes}$, where $B_{sum}$ is the sum of the stakeholder groups participating in the codes of one activity or stage of the process, and $B_{codes}$ is the count of all codes that described one idea from an activity or strategy.
2) *Depth* of participation = $D_{sum} / D_{codes}$, where $D_{sum}$ is the sum of rankings based on the typology of participation in Table 2, $D_{codes}$ is the count of units of analysis that described how the strategy was developed and whose ranking was greater than 0 (we excluded "passive participation" in Table 2).
3) Also, to avoid disproportionate averages of *depth* of participation, we ensured that $D_{codes} \leq B_{codes}$

We provide an example of how we calculated the averages of participation in our analysis. In reading the documents of Fargo, ND, we found this quote:

> We invited community members and guests to join us in brainstorming ideas, sharing knowledge and expertise and strategizing about how we can take the Go2030 Energy chapter goals and implement them for both an impactful start and long-term benefits. We met with legislators, North Dakota State University knowledge experts, arts and outreach community members, business organizations, K-12 teachers and community members creating partnerships and gathering ideas (efargo, 2014, p. 13)

This is a code where the object was "Goal Setting"; the subjects were: (SC) teachers, (UN) North Dakota State University, (CO) community members, (GO) Community Development Administration and legislators, (BS) consultant and businesses organizations; and the mode of participation was Seeking ideas. Therefore, $B$ = 5 and $D$ = 6. However, this was not the only code we found in analyzing Fargo's documents that described "Goal Setting." We found five in total, each of which had different rankings for *breadth* and *depth*. We calculated the averages in the following manner: *Breadth*: $B_{sum}$ = (1 stakeholder x 2 codes) + (2 stakeholders x 2 codes) + (3 stakeholders x 4 codes) + (4 stakeholders x 2 codes) + (5 stakeholders x 2 codes). Thus, $B_{sum}$ =36 and $B_{codes}$=12. Therefore, the average *breadth* of participation in "Goal Setting" for Fargo was $B_{sum} / B_{codes}$ = 36/12 = 3. *Depth*: $D_{sum}$ = (ranking 1 x 2 codes) + (ranking 2 x 1 code) + (ranking 5 x 5 codes) + (ranking 6 x 4 codes). Thus, $D_{sum}$ =53 and $D_{codes}$ =12. Therefore, the average *depth* of participation in "Goal Setting" for Fargo was $D_{sum} / D_{codes}$ 53/12 = 4.4.

## 2.5 Results

The calculation method described above results in numbers that can be visualized in maps that show participation in individual communities and in maps that allow us to compare participation across communities, as we describe below.

### 2.5.1 Mapping participation in a single community during GUEP

We present the results of the winning community, Fargo, ND, as an example of how we mapped participation in a single community. Figure 4 provides an overview of the *breadth* and *depth* of participation that we identified in Fargo's data. We used the code structure presented in Table 3 to organize the activities which build the x-axis. These activities and stages of the process are not necessarily arranged chronologically, but rather they follow the order we assigned through our qualitative analysis. The y-axis shows the degrees of *breadth* (top map) and *depth* (bottom map) of participation. The circles and squares represent the codes identified in the intersection of that activity and form of participation; the darker the color the greater the number of codes identified. The small numbers with a star marker indicate the averages of participation by each activity. Each number represents either the averages of the typologies of participation or the averages of the number of stakeholder groups involved as defined in the previous section. These averages were calculated by the formulas presented in section 4.3.

The maps provide a summary of how participation was performed across the activities of a project. For example, the top map in Figure 4 shows that we identified nine codes describing the conducting of audits and retrofits at three forms of participation: informing, consulting and educating. Fargo organized outreach events where they informed the public about audits and retrofit programs, conducted trainings about weatherization strategies, and community members gave consent to conduct energy efficiency initiatives. The intensity of color in the markers (squares for typologies of participation and circles for number of stakeholder groups involved) indicates that consulting (ranking: 2) had greater repetitions followed by educating (ranking: 3) and informing (ranking: 1) with an average of 2.1. On the other hand, the bottom map suggests that—in the same activity: conduction of audits and retrofits—one to two stakeholders were engaged, with an average of 1.6. The number of circles and squares in an activity can be different because the typology of participation is independent to the stakeholder involved. Thus, an activity that was described in 5 codes, say "promoting renewable energy" in Figure 4, might have five codes classified as functional participation, while four codes showed only one stakeholder involved, and only one code showed that two stakeholders were involved.

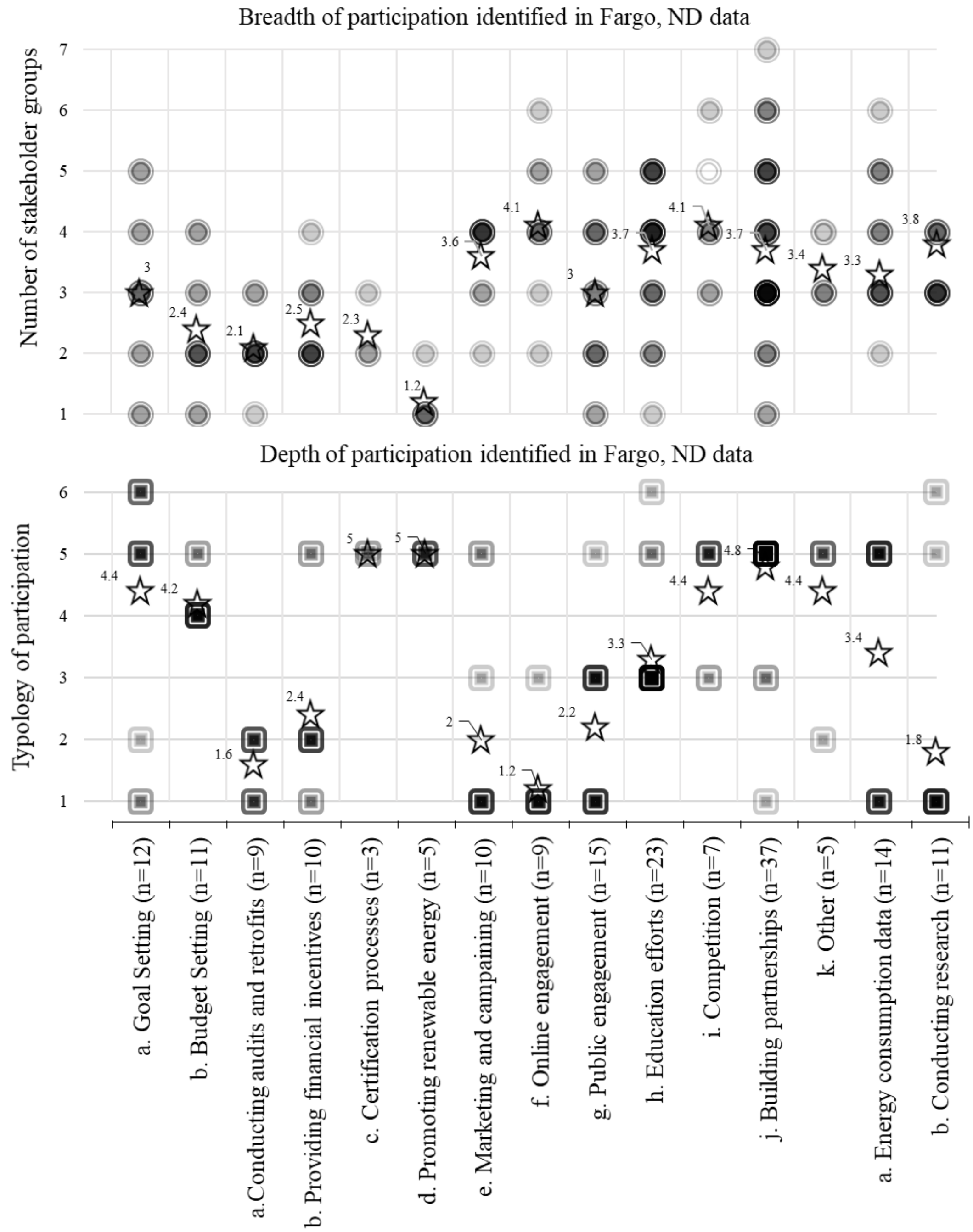


Figure 4. Breadth and Depth of Participation During GUEP in Fargo, ND

Inside the object of participation named “education efforts”, we found that graduate students and faculty from the North Dakota State University worked together to create “Let’s play e-Fargo.” This game and curriculum allowed students in the K-12 system and the wider community to learn about energy efficiency as a strategy to reduce consumption of electricity. We also identified that Fargo conducted workshops, and mind mixers to seek ideas from community members. These activities suggest that “functional participation”, “educating”, and “seeking ideas” were types of participation utilized in “Education efforts.”

Overall, we can say that “goal setting”, “educational efforts” and “conducting research” recorded the deepest participation. Fargo conducted brainstorming sessions to set goals of the project, workshops, and surveys in which participants shared their input and ideas about the development of the project. Additionally, the activity “building partnerships” had the broadest participation with up to seven stakeholder groups working together, while the promotion of renewable energy had the narrowest participation with only two stakeholder groups.

There are many other kinds of questions we can quickly answer using these graphs, like which the stakeholders were involved during the planning stage, how stakeholders were participating during specific activities and stages of the process, what activities were developed during the project and so on. In short, this map can quickly convey large amounts of information that can be used for the purposes of evaluation and reflection. This map was created by analyzing about 350 pages of information. However, when discussing how participation unfolded in Fargo, depending on the situation, one may not need to read through all of those pages, but simply look at a map like this.

For a higher level of aggregation, we can illustrate community results only by stages of the process and a final score, as seen in Figure 5, which summarizes the elements in Figure 4. It shows the forms of engagement and averages identified across the stages of the process and both dimensions of participation in the final score. These maps suggest that in Fargo, broader participation happened during the planning stage. They also show that up to seven stakeholder groups worked together during implementation.

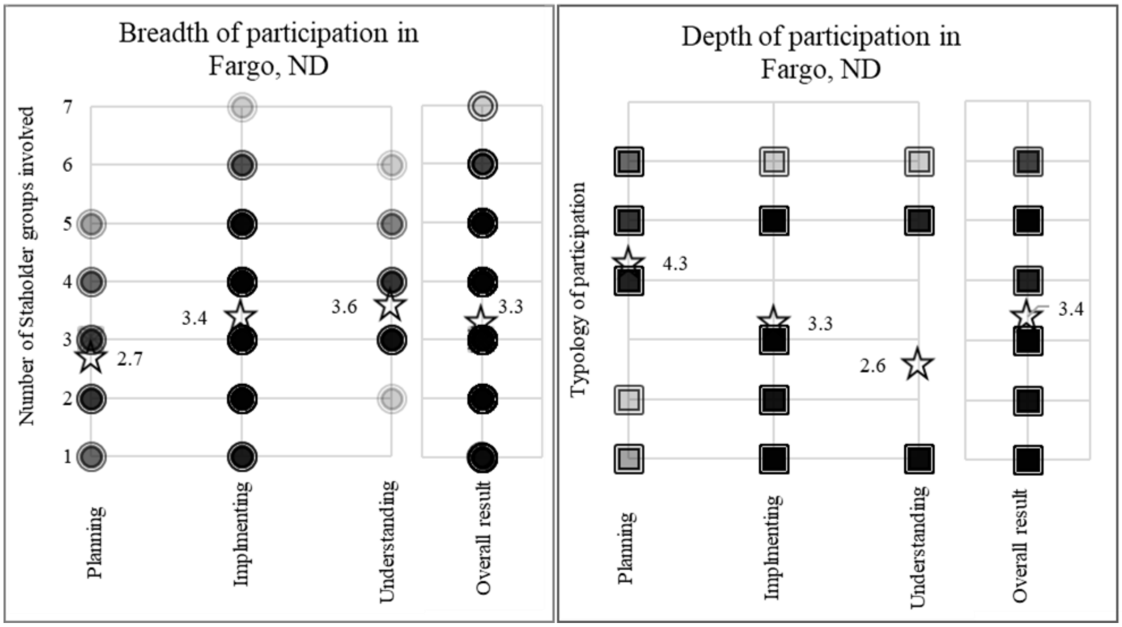


Figure 5. Breadth and Depth of Participation by Stages of the Process in Fargo, ND

**2.5.2 Maps that compare of 12 diverse communities participating in GUEP**

Now that we have shown how we can create a map of participation in one community, we can do so for 11 more, compare them on the same map and get aggregate understandings of how participation unfolded across all twelve communities over the entire two-year duration of GUEP. We used the same structure and the indicators of *breadth* and *depth* of participation to provide an image that summarizes the activities implemented by 12 GUEP communities. Figures 6 and 7 are complementary and should be read simultaneously to have a clear understanding of how we obtained such results. Figure 6 shows, on the y-axis, the averages of *breadth* (top map) and typologies of participation *depth* of participation (bottom map), whereas the x-axis shows the activities performed. Figure 7 discloses the number of codes (y-axis) we analyzed by activity (x-axis).

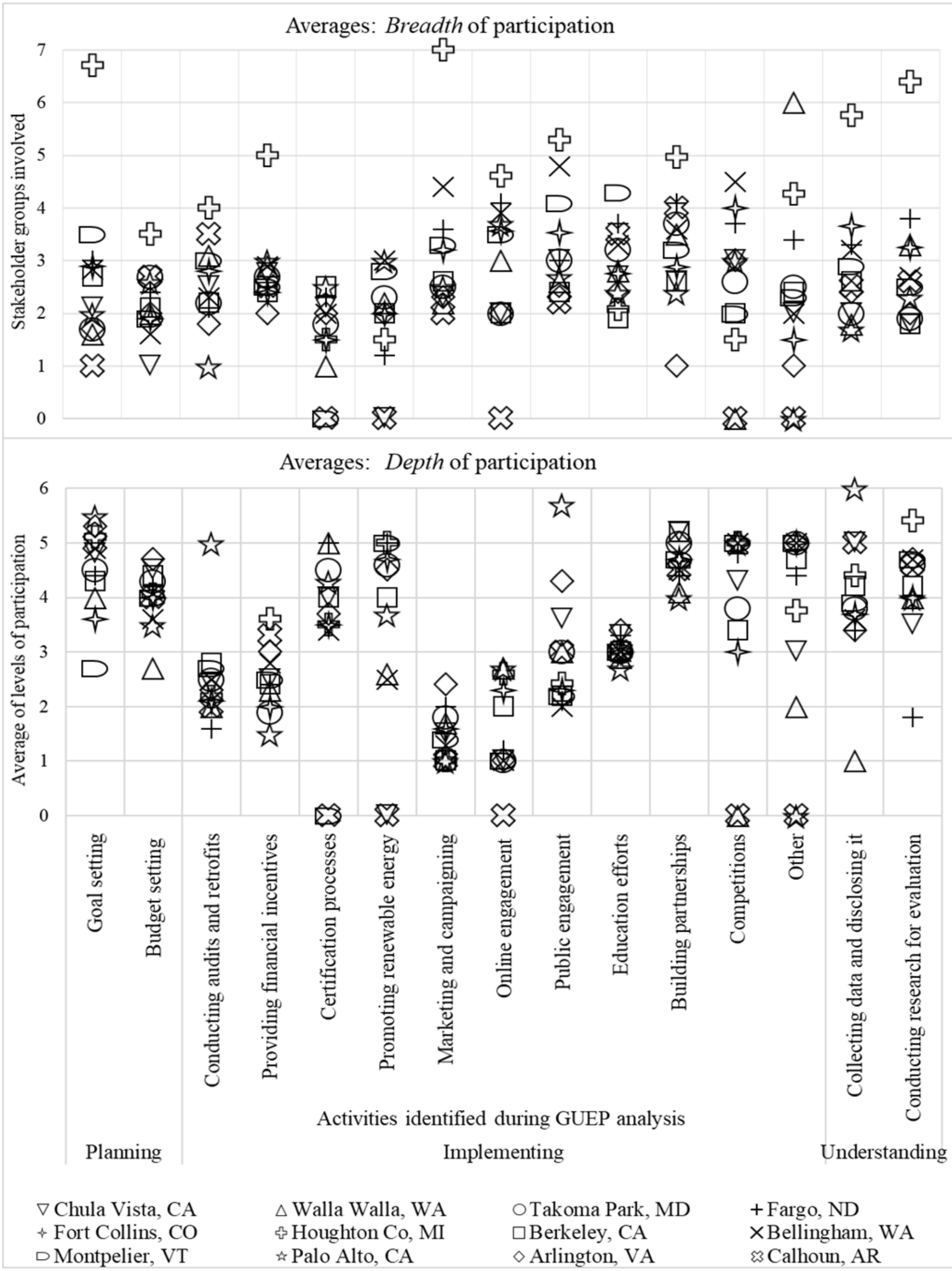


Figure 6. Breadth and Depth of Participation by Activity in 12 GUEP Communities

Both figures help us understand, for example, that even though Palo Alto, CA obtained the deepest level of participation for “energy consumption data,” only one code was recoded which described that city buildings were benchmarked, and ideas were discussed about how to proceed with these data. As another example, Houghton, MI described (through eight codes) that the activity “marketing and campaigning” was conducted by an average of seven stakeholder groups working together for which they obtained one as *depth* average. This means that on average, Houghton, MI had a large number of stakeholder groups working together to inform the community about their plan.

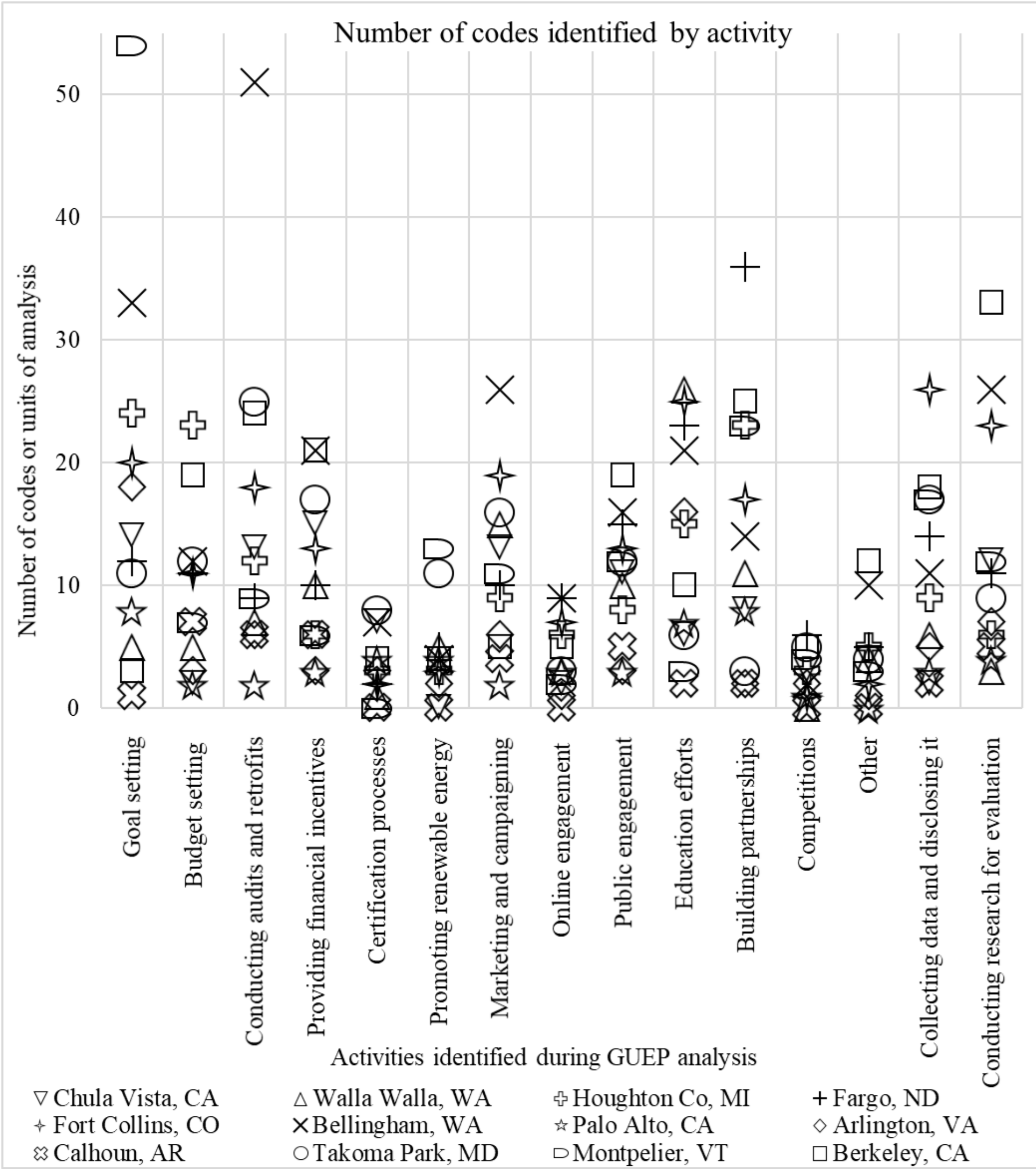


Figure 7. Number of Codes by Activity in 12 GUEP Communities

Figure 7 shows that some communities did not talk about certain activities in the data set that we analyzed. For example, the data that we had from Calhoun, AR did not indicate that they were conducting the following activities as part of GUEP: certification processes, promoting renewable energy, online engagement, or competitions. Figures 6 and 7 thus show the results of our calculations and tell an overarching story that is backed up with the qualitative analysis that we conducted.

Figure 8 shows the averages of both dimensions of participation by stage of the process and overall. The map on the left in Figure 8 shows the *breadth* of participation, for example, in most of the communities under analysis, 2.1 to 3.3 were the average of number of stakeholders working together across the process, except for Houghton, MI which had an average of 4.7 stakeholders working together. Houghton, MI got this higher score because its leadership team named Houghton Energy Efficiency Team (HEET) was grassroots, community-based collaborative group of six stakeholder groups formed in 2014. They thus obtained a wider participation score in comparison to the other communities.

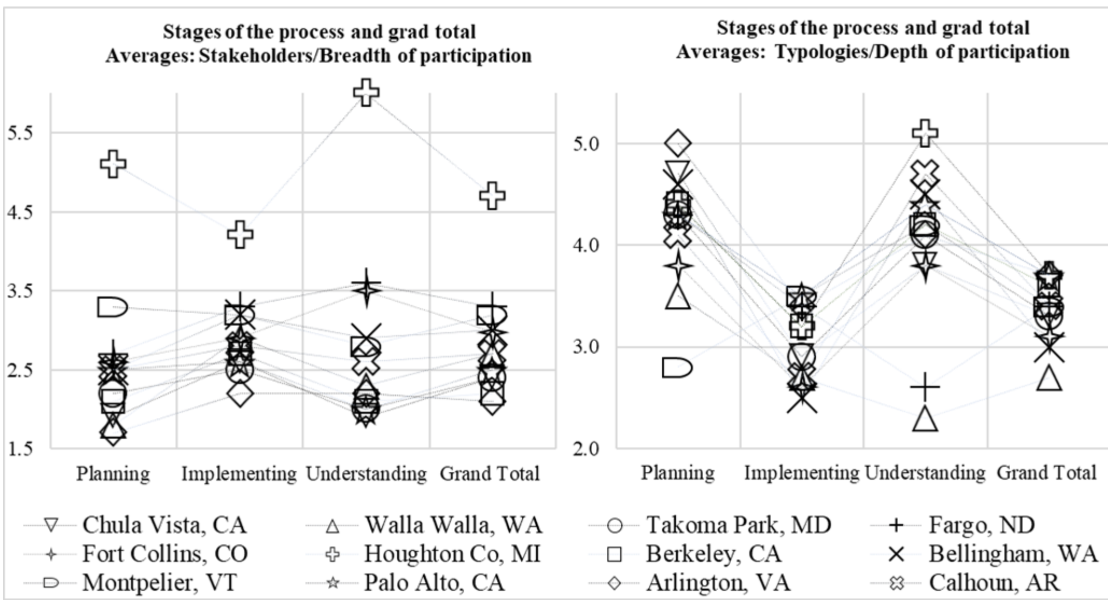


Figure 8. Breadth and Depth of Participation in GUEP Communities

The map on the right in Figure 8 shows the typologies of participation, and we see that all communities obtained average scores that range from 2.7 to 3.7, while showing that higher forms of participation occurred during the planning and understanding stages. *Depth* in Fargo shows an average of 2.6 in the understanding stage; however, Figure 6 shows that functional participation and seeking ideas were also part of this stage. This result suggests that overall, we identified more codes that described informing as the form of engagement.

## 2.6 <u>Discussion</u>

GUEP was a competition that evaluated not only the overall energy savings in communities, but also how innovative, replicable, scalable and durable the project implemented was. The outcome of our analysis complements GUEP evaluations with figures that provide a *map of participation* that visualizes participation in *breadth* and *depth*. These visualizations mapped a process that explains how 12 communities were able to organize and reduce their energy consumption during GUEP.

**2.6.1 Participation and energy transitions**

Practitioners and researchers must articulate how and why they use the term "participation." For us, participation is both an instrument that could be used to achieve the acceleration of energy transitions, as well as a transformative component that could help address procedural justice issues and equality. In order to realize such goals, we believe it is necessary to add clarity to the diverse components of CPP. In exploring how participation may advance the goals of a cleaner and just energy system, we tested if higher forms of participation and/or higher levels of engagement as measured through *breadth* and *depth* of participation would be directly proportional to energy savings.

In Figure 9, we compare the averages of *breadth* and *depth* of participation (x-axis) of 12 communities across the process with the communities' OES achieved during GUEP (y-axis). The higher the number in the y-axis, the greater the energy savings. These plots show how Chula Vista, CA, which had the greatest energy savings, had *lower* averages in *breadth* than Houghton MI, Fargo, ND or Montpelier, VT, which had *lower* OESs. On the other hand, even though Chula Vista, CA, Takoma Park, MD, Fargo, ND, Montpelier, VT and Calhoun, AR, had similar averages of participation (ranging from 3.1 and 3.4), they all obtained significantly different OESs that ranged from 2.4 to 9.5. Thus, a high score in participation does not necessarily represent a participation that secures success in energy savings.

These results allow us to demystify normative ideas that only higher or "authentic" forms of participation will produce better outcomes, as some literature suggests (Anderson, 1998; King et al., 1998). We argue that participation and its diverse dimensions must be planned based on the purpose at hand (Cornwall, 2008). If participation is measured by the actions conducted explicitly and only as a form of action to save energy at home (e.g. turning off lights, reducing the use of electric devices, conducting retrofits and weatherization programs, setting thermostats to certain temperature, etc.) then higher participation might become an indicator of higher energy savings. On the other hand, if we regard deeper participation as efforts that allow participants to have influence over major decisions in a given project, then participation might translate into higher project acceptability (e.g. (Liu et al., 2019)).

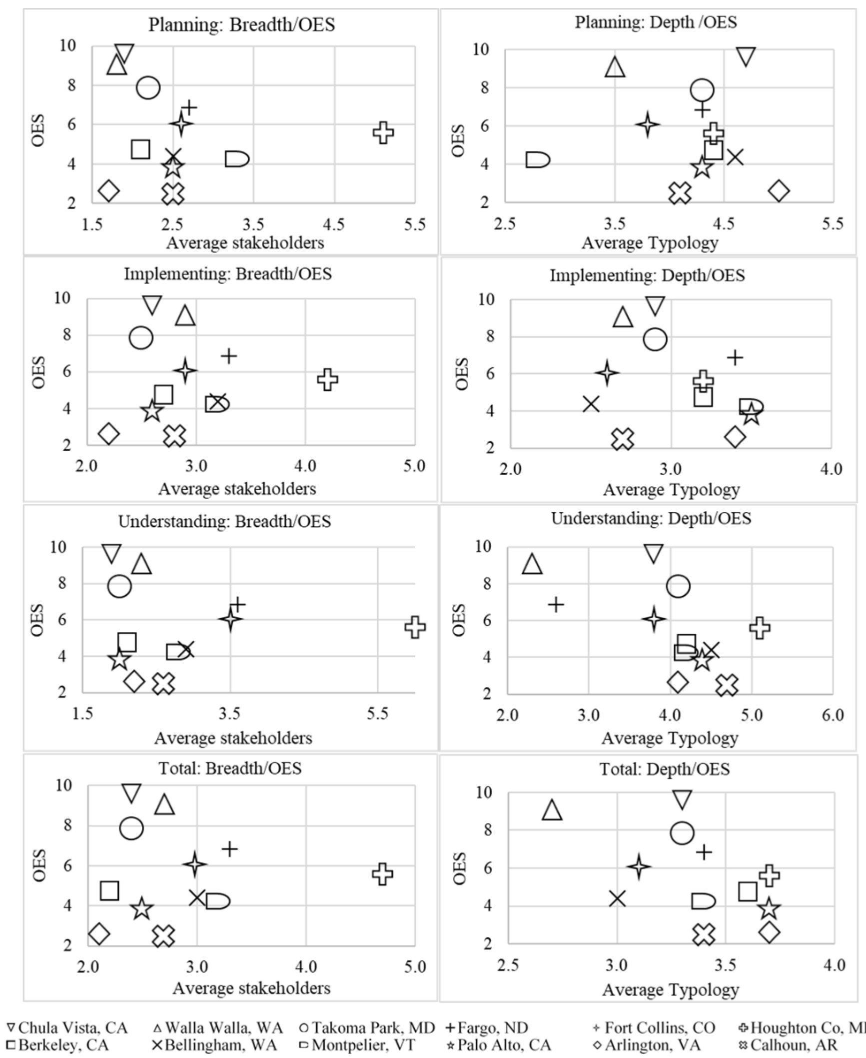


Figure 9. Participation and Overall Energy Savings (OES) of GUEP Communities

The maps shown in Figures 6 and 8 help us make quick high-level comparisons of the activities implemented between communities in a program like GUEP. They provide insights on the forms of participation implemented and who was part of such activities. The presence and resources of stakeholders like the government, utilities, businesses and community groups during the implementation of GUEP efforts were essential to achieve energy efficiency goals and energy savings during the competition. Within the context of the data and documents used to develop the tool, these maps explain how communities organized to achieve energy efficiency and reduce consumption of gas and electricity at a residential and municipal levels during GUEP. For example, Figure 9 compares the OES and the averages of *depth* and *breadth* of participation in each community across the three stages of the process identified in this analysis.

### 2.6.2 Participation as a process and a numerical score or outcome

Our analysis allowed us to differentiate between participation as a *process* and participation as a *numerical score* or *outcome* that measures the overall intensity of participatory efforts according to our framework and prioritization of each variable. The former was summarized in Table 3 and visualized, for example, in Figures 3 and 5 which provided an approximation of the complexity in the process of participatory practices. Figures 3 and 5 also showed similarities and differences between the intensity of participation that occurred inside and across GUEP communities. Participation as *numerical scores* are illustrated in the average of the overall results in figure 4 and the average in the grand totals in Figure 7 both final scores describe a value for *breadth* and *depth*. In other words, participation as a *numerical score* or *outcome* indicates a quantification of participatory efforts.

### 2.6.3 Benefits and uses of this framework and instrument of measurement

The use of this method summarizes in few images narratives that describe the process of participation and community engagement. In our case, we visualized more than 2,000 pages—generally confined to large reports and case studies that can require significant investments of time to read—into three images (Figures 5-8). Our framework to map participation in a program like GUEP can be used to create bespoke tools to keep track of participatory efforts, tools that can be easy and quick to use. While we mapped efforts that happened in the past, based on our framework, one can easily create a way to collect and visualize participation related data of who is doing what and when in energy and development programs. There are many benefits of our method and framework:

#### 2.6.3.1 The framework and method of analysis could be used to plan, organize and implement participatory projects

Our framework can be applied beyond a research project like this one. We provide a flexible step by step exercise that creates a bespoke monitoring tool to keep track of how the tangible aspects of CPP unfold in virtually any type of project. This is our suggested step by step list:

1. Define the *goal* of the project
2. List the *activities* that you will conduct to get you to that goal
3. Define the *spaces/places* where participation will take place
4. Define who are the *stakeholders* or subjects you will be engaging to reach your objectives
5. Build your own *typology of participation* that describe the forms of participation that the leadership team and the community believe will take you to your objectives
6. Plot these ideas in a map/graph
7. Share the plan with the community and evaluate it after completion

#### 2.6.3.2 It adds transparency to the decision-making process in energy and development projects.

The figures generated by our method quickly show who was part of the planning and implementation stages of a project, how these individuals and organizations participated and what activities they participated in. Such visualizations could build trust between community members and other stakeholders, as they add transparency on how organizations conduct community engagement processes in energy projects. They show, for example, the stakeholders that were part of the planning stage where most of the decisions about a project are made.

Additionally, the method allows the disclosure of different forms of engagement or participation that occur in one single object of participation. This is particularly important when we are analyzing participation in practice where diverse forms of engagement often happen in one single event. Overall, these maps of participation can help stakeholders plan for and keep track of the kinds of community engagement efforts worthy of attention.

#### 2.6.3.3 The method is flexible and facilitates the comparison and evaluation of participatory strategies across projects, communities or time.

As suggested above, while the method offers a rigorous framework to understand participatory processes, it also offers flexibility for stakeholders to provide input to reconfigure the main components of the instrument (for example the who, what and how of a project). The objects, typologies and subjects of participation can thus reflect the interests and goals envisioned by stakeholders and community members. In the case of this study, the method allowed us to conduct a deductive-inductive analysis that took advantage of the themes that emerged to identify some components of the tangible participation that occurred during GUEP. The tables we present in this study summarize the different code structures that we used to create the maps of participation that compare participatory efforts in similar projects across communities or of diverse projects in one community. It could be used to monitor and evaluate when, how and who participated in the activities planned across projects. Researchers could use this method to theorize and generate hypotheses that explain how diverse components of CPP trigger specific outcomes.

#### 2.6.3.4 Besides the cost of conducting research, the method does not add administrative costs.

The data used in this research—reports that describe community practices—are normally produced in virtually all energy and development projects. For the cases where the analysis is retrospective, the analysis can be conducted without extra administrative or operating costs. For example, this study used data that were already created by GUEP participants. Hence, this analysis did not add further administrative costs in GUEP.

### 2.6.4 Recommendations based on limitations of our analysis

We recognize the importance on discussing the limitations in our work that exist widely in program evaluation, qualitative analysis and in participation-focused research. The data we analyzed from community plans and progress reports only tells a story from the perspective of certain stakeholders; not all stakeholders in these results participated in the development of the dataset under analysis. In fact, it was greatly driven by the government as the *breadth* of participation showed. There are participatory efforts not captured in the plans and reports. While the theoretical framework was built from conversations by both authors, and the results were discussed by and between both authors, the qualitative analysis itself was done by only the lead author.

Our application of the method simplifies differences within stakeholder groups. For example, while this analysis may indicate that ‘Community Groups’ were part of a given activity, it does not specify the wide array of diverse identities and networks within this group. We recommend that users of this method rethink the *breadth* of participation based on, for example, differences like gender or race inside the stakeholder groups under analysis to address issues of representation and procedural justice. Authors have already suggested to pay attention to types and levels across actors (Avelino, 2016).

The data in this study did not provide enough information to systematically analyze the *space* and *time* of participation in each code. An analysis of the spaces where participation occurred and how it unfolded across GUEP are elements for further research. Additionally, our data analysis could be complemented by an analysis on subjective aspects of participation that explain the learnings and experiences of participants in an effort like GUEP.

Both scales of *breadth* and *depth* of participation set normative assumptions and suggest that higher forms of engagement and more stakeholder groups involved may be ideal. However, we recognize that communities experience different social, political and economic contexts that might make some forms of participation difficult or even impossible to achieve (Guijt & Shah, 1998). We suggest that community members and leaders may not only look to participate in wider or deeper forms, but they may want to fulfill other rungs in the ladder of participation that they believe are important to achieve their goals.

The scale of *depth* of participation reduces the possibilities of engagement into few categories which might "hinder innovation" (Guijt & Shah, 1998, p. 10). Therefore, to expand the options on the typologies of participation, we encourage the reader to reflect on the forms of engagement that they have performed in the past to imagine new forms of engagement that enrich the *depth* of participation. We also suggest to expand their options by learning from other experiences, for example: community energy (Hargreaves et al., 2013; G. Walker, 2008) and material participation (Ryghaug et al., 2018).

While such limitations might exist in one form or another, this method is promising if enriched with the input of community members and diverse stakeholders. We suggest that the definition and classification of the stakeholder groups, as well as the scales of *depth* and *breadth* of participation, should be accepted by stakeholders who are part of a project (Webler & Tuler, 2001). We also recognize that our method does not capture how the participation performed during GUEP led to changes in social capital, knowledge and the strength of relationships between stakeholders. Further research needs to be conducted to explore the different forms of individual participation inside the community and other impacts triggered by GUEP.

## 2.7 Conclusion

The method we have created allows researchers and practitioners to quickly visualize and analyze participatory processes in energy projects in ways that can help diverse stakeholders collectively address climate change. Our method and framework can be used to keep track, in real-time, of the decision-making process and community engagement efforts in an energy project. It adds transparency to decision-making. The disclosure of such processes, we believe, could increase trust between researchers, practitioners and communities. Our method facilitates the comparison of participatory efforts across projects, communities and time. We presented a flexible framework which explicitly discloses some tangible aspects of participation that can be used to plan, implement and evaluate future participatory interventions in energy and community development projects.

The Georgetown University Energy Prize encouraged communities in the US to increase energy efficiency and reduce greenhouse gas emissions. Our study of how participatory processes unfolded in 12 communities during this nationwide prize shows that deeper and wider participation do not necessarily lead to greater energy savings. This result suggests that certain forms of participation are not necessarily more meaningful than others. Instead of blindly yearning for deeper and broader participation, we support the idea of other authors who argue that *breadth*, *depth* and objects of participation require to be strategized based on the objective of the project (Cornwall, 2008; Krütli et al., 2010; Späth & Scolobig, 2017; Stauffacher et al., 2008). We encourage organizers and researchers to continue innovating instruments and approaches that seek for the *optimum* (Cornwall, 2008) combination of community participatory practices that are sensitive to the community context, feasibility and project goals.

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CHAPTER 3

# ENERGY PARTICIPATION AND SOLAR PHOTOVOLTAIC TECHNOLOGY ACCEPTANCE BY RALÁMULI USERS IN CHIHUAHUA, MEXICO

**Abstract**

User satisfaction and technology acceptance of renewable energy technologies are key in a low-carbon energy transition. This paper compares five solar electrification programs in Ralámuli communities in the Sierra Madre Occidental (SMO), Chihuahua, Mexico, that disproportionately experience low rates of electricity access and high rates of energy poverty. I apply energy participation as a framework to differentiate the characteristics of engagement among five solar programs and explore the factors that influence user satisfaction and technology acceptance. The analyses are based on official documents that describe the solar projects, participant observation in fieldwork during January-March 2021 and November-December 2021, 57 interviews with community members who were users of the solar PV modules, and 6 interviews with project leaders who were involved in the development of the solar projects. Results suggest that high material participation, that refer to money spent in paying for monthly feeds of program, became detrimental to user satisfaction and technology acceptance. This finding indicates that benefits of participation reach a limit when participation surpassed the budget (in the form of cash/money and time availability) of solar users. Findings also underscored the responsibility of solar developers to strategize user participation and make the best use of users' resources, including time and commuting costs. Other recommendations include: (1) inform users in their first language about the costs and forms of payments before users consent to participate in solar programs; (2) seek ideas from the public at early stages of the process to design the strategy of participation and the capacity of the solar modules; and (3) reduce costs through collective ownership and understanding electricity needs of future users. The findings and recommendations in this study contribute to understanding how participation occurred in practice and provide recommendations to future solar projects that aim to avoid low rates of solar technology acceptance and that would ultimately contribute to a transition towards low-carbon energy systems.

## 3.1 Introduction

Indigenous communities in Mexico suffer from disproportionately low rates of electricity access. In the State of Chihuahua, for example, only 50% of households had electricity access in the Indigenous-majority municipality of Batopilas, compared to 97.5% of households in the rest of the state (CONAPO, 2015). To address these disparities, numerous programs have been launched to provide electricity for Indigenous communities using solar photovoltaics (PV) or solar home systems (SHS).

The literature suggests that active participation plays a crucial role in energy transitions (Chilvers et al., 2018; Gjørtler Elkjær et al., 2021; Renn et al., 2020; Urquiza et al., 2018). Numerous studies have argued that public participation in energy and environmental programs is needed to achieve the best outcomes (Fenton et al., 2016; Pasqualetti & Schwartz, 2011; Rowe & Frewer, 2000). Authors have suggested how participation influence successful energy projects. For example, Huacuz & Agredano argue that users need to participate beyond only passively receiving solar programs (1998), and Murni et al. suggest that the participation of all actors must happened in the panning of micro hydro power systems that provide electrification to remote communities in Indonesia (2012). The literature also presents participation as the means to achieve energy transitions goals through decreasing the opposition to energy-saving behaviors (Bhushan et al., 2018; Endrejat & Kauffeld, 2018), finding cost-effective efforts in behavior change/energy consumption efforts (Romanach et al., 2014), or increasing acceptance of renewable energy projects like wind farms (Baxter, 2017; G. Walker & Devine-Wright, 2008) and solar water heating technologies (Mallett, 2007).

Previous studies have warned about the dangers of uncritically using participation in energy transitions (Urquiza et al., 2018; Cohen & Uphoff, 1980; Cooke & Kothari, 2001). While authors suggest that higher participation contributes to higher acceptance and support to renewable energy systems (Capaccioli et al., 2017; G. Walker & Devine-Wright, 2008), other studies have contradictory results where higher participation does not always secure the intended outcomes, like more energy savings (Morales-Guerrero & Karwat, 2020). Thus, it is still unclear how participation matters for energy transitions and what forms and how much participation is needed and when (Bidwell, 2016). This paper fills this gap through an analysis of solar PV projects in SMO that sheds light on when and how much participation is needed to achieve some of the desired outcomes in energy transitions, like higher acceptance and user satisfaction.

This paper compares five programs for solar electrification among Indigenous communities in the Sierra Madre Occidental (SMO) in Chihuahua, Mexico. The objective is to explore how features of the program design – in particular, the nature of community participation – influences user satisfaction with solar PV technologies. I conducted 63 interviews, three months of participant observation and document analysis to answer the following two research questions: (1) what modes of participation were deployed in solar home system programs that granted electricity access to Ralámuli communities in the Sierra Madre Occidental, Chihuahua, México? and (2) what is the relationship between participation in programs and higher or lower solar acceptance and user satisfaction?

This project contributes to the literature by empirically analyzing the process of participation in the electrification of rural communities in México. Additionally, I explicitly conducted a larger number of interviews with end users to focus our attention to understand the user experience and to break the tradition of energy research that focuses on understanding the experiences of industry representatives and technocrats. By examining whether and how public participation matters in solar electrification programs, this paper generates practical insights about renewable energy policy and program design that can account for a fair process in the deployment of systems that grant electricity access to disenfranchised communities.

This chapter proceeds as follows. Section two offers a review of literature on previous studies on participation in energy research, and presents the framework used to assess participation, which borrows concepts and definitions from a Science and Technology (STS) co-productionist framework to understand ecologies of participation (Chilvers et al., 2018). Section three presents details on the solar projects in SMO in this analysis. Section four describes the research design, including the selection of communities and programs, the type of data and the sample collected, the process of data analysis, and the process of creation of the dependent variables (desired outcomes) in the study. Section five presents the main results of the analysis in which I present the results of the federal policy solar program as a local example of the process of participation, and the global results of all five solar projects in this research that show the possible links between user participation and technology acceptance and user satisfaction in solar electrification programs. Lastly, section five concludes by offering policy implications and key findings to inform future rural electrification projects that account for a process of participation that secures higher acceptance and user satisfaction.

## 3.2 Literature review

### 3.2.1 Benefits and barriers to participation.

Although participation has not been a focus of the literature on rural electrification in México, there are many reasons to believe that it could improve program success. Many studies have suggested that user participation could improve the design, maintenance, and community acceptance of rural electrification projects. Huacuz and Agredano (1998) suggested that the user must participate actively during the installation and by paying for at least part of the SHS based on their economic possibilities “otherwise, even when the system Is well design, soundly built and properly installed, it is bound to fail sooner rather than later” (Huacuz & Agredano, 1998, p. 13). The inclusion of the end user in the definition of the problem to be solved are cited as key components, including education and trainings that drive user’s positive attitudes towards solar PV and influence good operation and maintenance (O&M) (Huacuz & Agredano, 1998). Additionally, the participation of the public in the design of projects has gained popularity to explain the mistrust and opposition of the public to renewable energy adoption (Devine-Wright, 2011).

In addition to these instrumental benefits, another body of literature focuses on the social benefits of including of minorities or oppressed social groups (identity based, racial groups, ethnic groups, nationalities, etc.) in decision-making for policies and projects affecting their communities. In this tradition, participation is achieved as the public takes control of decisions that were traditionally dominated by experts in public offices (Beierle & Cayford, 2002), as citizens influence decision-making in watershed management (Webler & Tuler, 2001), or as participants decide how to “redistribute a share of energy linked to collective virtuous consumption behaviors” (Capaccioli et al., 2017, p. 621). Therefore, participation is perceived as “a process in which individuals take part in decision making in the institutions, programs and environments that affect them” (Heller & Heller, 1984, p. 339).Yet some authors have argued that it is still unclear the role of the public influencing the decision making processes in energy transitions (Bidwell, 2016).

In addition to describing multiple benefits of participation, scholars have identified enablers and obstacles that community members face when they participate (Breetz et al., 2005; McNulty, 2015; Ravensbergen & VanderPlaat, 2010). Examples of participation enablers: are trust and communication (Breetz et al., 2005), information about neighborhood characteristics to make informed decisions (Stoecker, 2006), communication networks (Nah et al., 2016), storytelling (Pstross et al., 2014), the use of multiple intelligences frameworks (Hollander, 2012), the acknowledgment of heterogeneity in a community (Chilvers, 2008; Godfrey, 2004), the inclusion of “perception differences between stakeholder groups” (Mercelis et al., 2016, p. 1,458), connection of policy-makers with on the ground initiatives (de Graaf et al., 2015), visualization of information (Jenkins & Konecny, 1994, p. 213), development of indicators through participatory processes (Morrissey, 2000), and starting where people are at (Kane, 2010; Ledwith & Springett, 2010).

Studies have also identified the following barriers to participation. For example, in Peru gender roles prevented women to attend participatory budgeting sessions (McNulty, 2015), and in Phoenix, Arizona lack of trust and power structures have prevented participation of stakeholders in an industrial and contaminated area (Foley et al., 2017). On the other hand, demographics like social class, gender, level of education, and public opinions have been predictors of participation (Matarrita-Cascante et al., 2006; Ziersch et al., 2011). For example, high education levels and more affluent individuals have been identified as predictors of more participation (Nah et al., 2016). However, results are contradictory; for example, poverty has been defined as both a barrier (Ravensbergen & VanderPlaat, 2010) and as a trigger of participation (Samanta & Nayak, 2015).

This project will contribute to this body of literature by empirically exploring how participation influence technology acceptance of solar technologies. To explain how I reached this goal I first present the framework I used to organize data and answer the research questions.

### 3.2.2 Energy participation framework and concepts for measuring participation

To assess the impacts of participation, it is important to be clear about how participation is conceptualized and measured. Numerous scholars have suggested the need for transparency and clarity in the use of participation as a research concept (Cohen & Uphoff, 1980; Cornwall, 2008), the need of systematic analysis of participation (Devine-Wright, 2011), and the importance on mapping the complexities of participation to shed light on the participation patterns that secure a systemic change (Chilvers & Longhurst, 2016). In this paper, I used *energy participation* (see Chapter 2; Morales-Guerrero & Karwat, 2020) as a framework to compare how engagement occurred across similar projects and to explore its impact on user satisfaction. Below I explain the concepts in the framework.

Chilvers et al. in STS use three dimensions in the co-productionist framework to understand participation: Object, Subjects and Models or forms of participation (Chilvers et al., 2018). (1) **Objects** (O) of participation (see Chilvers et al., 2018; Chilvers & Longhurst, 2016) refer to the activities or events in which participation occurs, for example, some solar projects offered workshops to new users to learn best practices during operation and maintenance, while others did not offer that “object” of participation. In the Conceptual Model of Public Participation (CMPP), this element is called the *Type of Mechanism* (Beierle & Cayford, 2002; see page 37 in Chapter 2). (2) **Subjects** (S) of participation refer to *Breadth* of participation or the diversity of actors participating. Lastly, (3) **Models** or *Depth* of participation (P) refers to the form of participation as explained in ladders of engagement like  (Arnstein, 1969; Jackson, 2001; Rowe & Frewer, 2005). Rowe and Fewer have suggested that such typologies are crucial to theorize what is working best and when (2004). I complemented this framework with the identification of When and Where (W) these collective participatory practices or Energy Engagement/Participation occur (Morales-Guerrero & Karwat, 2020).

*Breadth* (subjects) and *depth* (models) of participation describe the intensity of the engagement. A wide participation occurs when utilities, government organizations, businesses, and community members engage in activities to design the solar PV systems in a government initiative, while a narrow process occurs as only technocrats decide the solar capacity of a national solar program (Cornwall, 2008, and Morales-Guerrero & Karwat, 2020). For example, *informing* users about the benefits of solar PV is a shallow form of participation because *informing* is often located in the first rungs of the ladders of participation. On the other hand, *seeking ideas* (form of participation often in the high rungs in ladders of participation) is a deeper form of participation. *Seeking ideas* can occur during participatory workshops where a solar PV developer *seeks ideas* from future users about the number of bulbs or outlets needed, or when a solar PV developer conducts surveys to understand the electricity needs to set the size of the battery of the systems they plan to offer.

I use a multi-actor perspectives (Avelino & Wittmayer, 2016) to differentiate between actors and levels of aggregation (like the specific agencies in the actor called government or difference among community members like women, men and/or youth). This perspective has been helpful for me to identify who is included, excluded, and self-excluded (Cornwall, 2008) in the process of participation.

Chilvers et al. also highlight that participation should pay attention of the relational interdependence of the multiple processes that occur in energy transitions (2018). Thus, I understand participation as a set of independent objects of participation that build intersecting processes (Cornwall, 2008; Reed, 2008) through which actors perform different types of engagement that support or challenges wider systems (Chilvers et al., 2018; Morales-Guerrero & Karwat, 2020).

I also used an indicator for directionality to clarify how participation is performed in practice. As I developed and used this framework to understand participation processes, I found it important to use *directionality* as an analytical term that indicates the actor that is leading the form of participation. For example, *user-led informing* refers to the public informing a nonprofit about their electricity needs, while *not-user-led informing* might refer to a solar developer offering information about the use of solar module. Previous studies have also included directionality in how information flows in evaluations of how the intensity of participation influence decisions making that reflect the social goals of the public (Beierle, 1999). Directionality has also been used in other typologies that specify the flow of information (Rowe & Frewer, 2005, p. 285).

For this research I have used the labels *user-led* to describe forms of engagement where the dominant group, in this case the solar developer or the government, leads the form of engagement. *not-user-led* describes instances when the end user leads the form of engagement under analysis. For example, if the solar developer informed the public about how to properly use a SHS then the user was a passive receiver of information, and the activity was identified as *not-user-led* On the contrary if the user commuted to the a nearby town to pay for their electricity bill, then the activity was defined as *user-led*.

### 3.3 <u>Rural Electrification in México and Solar Cases</u>

Decentralized energy systems like solar home systems (SHS) and mini-grids are regarded as solutions to grant universal electricity access (Alstone et al., 2015; IEA, 2022). Currently, 9% of the world's population still lacks electricity access—77% of this population live in Sub-Saharan Africa and lives in remote community with difficult access (IEA, 2022). Such efforts will ultimately help us transit to a low carbon energy system (Alstone et al., 2015).

Rural electrification research in México has been dominated by engineering design studies, with little analysis of the role of participation. Scholars have analyzed the best technological options for rural electrification in the state of Hidalgo, Mexico (Vera, 1992), analyzed how hybrid power systems (including diesel, solar, wind and hydro) could secure economic growth in the State of México (Gutierrez-Vera, 1994), and evaluated the technological competitiveness analysis of electrification hybrid systems using solar, wind, diesel, and grid connection in Ensenada communities with GIS analysis (Corral Osuna et al., 2013). Gómez-Hernández et al. used participation to evaluate rural electrification rural plans in Chiapas, Mexico

(2019). Barragan-Contreras analyzed how participation unfolded the process of consultation for an utility scale solar plant procedural justice issues (2021), and Zárate Toledo & Fraga studied the process of consultation in utility scale wind plants in Oaxaca (2019).

In México, solar PV has been a technology used for electrification since the 1970s. The government, private companies, and universities have participated in solar PV R&D in research. They developed PV materials and technology design that have offered solar PV electrification since 1980 to rural, dispersed, and remote communities. Projects include lighting in boarding schools for Indigenous youth, PV powered rural telephones, and PV water pumping (Huacuz & Agredano, 1998). By 1998, the Mexican government had financed around 20,000 solar PV home systems in 1,250 rural communities (Huacuz & Agredano, 1998) , and policies like the "Law for the Use of Renewable Energy and Funding of the Energy Transition" secured funding for rural electrification with PV systems in the states of Oaxaca, Chiapas, Guerrero, and Veracruz from 2007 to 2012 (Mundo-Hernández et al., 2014). The area covered in this project includes the Bunicipalies of Batopilas, Bocyna, and Guachochi in The Sierra Madre Occidental in the State of Chihuahua, Mexico. I now offer an overview of the context of this place.

### 3.3.1 Context and geographic scope

The Sierra Madre Occidental in the State of Chihuahua is the homeland of the Ralámuli, Guarojío, O'odham Nations and Mestizo communities. It is a mountainous region with canyons which altitude vary between 700 and 2,400 mts.  Figure 10 shows the municipalities with very low to very high level of marginalization which includes indicators on poverty, literacy and education, housing that includes access to electricity, sewage, concrete floors, and number of people living in one house, income, and percentage of population living in communities of less than 5,000 people (Bustos, 2011).

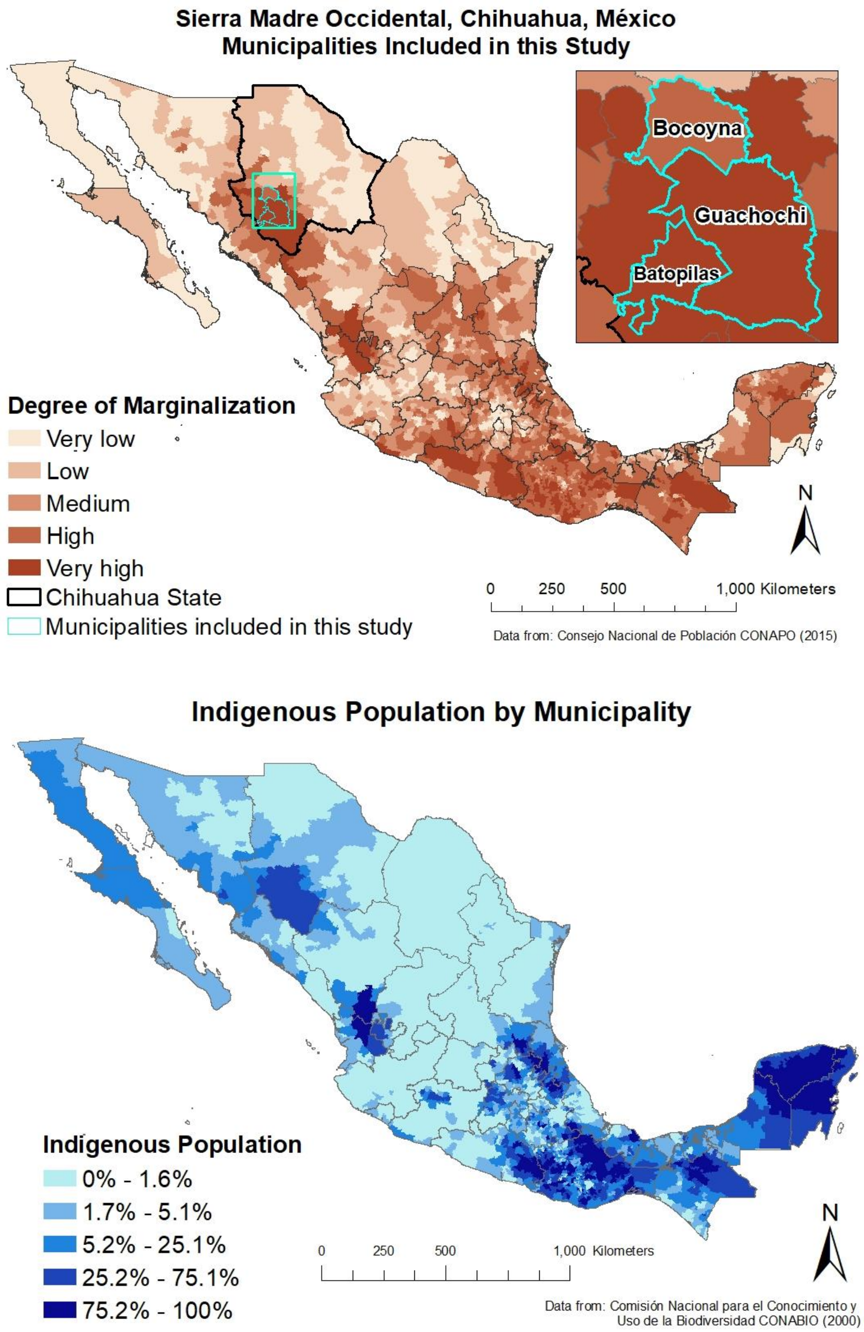



Fig. 10 Maps of the Region Under Analysis

### 3.3.2 Federal program

The Fondo de Servicio Universal Eléctrico (FSUE) was created through the article 115 in the Ley de la Industria Eléctrica, a secondary law from the 2014 Mexican Energy Reform. This initiative intends to grant electricity access to users living in remote and marginalized communities. From 2017-2021, FSUE aims to cover 45 thousand users in the first stage with a budget of 438 million Mexican pesos, and 180 thousand with a budget of 200 million pesos in a second stage (Peniche Sala, 2019). The policy is meant to generate a budget to pay for grid infrastructure and off grid systems in three ways: the excess of revenue from technical loses in the electricity market, the industry fines collected by the Centro National de Control de Energía (CENACE), and donations from private investors. FSUE is administered by Fideicomiso para el Ahorro de Energía Eléctrica (FIDE) and executed by enterprises that won the biddings organized by the government. Three companies working in the municipalities selected were: Veta Verde, Suncore and Iluméxico. This project started in December 2017, and 109 communities have participated across 16 municipalities in Chihuahua including Casas Grandes, Temósachi, Guerrero, Bocoyna, Carichí, Guazapares, Chínipas, Morelos, Balleza, Santa Isabel and Manuel Benavides.

FSUE has been implemented in other states in México like Campeche, Chiapas, and Guerrero. Additionally, FSUE also includes an electrification program that extends the grid infrastructure to connect communities, this piece of the FSUE program is beyond the scope of this research. According to the FSUE guidelines, users have to pay a monthly fee or "Couta de Sostenibilidad" of no more than $175-195 pesos, and the company is responsible of offering O&M, replace the first battery before or when the life cycle is over, and replace the panels in case of weather damages.

### 3.3.3 State and municipal programs

These programs are the continuation of tradition of government funded solar PV projects. These programs have included the participation of the government, utility, industry, and community (Huacuz & Agredano, 1998). Budgets in this program have been secured through policies in the federal and state level. The actors leading these programs include the Mexican utility (CFE Comisión Federal de Electricidad) who provides the technical specifications and design guidelines. The implementing agents (government local agencies at the municipal or state levels) plan and administer the project locally. The industry—hired through public bids—provides the technology and are required to train end users during the installation of system. The community or end user who is responsible of the Operation and Maintenance (O&M), disposal, and the proper use of the solar systems. The state agency Comisión Estatal para los Pueblos Indígenas (COEPI) offered these programs in 2017 and 2018. Thirty-eight percent and 33% of these solar systems are owned by women respectively. This program is present in more than 11 municipalities that include Guachochi, Bocoyna, Batopilas and Urique. Additionally, actors in the municipal branch of the government have also offered solar PV panels, like in Osachi and Wajurana in Bocoyna, El Pandito in Batopilas and other communities in Guachochi like Sarabéachi.

### 3.3.4 Gas-pipeline consultation

This solar program was requested by local communities that participated in a gas-pipeline (El Encino-Topolobampo) consultation during 2014 and 2015. The pipeline crosses nine municipalities in Chihuahua (including Bocoyna and Urique which are municipalities included in this study) and three municipalities in Sinaloa in an area of 1,507.93 has which affected 85 and 16 Indigenous communities in Chihuahua and Sinaloa respectively (TGNN, 2015). Communities participated in a Consultation process organized by la Comisión Federal de Electricidad (CFE), SENER, and the private company Transportadora de Gas Natural del Noroeste (Trans Canada) who started building the gas pipeline El Encino Topolobampo in 2015.

The consultation was implemented in *three phases*: “previous agreements” (July 7, 2014 – Jan18, 2015) in which the rules of the process were discussed, the “informative phase” (Jan 9, 2015 – Jan 17 – 2015) where community members received information about the project, and the “consultative phase” (Feb 7, 2015 – March 15, 2015) where community members expressed their consent (SENER, 2015). The process was criticized by local non-profits and activists because the consultation occurred after the construction of the pipeline had already started, so, the free, prior, and informed consent (FPIC) in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the International Labor Organization Convention 169 was not fully enacted (Guerrero Olivares et al., 2016; Valdivia Ramirez & Quintana Zapién, 2017). Each community that participated in the process of consultation negotiated the cost of having the gas-pipeline cross their communities, some communities negotiated the construction or renovations of schools, construction of health centers, some communities requested cash, and others requested solar PV systems.

### 3.3.5 Solar program offered by a nonprofit organization

This was a pilot program (only 25 solar systems were installed) developed through a partnership between Soriana, a Mexican retailer company, and the Fundación Tarahumara José A. Llaguno (FTJALL), a nonprofit created in 1992 after the death of Bishop Llaguno. Soriana expressed their interest in donating solar PV systems to the communities where FTJALL was working, while community members informed the organization of the needs of such systems during a watershed management workshop. Users paid for their systems with labor as they built a room that is utilized as health center and a classroom in two communities.

### 3.3.6 Privately owned

The last project in this analysis were second-hand PV systems that users received as a retirement gift and as a contribution to their work when they migrated to find a source of income. In this program the user was responsible for all the O&M.

**Table 4**. Solar programs, technological description, and costs

| Type of program | Technical description | Solar developer or executor | Costs or business plan |
|---|---|---|---|
| Federal | This program offers a Solar PV panel with 300 watts of solar capacity, 5 bulbs, two flashlights, a battery capacity of 115 Ah to 24 Vcc, a charge controller, and inverter to 60 Hz and 120 V | Ilumexico, Suncor, Veta verde, etc. | Users make monthly payments in exchange of a battery replacement and panels can be replaced if affected by bad weather |
| State/municipal | COEPI offers PV modules with 36 cells, 1 battery 115 Ah/110Ah 12V, 4 LED bulbs of 9 watts, 4 porcelain plug, 4 switches, 1 200 watts power inverter | COEPI, Municipalities | Program free of charge where users are responsible for the O&M after installation |
| Gas-pipeline | PV module with 36 cells, 1 battery 115 Ah/110Ah 12V, 4 switches, and 1 200 watts power inverter | Gas-pipeline companies | Program was offered as a compensation for the use of land in gas-pipeline infrastructure |
| Nonprofit | 270 watts or 60 cells, 4 LED bulbs of 9 watts, 4 porcelain plug, 4 switches, 1 200 watts power inverter | FTJALL | Users paid for the system in the form of labor, according to their possibilities |
| Private | Similar to state/municipal program | Private user | Second hand SHS bought by user |

## 3.4 <u>Methods</u>

I used participant observation and interviews to understand the experiences of users with Solar PV technologies in SMO. I collected data during two seasons of fieldwork during Jan-February and Nov-December 2021. I used content analysis and a codebook to organize data in MAXQDA and I generated the graphs and visualizations in Excel. The following subsections specify the sample, the process of analysis, and the questions in this research.

### 3.4.1 Sample from study communities

I visited communities in three municipalities for field work: Batopilas, Guachochi, and Bocoyna (see Figure 11). The communities included in this sample are small communities with less than 300 people in remote areas with altitudes from 1,250 to 2,500 meters above sea level. I excluded communities below 1,250 meters because people living in warmer places might have different electricity consumption patterns. To choose the sample of this study, I first identified the types of solar programs implemented in the area of study. Then I decided to start visiting communities close to the paved road (see figure 11). I also used snowball sample and participant observation to find next interviewees, and I tried to balance the number of interviews of each program that reflected the total number of solar modules in the area of study.

I conducted 63 semi-structured interviews (Table 5) with community members and engaged in participant observation across the two field seasons. I piloted the interview protocol with local friends and professors to incorporate feedback and suggestions before starting to collect data. I hired a community member that helped me translate interview questions from Spanish to Ralámuli and facilitate a good communication between researcher and participants. I conducted data analysis between the two seasons to fill gaps I had in the data collected and balance the number of interviews across solar programs. As show in Table 5, I prioritize most interviews with users to have a clear understanding about the experiences of end users. In addition, I conducted only 6 number of interviews with solar developers to fill the gaps in understanding the process of the solar project after having reviewed official documents and public data that explained the solar programs.

Table 5. Interview Demographics

| Interviewee | Total Interviews | Female | Male |
|---|---|---|---|
| Ralámuli users | 57 | 27 | 56 |
| Solar leaders | 6 | 4 | 2 |
| Total | 63 | 31 | 58 |

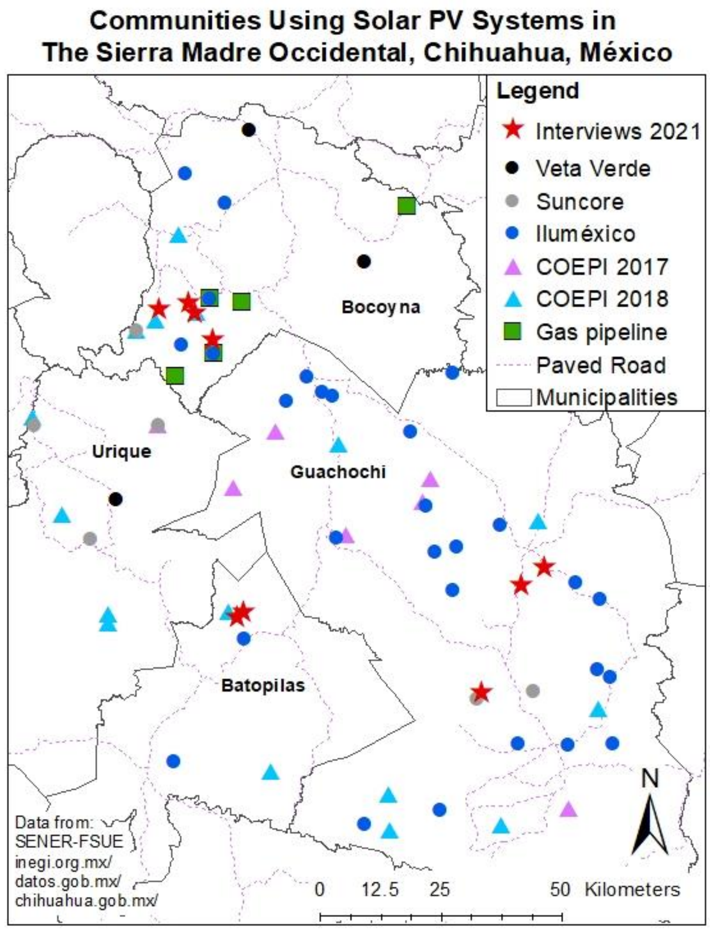



Figure 11. Map of Solar Projects in the Region of the Study

### 3.4.2 Data analysis

I used content analysis organized in three levels (Gioia et al., 2013) to analyze interview data. The protocol, found in Appendix A, was divided into four sections: (a) descriptions of technology and acquisition process, (b) benefits and obstacles while using solar PV, (c) technology evaluation, and (d) evaluation of participation in the project (perceptions and attitudes about participation).

To analyze the solar cases explained in the previous section, I developed a codebook (DeCuir-Gunby et al., 2011; Mihas, 2019) to analyze information from documents and interviews. I used inductive (information emerging from data) and deductive (categories borrowed from literature) coding to generate a codebook that organized information in categories. I used methods described by Deterding & Waters to differentiate information and create the categories (2021) in my codebook. The analytical codes (Deterding & Waters, 2021) I used in this paper are three dimensions of participation (objects, breadth, and depth of participation), directionality of participation, and two types of user outcomes (technology acceptance and user satisfaction).

#### 3.4.2.1 Analysis of program participation

The coding of participation occurred in two stages. In the first stage, I coded the **objects, breadth,** and **depth of participation** according to the framework of energy participation. In a subsequent revision, I added the **directionality** as I double checked the prior coding of objects, breadth, and depth. The categories for directionality are explained below.

(1) User-led: Users were the actors actively performing the form of participation

(2) Not-user-led: Users were passive actors while performing the form of participation

(3) Two-way communication: Actors shared ideas and listened to each other's opinions

#### 3.4.2.2 Analysis of user satisfaction and technology acceptance

The interviews included two questions that measured the program outcomes from the perspective of the users. To understand acceptance of the technology, I asked a yes/no question to whether the user would get the same system again. To measure user satisfaction, I included a five-point Likert scale that went from really sad to very happy to capture their degree of satisfaction with the technology.

#### 3.4.2.3 Three Components from Public Participation: Context, Process, and Results

Finally, I used the three components from the public participation framework to explore the impact of participation (Beierle & Cayford, 2002) in user satisfaction and acceptance of technology. Specifically, the context, process, and results of participation are all important factors influencing the quality of participation and associated outcomes.  Context includes the current relationships between the public and the lead agencies and the local institutions, the cultural context, knowledge systems, historical oppression, and exploitation, etc., this context is specified in the beginning of section 3. Process refers to the order in time in which objects of participation occurred with the different intensities in breadth/subjects or depth/models of participation. I have divided the process in three stages: planning in which the project goal and design is developed, implementation that describes the activities when the project is executed, and evaluation that includes technology disposal and the type of evaluation that the project conducted. Results refer to participation as an outcome and the dependent variables or user outcomes against I am evaluating the process of participation. Participation as an outcome is calculated through the averages of the sum of the values in each rung in the ladder of participation or depth, and the average of the count of different groups of actors participating together or breadth of participation. For more information on the differences between participation as a process and outcome please see (Morales-Guerrero & Karwat, 2020).

Both the STS co-productionist framework in ecologies of participation (Chilvers et al., 2018) and the components in the public participation framework (Beierle & Cayford, 2002) are the lenses we I used to analyze data and answer our research questions. Additionally, I got inspiration from previous research to visualize the process in graphs like (Krütli et al., 2006; Stauffacher et al., 2008), to plot results and visualize the process of energy participation. This qualitative framework has allowed us to test hypothesis on how participation influence diverse outcomes like the different rates on acceptance and user satisfaction across solar projects or the role of participation in changes on gas and electricity consumption across communities (Morales-Guerrero & Karwat, 2020).

### 3.4.3 Assessing the impact of participation

I assessed the impact of participation through the generation of visualizations generated as I applied energy participation as a framework. Yet I don’t have enough data points for statistical analysis. I am using both the visualizations and qualitative insights during fieldwork to draw conclusions.

## 3.5 Results and Discussion

Results are organized in the following manner. First, I show the metrics that emerged for the depth of participation, which was visualized as a ladder with seven rungs. Then I present breadth of participation, which describes actors at different levels of aggregation. I then elaborate on how the process of participation occurred in the federal policy solar project. I then present the user outcomes (acceptance and satisfaction) for all five solar projects. The last section discusses patterns of participation in projects with higher or lower technology acceptance and satisfaction.

### 3.5.1 Depth and Breadth of Participation

I now present the deductive and inductive codes that resulted through this analysis. Table 6 shows the ladder of participation that emerged as I analyzed users' experiences with SHS programs in SMO. The rungs include deductive codes that I borrowed from the literature: *Informing* and *consultation* are rungs in (Arnstein, 1969) *seeking ideas* in (Jackson, 2001), *passive participation*, *material contributions*, and *functional participation* in (Pretty, 1995), and *technology use* inspired by electronic public engagement in (Rowe & Gammack, 2004; and Ryghaug et al., 2018), who describe the engagement of humans with material objects or technology like smart meters as a way to gain energy citizenship. Additionally, I used *absence of participation* as an indicator that activities were not conducted or lack of services or goods. Table 6 presents definitions of the rungs that became the analytical tool that I used to differentiate forms of engagement across the process of SHS programs. I then prioritized the rungs of participation based on my own understanding of participation. Thus, for future use, the order of this ladder could be rearranged with input from the public or users (for clarification see limitation section in the conclusion of this dissertation).

**Table 6.** Ladder of Participation across solar projects in SMO. Adapted from (Arnstein, 1969; Jackson, 2001; Pretty, 1995; Rowe & Gammack, 2004; and Ryghaug et al., 2018)

| Rung or type of engagement | Definition | Directionality identified in analysis |
|---|---|---|
| **7. Seeking Ideas** | Events in which stakeholders share ideas about a project, including working group sessions, and community meetings. It involves two-way dialogue | Two-way communication |
| **6. Functional Participation** | Users and actors performed tasks like organizing community meetings, requesting programs, traveling to make payments/buy equipment, solving tech issues, taking care of the system, migrating, negotiating budgets, disposing of technology, or participating in productive activities | User-led and not-user-led |
| **5. Use of Technology** | Participants explain how they use technology or energy resources for light or to charge gadgets | User-led |
| **4. Consultation** | Users or actors answer already formulated and closed-ended questions and/or sign contracts | Not-user-led |
| **3. Material Participation** | Material contribution in exchange for a service or good. Examples: Payments in pesos, payment in the form of labor, or by allowing energy infrastructure to cross user's communities | User-led and not-user-led |
| **2. Passive Participation** | Users are simply receivers of something: it includes instances where technology was free, and when users/actors did not actively do anything, they were just observing or following rules | Not-user-led |
| **1. Informing** | Users are informed about the solar program, how to use the technology, how to solve technical problems, how to pay, contract rules, etc. | User-led and not-user-led |
| **0. Absence of Participation** | When activities were not conducted, when the solar module is not working (due to technical problems or lack of payments), or when users did not have access to certain services or goods | User-led and not-user-led |

The groups of actors through which I measured breadth of participation were organized by different levels of aggregation as the multi-actor perspective (Avelino & Wittmayer, 2016). Through this analysis, I identified six types of actors that include end users or community members (this category includes actors' differences like men, women, youth, etc.); Indigenous government and organizations (this category includes Ralámuli government leadership and cross generational forms of organization like Siríame that refer to the Ralámuli governor); the Mexican or chabochi (for definitions see Morales-Guerrero, 2020) government agencies that include the Mexican utility CFE or the Energy Ministry SENER; businesses that include solar enterprises and local convenience stores; and religious actors like priests. Table 7 presents a list of the actors in each aggregated group.

**Table 7**. Actors Participating Across Solar Projects in SMO

| Community actors | Indigenous organization | Nonprofits | Chabochi Government | Businesses | Church |
|---|---|---|---|---|---|
| Women | Siríame | CEDAIN | State actors | Convenience stores | Priests |
| Children | Promotores | FTJ | Municipal | Ilumexico | |
| Youth | Mayora | CAPTAR | CENACE | Suncor | |
| Men | | FECHAC | SENER | Trans Canada | |
| Teachers | | Asolmex | SHCP | | |
| Students | | Acciones Colectivas | CFE | | |
| | | | FIDE | | |
| | | | FSUE | | |

To illustrate how these metrics are visualized in a solar program, I will now elaborate on the process of participation in the case of the federal program.

### 3.5.2 FSUE-Ilumex: Local Results of Participation as a Process

**Planning:** FSUE set the goals of the program as part of the Ley de la Industria Eléctrica, secondary law of the 2014 energy reform. FSUE established dialogue in 2015 with the energy ministry SENER, the Mexican utility CFE, FIDE, nonprofits, and solar companies through working groups in Mexico City where participants shared ideas about the rules of operation of the program. During an interview, Ilumexico staff detailed how Ilumexico influenced the FSUE program in two ways: (1) they proposed the incorporation of a monthly fee as a strategy to secure the user's sense of ownership (*apropiación* in Spanish) of the technology, and (2) the development of local capacity to secure a proper M&O of SHS. Despite deep participation among the government, nonprofits, and solar companies during planning, the size and capacity of SHS and the cost of the monthly fee were decisions made only by FSUE leadership.

FSUE then opened a bidding process through which the best solar programs that met the guidelines and technical design proposed by government leadership. More than 15 solar companies won the biddings and executed this national program. End users and Indigenous governments were also absent during these activities.

**Implementing:** Under the coordination of FIDE and SENER in 2017, the FSUE program was implemented by the companies that won the biddings. Users in Bocoyna and Guachochi explained that they did not request the program beforehand. Instead, the solar companies first visited their communities and informed future users and the Indigenous authorities about this initiative. The community then verbally consented to the offer and Indigenous authorities helped gather all the paperwork required to sign the contracts. The company returned to the community to install the systems. During this time, solar users and Indigenous authorities helped technicians with construction materials to install the systems and offered lodging and food to the company's staff. Users signed the contract, received the system, and were informed about their rights (e.g. the company is expected to change the battery during the first 4 years of use) and responsibilities (e.g. monthly payments).

Informants mentioned that most of this information was shared in Spanish, yet most of the users in these communities speak Ralámuli as their first language. Trainings might have been conducted for the company staff, but end users shared that they did not attend any sort of meeting or workshop where they could learn about the technology they acquired. This suggest that FSUE did not facilitated enough events to inform users in their first language about the contract rules and best practices for a successful use of solar modules.

A few months after the installation, Illumexico installed meters in the SHS that required users to enter a code that they receive after their monthly payment. If customers do not pay, the meter stops delivering electricity to the household. Customers can only pay their bills in nearby towns where there is internet and cellphone signal. The commute includes 1-2 hours hiking to reach the paved road where users then take a $30-50 pesos bus ride. The same commute had to be done to return to their communities or they could pay a $700-1,500 pesos taxi ride to return home.

Suncore, another solar company executing FESUE in SMO, did not offer the same M&O services neither they installed the meters that Ilumexico did. Suncore simply did not have the infrastructure in place to receive payments, as Illumexico did. As confirmed by Ilumexico staff during fieldwork, after two years of operation Ilumexico expanded their operations and were in the process of installing the same meter and payment system in Suncore SHS. By the time the interviews were conducted, all Suncore systems were still up and running, and users had not paid the monthly fee as Ilumexico had done. Yet, the users were already informed they would get the same meters as the Ilumexico users and that they will cut the electricity service if no payment was made.

**Evaluation:** Since the program was at an early stage, no evaluation had been conducted at the time of the data collection for this research.

Figure 13 below visualizes the process described in the paragraphs above. The x-axis shows all the objects or the events that happened across the process of the program. The y-axis in the top shows the quantification of actor groups collaborating across the process of the project. This is similar to what other evaluations have done in participatory research (Cornwall & Aghajanian, 2017).

The next two y axes represent each of the actors or the levels of depth of participation illustrated in Figure 12. The y-axis with the name 'actors' further shows the actors included and excluded (each number represent one actor as showed in figure 12) across the process. The y-axis at the bottom shows the forms of engagement (each rung is represented by numbers as showed in figure 12). Each of the markers indicate the presence of the form of engagement (circles) or actors participating (squares). The darker the marker the more codes were identified in such category.


Figure 12. Scale Numbers for Breadth and Depth of Participation in SMO Solar Projects

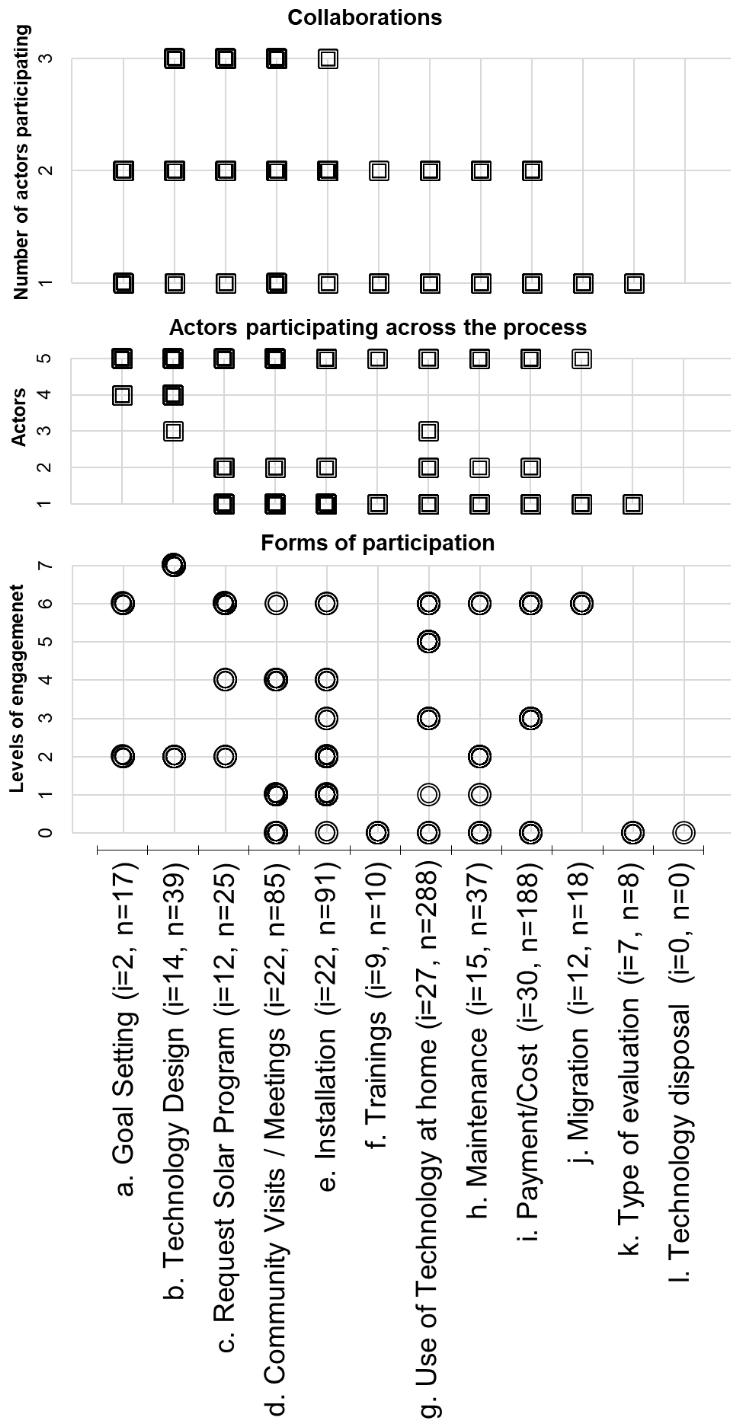



Figure 13. Visualization of FSUE Participation Process

### 3.5.3 User outcomes for all five solar programs

Figure 14 now presents a comparison of results in the process of participation across the five solar programs. The x-axis remains the same as in figure 6, while the y-axis shows the results of averages of both depth (bottom y-axis) and breadth (top y-axis) of participation. The graph shows an overview of different intensities of participation across the process of solar programs.

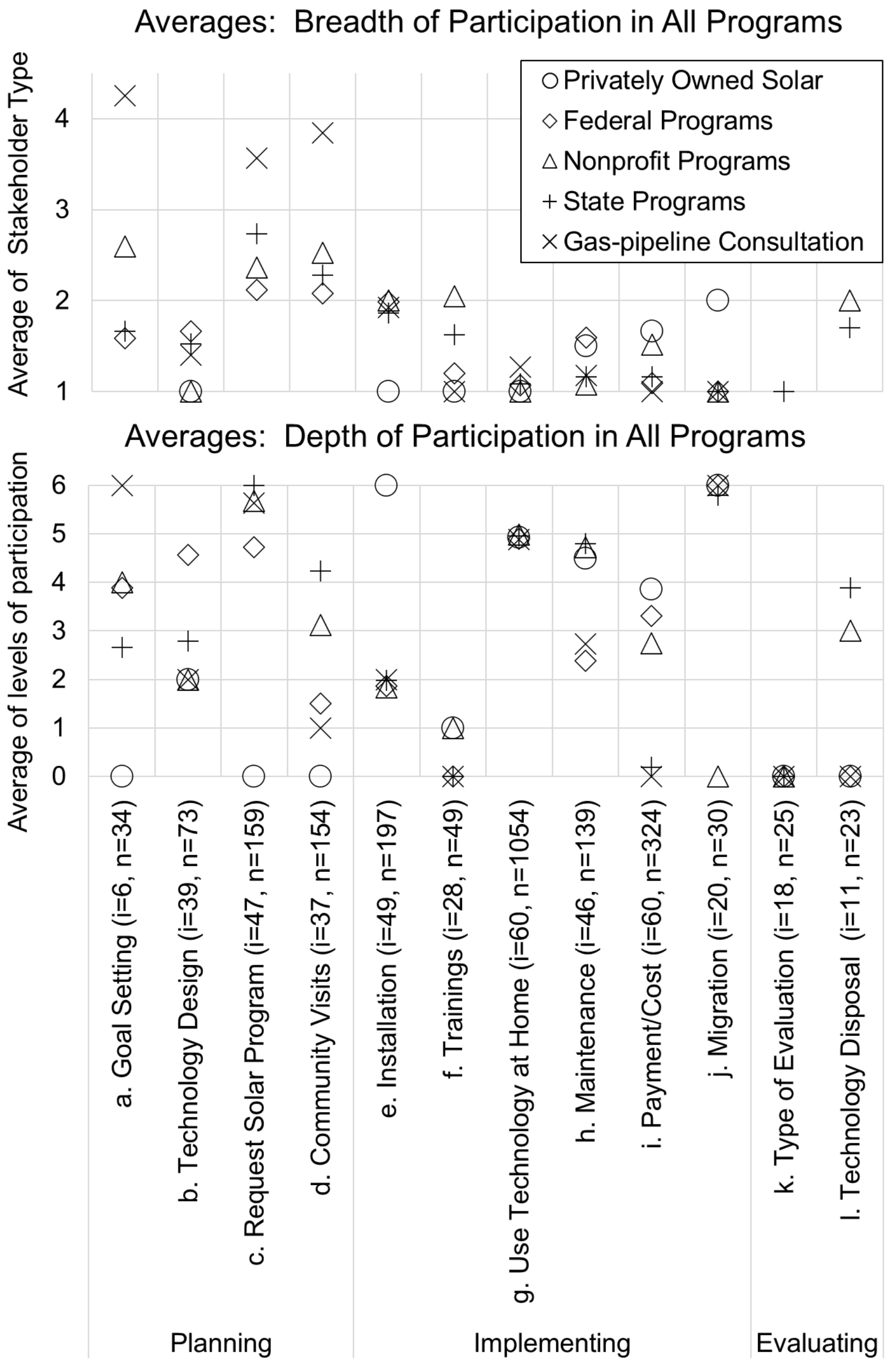



Figure 14. Averages of Breadth and Depth Across Solar Projects in SMO

I see that a greater number of actors collaborated during the first stages of the process, and collaborations decreased as the process unfolded. The highest scores of collaborations were performed during 2014-15 in the gas-pipeline consultation process organized by the Mexican utility (CFE), the Secretariat of Energy (SENER), and the private company Transportadora de Gas Natural del Noroeste (Trans Canada) who started building the gas pipeline "El Encino Topolobampo" in 2015.

Figure 14 also shows how Goal Setting, Request Programs, Installation, Maintenance, Technology Disposal, and Migration were the objects of participation with higher depth of participation. Additionally, the graph shows that some programs did not conduct some activities as their marker was placed on level 0 in the bottom x-axis.

### 3.5.4 Technology acceptance and participation

To explore how the process of engagement might influence user satisfaction and acceptance of technology, I now present the following summary tables (table 8 and 9) that show that the FSUE is the program with the lowest scores for acceptance and satisfaction while it is also the program with less working systems.

**Table 8.** Summary Tables of Acceptance and User Satisfaction

| Type of program | Number of codes | Interviews | "It's working" | "I'd get it again" | % systems working | % of accept | User Satisfaction *(Likert scale)* |
|---|---|---|---|---|---|---|---|
| **FSUE** | 658 | 30 | 14 | 6 | 47% | 20% | 2.7 |
| **State** | 623 | 29 | 20 | 27 | 69% | 93% | 4.8 |
| **Consulta** | 233 | 12 | 8 | 12 | 67% | 100% | 4.5 |
| **Nonprofit** | 242 | 9 | 8 | 9 | 89% | 100% | 4.8 |
| **Private** | 68 | 2 | 2 | 2 | 100% | 100% | 5.0 |
| *All* | *2007* | *82* | *52* | *56* | *63%* | *68%* | *4.4* |

**Table 9.** Summary Tables of Breadth and Depth of Participation

| | Depth of Participation | | | | Breadth of Participation | | | |
|---|---|---|---|---|---|---|---|---|
| **Type of program** | **Plan** | **Implementation** | **Evaluation** | **Total** | **Plan** | **Implementation** | **Evaluation** | **Total** |
| **FSUE** | 3.0 | 3.8 | 0.0 | 3.6 | 1.9 | 1.2 | 0.7 | 1.4 |
| **FTJALL** | 4.0 | 4.1 | 0.9 | 3.9 | 2.2 | 1.2 | 1.2 | 1.4 |
| **State** | 5.0 | 4.0 | 2.9 | 4.1 | 2.4 | 1.2 | 1.5 | 1.4 |
| **Consultation** | 4.0 | 4.1 | 0.0 | 4.1 | 3.6 | 1.3 | 0.0 | 1.9 |
| **Private** | 0.5 | 4.7 | 0.0 | 4.4 | 0.3 | 1.3 | 0.0 | 1.2 |
| **All** | 3.8 | 4.0 | 1.6 | 3.9 | 2.4 | 1.2 | 1.1 | 1.5 |

Figure 15 summarizes the overall results for participation (depth and breadth) and user outcomes (acceptance and satisfaction) for all five solar programs. FSUE is an outlier with extremely low scores for user outcomes, while all the other programs have more similar, positive outcomes.  Regarding technology acceptance (graphs on top of figure 15), users of FSUE showed lower willingness to get the same program again while the average depth of participation was lower compared with the rest of the program that had higher levels of acceptance. Additionally, averages of participation (3.9 to 4.4) across the rest of the program showed similar acceptance rates, suggesting that the benefits of participation were achieved despite the presence of lower rates of breadth participation. The same occurred with depth of participation in which a higher number of collaborations across actors do not seem to influence users' decision to get the program again.

Regarding user satisfaction, the graph at the bottom in figure 15 shows that lower user satisfaction is present in the program with lower depth of participation. Yet the rest of the programs seem to have similar rates of user satisfaction with an average of depth between 3.9 to 4.4, which also suggests that the benefits of deeper participation were already reached in scores equal or larger to 3.9. On the other hand, breath of participation showed that more collaborations do not seem to play a role in user satisfaction. Thus, these results support the findings in Chapter 2 in this dissertation that suggest that more participation does not always translate to better outcomes. Section 3.5.5 now offers other explanations outside the numerical averages presented in Table 9 and figure 15.

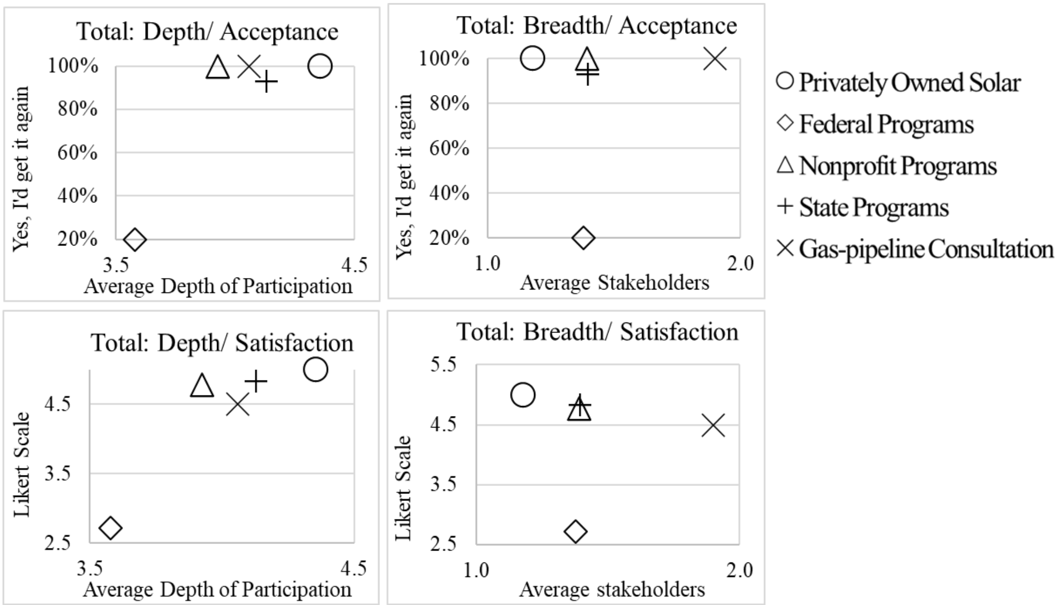


Figure 15. Acceptance, Satisfaction, and Averages of Participation Across Solar Projects

### 3.5.5 Possible drivers of SHS acceptance and user satisfaction

This section elaborates on the characteristics of engagement that emerged as possible drivers of technology acceptance and user satisfaction. The elements that might influence higher acceptance and user satisfaction were clear and sound information about program costs, understanding energy needs in planning stage, and affordable costs. Other factors that influenced lower levels of user satisfaction were triggered after community members didn't have much input during planning, but they were expected to shoulder a heavy burden once the solar was installed. These results contest the intrinsic positive connotation of participation and suggest that the benefits of participation decreased once it surpasses a certain limit.

Despite lower program acceptance and user satisfaction in the FSUE program, users still had a positive perception of solar technologies. A reason for these contradictory views could be explained through how useful users find solar modules. For example, solar technologies allow users to work after dark once they have finished outdoor activities during the day. Light at home enables users to produce handcrafts to sell and domestic use like baskets and wooden kitchen gear, do homework, sew clothes, shell corn, get ready to work early morning,  light the kitchen to cook, and even to just spend time at home without feeling sad. Electricity also enables users to perform cultural events at night like teswinadas—religious and non-religious celebrations where people drink teswino (fermented drink made of corn), cook, and dance pascol or matachín. Additionally, electricity enables users to charge diverse gadgets like cell phones that allow them to communicate with family members and friends, to charge torches to light up their way at night when there is no moonlight, and charge speakers and radios to play music and listen to the news. I elaborate more on these elements in the following subsections.

#### 3.5.5.1 Understand energy needs in planning stage

Programs that either sought ideas from the public or opened communication channels (user-led informing) with end users during the planning stage received better ratings in the indicators for acceptance and satisfaction compared to programs like FSUE that include users only after the implementation phase. The top graph in figure 16 shows the number of codes identified through this analysis that indicate the actors participating by seeking ideas during the during planning stage. Specifically, the FSUE program shows how they included businesses and the Mexican or chabochi government, nonprofits were mentioned less times, while community members and Indigenous governments and organizations were absent. This graph also shows how the gas pipeline and the state/municipal programs did include the community in seeking ideas activities during the planning stage of the process.

Additionally, the graph on the bottom in figure 16 shows the count of codes for directionality in the form of engagement informing during the planning stage of the projects. It shows how the nonprofit, state, and private programs included user-led informing, while the federal and gas pipeline programs only informed users about the program.

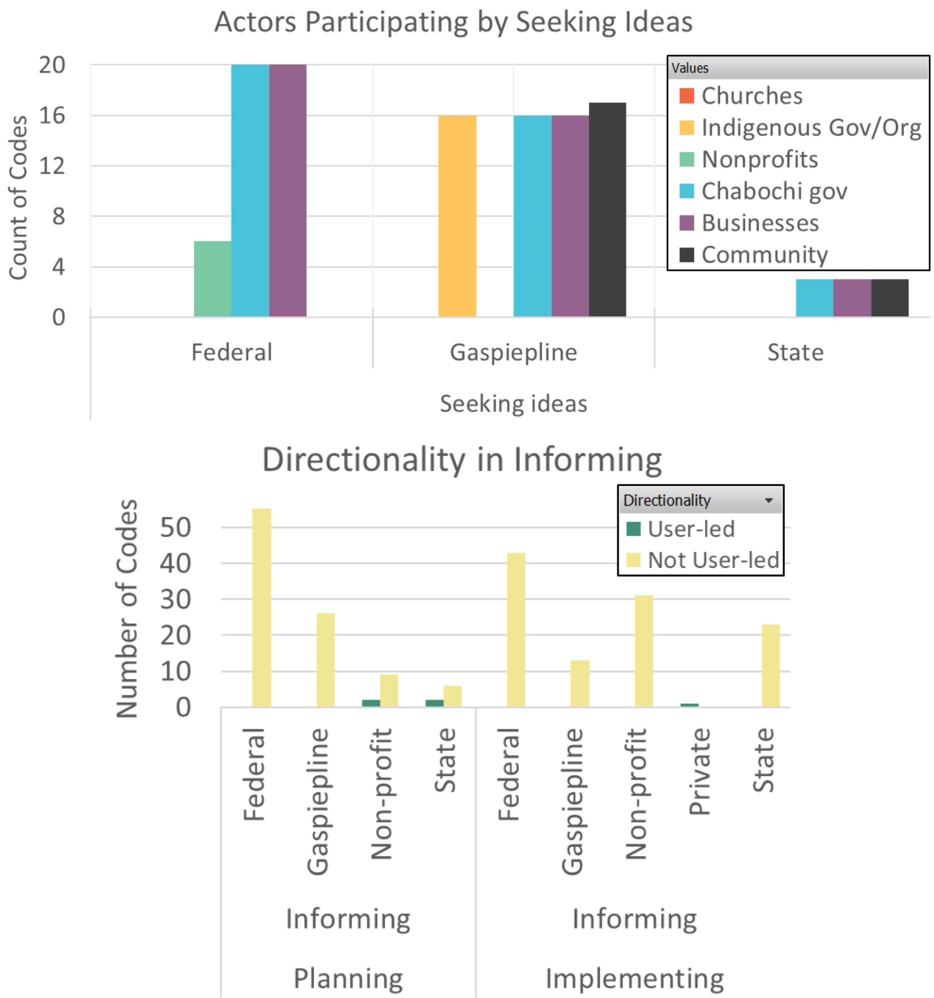



Figure 16. Count of Codes: Seeking Ideas and Informing

These insights suggest that prioritizing seeking ideas and/or bottom-up informing during the planning stage of SHS projects could secure higher acceptance and satisfaction. This is also consistent with literature that suggests the inclusion of the public in decision-making at early stages of the projects will secure acceptance and support of solar infrastructure (Pasqualetti & Schwartz, 2011).

### 3.5.5.2 Clear information is important for technology acceptance and user satisfaction

Unclear information about ownership, costs, and payments of solar programs might be drivers of lower acceptance and satisfaction. Despite the community being informed about the program during planning and implementation stages, FSUE users had a lot of doubts about their responsibilities and rights they consented to when they signed the contract. People in these communities are used to signing or putting their digital prints in exchange for receiving government and non-profit programs like the solar program offered by the state. Additionally, must of users in this program do not know how to read and write and the contract was written in Spanish while their first language is Ralámuli. Thus, some users mentioned they were not aware the FSUE program would require them to pay a monthly fee. For example, one user told me: "I did not know they required to pay money, I had to pay 200 pesos at the beginning of last year." Additionally, it was not clear where they had to make such payments.

A mismatch of information about the ownership of the SHS was present in the interview narratives and participant observation experience. Users said that the systems will be theirs after four years of payments, while the solar company executing the FSUE said that the system will never be owned by the user. One user told me the following:

> "They [Ilumexico] said that we had to pay $200 pesos each month for four years [and]… after paying around nine thousand pesos the system will be ours …that is why I accepted it, because I said at least then the system will be mine."

However, in conversation with the FSUE executor, I asked whether the SHS would be owned by the user after four years of payments and they answer the following:

> "No, the system is owned by the FSUE. It is not owned by the executor either. For example, if a family stops paying the sustainability fees, then the executor would notify FSUE that the user is not paying to relocate the system to other family. Then FSUE would have to approve the relocation of the system."

Reasons for this mismatch of information could have been due to the language used to share information. As one user mentioned:

> "People gathered around the health center, they asked us whether we wanted the panels, but all the talk was in Spanish. That is where they explained the payments and all of that, they said that after paying the monthly fees the solar panel will be ours."

Therefore, a clear communication plays a big role in higher user satisfaction and technology acceptance.

#### 3.5.5.3 Costs

The quantity or the amount of money users must pay influence technology acceptance. First, users are willing to pay for the SHS as long as they can afford it. One user mentioned: “We would like a program that is less expensive. The price is the problem [with the FSUE program]. There in San Elias [a community that has access to the grid] people are paying only $60 pesos each month. …that is a good price.” Other uses mentioned that they are willing to pay with labor in exchange for technology: “I would get the program again, if we could pay with labor, like this one [non-profit program] we got. If so, yes, I would get it again.” Others explained that they have invested in their SHS to meet their electricity needs “These [solar panels from the state/municipal program] did not have outlets to charge the phone, but I bought one power inverter, and now it works. That is how we are charging our phones. …it was cheap, I invested about a bit more than 200 pesos.”

On the other hand, users mentioned that the price of the FSUE program is high and highlighted the lack of job opportunities in their communities: “Yes, we received [the FSUE program] first because we did not know the panels were that expensive. Later we found out they were charging a lot” and “people [are] now upset with the large solar panels [FSUE solar program] because it is really expensive to pay for it.” Users mentioned they need to decide to pay their electricity bills or pay for food:

> “I feel sad because [the solar panels are] leaving us without money after we pay for it. Once we pay, we do not have money to buy food, to buy salt, not even for coffee, we can only afford to pay the panels”, and “Instead of giving us a benefit, [the solar panels] are leaving us without money, a lot of people say they will quit the program, they do not want to pay anymore.”

Users also mentioned how difficult it is to get a regular job to pay for the SHS. This is illustrated by the following quote:

> “Sometimes I am happy, but sometimes I am not. I tell myself that they are going to take it [the FSUE solar panels] away from me. Because to be honest I am not paying the monthly fees. They are going to cut the electricity … but where am I going to get that much money? There are not jobs here. So, yes, I am afraid.”

Additionally, some users mentioned that they needed to migrate to pay their electricity bills. Users mentioned they need to go to La Junta or Sinaloa to get jobs. This is illustrated by the following quote: “there in my community there are no jobs …that is why I came to la Junta. My family at home does not have food, people do not have enough corn, that is why I migrated. That is why they are late in their payments; people are buying food.”

Users mentioned that the costs to commute to nearby towns and the time they need to invest to go the nearby towns to make the monthly payments are also high:

> “It is hard to go to Creel, you spend a lot of money commuting, we need to walk [for about an hour] to the paved road and then take a bus. We spend 30 pesos on the way to Creel and 40 pesos on the way back.”

They payment methods and technology design in FSUE erase the benefits of the low marginal cost of electricity that SHS could offer. For example, if a user did not pay for 6 months, they would have to pay $1,200 pesos to get their electricity back. This is illustrated by the following quote where the user paid a good amount of money, but they did not get their service back: “I paid about $1,000 pesos, but it did not work at all …I paid, but I did not get the electricity back. What would have happened?” Users interpreted this form of payment as an expression of selfishness form the company:

> “they [FSUE staff] come here to ask for the payments, but no one has money to pay. It is really difficult to get the money to pay the fees. Then they [FSUE staff] cut the electricity to people that did not pay. They changed the device [installed the meters] so that it does not work when you do not pay. They were selfish.”

The lower acceptance of FSUE program might also explained because users are also aware that solar PV is a reliable technology with low marginal costs. For example, users in the state/municipal program mentioned the following:

> “the electricity from the grid is not reliable, after a small rain there is no power anymore, …solar panels are more reliable, and you do not have to pay to use them. You just need to pay once when you buy them” or that “solar panels are good for the community because you do not need to pay month by month as you do when you get electricity from the grid.”

These narratives suggest that the benefits that participation could generate are finite. Once the solar program demands more than the user can afford, the benefits of material contributions are diminished. Thus, high costs and demanding a lot of time form users can become detrimental to technology acceptance and user satisfaction. This idea is illustrated in Figure 17.

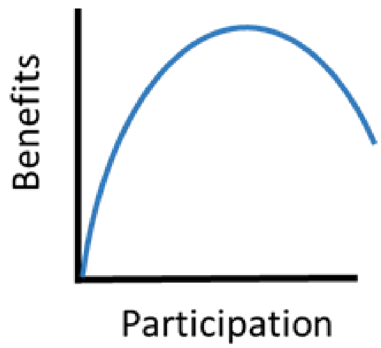



Figure 17. Illustration of the Limits of the Benefits of Participation

As other authors have suggested, solar technologies can have negative consequences across different scales, demographics, interspecies and cross generational (Sovacool et al., 2022). In this case, narratives show how the federal program, which is supposed to help communities to overcome poverty, is instead pushing users to migrate to find sources of income, and it has generated users' debt. This results are similar to other experiences in developing countries where solar programs are increasing consumer debt and financial dependencies (Baker, 2022). In the case of the FSUE, electricity has become a service offered by private enterprises like Ilumexico who has become the dominant enterprise offering the FSUE service in SMO. This case suggest that the FSUE energy access programs is now accumulating capital at expense of marginalized communities, similar to what others have called the "new frontier of electricity capital" (Baker, 2022). Baker has denounced how electrification projects support the accumulation of capital while leaving users and marginalized populations behind (2022).

### 3.5.5.4 Greater user-led participation during implementation does not secure acceptance

The analysis of directionality shows how certain forms of engagement had greater number of codes of one directionality. Absence of participation, informing, passive participation, and consultation were dominated by top-down approaches, while material participation, functional participation, and use of technology had a higher number of bottom-up efforts. Additionally, the only form of engagement with two-way communication was seeking ideas. This is illustrated in Figure 18.

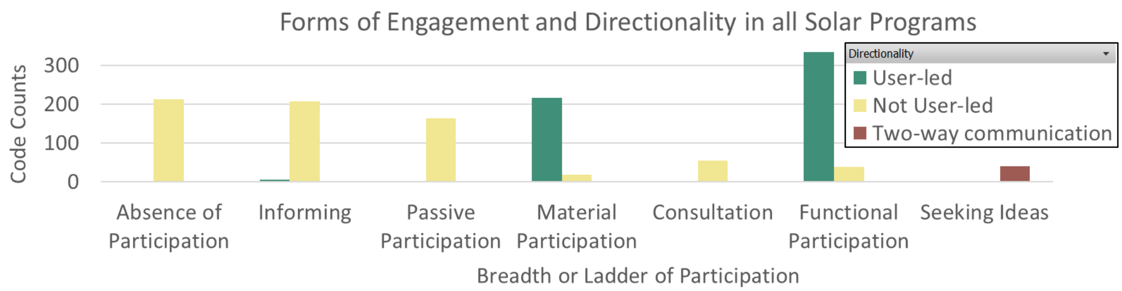
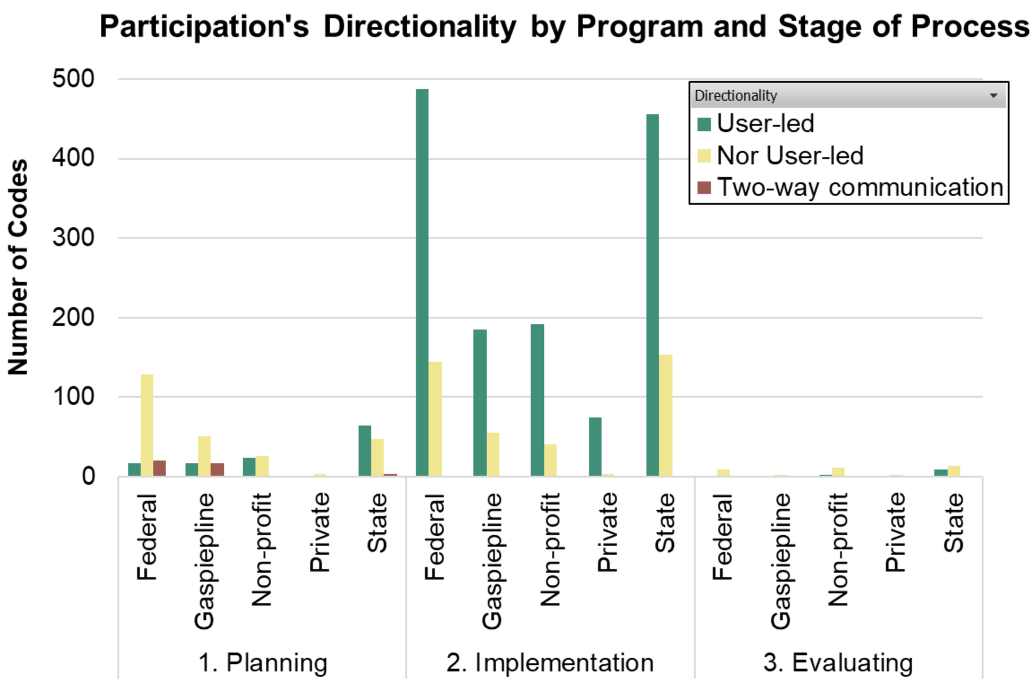



Figure 18. Directionality and Forms of Engagement

Figure 19 below reveals the complexity of user-led/not-user-led participation across programs and across stages of the process. Both graphs show how most user-led approaches of participation occurred during the implementation phase of the programs—the code *g. use of technology* had the larger number of codes. The graph on the bottom excludes the code "*g. use of technology*" to show that the federal program had higher user-led efforts during the implementation, as compared to the rest of the programs.

This analysis illustrates how, during the planning stage of the FSUE, the decisions were made by not-user-led efforts during policy discussions in Mexico City, while high number of user-led efforts were performed during the implementation phase. This suggests that higher number of user-led activities, decided by technocrats, do not secured higher acceptance and satisfaction. On the contrary, such combination of participation was detrimental to user satisfaction and program acceptance. This analysis suggests that the stage of the process where user-led and not-user-led approaches are performed matter a lot for the outcomes we need in energy transitions.



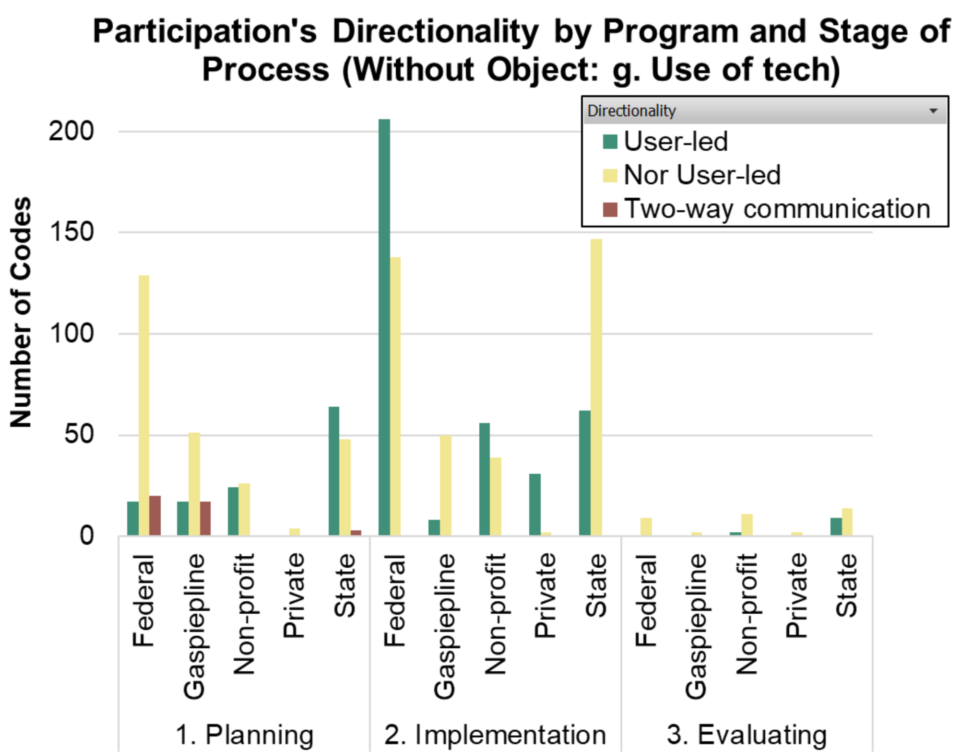




Figure 19. Directionality of Participation Across the Process

#### 3.5.5.5 Distributive issues

This analysis also showed that the incentives in the FSUE program to install a greater number of SHS might be preventing an equitable distribution among users and communities in the area. For example, through interviews and participant observation, I was able to identify that some households often had more than one SHS. This occurred due to the absence of coordination between the FSUE program, and the local programs offered by the State of Chihuahua and municipalities. FSUE executors' staff mentioned during conversations that there are economic incentives in the company to reward staff that install higher numbers of solar systems. Such internal incentives materialize in an overflow of SHS even when households have already one system that covered their electricity needs, as the following example suggests.

Figure 13 shows two houses that belong to the same family, each household had the gas-pipeline consultation SHS (installed 2017) and the FSUE SHS (installed in 2019). This group of houses are in the "center" of the community that is connected to the dirt road. However, there are households nearby that did not have electricity access yet. In fact, the person that supported me with translations during the interviews did not have electricity at their place, they mentioned their house is about 45 away (hiking) from the center of the community. This issue is illustrated in the following quote by a FSUE executer staff member:

> "The company did not survey the energy needs of households. …This is common in the history of Rarámuli lands and other Indigenous territories. What they need is not important, go and offer them stuff, what companies care are the number of the solar systems installed, that we have x generation capacity installed, etc. and that is it. …you might have seen it already. The FSUE says that solar companies need to install a specific number of bulbs and outlets, then you find a one room house with two bulbs inside and two bulbs outside and you say, really?"

This quote also illustrates how the capacity of FSUE systems really surpasses the electricity needs of households in this area. Since the FSUE systems are supposed to be installed in 48 square meter households with a living room, kitchen and two bedrooms that would consume at least 750Wh per day (FSUE & SENER, 2017). Figure 20 showed that FSUE households in SMO were smaller than the guidelines. Additionally, the following section illustrates how the households interviewed did not have such rate of electricity consumption.

Figure 20. Overlapping Solar Programs in Households

**3.5.5.6 Systems are useful for participants which drives positive perceptions of SHS**

Despite the low rates of technology acceptance of the program developed after federal policy, users had a general positive views of solar technologies. I explain these perceptions through the benefits that solar already grant to their communities. After I asked participants if they were happy/a gusto with the SHS, the often replied something like “Yes, I love it.” Such positive views might be explained by how useful the SHS are for individuals and the community at large. Here I present the some of the benefits or the social value that SHS grant to communities.

Light enables productive and leisure activities after dark when they had finished outdoor activities. For example, users shared during the interviews that light at home is useful after they finished outdoor chores like grazing goats, work in agriculture, or after a working day. This is illustrated by the following quotes: “We use light late in the afternoon when one arrives from work, sometimes one is working far away and arrives home late. It allows us to produce handcrafts after work." and "A lot of people go out during the day to graze goats. People deal with goats during the day and arrive home late in the afternoon. Then one has the chance to sew clothes, it is in the afternoon that women do that." Additionally, solar modules are useful to light up the house to hang out with family members "We also use it to hang out inside and talk. It has been useful for us; it is really useful", especially during winter "because we [users] stay more time inside the house."

Light is also useful in the kitchen to be able to cook when it is dark. The following quotes illustrate how users use light to cook: "we need only one bulb because we do not have a lot of rooms at home. If we had many rooms, then we would like more bulbs …we need only one bulb to light up the kitchen", and "we need light at night, so that it is not dark inside, to light up the space where we cook." Others mentioned that the lack of electricity at home triggers feelings of sadness: "I feel sad because I cannot see well at night …to cook food, it is really hard to cook without light at night."

Light has the potential to generate economic benefits. Light is useful to get ready for work in the morning: "We use the light when cooking and when we get ready for work early in the morning when it is still dark." Children benefit by solar technologies as well because they can do homework after dark. Light also enables women to produce wares (baskets made of pine leaves and/or sotol) and other handcrafts that could be used at home or traded for other goods. This is explained in the following quote:

> "I sell wares in Creel, sometimes I go to Quirare, other times to Samachique. There I can barter wares for corn. … [I use SHS] to light up the house at night and produce handcrafts … during the day we need to do other things."

Light is also useful during the cultural rituals and celebrations including the day of the death rituals. For example: during these celebrations "women use it [light] all night when they are cooking. [they cook the whole night], at dawn when the sun is rising, they offer food to people." Light is also used outside, for example: "when we have long extension cords, we put them close to the crux to light it up. It is useful for many things", and "we use bulbs so that we can see how to dance Pascol [laughs], so that we see it well."

Users also use electricity to charge gadgets like phones, speakers, radios, and torches. Cellphones and speakers were the technologies that users mentioned they use the most, torches were mentioned at a lower rate, while only one user said they use the SHS to charge a tablet. Here are I present a quote that illustrate how cell phones are important to keep communication with loved that are outside the community:

> "I only use it [SHS] to charge my cellphone when I want to talk with someone. There are family members that are outside from here [they migrated]. It is good because one can charge it [the cellphone] here, it is easier because we do not have to be looking for electricity in other houses. So, we get electricity from it [the SHS] to talk to our family."

Torches are useful for safety at night when users need to do something outside or when they commute between houses. This is illustrated by the following two quotes: "Sometimes [at night] there is moon, so we can walk fine outside. But when one needs to commute farther away, … you need a torch to light up your way," and "at night, [people] fall when they walk. When there is no moon, it is really dark outside when one is walking. Sometimes we do not have electricity to charge the torch."

Solar modules could also provide economic benefits through savings from radios that use external batteries. One user that was using a radio powered by batteries detailed the following "batteries are really expensive now. …they cost $15 each … and the radio uses four. Batteries last three weeks."

The previous elements detailed the social value (Miller et al., 2015) that solar modules grant to Ralámuli users. Some scholars have studied the relationship between electricity access and political participation and suggest that electricity access decrease political participation (Brass et al., 2021). In this case, these results show how electricity access do enables other forms of engagement, like functional participation in productive activities though which some users have found a source of income. However, this income has not been enough for users, they have had to migrate to nearby cities where they find job offers. Additionally, solar modules are useful in traditional celebrations, to keep in touch with families and friends, to light up their way during nights without moon, and to just simply spend time at home with family members.

Results show that the benefits of solar modules are multi-dimensional and despite solar technologies do not offer enough economic benefits to cover their costs, they do offer other benefits to users translate in feelings of happiness, the performance of cultural expressions, safety, etc.

### 3.6 Conclusion and Policy Implications

This paper detailed the user experience in five SHS projects that aim to provide electricity to rural communities in Mexico. This project aimed to understand how participation occurs in practice and explore how different forms of engagement across the process might influence the outcomes for an energy transition like high technology acceptance. The solar program that was developed after federal policy had the lower acceptance according to users in my interviews. Reasons for these results are high electricity prices, limitations to access electricity if payments are not received, and extra economic costs in the payment methods. Thus, this research showed how the design of some solar programs influenced the low acceptance of solar technologies.

Results support the argument in studies that have showed how solar technologies could have negative outcomes among social groups, geographic scales, interspecies, and across generations (Sovacool et al., 2022). Additionally this study suggested that participation does have unintended consequences in programs with the best intentions (Cooke & Kothari, 2001; Guijt & Shah, 1998; Joseph, 2002; Morales-Guerrero, 2020). Thus, this analysis showed that efforts that aim to visualize, map, and keep track of participation are important for anticipating such negative outcomes. The results suggests that it is necessary to set rigorous protocols to secure a just energy transition, especially if practitioners and researchers are working for historically marginalized communities. Here I list a set of recommendations to anticipate such negative and unintended outcomes

The language used to communicate program information with the public is important for technology acceptance and satisfaction. Clear and sound information—specifically about solar program costs and users' rights and obligations— must be offered in the beginning of the project and should continue in the test of stages of the project. It should be offered in the language people use as first language at home.

Results also suggest that prioritizing seeking ideas with end users or user-led informing during the planning stages might be key for SHS success. Programs that included the end users in bottom-up information sharing or seeking ideas during the planning sessions received better scores for user satisfaction and acceptance. Additionally, projects that had a more diverse participation across the process, like the federal program, did not achieve better outcomes. These results reaffirm what paper one suggested (Morales-Guerrero & Karwat, 2020), strategizing participation is important (OECD, 2022; Renn et al., 2020).

Users must be included in the configuration of the costs and fees (like the FSUE sustainability fee). Financial issues might be the most cited barrier for client participation, especially in low-income users (Reames, 2016). To lower the costs, the SHS installed capacity should match user’s electricity demand.  Cost should be set according to what users can afford, like previous research has pointed out, users could pay “for at least part of the systems cost if [they] can afford it” (Huacuz & Agredano, 1998, p. 391). Thus, material participation must be planned with a limit based on economic factors including affordability.

Reducing the capacity installed could help to reduce costs. Higher acceptance and user satisfaction were present in SHS that offered and installed capacity that matched energy needs. Solutions to address the inequalities of solar adoption should include systems with enough capacity installed that meet (and avoid surpassing) the electricity needs of users, as others have already suggested (Sovacool et al., 2022).

Costs of solar PV could also be reduced by offering the possibility for users to decide between individually owned SHS or multiple households to a shared system. Users mentioned that FSUE program do not allow them to share electricity with households nearby. Thus, I suggest that community owned SHS might be an avenue to reduce costs. For example, cooperatives can help users share the capital costs of systems (Sovacool et al., 2022) and mini-grids might also be a possibility to change the current individual ownership of systems.

Payment methods could also be improved to make a more efficient use of time and resources of users. One possibility are pay-as-you-go mobile banking models like the ones used in solar home systems in rural electrification in sub-Saharan Africa (Baker, 2022). This system methods would reduce costs and time users need to invest to pay monthly fees. Additionally, if companies and government decide to offer SHS as a rent, then pay as you go models could be a fairer model that would allow users to pay only for the electricity they will use. The current FSUE system requires users to pay their whole debt to be able to use electricity again, so users need to pay for a service that they did not use. Since the adoption of cellphones is widespread, mobile banking payment methods might offer a good solution to extra time and money users need to invest to pay their electricity bills.

In this paper I analyzed five solar programs that grant electricity to Ralámuli communities in the municipalities of Bocyna, Batopilas, and Guachochi in Chihuahua, Mexico. I identified solar programs with lower technology acceptance and user satisfaction, and I explored how participation could have influenced such low scores. Material participation in the form of costs seem to be an important driver of such results. Despite these low scores, communities have positive views of solar PV technologies because they are useful to community members, and they enable users to participate in economic/social activities. Thus, the issues highlighted in this paper could be addressed to offer better electricity services that realize a just future for the Indigenous nations who have faced generations of exclusion and marginalization across the Mexican territory.

CHAPTER 4

# WHAT INFLUENCES THE LONGEVITY OF OFF-GRID SOLAR HOME SYSTEMS? INSIGHTS FROM RALÁMULI SOLAR ENERGY PROGRAMS

**Abstract**

Active participation and material contributions in forms of money and labor are known as elements that secure a longer use of solar photovoltaic home systems (SHS). This paper uses a case study analysis to understand the process of participation in a free-of-charge solar program that grants electricity access to Ralámuli users in the Sierra Madre Oriental, Chihuahua, Mexico. I make use of the literature, field notes, and participant observation to identify hypotheses about the effects of participation on the longevity of SHS. Then, I use energy participation as a framework to analyze interview data and understand the process of engagement across user's experiences to then test narratives I heard during fieldwork that explained the role of participation in the longevity of solar programs. Results suggest that free programs are not necessarily set up for failure. Results show that material participation in the form of costs are the main barrier for a prolonged use of SHS, which include replacement of batteries and other spare parts of the solar modules. Such costs can be exacerbated by bad weather and thefts. Functional participation in the form of the re-use of old truck batteries or changing and installing batteries from other solar systems are informal practices that secure longevity of solar systems. Also, participation in the form of active use of solar technologies helped users to gain knowledge about how to take care of their solar systems and avoid technical issues caused by weather. Thus, knowledge and capacity building are also drivers for longer use of SHS. Recommendations to prolong longevity of solar systems include (1) informing key actors like women and youth about the use and maintenance of solar systems and (2) offering solar systems with low maintenance and operation costs. The empirical evidence in this research could inform future solar projects that secure the longevity of use of solar technologies, a topic currently overlooked by energy transition literature.

## 4.1 Introduction

Solar home systems (SHS) is an affordable technology that could help grant electricity (Alstone et al., 2015; IEA, 2022) to the 1.3% of the Mexican population that still lacks access to this service and that lives in disperse and small rural communities with difficult access (IEA, 2021). Mexico has been utilizing SHS to offer electricity access programs to rural and disperse communities since at least 1992 (Huacuz & Agredano, 1998). One challenge with these systems, however, is ensuring their reliable operation over time, which can require local resources and capacity for maintenance. Determining the factors that contribute to the longevity of systems is a crucial element in an energy transition towards a low carbon electricity system.

Activists and scholars have suggested that one important factor in successful SHS programs may be the active participation of users, including engagement in design as well as contributing with money or labor. To advance our understanding of whether and how users' participation affects the longevity of solar projects, this paper examines programs that grant electricity access to Indigenous Ralámuli communities in Sierra Madre Occidental (SMO), Chihuahua, Mexico SMO Chihuahua, Mexico. It focuses on a program offered by municipal and state governments as a case study to explore the factors that secured a longer use of SHS.

In this case study, I draw on interviews and participant observation during fieldwork in Ralámuli communities. To characterize broad findings, I describe the overall planning and implementation processes and discuss users' experience. To provide more details about variation at the project level, I code each project's level of energy participation (Morales-Guerrero & Karwat, 2020) and examine how that relates to technological longevity.

I find that lack of material participation in the form of time and money invested to fix technological issues or replace batteries are one of the main barriers for longevity of solar programs. In some cases, costs were exacerbated by bad weather and thefts. Other elements that secure longevity of solar systems are functional participation that include informal practices like re-using of old truck batteries or changing and installing batteries from other solar systems. Using solar technologies and visiting hardware stores were elements in participation though which users gained knowledge and built capacities to address technological issues and secure longevity.

The chapter proceeds in the following manner. I first present a literature review about participation in energy transitions. Second, I offer an overview of the role of payments in the success of programs. Third, I elaborate on literature about energy transition in Mexico. I proceed to explain the research methods and research questions. Section four present results, I present the state/municipality SHS program as a case study that details how energy participation unfolded across successful/unsuccessful programs based on the longevity of SHS. This information is then contested with the hypotheses previously formulated to illuminate what might drive longer use of SHS. Section five offers a discussion of the possible drivers that secure the longevity of the SHS, and section six concludes.

## 4.2 Literature review

### 4.2.1 Participation in energy projects

Participation is important in energy transitions. For example, participation is regarded as an instrument to change individual and collective behaviors (Renn et al., 2020; Schot et al., 2016), address the mismatch timing between demand and of electricity production (Krietemeyer et al., 2021; Sloot et al., 2022), and grow the acceptance of renewable technologies (Devine-Wright, 2011). Additionally, authors argue that public support in the German energy transition is a product of the inclusion of everyday people, instead of privileging only technocratic visions (Renn et al., 2020).

Research has showed that participation is not one-size-fits-all. Authors have suggested that participation in energy transitions must be strategically designed, evaluated (OECD, 2022; Renn et al., 2020) or mapped (Pallett et al., 2019) to understand the system dynamics and complexities where transitions occur (Chilvers & Longhurst, 2016). Participation requires to find a balance between enough technical knowledge and public perceptions to realize a democratic process (Renn et al., 2020) wherein the public can influence the decisions of the energy projects that affect them (Van Veelen, 2018; van Veelen & van der Horst, 2018).

Scholars have reviewed the literature to expand our understanding of participation beyond the planning stages of wind projects and propose local, collective, and virtual modes of coproduction (Solman et al., 2021). Local participation refers to local investments of wind infrastructure in communities' land, or more involvement of local public in energy production and decisions. Collective participation is described as community owned wind projects and cooperatives. Virtual modes of co-production include digital networks or online platforms where the public can participate and share their views and learn about wind projects (Solman et al., 2021).

### 4.2.2 Payment as a specific type of user participation

In addition to the theoretical and energy transitions literature on participation, this study engages with debates from development scholars and practitioners about how material contributions from users may contribute to the success of solar and other projects. Research about solar experiences in Mexico has suggested that *active* user participation, especially in the form of payments, during the installation of SHS could increase the possibility of program success (Huacuz & Agredano, 1998, p. 13). Education, trainings and knowledge about the use and maintenance of the system are also cited elements that secure longevity of SHS (Gómez-Hernández et al., 2019; Huacuz & Agredano, 1998). Several cases identify how costs affect participation in solar programs abroad in Malaysia (Lau et al., 2020) Wisconsin Schelly, 2014) and Australia (Sommerfeld et al., 2017), while in Mexico research shows that users' budget and operation and maintenance (O&M) costs are also elements that influence the longevity of SHS use (Gómez-Hernández et al., 2019), suggesting that ongoing financial contributions are important in addition to up-front purchase payments.

Literature in economics and development studies offers further insights on the role of payments in the success of programs like biomass stoves in Ethiopia (Bluffstone, 2021), home water purification efforts in Zambia (Ashraf et al., 2007), and mosquito nets to prevent malaria in Kenya (Cohen & Dupas, 2010) and Uganda (Moscibrodzki et al., 2018). Many development practitioners believe that free programs are less successful. For example, Population Services

International—a non-profit based in DC that works on malaria, HIV, and reproductive health in developing countries—mentioned in their website that, “when products are given away free, the recipient often does not value them or even use them.” (PSI, 2007).

Empirical research on the importance of payment shows mixed findings. For example, Ashraf et al. found that payments do not cause greater use of water disinfectant; instead, payments actually help to screen out people who don’t care about the solution offered in the very beginning of the project (Ashraf et al., 2007). Some literature has found that free projects have been successful despite the lack of costs. When comparing three different models of payments of biomass stoves (free, with cost, and receiving a payment to use stoves), authors found that free distribution stoves secured “longer-run regular use” (Bluffstone, 2021, p. 188). Additionally, women who received free nets used them at similar rates to those who have paid for a subsidized price in Kenya (Cohen & Dupas, 2010).

On the other hand, free projects have also been unsuccessful. For example, households who got mosquito nets for free were significantly less likely to use them correctly in Uganda (Moscibrodzki et al., 2018), and in a cross country analysis, mosquito nets that were received through free campaigns were nearly six times more likely to be given away (Koenker & Kilian, 2016). Such mixed results suggest the need of further research to understand the role of upfront payments in the longevity and success of development projects.

Moreover, it is important to recognize that money is only one way for users to contribute to projects. During interviews, government staff mentioned the following:

> “sometimes beneficiaries [of SHS] pay with labor, like building stone barriers for watershed management. The reason is that this labor makes them [the beneficiaries] feel they own the system, while their labor provides other benefits to communities.”

Another example of this argument is a conversation I had with one Ralámuli friend who, during the fieldwork season of this project, explained how the nonprofits in the area ask users to pay with labor or money when they receive water filters. He mentioned that payments vary according to the economic possibilities of participants. He also supported this argument and told me that he believes upfront payments increase their sense of ownership (*apropiación* in Spanish) and enables community members to take good care of the things offered by government and nonprofits.

To further illustrate this argument, I now present the experience of one participant who reflected on the role of organizations in successful projects:

> "we developed a methodology across three and a half years of work, … [we care] about public participation, about decision making, about empower or re-empower communities so that they realize that they have the agency for change, and that [their agency] does not depend on someone giving away stuff …like the government, nonprofits and people do. It becomes a dynamic where people say yes, I am here to receive whatever you want to give me."

### 4.2.3 Energy transitions in Mexico

At a local level, energy transition research in Mexico has used similar frameworks as in international literature. Authors have used the MLP and a governance and agency perspective to qualitatively understand the social, technical, and environmental aspects in the interactions that have shaped the energy sector in Mexico including the legacy in present regulation from past policies, the important role of the government in promoting market actor investments in low-carbon technologies, and the opportunities that natural gas industry provides to Mexico (Jano-Ito & Crawford-Brown, 2016).

Socio-technical frameworks have also been deployed to assess the implementation of Social Impact Assessments (SIA) in energy projects. The energy reform in 2014, in particular "La Ley de Transición Energética", Ley de la Industria Eléctrica and Ley de Hidrocarburos, provided the legal frameworks to facilitate the deployment of clean energy only after the Social Impact assessments to secure a just development of these technologies in communities and Indigenous territories (Peniche Sala, 2019). However, SIA's implementation resulted in shallow participation of the affected communities (Martinez, 2022).

Despite the SIA mechanisms in Mexican energy policy, solar utility scale projects in Yucatan (Barragan-Contreras, 2021) and wind utility scale in Oaxaca (Zárate Toledo & Fraga, 2019) are examples of how RE opposition has not stopped. This highlights the importance of being clear about how public participation of the public will be implemented across energy transition processes. Martinez shows how official guidelines in the SIA do require "participatory methodologies" in such processes, yet the definition of the term is not clearly defined and executors then can use a regular survey as a way to check this requirement (Martinez, 2022). Such research suggests that social dimensions are important in energy transitions in Mexico as well as strategizing the forms and instruments of participation (Martínez et al., 2019).

The previous studies on the role of participation in energy transitions have focused on understanding the factors that secure acceptance, sustained policy support, and inference in decision making. Yet, to our knowledge, there is no study that looks at the role of participation in a longer and sustained use of renewable energy technologies. This essay fills this gap.

## 4.3 Methods

### 4.3.1 SHS cases

To address the disparity in electricity access that remote and rural communities face in Mexico (CONAPO, 2015), various actors have offered solar SHS to remote communities in SMO in recent years. Solar programs for Ralámuli households have been developed by five different organizations: state and municipal government agencies, federal policy, nonprofits, a gas-pipeline consultation, and privately-owned systems in SMO. Table 10 provides an overview of all the SHS programs ranked by the longevity of use, with information about the number of interviews conducted that describe each solar programs, the number/percentage of systems working well, and the percentage of systems working with low performance. I grouped systems by year of use to give an overview of the universe of data in this analysis and the interviews included in this analysis.

**Table 10**. Comparisons of Number of Interviews by Longevity of Time and Type of Solar Program.

| Type of program | Length of use | Total interviews | % working | % with issues |
|---|---|---|---|---|
| Federal-Iluméxico | 1.5 | 15 | 26.7% | 26.7% |
| Federal-Suncor | 2 | 13 | 76.9% | 76.9% |
| Gas pipeline | 3 | 13 | 61.5% | 75.0% |
| State/municipal | 3 | 3 | 100.0% | 66.7% |
| Non-profits | 4 | 8 | 100.0% | 12.5% |
| State/municipal | 4 | 4 | 100.0% | 25.0% |
| State/municipal | 5 | 4 | 75.0% | 33.3% |

| | | | | |
|---|---|---|---|---|
| Private | 5 | 1 | 100.0% | 100.0% |
| State/municipal | 6 | 2 | 100.0% | 50.0% |
| State/municipal | 7 | 9 | 44.4% | 25.0% |
| Private | 7 | 1 | 100.0% | 0.0% |
| State/municipal | 8 | 1 | 100.0% | 0.0% |
| State/municipal | 14 | 4 | 75.0% | 100.0% |

The first part of the analysis compares all the programs on their participation processes and longevity outcomes. The second part of the analysis then provides a deeper dive into the state/municipal program, since it accounts for most of the SHS programs with five or more years of use. In total 22 SHS systems met these criteria, including 20 offered by the state/municipal program and 2 by privately owned programs (only two interviews descried this type of solar program). Given that state/municipal projects are the predominant type with a longevity of five or more years, they were selected for the in-depth case study.

### 4.3.2 Data Collection and Analysis

In order to understand the user experiences in diverse solar programs in SMO, I used qualitative methods (DeCuir-Gunby et al., 2011; Gioia et al., 2013; Mihas, 2019) to analyze official documents, 63 interviews, and fieldnotes I collected during two field visits: January-February and November-December 2021.

To provide context for how the state/municipal program compared to other types of programs, I started by coding and analyzing the data to characterize their community participation according to the framework in Morales-Guerrero & Karwat (2020). The coding captured the *breadth* of actors participating and the *depth* of their engagement (Bebbington & Farrington, 1993), as well as the *objects* of participation that includes the issue or a particular event of participation (Chilvers et al., 2018).

I used the previous categories to code all information MAXQDA. Then I exported data to a spread sheet to generate the visualizations and graphs of participation. These graphs were then used to increase the code reliability; I reviewed the codes in each marker in the graphs to confirm that the information matched the theme in each category. The information that was misplaced was then re-coded in the right category. I created a master document with the codes organized by how the processes unfolded that was latter used to write results. I also used pivot tables in excel to explore how the different variables behaved across the process.

I also used information about the “meta data” of the interviews or documents—like the type of system, the longevity of use, whether the system discussed was working or not, or the community’s name from where the information was coming from—to filter data and create different graphs that compare processes. I also used the graphs and coded segments to write results and to reflect on and explain the process of how participation unfolded across the projects under analysis and answer the RQs. The visualizations generated through this process facilitated the comparison between these participation processes and users’ experiences with program longevity and satisfaction.

I now proceeded to do a deeper analysis of the state/municipal program to explore how elements in the process of participation could be influencing or driving higher/lower longevity of use of the SHS.

## 4.4 <u>Results</u>

### 4.4.1 Comparing Longevity and Participation Across All Program Types

Figure 21 compares all solar programs grouped by years of use (x-axis) and the percentage of SHS working (y-axis). The graph on the right shows the same programs grouped by years of use (y-axis). The programs to the right of both blue lines have a longevity greater or equal to five years of use.

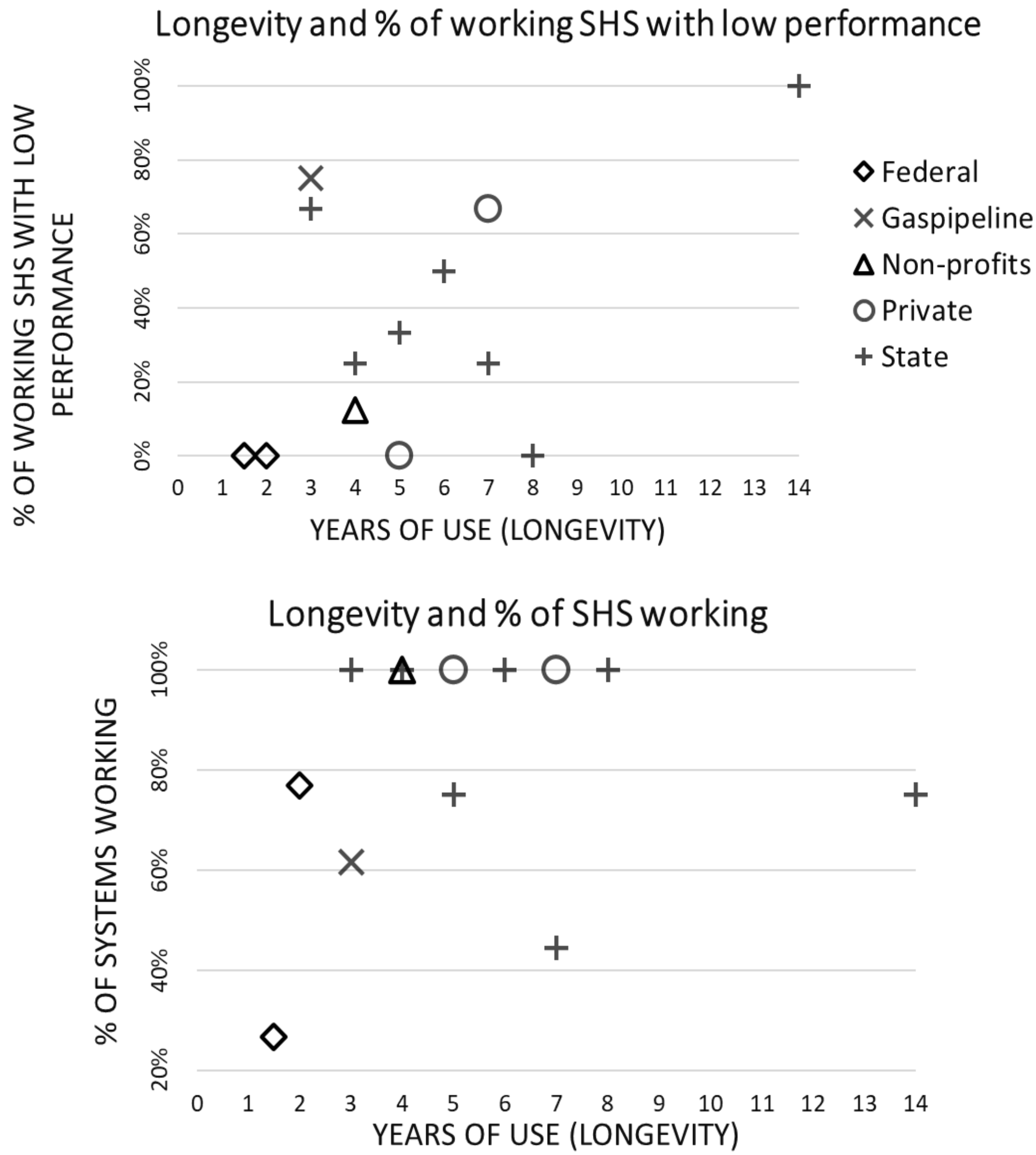



Figure 21. Longevity and Performance of SHS

Additionally, Figure 21 plots the visualizations of breadth and depth of participation against the longevity of time of systems. It shows the averages of breadth and depth of participation in SHS that were working (markers in black) and averages of breadth and depth of participation in SHS that were broken (markers in red). The blue lines indicate that markers or SHS above the line had more than five years of use.

Figure 22 shows that the state SHS that were not working in years 14 and 5 had deeper averages of participation than the ones working in the same years, while systems in year 7 show the opposite relationship about depth of participation. Similar contradictory results are present in the averages of breath of participation where years 17 and 5 had narrower breadth averages in broken SHS, while SHS in year 7 show that wider participation was present in broken SHS.

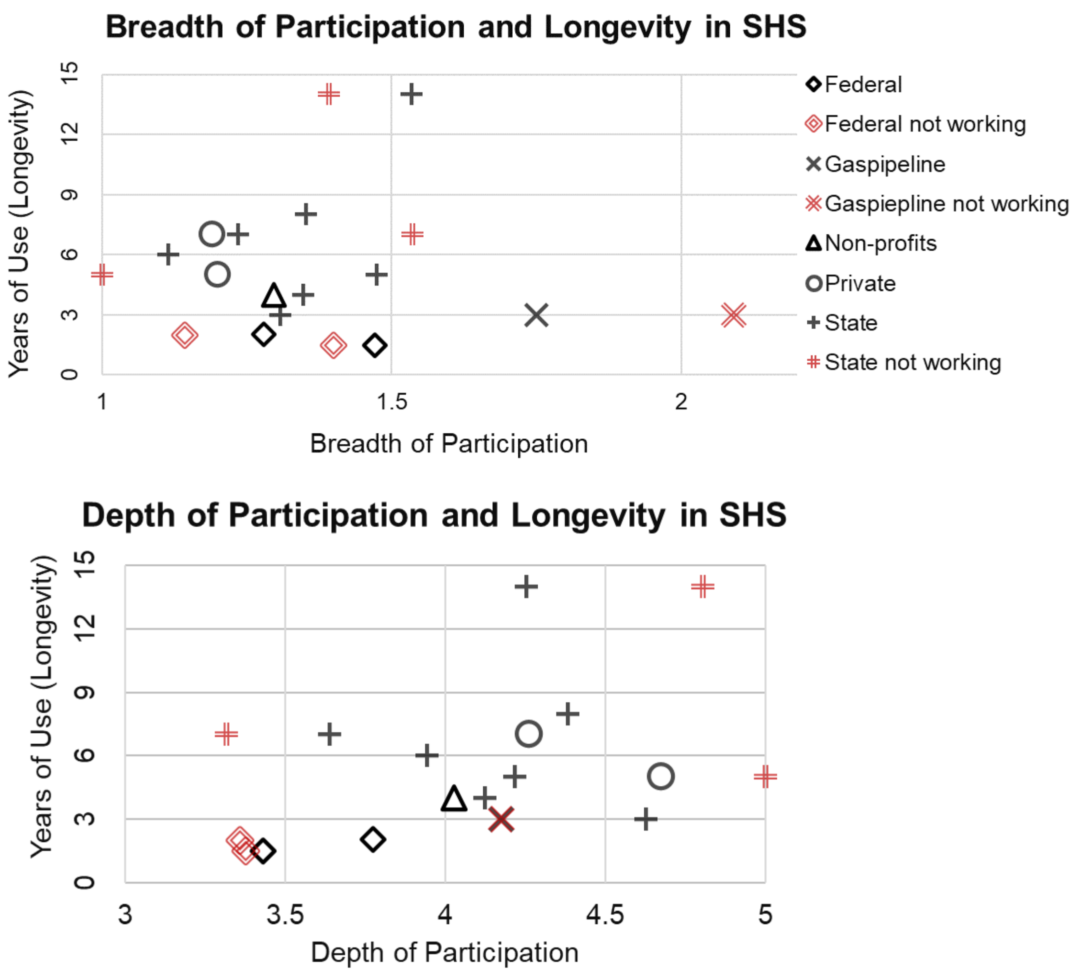


Figure 22. Breadth and Depth of Participation by Longevity

### 4.4.2 Analysis of the State/Municipal Solar Program

The state/municipal program was co-created with input from universities, businesses, and governments. It aims to provide solar photovoltaic systems for rural and dispersed communities that could not be connected to the Mexican grid due to infrastructure costs and the low population density of such communities. Here I describe features of their planning and implementation processes that may contribute to the longevity of SHS projects, and then I use visualizations of energy participation to explore how participation varies across projects that are working or not working after five years.

#### 4.4.2.1 Planning

In the case of the state/municipal program, SHS were designed through a collaboration between the private sector and government agencies like the Centro de Desarrollo Indígena (CDI) and the Coordinación Estatal de la Tarahumara (CET). Today those agencies are known as the Instituto Nacional de los Pueblos Indígenas (INPI) and the Comisión Estatal para los Pueblos Indígenas (COEPI).

The first step in the state/municipal program was the identification of electricity needs. In conversation with COEPI staff they mentioned how they were aware of the electricity needs of local communities. This is illustrated by the following quote: "[COEPI] conducted an analysis of the community [electricity] needs, we found that systems required enough capacity to power a couple of bulbs, and a radio." This information was then used by the CDI and the CET to design the size of the SHS. In recent years SHS include 1 battery (115 Ah/110Ah 12V), 4 LED bulbs of 9 watts, switches, cables, and outlets that would power a couple of bulbs, a speaker/radio, torches, and cellphones.

Local projects are initiated when a community requests SHS installation. Community health were mentioned in interviews as one of the main reasons why communities request SHS. Some communities requested solar programs after children were stung by scorpions at night, and after teachers realized that children were using ocote (wood sticks with high concentration of tree resin that are easy to light up) to light up the house while doing homework. Lighting up the house with ocote produces a lot of smoke that affect the respiratory health of the household. These are some reasons why community members submit SHS request to local governments.

Request for the solar program have been submitted by teachers, Indigenous governments, and/or users. Submitting a request would require the Indigenous government and leaders to organize a community meeting where people agree on requesting the solar program. Leaders gather signatures or fingerprints from community members to then deliver this paperwork in the government offices that are located in larger towns where the government has offices (e.g. the town of Batopilas or Creel).

Government agencies like COEPI receive requests from the community all year around. Through these documents the community informs the government agencies about their needs. These practices are not only done to request electricity access programs, but communities also request supplies for roofs, water containers, and latrines.

Based on the government budget and how the current administrations—including state and federal levels for government and agencies like the CDI or IMPI—want to spend the money, the projects are created, and requests are fulfilled. In 2017 and 2018 this program was funded through housing programs that granted 722 SHS across twelve municipalities in SMO. In 2017 132 out of 339 SHS systems (38%) were owned by women, while in 2018 128 out of 383 systems (33%) were owned by women.

Currently there are more requests than SHS programs offered. Users in several interviews mentioned that they had submitted already requests for more SHS because either households in their communities still lack access to electricity, or the current systems had already passed their life cycle. During fieldwork COEPI staff confirmed that they have more request than resources to fill these needs.

#### 4.4.2.2 Implementing

Once the budget was approved government staff visited the beneficiary communities to inform about the SHS program. During these visits, government staff consulted if users still needed or wanted the SHS program because requests sometimes take more than a year to be approved and some users might have got a SHS from others.

In these visits users learn about the program costs, and best practices to take care of their systems. They were also informed that they will be responsible for any operation and maintenance (O&M) costs that the system requires in the future. COEPI staff mentioned the following: “Sometimes users want the government to solve all their problems, including a replacement of battery.” Thus, the government agency has been clear by emphasizing that even though the programs was free, all future costs in SHS would have to be paid by users.

During the installation one member of the community helps to translate information (Spanish to Ralámuli) offered by the technician who installed the systems. Through repeating this exercise in every household who is receiving the SHS, the community member who is translating learns how to install and fix common problems. This type of training was conducted only during the installation of SHS, and no other formal trainings were organized to offer information to the wider community. This practice builds local capacity in the communities using SHS and helps communities face future tech issues. This capacity is present in communities, for example, during interviews users mentioned that they have been able to uninstall and re-install SHS in another house.

Installation also requires other forms of participation from community members. Community members also helped carry materials from the paved or dirt road to their communities and contribute with labor and materials like sand and water to install the SHS. In one case, the user paid a subsidized price for the system, but the majority of these SHS were free. Some Indigenous governors and comisarios received the system without costs after serving as Indigenous government.

This SHS program does provide a follow-up visit during the first year of use. Staff mentioned that “after one year of the installation, we follow up with the person that received the training to see if everything is working fine. …sometimes the tech issues are simple like changing a blown fuse.”

Although the program is granted for free (no upfront cash payments), users do invest their time and labor and money to cover future O&M costs. For example, some users mentioned that their SHS in previous years did not include outlets to charge cellphones: “I had to buy an inverter to be able to charge cellphones … it is cheap, I paid a little bit more than $200 pesos.” Others have invested in new bulbs, lamps, and batteries: “in the kitchen I installed one of those long lamps, …we have invested, I do not know. Regarding the batteries, I have bought batteries three times …each battery is about $2,000 pesos." Additionally, users need to commute to bigger towns to buy new bulbs or batteries which requires investment of extra time and money. Users have also used their social networks like nonprofit staff that live in Chihuahua city or Creel who can bring with them batteries inverters or other spare parts needed to fix O&M issues.

#### 4.4.2.3 Evaluating and technology replacement

The state/municipal program did not offer any type of evaluation for the systems. A few users mentioned that, in previous state/municipal programs (before 2017-18), the government offered the possibility to exchange old modules once the life cycle of the SHS was over. Yet this was an exception. In an interview, COEPI staff mentioned that once they complete the follow-up community visits within the first year of use, they conclude their responsibilities in the SHS program.

During this stage of the process, community members shared some experiences dealing with technology once their lifecycle is over. For example, some stores in nearby towns receive old systems and batteries in exchange for a discount in the purchase of a new battery. Others mentioned that they gave their old SHS to family members who bought a new battery and continued using the SHS.

#### 4.4.2.4 Comparison of SHS processes to reflect on possible drivers of longevity

Now that I have explained the state/municipal program, I will further analyze it using the energy participation framework detailed in Morales-Guerrero & Karwat (2020). Specifically, I will compare the type and amount of participation across SHS projects within the state/municipal program. Figure 23 and 24 compares the process of energy participation in SHS projects that were operational (figure 23) with the process of participation in SHS that were not working (figure 24). Both graphs use the same format for the y axes. The y-axis at the top shows the number of partnerships among different actors, the y-axis in the middle represents each of the actors that I grouped through inspiration from the multi actor perspective (Avelino & Wittmayer, 2016), and the y-axis at the bottom represents each of the rungs in depth of participation that were generated iteratively by comparing the themes emerging from data and previous ladders of engagement like (Arnstein, 1969; Jackson, 2001; Pretty, 1995; Rowe & Gammack, 2004; Ryghaug et al., 2018).

Both scales for actors and models of engagement are detailed and specified in figure 23. Thus, the y-axis in the middle and the y-axis at the bottom of figure 24 and 25 must be read with the specification of actors and forms of engagement in figure 23. To generate the two graphs in figure 24 and 25, I used meta data that specified if interviewees mentioned whether the SHS were working or not by the time the interview was conducted. The graph that included only the SHS that were working with some issues was similar to the graph on the figure 24, so I excluded it form this paper.

Figure 23. Scales in Breadth and Depth of Participation

The graphs in figures 24 and 25 are helpful to identify elements of participation present (or not) across SHS experiences with systems working/notworking. The graphs show, for example, that material investments during M&O were absent in systems that were not working. This is identified by simply looking at rung 3 in the ladder of participation (y-axis at the bottom) across the graphs on the left and right. Material participation (rung 3) was also present in systems working with low performance.

The visualization also shows that less forms of engagement and fewer actors were present across the process of broken systems. For example, systems that were not working did not report community visits during the interviews. Also, larger number of actors participated during the object *use of technology* in SHS systems that were working, and, in general, the graphs shows that more actors were participating across the process in systems that are working (this includes low performance SHS) than in the process of the SHS that were broken at the time of the interview.

In general, this broad analysis suggests that investments during O&M are key in the longevity of the system. Moreover, the inclusion of more actors and forms of engagement across the process were present in SHS that were working at the time of the interview, while less participation was identified in broken SHS.

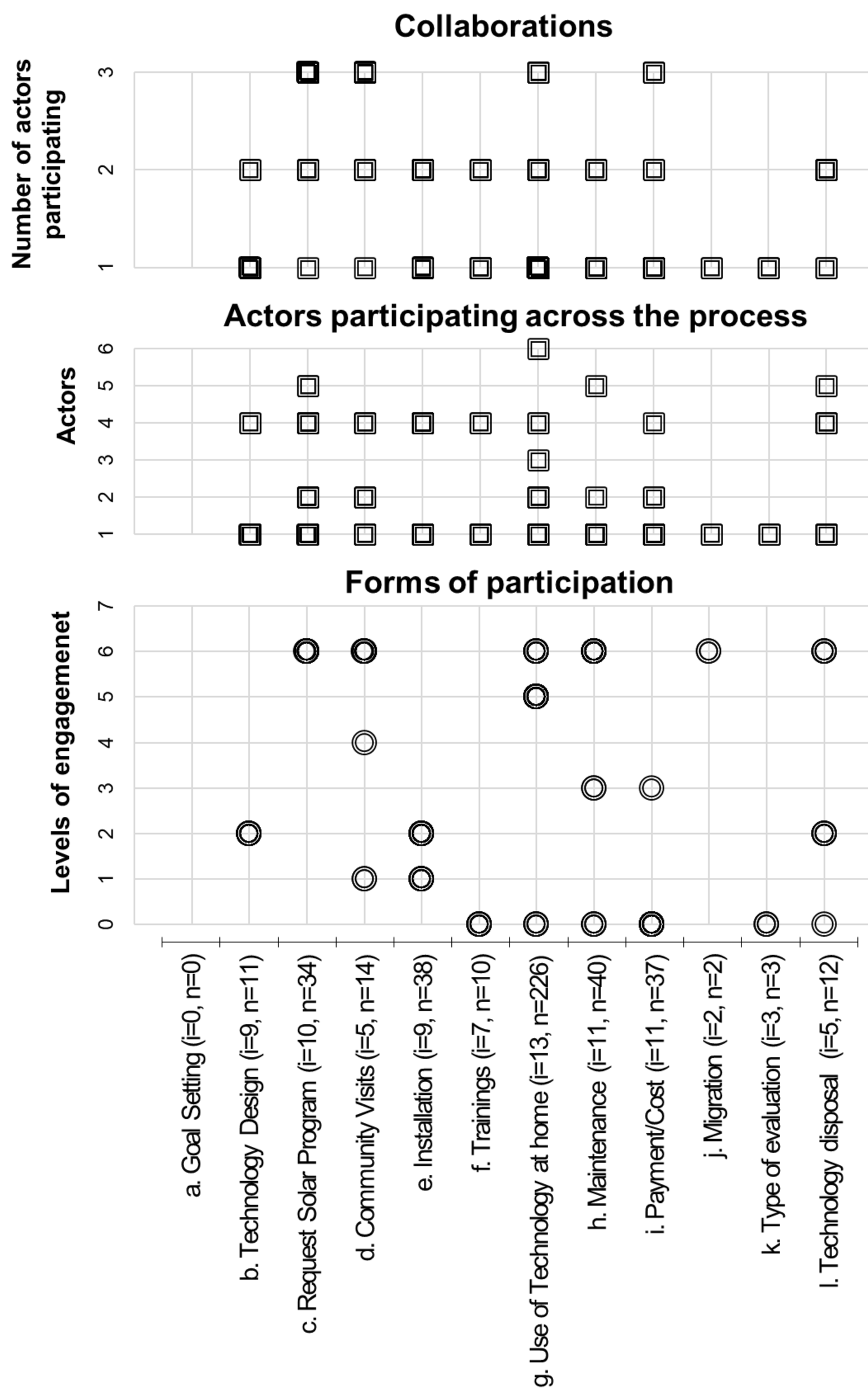



Figure 24. Energy Participation Process in Systems That Were Working

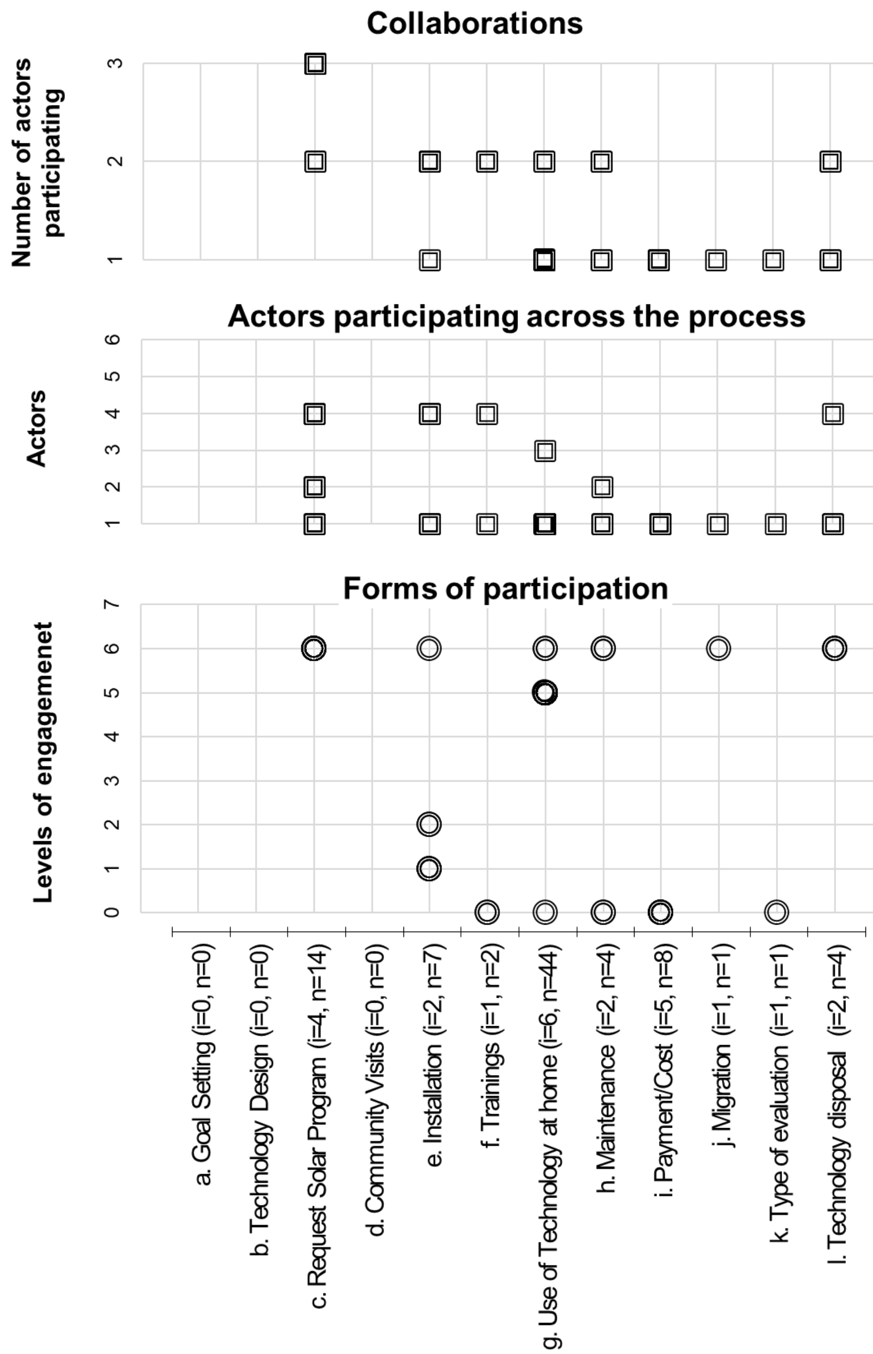



Figure 25. Energy Participation Process in Systems That Were Not Working

## 4.5 <u>Discussion: Possible Drivers of Longevity</u>

### 4.5.1 Barriers for longevity: O&M costs

The main barriers for SHS longevity that were identified through this analysis were related to O&M costs, including replacements for batteries and other spare parts. O&M costs can be exacerbated by bad weather and thefts. Here I present narratives that explain these barriers.

When the battery reaches the end of its life cycle, some users mentioned that their SHS started to shut down after an hour or so of use and eventually their systems stopped working. For example, one user mentioned: "it's been two years that I do not use it [the SHS] because it is broken. The battery is the problem." Other users explicitly mentioned that lack of money prevented them to buy a battery replacement:

> "It has been like six months that it [the SHS] started having issues. Out of the sudden it [the SHS] was not working. It lasted on like half hour, and it shut down, then it started working again and shut down again. It could only last half an hour on and then it shut down. I could not buy a new battery. People say that batteries are expensive, they are around $3,000 pesos"

Despite the state/municipal program was granted for free, users have invested in batteries and other spare components, like inverters, to keep their SHS working. For example, one user replaced batteries after 6 years of use:

> "I have had this [SHS] for almost ten years, …our [SHS] is still working because we have replaced the battery, but almost no one in the community has replace batteries. … they panel is still working but the battery is not. …the first battery lasted around six years …I went to Guachochi last year during December to buy a new battery."

Another user mentioned the following:

> "In the kitchen I installed a new lamp [and] one of those long bulbs, … I have invested about, well we have bought three batteries already … each one costs like $2,000 pesos …and the inverter costs about $700 pesos …and I have bought like six bulbs that are about $100 to $150 pesos, and the lamp was $200 pesos."

Another user mentioned that the investment was worth it because their SHS did not require monthly payments like when you are connected to the grid:

> "the municipal government gave me one [SHS] that lasted me for about 10 years, …the panel keeps working fine, the battery is the one that stops working …but it [replacing it] is worth it because you do not to be constantly paying, like those other programs or when you get electricity from the wires [the utility poles] …the battery costs less than $2,000 pesos."

Other users have replaced small batteries that respond to their budgets, yet their SHS have a low performance. This example shows how users used their social networks to get a new battery, yet the new battery does not fully meet their needs. One user mentioned the following:

> It has been two years that the battery stopped working. It [the battery] stopped charging power, I have it over there, it is big, it should weight around 25 to 30 kilos, it came initially with the whole SHS. …the new battery is smaller; it is the one that [local nonprofit staff] brought from Chihuahua. I do not know if it is good for the SHS because it does not work well …the bulb lasts on for less than one hour. …The SHS has one device before the bulb that might be using power. …the battery is small, and it seems that it does not provide enough power.

Bad weather has damaged SHS systems and increased O&M costs. Some users mentioned they had to pay 700 pesos to replace an inverter that was broken by a thunder during summer:

> "the inverter broke, it was by the beginning of the rainy season. Thunders were loud in the sky while the inverter was on. A thunder landed not too far away from here, and it brought electric current to the house. … [to fix this issue] I had to buy a new inverter …it was $700 pesos …I installed it myself, it is not hard."

Yet some users mentioned that once weather broke their systems, they were not able to put it back online:

> "at home the inverter is not working, …it is possible that a thunder had burned it, …when you have it [the SHS] on, it attracts the thunder and breaks it. I think that was the problem" and "The problem is the battery, people that can buy a replacement they still use it [the SHS]. I could not make it work again. Wind dashed the panel, a whirlwind, the wind broke it and I couldn't fix it."

As an exception, one user shared that government was able to replace their broken SHS after windy weather:

> "I got one [SHS] the small one over there after I returned the one [SHS] that a whirlwind broke. …I notified the government about this problem; they told me that I had to return the old broken system and then they reinstalled a new one."

Another barrier for long use of SHS that increases O&M costs are SHS thefts. SHS have been stolen when users are working outside their community or when they need to go to nearby communities to buy food or visit family. For example:

> "My uncle had to go to work [for a season]. When he came back home, [someone] had stolen the small panel and the battery. He had to go to work to the apple fields to work, and when he came back …they had stolen it [the SHS]. They broke in through the stove pipe [calentón or biomass stove that is used to cook food and warm up the house]. They stole the battery and the inverter."

### 4.5.2 Drivers of longer use of SHS: knowledge and capacity building

In addition to investing in maintenance, knowledge about the SHS technologies and capacity building were also important elements that explain longer use of SHS. Knowledge about SHS was already present in the community; some users were using SHS for the third time, and they shared strategies to avoid technical issues during bad weather. In some cases, youth played a key role in fixing technical issues, others took advantage of visits to hardware stores to gain knowledge about how to face technological issues they find in the towns they visit, and some of them are motivated to use SHS and save money for their households. One user mentioned that someone in the community knew how to fix technical problems charged a fee for their services.

Narratives also showed a knowledge gap among users. Some users detailed how they were working in nearby towns when the solar system was installed, this prevented users to receive key information about the use of their solar modules. Narratives also showed a knowledge gap between men and women that requires further research. Despite the capacity and knowledge in the community, some users—especially women—shared that they have not being able to fix the technical issues in their SHS. The following paragraphs illustrate each of these ideas with narratives form users.

Knowledge to fix technological issues was present in the community. Some users have been using SHS for 3 lifecycles already. The following example is from a user that served as an Indigenous authority and received the system as a reward for public service:

> "The one [SHS] that I had before, yes they [CET] charged 800 pesos during the installation, but they told me that the payment was not necessary because I was 'comisario de policía' (one of the public charges in the Indigenous government). When you have that type of commitment you spend money, so they told me that I did not have to pay. The people that sometimes ask for payment are the people working in the municipality of Bocoyna. We have received three modules since the first one they gave us. This is the third time they install these type of panels."

Users gained knowledge through using their systems. For example, users have strategies and knowledge to prevent thunders break SHS. Two users mentioned they learned that when a thunderstorm was coming, especially during summer, it is important to avoid using the SHS because it could attract the thunder and break the system: "when there is a thunderstorm, you need to turn everything off."

Youth was mentioned as being key in fixing technological issues, and they also added features to their SHS to meet their needs. For example, one participant mentioned that youth were able to install an outlet to the SHS so that they could charge their phones:

> "[My SHS] is 7 or 8 years old" Interviewer: "Is this the same program they have in Huillochi?" Answer: "Yes, I believe it is the same one" Interviewer: "they mentioned that this did not come with outlets, is it true?" Answer: "…Oh yes, all of them did not come with outlets, but youth (muchachos) [add them]. I do not know how they do it, but they fix everything, they install it, they do something so that they can charge their phones."

Adults have also learned about options to meet their electricity needs while visiting hardware stores in nearby towns. One user mentioned that when they visited a hardware store (ferretería) "[people in the store] recommended this, when I went to ask for something to charge gadgets. …So, first I got the SHS, then after some months I went to look for something to charge gadgets." Another user mentioned that in order to be able to charge gadgets like cellphones in their SHS, they did the following: "So that I could charge [electronic gadgets], I connected one of those things that the cars use to charge phones [interviewer asked: the one that you use to light up cigarettes?], yes that one I use to charge speakers or the cellphone."

Others went looking for ideas on how to save money by switching to devices that do not use external batteries that are expensive to avoid producing trash:

> "I looked it up myself, I learned how you can charge devices, how to plug the cables of a radio so that it gets power, … I looked for ideas, I found devices that use power, because on the other hand you need to be buying batteries, the do not last. After a week or two they become trash. You generate a lot of trash when you are constantly buying batteries. When you do not know that you can plug devices. …that is what I have learned …it could save money."

Others mentioned that people in the community that know how to fix SHS sometimes they charge money: "the person that lives here …he repairs [SHS] ..he charges $200 pesos."

Additionally, narratives suggest a gender disparity of knowledge regarding SHS. When I asked women if they had received trainings to learn about SHS they often mentioned that they did not receive any training or that their husbands were the ones that knew more about the technology as illustrated in this quote: "No, no one came to say anything, well, my husband is the one that knows better." Additionally, migration prevented users to be during the installation when the technicians and government staff teach users about the use of SHS. "That one [user pointed to solar panel with his finger] was installed like seven years ago. I know this because I was in Sinaloa. When I came back, those solar panels were already here."

Despite the knowledge and capacity in the community, sometimes users couldn't find a solution. For example, after I asked why the SHS was not working properly, one user told me:

> "[cables] might not well connected, I do not know, before it [the SHS] was working fine. Once it started doing the same [the system was constantly turning off], …we tighten the battery and cables, and it worked fine. But now it suddenly stops working even after we try to fix it."

### 4.5.3 Informal practices to reduce O&M Costs

The last theme that explains longevity of SHS are informal practices that users use as solutions to save money and keep their SHS up and running. For example, users have found ways to replace batteries at minimum costs, like using batteries from other SHS from other programs or using batteries form cars that are no longer in use. Others have given away their SHS for a second use to family and friends. Additionally, local stores exchange old batteries for a discount when they buy a replacement. Finally, and as an exception, more than ten years ago, the state/municipal program offered users a replacement of the SHS when they returned the old system after their lifecycle was over. The following paragraphs present narratives that explain in each of these ideas.

Users mentioned they have fixed their SHS with batteries from other SHS programs:

> "I really like this [the SHS] because we do not need to pay anything. I have the small one [the SHS granted by the state], but I changed the battery. I used the battery form the other program [federal program], that is the one [battery] I am using because the old one, the one from the municipality, did not have change anymore. Now it is working fine."

Additionally, other user mentioned the following: "the battery of a truck was not working anymore, so I said, why don't we connect it to that one [the SHS], … we connected the battery, and it is still working."

Users have found other ways to reuse their SHS. Some users have given their SHS a second life cycle by giving it to family members who bought a new battery. "I gave it to my niece, …she told me that she needed it …she told me it is still working. …they told me that they bought a new battery. …they installed it in another community where they live."

Stores in nearby towns buy old SHS and batteries at a low price or they offer discounts when customers buy a new battery. “I exchanged the battery in Bocoyna, …they sell it, I gave it to them because it was not working anymore, they bought it in $100 pesos …I accepted the deal because otherwise I would have a battery sitting here without any purpose.” Another user mentioned: “when batteries are old, they take them to Guachochi where they take them …we exchange it [the battery] in a store in Guachochi. They give you a discount, …batteries are more expensive if you do not bring the old one.”

The old versions of the state/municipal programs replaced old systems after their life cycle, yet this practice did not continue. One user explained:

> “I think it was about twenty years ago. …my mom was the one who got it [a SHS] first. …then they [the government staff] came to pick it up and replace it with a new one. …they did it when the battery did not charge anymore, …they install other [SHS] year after year in households that needed it. For example, they first installed [SHS] in five or eight houses, and then some other once until the completed all, then others stopped working and they replaced them.”

## 4.6 <u>Conclusion</u>

This paper presented a solar program offered by state agencies in SMO, Chihuahua, México as a case study to explore the role of participation in the longevity of SHS that grant electricity access to Ralámuli communities. Results suggest that absence of material participation in the form of maintenance and operation costs are the main barrier to longevity. Costs include the replacements of batteries and other spare components like inverters or bulbs. Costs are also exacerbated by bad weather like thunderstorms or strong wind and thefts.

Functional participation, in the form of efforts to fix technological issues and informal practices to re-use batteries, play also a key role in the longevity of solar systems. Though these activities users mentioned how they gained knowledge and built capacity that ultimately secured a longer use of solar technologies. Youth has also played a key role in the longevity of systems in some communities as they have fixed issues that adults could not fix. Visits to hardware stores were also important activities to find solutions to problems users face. Additionally, users have found alternative practices to reduce O&M costs like the use secondhand batteries form other systems or by exchanging old batteries in local stores that offer discounts.

Even though the program was offered for free by state and municipal agencies, the case study revealed that users invested time, skills, and money as they bought replacements of batteries and other spare components. Thus, this study suggests that free programs are not necessarily set for failure, yet there are elements like the lack of job opportunities to have economic solvency to afford the O&M costs that solar modules require for a longer use across time. Results could be used by state agencies to plan strategies that minimize the barriers for longevity.

Though the analysis of one solar case study organized by state agencies I was able to identify characteristics of participation that secure a longer use of solar technologies. These activities include material participation in the form of maintenance and operation costs and functional participation in the form of visits to hardware stores to find technical solutions, The study of participation in energy transitions has overlooked how participation influences the successful and long use of solar systems. This paper contributes to the literature by identifying the elements or factors that could be influencing longevity of SHS in efforts that aim to grant electricity access to remote and disperse communities.

# CHAPTER 5

# CONCLUSION

This dissertation explored the role of participation in energy transitions. I used energy participation as a framework to understand how participation occurred in two different settings (1) a competition that encouraged communities to decrease gas and electricity consumption in US communities, and (2) projects that granted electricity access to remote and rural communities in Mexico. Results across the three empirical analyses in this research emphasized the need to strategize participation to avoid unintended consequences and achieve the outcomes needed to transit to a low-carbon energy system.

The analysis of the Georgetown Energy Competition (GUEP) showed that communities with low averages of breadth (number of actors participating) and depth (as measured by the typology or ladder of engagement) of participation did not necessarily achieve lower energy savings. The analysis of the GUEP suggested that instead aiming for high levels of participation to achieve higher energy savings, participation could be strategized based on the goal of the intervention. For example, *informing* about energy saving strategies, like washing clothes with cold water, could be a successful form of engagement regardless of being a shallow form of engagement when compared with *seeking ideas* as typologies of participation indicate.

Through the analysis of the role of participation in the acceptance of solar technologies and user satisfaction in programs offered in Ralámuli rural communities, I found that the benefits that participation have a limit. For example, if participation demands an amount of time and resources that users cannot afford, then participation might become detrimental to technology acceptance. This is the case of the federal policy solar program that offers solar modules with monthly costs that surpass what users can afford. This program had a high number of users without electricity at the time of the interview because these solar modules have a meter that stops delivering electricity if users do not pay for their bills on time. Thus, the solar program from federal policy has increased user’s debt, exacerbated energy poverty in the region, and has the lower scores for technology acceptance and satisfaction among the five solar programs analyzed in this paper. I argue that future solar projects need to plan and strategize participation by finding a balance between users' income level and electricity needs with the power capacity of solar modules/batteries and monthly payments/costs.

The last study in this dissertation explored the role of participation in the longevity of use of solar systems in rural Ralámuli communities and showed that *material* participation, in the form of money invested to cover operation and maintenance costs, was crucial for a prolonged use of solar systems. Active *use of solar modules*, *informing* (sharing information about technology use and maintenance*),* and *functional* participation (in the form of informal practices like reusing old batteries form trucks or visiting hardware stores) were forms of participation through which users gained knowledge that secure a longer and successful use of solar systems. In this study I also found that free of cost solar programs had a higher rate of systems working when compared with the federal policy program at the time of the interviews; this finding suggests that free of cost solar programs are not necessarily set up to fail—as opposed to what local narratives from organizers, solar industry staff, and nonprofits advised. However, lack of income to pay for maintenance and operation costs was a crucial factor that prevented the longevity of solar systems.

Overall, this dissertation has shown that the energy participation framework Morales-Guerrero & Karwat, 2020) could be applied to understand processes of participation and explore their influence in desired outcomes like energy transition goals. The energy participation framework proved to be flexible enough to understand engagement processes in diverse contexts including the global north and south. These analyses also allowed me to create a step-by-step guide that researchers and practitioners can use to imagine, plan, and evaluate participation. Additionally, the results in the three papers in this dissertation emphasized the need to strategize participation because "more participation" does not always translate into the outcomes needed for an energy transition. Results also suggested that the benefits that participation start to decrease once programs demand more than the user can afford. Thus, the design of intensity of participation in energy transitions needs to balance users' energy needs with users' resources available. This research showed the importance of a critical reflection on the process of participation to theorize about what works best and when in the interventions that aim to challenge the status quo and address climate change issues.

This concluding chapter offers reflections on how energy participation could help researchers and practitioners find strategies, co-design, and empirically evaluate participation in energy transitions and beyond. Section one elaborates on the practical contributions of the framework used in this dissertation which includes a flexible step by step list to plan and keep track of participation. Section two offers a list of the limitations in the framework, and I elaborate on the possible avenues to address them. Section three summarizes the theoretical contributions offered through the three empirical analyses in this dissertation. Finally, section four offers a summary of the main takeaways and the recommendations I was able to articulate through this research.

## 5.1 Contributions for Practice

The analyses conducted in this dissertation shows how the energy participation framework (Morales-Guerrero & Karwat, 2020) can be used to understand engagement in different contexts. As I applied the framework, I was able to systematically interpret and make sense of urban energy interventions in the global north and energy efforts in rural and dispersed communities in the global south. This was possible because the framework is flexible, it allows to incorporate input from data to define the three main components of participation: objects, subjects, and models of participation. Despite this flexibility, energy participation offers a rigorous structure that allows to compare different processes and interventions and test such characteristics against the goal of the project. This process sheds light on best practices.

The use of my participation framework could be useful for community members, non-profits, governments, and academics to disseminate the tangible aspects of participation (e.g. what we can observe or experience; see section 2.2.1 for definition). This analysis adds transparency in decision-making and evaluation processes, as it shows the actors and the forms of engagement that were present across projects. The visualizations and graphs facilitate the comparison of participatory and non-participatory efforts across projects, communities, and time.

Visualizations and framework also facilitate the dissemination of information because they summarize several pages of text in few images that specify the who, how and what of the different stages of a project. Additionally, the graphs can be used to test popular hypothesis about the role of participation in best practices.

The framework and research outcomes of energy participation could be used to clarify the meanings researchers and practitioners assign to participation and engagement efforts. Results could be used as an educational tool to promote a critical understanding of community engagement efforts. In addition, the visualizations and results created while applying this framework could be employed in future research to analyze the subjective aspects of participation (see section 2.2.2 for definition) or the opinions of participants about the process of participation. For example, the graphs and results in this document could be shared with community members to get their opinions their experiences participating in the solar programs in this dissertation. Examples of the subjective aspects of participation are the perceptions of manages and residents in geothermal projects (Ruef et al., 2020), evaluations of public opinions about participation processes in a cleanup of Waukegan Harbor in Illinois (Danielson et al., 2009), or perception of stakeholders about procedural justice in wind projects in Canada (C. Walker & Baxter, 2017).

Energy participation could also be used as a framework to plan, strategize, and evaluate participation. For example, energy participation could be used to illustrate and explain how participatory budgeting efforts occur in practice, to tell a story on how energy cooperatives emerged through social mobilization, or to plan an engagement effort in future solar projects. The analysis that this framework offers can also be developed independently without the need of extra administrative costs. For instance, in paper one in this dissertation I only used official documents that detailed the process of participation in the GUEP to develop the analysis. Thus, this approach could be implemented to understand participation without extra administrative costs.

Energy participation framework can be applied to understand interventions outside energy research. For example, I have applied this same framework to understand the process of engagement in a women-led cooperative called Napawika Simabo in Creel, Chihuahua by coding a document that detailed the story of how they became a cooperative. I shared results with cooperative staff during the fieldwork of this project, and, during the discussion of results, participants and I reflected on how much their store has grown across time. I also used the same framework during a university class where my classmates and I partnered with local nonprofit organizations like Chispa Arizona to co-create a project that aimed to help the organization meet their goals. The last context where I have applied this framework is in a literature review that aimed to understand the process of engagement among actors, like Indigenous nations and setter groups, in the Gila and Salt rivers in the Phoenix metropolitan area since 1,500s to today.

The previous paragraphs detailed the benefits and practical uses that I was able to identify as I developed this dissertation. Now I provide a step-by step guide to put this framework into practice.

**How anyone can implement energy participation in practice**

The analysis of energy participation has allowed me to create a step-by-step guideline that can help communities understand and research ongoing participatory and non-participatory interventions. This section provides a seven-step guide to create a practical instrument to keep track of community engagement efforts. These steps are only suggestions; they should be adapted to specific project needs, objectives, and contexts. Yet, they offer initial thoughts on how to apply this framework.

**Step 0:** Before starting this process, prepare a list of the main goals of your project or the intervention you wish to analyze. Those goals could change across the process of the project or intervention, yet it is important to list them because they should guide the next steps.

**Step 1:** Based on your objectives of your project, provide a list of the activities that you plan to implement to reach your goals. You could specify the place (geographical or virtual space) and the date/time for the activity. Group these activities by stages or phases of the process (e.g. you could divide them by month, year, or by stages like planning/implementing/evaluating).

**Step 2:** Identify the actors or subjects that you want to include as part of the intervention. Reflect on who are the stakeholders, community members, organizations or the “subjects” of participation that will be part of the activities listed in step 1. You could think of actors by groups like governments, nonprofits, schools, etc., or in terms of demographics like the Latino or the LGBT communities. Make this list based on the type of project you will develop and its goals. For example, if researchers or practitioners are working on a community project about a circular economy, participants might want to involve certain industries, government agencies, community members, etc.

**Step 3:** Create the typology of participation or the forms in which actors in your project will be engaging. These forms of participation should be aligned with your goals. I encourage users to brainstorm ideas about how they want to participate and how they want the public to participate. The literature offers vast options to structure your own typology. For example, visit: [https://www.iap2.org/.](https://www.iap2.org/) Once identified the forms of engagement, practitioners or researchers need to prioritize these forms of engagement. The final product will be the scale users of this instrument will use to track participation. Thus, it is important that the public or the research team validate the typology before using it.

**Step 4:** Plot it! Now it is time to create for our graph (See figure 26). In the x-axis you will list all the activities that you want to implement across the process, these were defined in step 1.

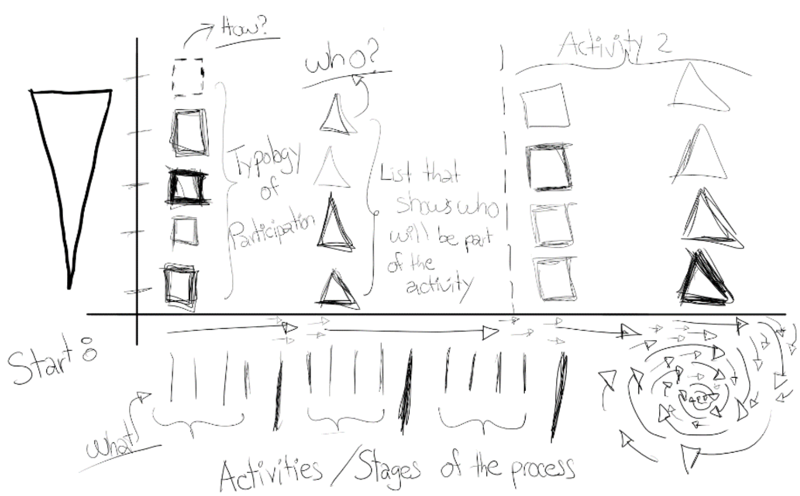



Figure 26. Example of graph that could be used to plan participation

The graph could have two y axes, one that will represent the intensity of involvement or typologies of participation, defined in step 3. The second y-axis will specify the actors that will be part of the activities in the process, these were defined in step 2. Figure 26 represent the two axes with the triangle and square markers. Now it is time to revisit each activity that was proposed. Use both scales to decide the forms of engagement and the actors that will be included or excluded in each activity. Now the graph is ready for validation.

**Step 5:** Organize a workshop to validate the plan with community members and participants in general. During the workshop the facilitators could present the graph and guide the public through steps 1-4. In the workshop facilitators could ask the public for their input and validation about the activities that will be implemented, who will participate, how they will be involved, and about the time and place where this will happen.

**Step 6:** During the implementation of the project, community members could document the process in the graph previously created. Participants could use this visualization to evaluate how participation occurred. They could simply draw an “x” at the end of each activity or session to indicate who participated and how. The documentation of how participation occurred in each session could allow participants to keep track on the engagement process and could also be an instrument to evaluate the project.

**Step 7:** After concluding step 6, community leaders could prepare a participatory evaluation session in which the community is informed about how the process went, if the goals were met, and to plan future steps. The results of this process must inform the next research/project cycles.

## 5.2 Limitations

Now I provide a reflection on the limitations of energy participation as a framework and elaborate on the possible avenues to address them. Limitations in the literature about the concepts I used to create energy participation as a framework include the following: typologies of engagement reduce participation into few categories that ultimately could hinder diversity (Guijt & Shah, 1998); typologies of participation can portray engagement as a static picture that overlooks differences between the actors (e.g. men, women, nonbinary people, etc.) performing such form of engagement (Guijt & Shah, 1998); numerical scores that measure participation might also contribute to create a static picture of participation and overlook the diversity of the process of participation; typologies of participation also suggest normative assumptions that higher rungs in the ladder of engagement are better than others which infers that projects need to move to higher forms of engagement and disregards the context and the feasibility of such forms of engagement (Guijt & Shah, 1998); additionally, participation has impacts beyond energy transitions objectives that were beyond the scope of this research and that need further research. I now proceed to detail each of these limitations and I elaborate on how I addressed them as I developed this research project.

Depth of participation represented only in few categories reduces options for imagining new forms of engagement (Guijt & Shah, 1998). In the case of this research, my objective was to synthesize the forms of engagement into few categories that could help us understand how participation occurred. I took two approaches to imagine new forms of engagement: (1) I explored the literature to find previous typologies of participation and get inspiration to create both ladders of engagement I used in the three research projects in this dissertation, and (2) I had an open coding analysis to identify forms of engagement that emerged as I analyzed data in this project. To avoid hindering the diversity of forms of participation, typologies must include input from the public.

The typologies of engagement in this project could also be enriched by comparing or juxtaposing the ladders of engagement created in this research with the local people's input and perceptions about the ladder of engagement. For example, in the future, I hope to present results to Ralámuli communities that were part of the solar projects analyzed in this research. I hope to facilitate a workshop session to discuss user's opinions about the ladder of participation I used, and I would like to re-order the rungs based on public's prioritization of the forms of engagement. A workshop like this could be an opportunity to enrich this framework and to include users in the co-creation of the future solar projects that will occur in their communities. The input from local communities is crucial in imagining other forms of engagement and to improve research practices.

Ladders of participation have also been critiqued because they reduce participation into few categories and ultimately portray participation as a "static picture" (Guijt & Shah, 1998, p. 9).

To address this limitation, energy participation framework allowed me to describe the process of participation through listing activities during the process under analysis and I was able to identify the different forms of engagement performed and the actors involved in each activity. This structure allowed me to indicate the diversity of form of engagement and actors participating in each activity of the process of participation. For example, the visualizations of the process of participation that I used to generate the findings of this research added complexity on how solar projects included diverse forms of engagement and actors across the process of multiple solar projects.

The numerical scores of breadth and depth of participation helped me characterize and compare intensities of participation, yet they could reduce participation to a number that overlooks the diversity of participation. Therefore, average scores of participation should always be used with a deep analysis of the process under analysis. For example, as done in the second paper of this dissertation, I took a closer look at the solar project created after federal policy to understand how participation occurred in the whole process of the project and to explore the reasons of low acceptance and user satisfaction. In paper three, I looked at the solar program offered by the state to explore how elements in the process of participation might influence longer user of solar systems. The understanding of the differences of breadth and depth of participation across processes and projects allowed me to provide recommendations for future solar projects.

Multi-actor perspectives (Avelino & Wittmayer, 2016) offer a helpful structure to organize the actors in breadth of participation to keep track of who is included/excluded in the process of engagement. For example, the analysis in paper three allowed me to identify knowledge gaps between men, women, and youth while using solar home systems which unveiled the need for capacity building efforts that target women and youth. Similarly, to depth of participation, it could be beneficial to get the input from local members about the organization of the actors in the analysis. These suggestions are also supported by literature that has pointed out that tools that pretend to evaluate participatory projects cannot be universal (Webler & Tuler, 2001). Therefore, researchers and/or practitioners need to look for emerging themes as they analyze qualitative data and include the community voices in all stages of research.

This dissertation focused on understanding the role of participation in specific outcomes: energy savings, user satisfaction, technology acceptance, and longevity of solar systems. Yet, participation has other outcomes that go beyond the scope of this research. For example, participation has also a subjective component that is revealed when subjects that participated share their experiences and perceptions on their experiences as users of a technology, an energy system, and so on. I acknowledge that both aspects of participation are crucial to understand the effectiveness and impact of participatory processes, and they could also shed light on other outcomes of participation that community members might identify through their experiences. Thus, this research must be complemented with local voices about the subjective aspects of the process of participation.

Typologies of participation create a normative assumption that successful projects and interventions need higher form of participation to develop successful interventions. The results in this research showed how this is not always the case; higher participation as measured by typologies of participation do not necessarily contribute to the objectives in transitions towards low-carbon energy systems. For example, if participation is defined as the action of turning lights off when not in use, then yes, more participation might translate in lower electricity consumption. However, if we consider consultation as deeper form of participation when compared with informing, then 'deep' participation will not necessarily translate in lower electricity bills because what is needed is information about how to save electricity at home. So, I recommend seeking "*optimum* participation" (Cornwall, 2008, p. 276) based on the goal at hand and by trial and error. The three empirical analyses in this dissertation shed light on what strategies were presents in projects with specific outcomes and suggest that more is not always better. This research suggests that researchers and practitioners need to continue testing these ideas to help us accelerate an energy transition. Yet, it is important to remember that "the feasibility of 100 percent local participation is a myth" (Guijt & Shah, 1998, p. 10). Thus, the goal of participation could focus on making the best use of the resources available.

## 5.3 **Theoretical Contributions**

Here I list few theoretical contributions that this dissertation offers for the study of participation in energy transitions.

**Subjective vs tangible aspects of participation**

I used energy participation as a framework to keep track on how participation unfolded in projects and ultimately bring clarity on how participation occurs. Yet, as explained in the limitations section, the scope of this research covered only an analysis of the tangible dimensions of participation that can be seen, described, and experienced (see section 2.2.1 for definition). The subjective dimensions of participation that seek to understand what users and decision-makers think about the process of participation (see section 2.2.2 for definition) were beyond of the scope of this work. I actually tried to have a conversation with solar users about what they thought about their engagement process in the solar projects, but most users did not really understand my question during the interviews. This made me reflect on the gap there is between how academics have been using terms like participation in the literature to describe engagement efforts as opposed to what local people and communities experience in their everyday life. This dissertation excluded perceptions of users about the process of participation, and it paid closer attention on how the elements of the tangible dimensions of participation occurred in lived processes as detailed by documents or people's narratives.

To continue theorizing about the effects of participation on the outcomes, the visualizations and results in this dissertation could be shared with community members to reflect on the impact of participation in the projects that affect them. For example, results from the analyses presented in this dissertation could be shared with the public to seek ideas and opinions on who was included in the early stages of the projects when most decisions are made. The public should also discuss their opinions about the right intensity of participation that could meet their needs and budgets. This discussion could shed light on the subjective aspect of participation that pay attention to the perceptions and attitudes of participants about who was included, excluded or self-excluded in the forms of engagement that occurred across the process under analysis. I suggest that both tangible and subjective dimensions of participation are crucial to understand the process of participation and to draw links between engagement efforts and the desired outcomes of such interventions.

**Participation beyond influencing technocratic decision-making**

The systematic analysis of energy participation presented in this dissertation unveiled that participation goes beyond the conventional understanding of participation that looks at how actors and the public influence decision-making process of projects and policy (see Beierle & Cayford, 2002). This form of understanding participation advocates to include local communities in the decisions that will affect them like energy democracy (van Veelen & van der Horst, 2018). The results in this work support the goal of the previous literature, but it also suggests that participation includes other elements beyond the decision-making of policy and projects that often occur at early stages of processes.

This research showed how participation in energy transitions must include in its definitions the everyday experiences of users, as inferred by previous studies (Chilvers et al., 2018; Pallett et al., 2017). For example, paper two showed how payment methods required users to commute and spend extra time and resources as part of their experiences using solar modules. Additionally, operation and maintenance costs in paper three unveiled the importance of material participation in the longevity of systems. Thus, participation for me could be defined as the actions performed by different actors that secure or challenge emancipatory or oppressive systems that recreate the reality where we live.

**Directionality of energy participation**

Another contribution for theory is the directionality in the models or forms of energy participation which indicates the actors leading the form of engagement under analysis. For example, in the second paper in this dissertation, the analysis of directionality across the process of the five SHS programs in SMO allowed me to understand that participation could take different forms to achieve the same goal. In this analysis, the solar projects that received higher scores for solar technology acceptance and user satisfaction either had solar developers *seeking ideas* from the public about their electricity needs or had the public *informing* solar developers about their electricity needs at early stages of the project. Thus, both *informing* (led by final users) or *seeking ideas* (two-way communication between users and solar developers) might have had similar positive impacts as users were included during the planning stage of projects. This analysis suggests that if a project that does not have a large budget to run a workshop to seek ideas from the public, solar developers or practitioners could use other communication channels (like participant observation or a survey) to understand the needs and motivations of the community and end users. The analysis of directionality added complexity of how the forms of participation are performed and allowed me to find possible links between directionality and the impact of participation.

## 5.4 Final Remarks

This dissertation explored the role of participation in energy transitions through the analysis of a US competition and electrification programs with solar technologies in rural Mexico. Overall, this work indicates that researchers and practitioners need to carefully design, strategize, and evaluate participation to anticipate unintended consequences like the low acceptance of solar programs that grant electricity access to Ralámuli communities.

The recommendations that emerged through this research could be summarized in the following four key points: (1) strategize participation based on the goal of the intervention, (2) offer clear information in the user’s first language about the costs and maintenance of solar systems to avoid miss communication that could materialize in lower technology acceptance and user satisfaction, (3) seek ideas from solar users at the early stages of the intervention to design technologies and the intensities of participation that meet users’ needs and resources available, and (4) find strategies to reduce costs by offering enough solar power capacity that meet electricity needs and by offering collective forms of ownership like solar mini grids or cooperatives. The complexity of how participation occurs in practice, as demonstrated through the three analyses in this dissertation, indicates that it is important to keep conducting empirical research to expand our understanding on how participation might affect desired outcomes.

This research contributed to the literature on participation and energy research by offering a practical framework to research, plan, design, and evaluate participation and by providing evidence of how participation occurs in practice. The energy participation framework can allow practitioners and researchers anticipate and reflect on the unintended consequences caused through their practices and find strategies that secure the outcomes needed to realize a transition towards low carbon energy systems.

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# APPENDIX A

## INTERVIEW QUESTIONARIES

This appendix lists the questions I used to conduct the interviews in this project.

**Cuestionario para entrevistas con usuarios de comunidades**

1. **Participación en proyectos solares (5 minutos)**

   **Tipo de tecnología y Temporalidad**

   - ¿Qué equipo foto voltaico tiene? ¿Cuál es la historia de las placas solares que usa? ¿Cuántas celdas? ¿Tiene baterías, focos LED, cables, enchufes?
   - ¿Desde hace cuánto tiene paneles solares? o ¿Cuándo instaló sus paneles solares?
   - ¿Tu opinión se tomó en cuenta en la planeación y diseño del programa o la tecnología que usas?

   **Costos y financiamiento**

   - ¿Cómo conseguiste estos paneles? ¿Qué costo tiene el uso de los paneles? ¿dio trabajo solidario a cambio de la tecnología?
   - ¿Cuánto pagó por la instalación? ¿Cuál fue el costo que tuvo que invertir? ¿Tuvo que pagar o invertir dinero para el mantenimiento de este equipo en ese tiempo? ¿Cuánto?

2. **Beneficios y obstáculos en proyectos solares (10 minutos)**

   **Beneficios, uso de energía y temporalidad**

   - ¿Qué tipo de energía se utiliza tradicionalmente en su comunidad y cómo cambió con los paneles?
     - ¿Cómo se utiliza la energía en su vida comunitaria?
     - ¿Usó los paneles solares o focos durante fiestas de la comunidad, fainas, teswinos, etc.?
   - ¿Cómo le ha ayudado o para qué le sirve la tecnología solar PV?
     - ¿Qué otros beneficios han obtenido con esta tecnología? o ¿Qué es lo que le gusta de esta tecnología? ¿los niños pueden hacer tareas en la noche durante invierno, o algo así?
   - ¿En qué aparatos o cómo utiliza la electricidad?

- ¿Usa electrodomésticos como televisión, radio, luz, teléfonos, tablets, celulares, etc.?

- ¿En qué momentos del día utiliza la electricidad generada de sus paneles solares?
  - ¿Su uso cambia a través del año? Ejemplo: invierno VS verano; hay más luz durante el día en verano que en invierno
  - ¿Cambia con las estaciones?
- ¿Al tener estas placas solares, usted cree que mejora la economía familiar?

**Capacity building**

- ¿Qué ha aprendido de las celdas solares? ¿Recibió capacitación para el uso, instalación y mantenimiento de sus paneles?

**Problemas técnicos y de mantenimiento (obstáculos)**

- ¿Qué problemas ha tenido con esta tecnología y su comunidad? ¿Cómo los resolvió? ¿cuánto tuvo que invertir?
  - ¿Alguien de su familia o usted le dio mantenimiento a su equipo?
  - ¿Si en este momento ocurriera un problema técnico sabría cómo resolverlo? Sí/no
- Usó baterías, ¿cómo las desechó?
- ¿Qué es lo que no le gusta de las celdas solares?

**3. Cuantificación de aceptación de la tecnología (5 minutos)**

- ¿Si tuviera la oportunidad, volvería a adquirir esta tecnología? Sí/no

Del uno al cinco: uno es la calificación más baja y cinco la más alta (1-nada, 2-poquito, 3-masomenos, 4 mucho, 5 muchísimo)

- ¿Qué tan feliz/agusto está usted con el servicio de energía eléctrica que producen las celdas solares? y ¿por qué?
- ¿En su opinión, cómo cree usted que la tecnología fotovoltaica podría ayudar a mejorar su comunidad? (ejemplos: a mitigar la pobreza, movilizar los activos comunitarios).

**4. Evaluación y percepciones de la participación en proyectos de energía (5 minutos)**

- ❖ ¿Te gustó la forma en la que participaste en el proyecto? ¿Qué cambiarías?
- ❖ ¿Tu opinión se tomó en cuenta en la evaluación del programa o la tecnología que usas?

**Interview Questions**

1. **Participation in solar projects**

   **Type of technology and length of use**

   - ❖ What type of solar PV do you have? Does it have battery, bulbs, cables, outlets, etc.
   - ❖ Since when are you using these panels? When were the panels installed?
   - ❖ Was your opinion heard in the design of the technology or solar program?

   **Costs and ownership**

   - ❖ How did you get the panels? How much did you pay for them? Did you offer community work or other forms of payment for this technology? Have you spent money for maintenance?

2. **Benefits and obstacles in solar projects**

   **Past uses of energy**

   - ❖ What type o energy/assets do you use traditionally in your community before the solar panels? Did something change with after the solar panels were installed? Do you use solar PV technolgies for cultural events and traditional parties?
   - ❖ How is this technology helpful for you? How do you use the electricity? Who benefits form the use of this technology?
   - ❖ During which time of the day do you use this technology? Are there any changes among seasons?
   - ❖ Does this technology help to improve your household economy?

   **Capacity building**

   - ❖ What have you learned about this technology? Did you receive trainings for the use and maintenance of this technology?

   **Tech problems**

- ❖ What tech problems have you had or experienced? How did you solve them? How much did you have to invest?
- ❖ Is there something that you do not like about solar PV technologies?

**3. Quantification of technology acceptance and attitudes**

- ❖ If you had the chance, would you get the same program again? Yes/no
- ❖ If there was a technical problem, do you think you would be able to fix it? Yes/no

From one to five, 1-nothing, 2-a little, 3-more less, 4 some, 5 a lot

- ❖ How happy are you with this technology and why?
- ❖ Is this technology useful to you? why and how?
- ❖ Do you think that solar PV is beneficial to your community? How and why?

**4. Evaluation, perceptions of participation in solar projects**

- ❖ Did you like how you participate in this program, what would you change?
- ❖ Was your opinion heard in the evaluation of this program?

**Preguntas para líderes y staff de proyectos solares**

1. ¿Cómo surgió el programa?
   a. Por ejemplo: ¿Cuál es la historia del programa solar que implementó su organización o empresa? ¿Cómo surgió la idea de dar paneles solares a las comunidades que atienden? ¿Cómo se financia el programa?
2. ¿Cómo se diseñó la tecnología que se entregó?
   a. Por ejemplo: ¿Cómo se decidió el tamaño del panel y de la batería? ¿Cómo se decidió que los sistemas incluirían (o no) inversor para usar y cargar aparatos electrónicos como el celular? ¿Hubo proyecto piloto?
3. ¿Cómo se incluyó a la comunidad al desarrollar este proyecto?
   a. Por ejemplo: ¿Cómo se conocieron las necesidades energéticas de las familias? ¿Las comunidades metieron solicitud?
   b. ¿Los usuarios hicieron trabajo solidario a cambio de la tecnología? ¿El costo del sistema es pagado por la comunidad?

4. ¿Cómo se implementa el proyecto?
    a. Por ejemplo, ¿Las familias beneficiarias son dueñas del sistema solar? ¿se da capacitación a los usuarios? ¿Se ofrece algún tipo de mantenimiento? ¿Se remplaza el equipo después de cierto tiempo?
5. ¿Cómo se planea evaluar o se evaluó el proyecto?
    a. ¿Se reciclan las baterías al final de su uso?

# APPENDIX B

# CODEBOOK TO UNDERSTAND SHS EXPERIENCES IN SMO

The table below shows the categories used to analyze SHS in SMO

| | | |
|---|---|---|
| 1. Past Uses of Energy (before PV) | 1. Energy needs/ use | 1 a. Light |
| | | 2 b. Cooking + Heating |
| | | 3 c. Cultural expressions |
| 2. Solar PV Participation as a Process | 2. Planning | 4 d. Goal setting |
| | | 5 e. Technology Design |
| | | 6 f. Request solar program |
| | | 7 g. Community visits |
| | 3. Implementing | 8 h. Installation |
| | | 9 i. Trainings |
| | | 10 j. Use_Lenght of time |
| | | 11 k. Use_Time of the Day |
| | | 12 l. Use_light |
| | | 13 m. Other_Uses |
| | | 14 n. Maintenance |
| | | 15 o. Payment/costs |
| | | 16 p. Self-repair |
| | 4. Evaluating | 17 q. Type of evaluation |
| | | 18 r. Technology disposal |
| | Depth of Participation (Ladder) | 0. Absence of participation |
| | | 1. Inform |
| | | 2. Banking education |
| | | 3. Passive Participation |
| | | 4. Material participation |
| | | 5. Consultation |
| | | 6. Use of Technology/Assets |
| | | 7. Ownership |
| | | 8. Functional participation |
| | | 9. Request goods or services |
| | | 10. Seeking ideas |
| | | 11. Full Agency |
| | Breadth of Participation | 0. Solar Project Developers/ Leaders |
| | | 1. Other Actors |
| | | 2. Users |
| | | 3. Community Actors |
| | | 4. State Actors |
| 3. Technology | 5. Tech Design | 19. s. Bulbs |
| | | 20. t. Other components |
| | 6. Perceptions and Attitudes | 21. u. Perceptions |
| | | 22. v. Affective |
| | | 23. w. Cognitive |
| | 7. Indicators for Evaluation | 24. x. Things work fine |
| | | 25. y. Other Benefits |
| | | 26. z. Tech Performance |
| | | 27. za. Likert Scale |
| | | 28. zb. I'd get program again |
| | | 29. zc. Migration |

# APPENDIX C

## APPROVALS AND PERMISSIONS

The co-author Darshan Karwat in article "VISUALIZING ENERGY PARTICIPATION: A METHOD FOR PRACTITIONERS AND RESEARCHERS" has granted permission to use this paper as part of this dissertation.

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Darshan Karwat
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Dear Darshan Karwat:

On 12/18/2020 the ASU IRB reviewed the following protocol:

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|---|---|
| Type of Review: | Initial Study |
| Title: | Understanding Energy Participation: Electricity Access Through Solar Photovoltaic Deployment |
| Investigator: | Darshan Karwat |
| IRB ID: | STUDY00012985 |
| Funding: | Name: Consejo Nacional de Ciencia y Tecnología |
| Grant Title: | |
| Grant ID: | |
| Documents Reviewed: | • Consent Users (Interviews), Category: Consent Form;<br>• Consent_form_12-15-2020_survey.pdf, Category: Consent Form;<br>• email for solar orgs, Category: Recruitment Materials;<br>• Interview structure, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);<br>• Protocol SocialB, Category: IRB Protocol;<br>• Survey structure, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); |

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 12/18/2020.