Community solar: residents' willingness-to-pay and the role of values, beliefs and energy situation

by

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Abstract

As solar photovoltaic energy demand expands and develops, community solar has arisen as an option for providing solar energy to households with limited access, for rural communities, and for other segments of the population who may have limited access to solar energy. Community solar applies to solar power generated by local utilities or firms that is shared among multiple households, who subscribe as members of the community system. Unlike traditional rooftop systems, community solar allows individuals to benefit from shared solar installations, making it available to renters, lower-income households, and those unable to install panels themselves. Understanding what influences residents' willingness to pay to participate in these programs is needed for program and market development across different communities in order to develop rate structures and inform market, utilities and communities about the potential for such opportunities.

The purpose of this thesis is to examine residents' willingness to pay for a hypothetical community solar program. Furthermore, we wish to understand how values, beliefs, energy situation and household characteristics influence potential participation in such programs. We collected primary survey data from online panels in 2024 that resulted in 2910 usable observations across Kansas, Texas, Colorado, Oklahoma, Nebraska, and Iowa. Using a multiple bounded dichotomous choice (MBDC) valuation approach, we estimated the willingness to pay for community solar and how personal values and environmental beliefs; household demographics, household characteristics, and indicators of respondents' energy situation influence willingness to pay (WTP) and participate in a community solar program. In addition, we assessed how WTP differed across population segments based on their perceptions about solar energy.

We find that a number of factors including altruism toward humans and nature, self-interest, traditionalism, and openness to change values; environmental worldviews; energy security; demographics such as educational attainment, racial identity, household size; household characteristics such as electric heating; and state of residence can significantly influence WTP of individuals for community solar. In addition, perceptions about solar power influence the level of WTP across different population segments. This information can help to provide good insight for designing incentives and rate structures, help to develop marketing and educational strategies, and guide policy decisions that relate to community solar investments and projects.

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A special thank you to Dr. Jason Bergtold for not only guiding me through the creation of this thesis but also for supporting me throughout my entire graduate experience. His encouragement has allowed me to grow and learn in ways that I hope to share with others.

Dedication

This thesis is dedicated to my partner who sat through more late nights than they needed to during its creation.

Chapter 1 - Introduction

1.1 Problem Statement

The long history of fossil fuel use in the U.S. has resulted in the release of greenhouse gases that have altered the climate and changed the interval of extreme weather events (Fthenakis et al., 2009). Dependence on fossil fuels like coal, oil, and natural gas for energy generation continues to increase greenhouse gas emissions into the atmosphere, affecting ecosystems and human health (Fthenakis et al., 2009). Solar power is a growing alternative source of electricity that avoids potential emissions of greenhouse gases for energy production (Zhai et al.). As solar photovoltaic (SPV) technologies have evolved, so has business models for providing solar energy at utility and customer scales (International Solar Alliance , n.d.).

Solar power was initially adopted at a slow pace, but government incentives and improved affordability have helped solar power become more desirable and accessible (Sarzynski et al. 2012). Efforts to address climate change and be less dependent on fossil fuels has led to increased adoption of rooftop solar and investments in commercial solar projects (U.S. Department of Energy, 2021). According to NREL, Kansas ranks amongst the top 10 states for solar radiation with the highest energy potential being in southwestern Kansas. With this "The state has a small but growing amount of utility-scale (1 megawatt or larger capacity) solar generation, which was 10 times larger in 2023 than in 2018."(EIA, 2025). In 2024, solar production was 250 GWh of power with 83 GWh coming from utility scale and 167 GWh coming from small scale solar.(EIA, 2025).

A particular innovative solar option for households is community solar, which refers to solar power being provided by local utilities or firms that is then sold to households, who are community subscribers. These households can potentially receive credit on their electricity bills for their share of the power produced by solar, which occurs when solar energy costs are lower than buying energy off the local grid based on current rates in the market (US DOE, n.d.). Community solar programs make solar energy more accessible to consumers by avoiding some barriers present in rooftop solar. These barriers include direct property ownership and maintenance, structural issues, shading of households, being a renter, amongst others (Feldman et al. 2015)(Heeter et al. 2018; Michaud 2020; Abbott et al. 2022; Hausman 2022). Thus, community solar may improve renewable energy access for households, making it more affordable and inclusive, while supporting energy equity. These programs can also play a role in reducing dependence on fossil fuel energy sources and combating climate change, by fostering broader participation in clean energy initiatives. By aligning energy use with sustainability goals, community solar may contribute to environmental and societal benefits without requiring individual investments in solar infrastructure by households, enabling a more equitable transition to a greener energy grid (U.S. Department of Energy, 2021).

The purpose of this thesis is to examine the demographic, behavioral and social-psychological factors that influence individuals' willingness to pay for or participate in community solar programs. Specifically, we hypothesize that behavioral and social psychological factors, specifically values, environmental beliefs, and perceptions affect consumers' willingness to pay and participate in community solar projects. In addition, we hypothesize that a household's energy situation, in terms of energy security and burden, plays a significant factor in shaping participation in community solar programs. Finally, we hypothesize that perceptions about solar across communities and population segments will influence the participation and willingness-to-pay-for solar. We examine a unique community solar business model that is being piloted in Southwestern Kansas using primary survey data from six states across the Great Plains using a hypothetical choice experiment based on real community solar projects.

As the solar industry continues to grow, we want to better understand the demand for community solar by households and how consumers values and beliefs, energy situation, and solar perceptions influence their willingness to participate in and pay for community solar. Expanding solar in Kansas can potentially help lower the costs of electricity for its residents and businesses along with bringing additional investment into rural areas. This expansion can help many communities continue growing while reducing dependence on fossil fuel systems. This thesis aims to examine the monetary change in monthly electricity expenditures by households it would take to increase households' willingness to participate in a community solar program and identify demographics and attributes to help make effective policy decisions and market such programs effectively. To fully understand community solar and its potential advantages we need the knowledge of who would be willing to participate and support community solar design in regions where it could support and provide the best value to different residents and consumers.

The remainder of the thesis provides background on community solar, factors impacting support, and reviews relevant previous studies to support our methodology and findings. Using this background we will construct a willingness to pay model to assess what factors impact support and to what degree. We then describe the primary data collection and hypothetical community solar experiment conducted. We then present results from regression analyses of the willingness to pay model and summarize with discussion and conclusions.

Chapter 2 - Background

This chapter provides background on community solar and different frameworks and methods used for assessing willingness to pay for community solar. Section 2.1 will establish what community solar is and its current state in the midwestern U.S. Section 2.2 will outline the frameworks used to understand the behavior of consumers. It will give explanation and examples of Value-Belief-Norm (VBN) framework and the New Ecological Paradigm (NEP), which helps us to quantify and understand reasoning for supporting or participating in community solar projects and factor of particular interest in this study.

2.1 Community Solar Background

Community solar refers to shared solar projects that allow multiple individuals, businesses, and organizations to benefit from solar energy without installing panels on their properties. Subscribers either purchase or lease a portion of an off-site solar array and receive bill credits or debits based on the electricity generated (U.S. Department of Energy, n.d.). Due to the nature of community solar, such programs may be ideal for those who rent, have shaded roofs, or do not wish to invest in or manage solar infrastructure on their property. Community solar programs are designed to make solar energy more accessible, affordable, and convenient for a wider audience, offering benefits like transferability within service areas and avoiding the responsibilities associated with rooftop systems (U.S. Department of Energy, n.d.).

There exist varying business models for community solar. Funkhouser et al., (2015) outlined three broad models: utility-sponsored programs, third party-owned programs, and special-purpose entities or cooperatives. With utility-sponsored programs, the utility develops and manages the community solar project letting consumers participate through the utility company. In third-party models, a private developer installs and operates the community solar project, subscribers sign contracts directly with the developer, often outside of their existing utility company. Cooperative or special-purpose entity models involve local community members pooling resources to develop and govern their own solar projects. Each of these models have different impacts for financing, consumer engagement, and regulations they are subject to. A common attribute of these business models is the use of contracts for enrollment in or subscription to community solar programs.

The National Renewable Energy Laboratory (NREL) identifies several key factors that shape community solar contracts (Doris, Busche, and Hockett 2009). One important factor is the length of the contract. Doris, Busche, and Hockett (2009) highlight examples ranging from full-term contracts where consumers commit for the entire operational life of a solar project, typically around 20 years, to more flexible month-to-month agreements. Full-term contracts often require a higher upfront investment, whereas month-to-month options offer lower fees and easier participation. A hybrid approach is also possible, involving an initial upfront payment combined with a reduced monthly fee (Doris, Busche, and Hockett 2009). Another major element is the type of community solar program. Doris, Busche, and Hockett (2009) distinguish between project-based programs, where a customer's participation is tied to a specific solar installation, and portfolio-based programs, where participation is linked to an aggregated pool of solar projects managed by the utility. Subscription minimums and maximums are also critical components. These terms define the share of a system that a participant may subscribe to often ranging from a minimum of a single share to a maximum that covers up to 100% of the participant's annual energy use (Doris, Busche, and Hockett 2009). Finally, contract details regarding exit rules and transferability are crucial. These provisions outline any fees or conditions associated with terminating a subscription early or transferring it to another party (Doris, Busche, and Hockett 2009).

One example of a community solar project is that provided by Sunflower Electric Power Corporation in western Kansas, which began to offer a Community Solar program in 2023, advertising the accessibility of solar power without the need of rooftop installation . Residential members can participate by purchasing shares at $5 per share per month, with each share representing 125 kWh of solar energy from the 20-megawatt Johnson Corner Solar Facility near Johnson City, Kansas. The subscription rate refers to the base cost the customer pays for 125 kWh of energy or $0.04 per kWh. The customer's electric bill is credited monthly for the sale of power generated from the solar facility in Johnson City, Kansas relative to the cost of purchasing electricity at market or industry rates, which is not the same as residential rates. Estimates of potential savings by purchasing 8 shares (or 1000 kWh of energy per month from the community solar program) presented by Sunflower Electric for a home using 1600 to 2940 kWh per month ranged from -$14.75 (increase in electric bill) to $63.50, Average savings per month was $15.62 per month (Conine and Schmidt, 2023). In May 2024 the average market or industry price of electricity was ¢7.31 per kWh and the residential price was ¢14.06 (EIA, 2025). Members can adjust their participation level or unsubscribe at any time; however, re-enrollment is restricted for one year following cancellation. Sunflower Electric reports that this program has been fully enrolled since its inception (Olympia Community Solar 2022).

In 2023, Pioneer Electric Cooperative, located in Southwest Kansas, launched its community solar program, offering residential members a flexible, month-to-month style solar program. Participants can subscribe and purchase shares of the Johnson Corner Solar Facility near Johnson City, with each share representing 125 kWh of solar energy and costing $4/share. Subscriptions are limited to a member's average annual electricity usage, preventing oversubscription beyond 100% of their consumption. Members have the flexibility to unsubscribe at any time; however, re-enrollment is restricted for one-year, post-cancellation. Additionally, subscriptions can be transferred to another member within Pioneer's service territory, subject to approval (Pioneer Electric 2023).

In contrast, Evergy's Solar Subscription program, which started in 2023, offers customers in central Kansas a longer-term service. This portfolio-based program aggregates solar production from Evergy's facilities, such as the 10 MW Hawthorn solar array in Missouri. Customers can subscribe in 1 kW increments, each providing approximately 150 kWh per month, up to their average annual consumption. The program requires a minimum commitment of one year, with the option to participate for up to 25 years. After the initial year, participants may adjust their subscription levels or exit the program by providing a 30-day notice (Evergy 2024).

Not all populations may benefit equally from community solar. Reames (2020) raises concerns that, without intentional design, community solar programs can reinforce existing social and economic inequalities. Program structure is important for more vulnerable groups. For example, low-income families, renters, and minority households can face barriers to solar power because of things like credit checks, not owning a home, high upfront charges, and not knowing about programs (Reames, 2020). If these potential issues are not addressed, community solar may become an energy source that is not readily accessible for these population segments. Reames (2020) explains how important it is to include affordability, targeted outreach, and accessibility in design of community solar programs, making this renewable energy potion more accessible.

Previous studies have looked at solar and community solar adoption. Michaud (2020) examined why some states have higher solar adoption rates. Michaud (2020) found that mandates are more effective than just regulatory action, and factors such as political will, stakeholder engagement, and lobbying significantly influenced solar adoption. Nuñez-Jimenez et al. (2023) looked at community solar adoption using an agent model to test different policy scenarios in urban areas. They tested three different scenarios, no community solar being allowed, community solar allowed but placed directly adjacent to buildings, and community solar allowed only within a 100-meter radius. A key finding was that the 100-meter policy had a large impact on solar adoption. In their study, adoption was increased from households that could not support rooftop solar due to different barriers. Finally, Wolske et al. (2017) looked at the psychological and social variables effecting interest in rooftop solar. Wolske et al. (2017) found that pro environmental values and personal norms were strong predictors for interest in solar adoption using the Value-Belief-Norm (VBN) theory.

2.2 Behavioral Factors Influencing Solar Adoption and Participation

The Value-Belief-Norm (VBN) theory is a framework for examining pro-environmental behavior, which includes solar adoption and participation. The VBN framework is designed to capture support for social movements from non-activist people and quantify their different types of support. The framework looks at three different areas that may drive support, a person's values, beliefs, and norms. The values in the VBN theory refer to guiding principles and how individuals perceive environmental issues. The theory focuses on three value types, egoistic for the concern for oneself, altruistic for the concern of others, and biospheric values for concerns about the natural environment. (Stern et al., 1999, p. 82). The beliefs in the VBN theory refer to more specific thoughts about human responsibility and environmental conditions. Beliefs also include awareness of consequences and ascription of responsibility These beliefs translate general values into perceptions of environmental problems and moral obligations (Stern et al., 1999, p. 84). Personal norms are internalized expectations about how one ought to act. They help guide action when individuals recognize that there are threats to something they value (AC) and when they accept responsibility for taking action (AR). Personal norms then directly motivate pro-environmental behavior, such as conserving energy, recycling, or supporting environmental policies (Stern et al., 1999, p. 85). The focus in this thesis is on values and overall beliefs or environmental worldview. Awareness of consequences, ascription of responsibility and personal norms are left for future research.

The VBN theory allows us to look closely at what types of environmental or non-environmental support can be explained by social-psychological factors (Stern et al., 1999.). VBN theory has been used to examine types of support for the environmental movement, such as consumer behavior, environmental citizenship, and policy support, showing that it can account for a significant share of variance across individuals and households. (Stern et al., 1999.). Having this understanding we can model the sources of consumer support. The VBN framework shows the connection between values and beliefs that can influence individuals' sense of responsibility to act. With this structure, a connection can be made between values, beliefs, and norms of an individual to the likelihood of supporting pro environmental behavior, policies or sentiment.

The NEP scale was made to distinguish between respondents who would align themselves with a more ecologically sustainable view in contrast to the assumed world view, which places humans above and apart from nature (Dunlap and Van Liere, 2008). The factors that were originally asked about to make up the NEP scale were realistic ecological limits, the balance of nature, and the idea that humans are the central or most significant entities in the world (Dunlap and Van Liere, 2008). In 2000, an updated version of the NEP scale was created, expanding it to 15 items. Dunlap and Van Liere, 2008 added a focus on "human exceptionalism" and the "ecocrisis" along with modernizing the language used for future use (Dunlap and Van Liere, 2008). The NEP scale as a factor representing broad environmental beliefs has been used to examine support for environmental movements (Stern et al., 1999). Clark et al. (2003) used the new ecological paradigm (NEP) scale as a measure of environmental concern and found that such attitudes predict participation in green electricity programs.

Parkins et al (2018) drew broadly from the VBN theory and (Wolske et al., 2017) used and added in factors relating to solar exposure in the community and general understanding/interactions with their nation's energy system. The finding shows that perceived knowledge and understanding, biocentric (environmental) values, and public engagement were key factors in positive intentions towards adopting renewable technology. Particularly relevant is the study by Wolske et al. (2017). They explored factors influencing homeowners' interest in adopting residential solar photovoltaic (RPV) systems in the United States. The paper combines three theoretical frameworks: Diffusion of Innovations (DOI), Theory of Planned Behavior

(TPB), and Value-Belief-Norm (VBN) theory. The central question examined in the paper is, "what factors influence interest in contacting an RPV installer, as a key precursor to actual adoption" (Wolske et al., 2017, P135). To answer this Wolske used VBN theory to link personal values, beliefs about environmental issues and personal norms to pro-environmental behavior, adoption of RPV. When analyzing the VBN model for interest in RPV instillation, Wolske et al. (2017) considered both the direct and the indirect effects of the VBN variables. They found that personal norms and self-interest values had a direct effect on interest in RPV, while personal norms, awareness of consequences and altruistic values had an indirect effect through other VBN factors. It was noted that traditionalism and openness to change had no effect on interest in RPV. Findings from Wolske et al. (2017) indicate that people who view solar energy as environmentally beneficial, personally advantageous, and if it is socially endorsed are more likely to express interest in adopting RPV systems. Importantly they found that personal norms related to environmental concerns indirectly. Personal benefits increased interest in RPV directly, suggesting that marketing efforts aimed at environmentally concerned individuals may need to emphasize non-environmental benefits.

From this framework previous literature has made connections between the VBN framework and improvements to marketing and acceptance of environmental policy. Lima et al. (2024) reviews use of the VBN framework and its ability to segment markets. Lima et al. (2024) notes that when an ad's message aligns with a persons values, the intention of purchasing or participating in programs significantly increases. From this Lima et al. (2024) recommend targeting consumers with higher biospheric values with appeals to their biospheric and altruistic values, while appealing to non-ecologically concerned segments by basing their marketing on calls to their egoistic and hedonic values. Welsch & Kühnel (2022) is an example of using VBN for market segmentation in a non-advertising context. Welsch & Kühnel (2022) used the VBN theory to target interventions with the goal of increasing environmental engagement with the Peak District National Park in England, UK. To do this they segmented their target audiences into supporters, objectors, and those who were uncommitted. From this they found that creating market segments using VBN allowed them to use effective strategies of appealing to the biospheric and altruistic values of supporters and the egoistic & hedonic values of the objects being examined.

We plan to use the VBN framework, particularly values and the NEP scale to examine their influence on households' willingness to pay for community solar, especially given public views and debates about renewable energy. We do this with the goal of providing better insights into potential solar markets and enabling solar providers to target their marketing to those who would be willing to pay more for the programs. We also hope that this will guide local policy for community solar programs to be impactful and efficient.

Chapter 3 - Data and Methodology

This chapter lays out the methodology we developed and follow to estimate a willingness to pay (WTP) model examining residents' willingness to pay for and participate in a community solar program. We first present our conceptual framework that incorporates the values, beliefs and norms theory. We then talk about survey data collection, our choice experiment and how we constructed variables from the responses. Finally, we present our empirical WTP model, which is estimated using an interval regression approach in R.

3.1 Conceptual Framework

Our conceptual framework is based on a utility maximizing consumer who is considering whether to enroll in a community solar program with their local power company. By solving their utility maximization problem, the consumer will determine their optimal or maximum willingness to pay (WTP) for the program. Our conceptual model is based on the determination of the optimal willingness to pay, which we assume is influenced by environmental worldview (NEP), values, household energy situation, household characteristics and demographic factors. This is illustrated in Figure 3.1.

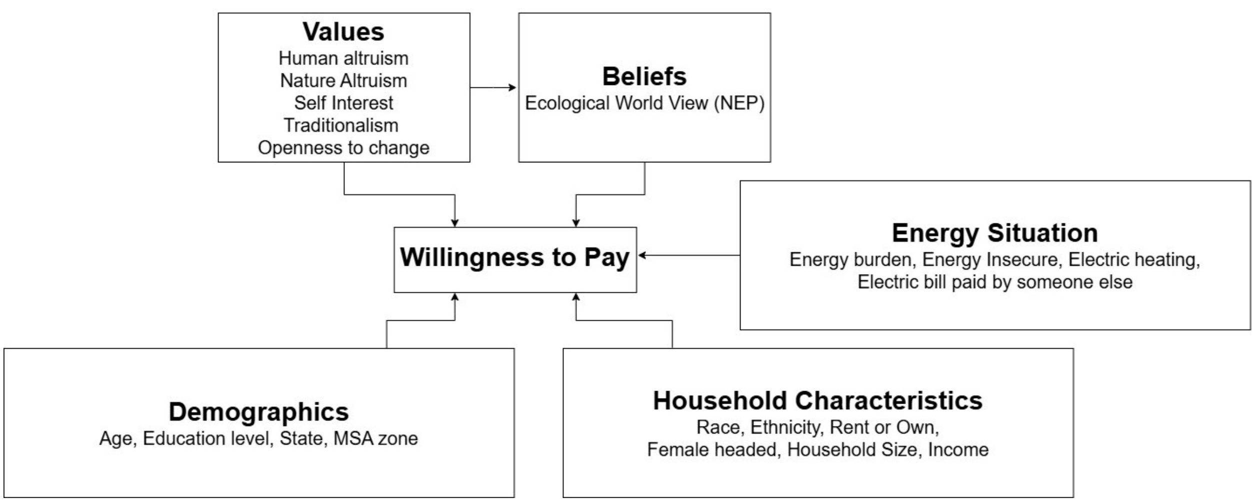

Figure 3-1 Conceptual framework

Values and environmental beliefs (VBN), as modeled by Stern et al. (1999), include the values of human altruism, altruism toward nature, self-interest, traditionalism, and openness to change. Environmental beliefs or worldview is captured by the New Ecological Paradigm (NEP), which is a measure of pro environmental beliefs (Dunlap et al., 2000; Sanderson et al., 2017).

We also consider other factors that may influence WTP. These include household demographics, characteristics, and energy situation. Demographics include the age, state of residence, education level, being a female headed household, ethnicity, race , if the they live a more rural or urban setting (Badole et al. 2024). For household characteristics, we assume that income of the household, if they rent or own their residence, and the type of structure that their residence (i.e. single family unit or not) influence WTP (Reames, 2020). For the energy situation, we assume energy burden, level of energy insecurity, if their bill is paid by someone else, and if they use electric heating as factors that influence WTP (Reames, 2020).

3.2 Data

We developed and administered an online survey in Fall 2024 using Qualtrics in the states of Kansas, Texas, Oklahoma, Nevada, Colorado, and Iowa. We contracted with Qualtrics, Dynata, and Toluna to utilize online panels to conduct the survey. We used three different online panels to enhance coverage of rural or non-metropolitan statistical areas. We received 1,106 responses from Qualtrics, 2147 responses from Dynata, and 420 responses from Toluna. Combining these we had 3673 respondents that completed the full survey. Of these, 1866 respondents were from non- MSA (metropolitan statistical areas with less than 50,000 people in their county or residence, which we labelled as rural) and 1807 from MSA regions (which we labeled as urban). All respondents were required to confirm that they were at least 18 years old and a resident in our area of study. We also asked for their electronic informed consent and shared information about the study that their responses would be used for. The survey and study methods were reviewed, approved, and found exempt by the Institutional Review Board for Human Subjects Research at Kansas State University.

The survey asked respondents about their values, environmental beliefs, energy situation, demographics and household characteristics. In addition, we had a choice question asking about their willingness to participate in a community solar program. At the beginning of the survey, we defined solar power concepts and asked a number of different questions about respondents' solar knowledge, asking about environmental and financial impacts. The responses available to respondents were I already knew this, I just learned this, I do not know about this, and I disagree with this.

For quality control, we filtered survey responses using three different criteria. First, we tracked if the respondents finished in a short time (i.e. they sped through the survey) using a threshold of less than 7 minutes as our criteria. Second, we included two captcha questions in the survey to assess if the respondent was reading questions and paying attention. Third we examined blocks of questions and tracked how often respondents didn't change their response across entire question blocks (e.g. they always answered the first response for each question in a question block). We used a quality threshold of having 5 or more question blocks meeting this criteria as a potential flag for problematic survey response. Using these criteria, we dropped any observations that failed at least one of these quality control criteria, as well as observations that had missing values needed to estimate the WTP model presented later. In all, we dropped 712 observations for failing the criteria tests and 51 observations for missing values (20.7 %). This left 2910 usable responses for analysis.[1]

3.2.1 Community Solar Choice Question

We designed a multiple bounded discrete choice (MBDC) question for this survey to assess households' willingness to pay for a hypothetical community solar project that was based on real community solar projects in Kansas. We assessed WTP using a range of values on how enrollment in the program would impact their monthly electric bill from reducing it by \$50 to increasing it by \$50. We asked if they would participate in the program for each level using a Likert-type scale.

To make sure that our question was incentive compatible and reduce potential hypothetical bias we followed recommendations for question design outlined by Vossler and Watson (2013). Our question emphasized consequentiality by stating that responses would help inform the design of future community solar projects in both rural and urban areas. We also make sure to include a statement that all respondents in a local area will receive the same rate and indicate cost uncertainty does exist. We used a realistic payment of the average monthly power bill and used cheap talk to answer honestly and remind respondents to consider their own

[1] We did examine alternative case and combinations of the quality choice questions in our research given the use of multiple panels, but this was beyond the scope of the present thesis.

income and current financial situation when making their choices.

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You have the opportunity to participate in a local community solar project, which is being offered by your local power company. The project would require at least a 1 year or 12-month commitment from you to enroll. Your power provider will manage all aspects of the project and there will be no solar installations on or directly adjacent to your property. The amount of energy allocated to your household each month from solar would depend on the performance of the solar installation, which may be uncertain at times and will vary throughout the year. All participating households in your local area would be charged the same energy rate for solar power received from the community solar project. In addition, there are no initial or additional transaction costs for participating.

Participating in the local community solar project may affect the monthly energy bill for your household. We ask you to consider if you would participate in the project with your local power provider given a change in your average monthly electricity or power bill. For each change in the table below, please indicate if you would or would not participate in the program or are unsure about participating.

Please answer honestly. The information provided will help with guidance on designing potential local community solar projects in rural and urban communities. In addition, please remember to take into consideration your average monthly power bill, your household's income, and your current situation.

Figure 3-2 Introduction to Community Solar Power Choice Question in Survey

Cost changes in dollars per month for their electricity bill presented to respondents included: lower by $50, $30, $20,and $10; $0 (no change); and then higher by $5, $10, $15, $20,

$30, $40, and $50.[2] The response options for each level provided were definitely no, probably no, unsure, probably yes, and definitely yes (Figure 3.3). We chose to represent the cost of the program as a change in a respondent's household electric bill, assuming that this would be more relatable and translatable. While community solar subscribers buy shares in the program at a set cost for a given amount of energy per month (e.g. $ per 125 kWh), presenting this to respondents would be difficult as they would need to know their monthly energy consumption. In addition, the actual net savings from enrolling in the program will depend on energy market fluctuations, which are uncertain (see Chapter 2). In addition, we felt that respondents would be more familiar with what they generally pay monthly for their electric bill, which as was asked prior to this question on the survey.

From the answers to the question we build an interval censored variables as the dependent variables use in our WTP model following Welsh and Poe (1998). We converted "definitely yes" and "probably yes" responses to "Yes" and all others to "No". This made a binary outcome for each WTP amount. Being conservative, we then define the WTP bounds using the first transition point from Yes to No (given WTP starts out negative and then goes positive). The lower bound is the point where a respondent switches from "yes" to "no" and upper bound is the next highest WTP value. For example, if the lower bound was $-30, then the upper bound was set to -$20. Doing this left no extra gaps between our bounds allowing for the participants' bounds to fall cleanly into the intervals asked in the survey.[3]

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[2] We found a typo in the survey question for the -$40, which was presented as -$30, which was presented twice. We assumed that the first $30 was likely interpreted as $40 by participants, but check this in model estimations. We did re-estimate models with the typo as presented and found no significant differences in the model results or findings.
[3] A potentially alternative way would be to set the lower bound as the first transition from "definitely yes" and "probably yes" to "Unsure", "Probably No" or "Definitely No" and then then the upper bound to the transition to "Probably No" or "Definitely No". This would take account of uncertainty. If you want to assess certainty you could also do the transitions using only "Definitely Yes" and "Definitely No". This examination was beyond the scope of the current thesis.

	Definitely No	Probably No	Unsure	Probably Yes	Definitely Yes
Lower by $50	○	○	○	○	○
Lower by $30	○	○	○	○	○
Lower by $30	○	○	○	○	○
Lower by $20	○	○	○	○	○
Lower by $10	○	○	○	○	○
$0 (no change)	○	○	○	○	○
Higher by $5	○	○	○	○	○
Higher by $10	○	○	○	○	○
Higher by $15	○	○	○	○	○
Higher by $20	○	○	○	○	○
Higher by $30	○	○	○	○	○
Higher by $40	○	○	○	○	○
Higher by $50	○	○	○	○	○

Figure 3-3 Response Options and Levels for Community Solar MBDC Survey Question

3.2.2 Dependent and Independent Variables

From the answers to the MBDC question we construct an interval censored variable as the dependent variable for our WTP model following Welsh and Poe (1998). We first converted "definitely yes" and "probably yes" responses to "Yes" (1) and all others (Unsure, Probably No, and Definitely No) to "No". This provided a simpler binary outcome for each WTP amount. Being conservative, we then determine the censored WTP interval bounds using the first transition point from a Yes (1) response to No (0) response using the binary outcome (i.e. WTP starts out negative and then goes positive). For example, if a respondent switches from Yes at a change of $-30 to a No at a change of -$20, then that respondent's censored WTP interval is from -$30 to -$20. This approach left no extra gaps between our bounds allowing for the participants' bounds to fall cleanly into the intervals asked in the survey.[4] Table 3.1 presents the number of respondents in each censored WTP interval

Table 3-1 WTP intervals with number of observations

Left Bound	Right Bound	Number of Observations
-Inf	$ -50	301
$ -50	$ -40	215
$ -40	$ -30	53
$ -30	$ -20	278
$ -20	$ -10	259
$ -10	$ 0	267
$ 0	$ 5	438
$ 5	$ 10	163
$ 10	$ 15	144
$ 15	$ 20	131
$ 20	$ 30	121
$ 30	$ 40	104
$ 40	$ 50	44
$ 50	Inf	392

Definitions and descriptions for the independent variables developed from the survey are presented in Table 3.2. We organize these into different categories, which include (i) Values from the VBN theory consisting of Human Altruism, Nature Altruism, Self Interest, Traditionalism, and Openness to Change; (ii) NEP that examines ecological catastrophe and

[4] A potentially alternative way would be to set the lower bound as the first transition from "definitely yes" and "probably yes" to "Unsure", "Probably No" or "Definitely No" and then then the upper bound to the transition to "Probably No" or "Definitely No". This would take account of uncertainty. If you want to assess certainty you could also do the transitions using only "Definitely Yes" and "Definitely No". This examination was beyond the scope of the current thesis.

ecological limits; (iii) Household demographics; (iv) Household Characteristics; and (v) Energy Situation. Each of these categories is discussed in more detail below.

Table 3-2 Variables and summary stats

Category	Variable	Description	Mean	Standard Deviation
Demographics	Age	Age of respondent in years.	52.372	16.112
Demographics	MSA status	Binary = 1 if respondent resides in a MSA county.	0.3605	0.4802
Demographics	College Edu	Binary = 1 if respondent has any amount of college education	0.4251	0.4944
Demographics	Household Structure	Binary = 1 if condo/townhome/apartment; 0 if detached home/other	0.2986	0.4577
Demographics	Household size	Number of people living in the home	4.7227	3.0681
Household Characteristic	Income	Midpoint of reported households' income range.	71750.23	53204.84
Household Characteristic	Female headed household	Binary = 1 if household has female head	0.344	0.4751
Household Characteristic	Rent	Binary = 1 if respondent rents living space	0.234	0.4235
Household Characteristic	Non-White	Binary = 1 if respondent reported as non-white	0.1096	0.3125
Household Characteristic	Hispanic / Latino	Binary = 1 if respondent reported as Hispanic or Latino	0.0962	0.2949
Energy Situation	Bill paid by someone else	Binary = 1 if electric bill paid by someone else	0.0326	0.1777
Energy Situation	Energy Burden	Percent of income spent on electric bill (0 if bill paid by someone else)	0.0501	0.071
Energy Situation	Heating electric	Binary = 1 if household uses electric heating	0.5268	0.4994
Energy Situation	Energy Insecure	Index created from energy insecurity questions	0.9399	0.2378
Value (VBN)	Human Altruism	Z standardized value of Human Altruism Factor	0.0043	0.9967
Value (VBN)	Nature Altruism	Z standardized value of Nature Altruism Factor	0.0034	0.9974
Value (VBN)	Self Interest	Z standardized value of Self-Interest Factor	0.0017	1.0034
Value (VBN)	Traditionalism	Z standardized value of Traditionalism Factor	0.0008	0.9984
Value (VBN)	Openness to Change	Z standardized value of Openness to Change Factor	0.0033	0.9982

3.4.1 Values

For values variables we followed the methodology in Stern et al. (1999) and Sanderson et al., (2017) that links the values of altruism, self-enhancement, traditionalism, and openness to change to pro-environmental behavior. There are 5 values examined: human altruism, nature altruism, self-interest, traditionalism, and openness to change. For each value we were asked a series of Likert questions on a 5-point scale ranging from strongly disagree to strongly agree. For human altruism we ask about agreement on: "Social justice, correcting injustice, care for the weak", "Equality, equal opportunity for all", and "A world of peace, free of war and conflict.". For nature altruism we ask about agreement on: "Unity with nature, fitting into nature", "Respecting the earth, harmony with other species", and "Protecting the environment, preserving nature.". For self-interest we ask about agreement on: "Influential, having an impact on people and events", "Wealth, material possessions, money", and "Authority, the right to lead or command." For traditionalism we ask about agreement on: "Self-discipline, self-restraint, resistance to temptations", "Family security, safety for loved ones", and "Honoring parents and elders, showing respect." For openness to change we ask about agreement on: "Curiosity, interested in everything, exploring", "A varied life, filled with challenge, novelty, and change", and "An exciting life, stimulating experiences."

Each value variable was constructed using confirmatory factor analysis to combine the survey items into a standardized z-factor score following Sanderson et al. (2017). We conducted the factor analysis in R using the base values from the survey instructing it to have a single output and use the varimax rotation using the correlation matrix. All factors developed met the needed reliability statistics for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure indicated adequate sampling adequacy for distinct and reliable factors with KMO values above 0.70 for all values variables (Kaiser, 1974). Each factor demonstrated strong internal consistency with Cronbach's alpha values exceeding 0.70 (Cronbach, 1951). Finaly, eigenvalues for all retained factors were greater than 1 in absolute value (Kaiser, 1974), supporting their use as the dominant element. All factor scores were z-standardized for use in defining the value variables in our model.

3.4.2 Beliefs (NEP)

Environmental beliefs were captured using a shortened version of the updated New Ecological Paradigm (NEP) scale developed by Dunlap et al. (2008). This scale was used to help us quantify alignment with ecological principles and views on the ecological limits of the world. Following Stern et al (1999) we use NEP as a measure of ecological beliefs.

We asked respondents how they agreed with NEP-based statements on a 5-point Likert scale ranging from strongly disagree to strongly agree. The statements were: “People are severely abusing the environment”, “Nature is strong enough to cope with the impacts of modern industrial nations”, “The earth is like a spaceship with limited room and resources”, “If things continue on their present course, we will soon experience a major ecological catastrophe”, and “The so-called ecological crisis facing us has been greatly exaggerated.” The statements “Nature is strong enough to cope with the impacts of modern industry” and “The ecological crisis is greatly exaggerated” were reversed so that all items had the same meaning of higher value in response indicated a higher pro environmental viewpoint.

Our NEP variable was constructed using confirmatory factor analysis to combine the survey items into a standardized z-factor score. We conducted the factor analysis in R using the base values from the survey instructing it to have a single output and use the varimax rotation with the correlation matrix. The factor developed met the needed reliability statistics for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure indicated adequate sampling adequacy for a distinct reliable factor with KMO values above 0.70 (Kaiser, 1974), demonstrated strong internal consistency with Cronbach’s alpha values exceeding 0.70 (Cronbach, 1951), and an associated eigenvalues the retained factor greater than 1 in absolute value (Kaiser, 1974). The factor score was z-standardized for use in defining the NEP variables in our model.

3.4.4 Household Demographics

We asked about and used information relating to the respondent’s household demographics to help control for differences across population segments in the study region. Demographic variables included respondents age, state of residence, and if they resided in a non-metropolitan statistical area (MSA). We constructed the MSA variable to be a binary with 1 being in a non MSA zone and 0 being in an MSA zone, to represent rural and urban residence. We also constructed binary variables for the race and ethnicity variables used in the model.

3.4.5 Household Characteristics

We asked about household characteristics in the survey and constructed variables to help account for factors at a household level rather than just the respondent. Here we made binary variables capturing if the respondent rented or owned their residence with a 1 representing them renting and 0 owning. We constructed a binary for building type, where 1 represents the building being an apartment, condo town home, or mobile home and a value of 0 represents a single detached home or other response.

3.4.6 Energy situation

We asked questions relating to the energy situation of the household. We constructed two variables here: energy burden and level of energy insecurity. Energy burden was calculated as the ratio of a household's monthly electric bill of their monthly household income. We also created a binary variable indicating if a household is energy insecure. We used a set of questions adapted from the Residential Energy Consumption Survey (RECS), asking whether the household had trouble keeping up with bills, kept their home at an uncomfortable temperature to save money, or faced service shutoffs. Based on how many of these challenges were reported and how severe they were, we created a summary index. For our model, we use a simplified version of this index, a binary variable that equals 1 if the household was classified as being "vulnerable" or "in crisis", and 0 otherwise (U.S. Department of Health and Human Services. 2003)

3.5 Survey Sample Representativeness

To see how representative our survey sample was to the actual population, we compared some of our demographic variables to the most recent American Community Survey (ACS) across the study region. Across all measures, our sample does differ in some respects to the ACS averages. For our age variable, the average respondent in our survey was 52.37 years old, while the ACS average was 47.46 years old, showing that older individuals were more often represented in our sample on average. For household income, the average in the sample was $71,750, which is lower than the ACS average of $83,245. Race and ethnicity showed some of the largest differences. According to the ACS, 37% of the population in our area of study identifies as non-white, while only 11% of our sample did. For our variable assessing if a respondent is Hispanic or Latino, 30% of the population is Hispanic or Latino in the ACS average, compared to just 9% in our survey. The findings from this study should be interpreted with these differences in mind.

3.6 Willingness to pay model

Our willingness to pay model for community solar participation incorporates the Value-Belief-Norm (VBN) framework and energy situation as unique factors to assess households' willingness to participate in and pay for a community solar project. The VBN framework lays out the connection from personal values that influence ecological worldview, that then forms the attitudes and willingness to engage in pro-environmental behavior, such as participating in a community solar program.

$$WTP_i * = \beta^0 + \beta_V \cdot Values_i + \beta_B \cdot Beliefs_i + \beta_{VB} (Values_i \times Beliefs_i) + \beta_D \cdot Demographics_i + \beta_H \cdot Housing_i + \beta_E \cdot Energy_i + \varepsilon_i$$

In this model we have *Values*, *Beliefs*, *Demographics*, *Housing*, and *Energy* representing our different vectors of explanatory variables (categories identified in Table 3.2) with the corresponding β vectors representing parameters to be estimated. $(Values_i \times Beliefs_i)$ represents a vector of interaction terms between our values and our beliefs to capture the indirect effect of values as moderated by beliefs (Sanderson et al., 2017; Wolske, et al., 2017). Given that the dependent variable is defined as censored intervals, we estimate the WTP model using an interval censored regression, which is based on a survival regression model assuming an underlying Gaussian distribution. This is a common approach adopted for modeling MBDC type data as shown by Vossler et al. (2003), who used interval-censored regression to estimate willingness to pay from discrete-choice CV responses. Given the large number of intervals used, we interpret the model similarly to a linear regression, with the coefficients representing marginal impacts of our explanatory variables (when they enter linearly) on WTP. That is, for each coefficient on a explanatory variable that enters linearly, that coefficient represents the marginal effects of a 1-unit increase of that explanatory variable on the WTP for participating in a community solar program. For variables with interactions, the marginal effect is represented calculates as $\partial WTP/_{\partial X}$, where *X* is the explanatory variable of interest. We estimated the model as an interval regression using the survreg function from the survival package in R assuming a Gaussian distribution (Therneau, 2023).

We estimated the average WTP to participate in the community solar program across households as the average of the predicted values from the regression. The asymptotic standard error for the average WTP was estimated using a bootstrap approach in R. We generated 500 pseudo-random bootstrap resamples with replacement from our cleaned and filtered dataset. For each resample a model was estimated and the average WTP estimated. The standard error for our WTP estimate is the standard deviation of the average WTP across the bootstrap resamples.

To examine differences between rural and urban households, identified using MSA and Non-MSA counties, we split our dataset into MSA and non-MSA households. We estimated models and average WTP for each subsample. This allowed us to examine differences between urban and more rural households and see what variables were more influential on willingness to pay to participate in a community solar program.

Chapter 4 - Results

This chapter will present the results from estimation of our willingness-to-pay (WTP) model. We present and compare the results between metropolitan statistical area (MSAs) and non-MSA households, as well. Finally, we examine if WTP estimates are influenced by solar perceptions.

4.1 WTP Model Estimations Results

Table 4.1 provides the model estimation results for the interval regression WTP model. We present average WTP across households and then discuss the results for each category of variables.

Table 4-1 Interval Regression WTP Model Results

Category	Variable	Coefficient	Std. Error	p-value
Values	Human Altruism***	3.954	1.112	0.00038
	Nature Altruism*	2.214	1.138	0.0517
	Self Interest***	2.802	0.826	0.00069
	Traditionalism***	-2.430	0.852	0.0043
	Openness to Change*	1.530	0.845	0.07009
Beliefs	NEP***	4.807	0.931	2.42E-07
Values & Beliefs Interaction	NEP : Human Altruism	0.459	0.878	0.6005
	NEP : Nature Altruism	0.588	0.912	0.518
	NEP : Self Interest**	-1.488	0.756	0.0492
	NEP : Traditionalism***	1.943	0.701	0.00561
	NEP : Openness to Change	-0.084	0.744	0.909
Demographics	Age	0.085	0.054	0.115
	Income	8.3E-07	1.85E-05	0.964
	College Education***	4.781	1.692	0.00473
	Non-MSA***	-8.860	2.960	0.00277
	Hispanic Latino	-0.354	2.593	0.8912
	Non-white***	-6.986	2.435	0.00412
	TX	2.546	3.155	0.420
	KS**	7.188	3.302	0.0294
	OK	3.373	3.341	0.313
	NE	5.739	3.567	0.108
	CO	1.484	3.572	0.678
Household Characteristics	Female headed	-1.663	1.633	0.309
	Household size***	1.450	0.405	0.000345
	House structure*	2.923	1.761	0.0969

	Rent	1.417	2.067	0.493
Energy Situation	Energy burden***	-31.783	11.934	0.00774
	Energy insecure	2.434	3.119	0.435
	Heat electric**	3.699	1.553	0.0172
	Bill paid by else*	7.0106	4.185	0.0939
	Intercept***	-18.355	5.861	0.00174
	Log(Scale)	3.634	0.0162	-

Fit Statistics	
Log Likelihood	-7494.124
AIC	15052.248
N	2910

Note: *** , ** an * indicate statistical significance at the 1, 5 and 10 percent levels

4.1.1 Willingness-to-Pay (WTP)

Figure 4.1 shows the distribution of predicted WTP across respondents for the community solar program in the MBDC survey question. Based on these estimates, we estimated an average willingness to pay of -$1.544 with an asymptotic bootstrapped standard error of $0.015 for the hypothetical community solar program. That is, respondents would need to save on average $1.54 on their monthly electric bill to participate in the program. Figure 4.1 shows the variation in WTP, with most of the mass below zero, suggesting households would more often require a reduction in their electric bill to participate.

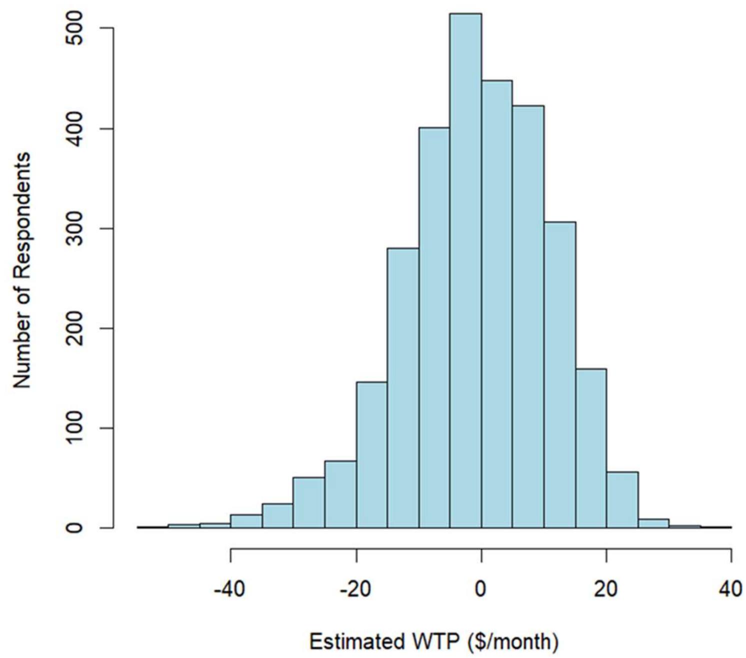

Figure 4-1 Histogram of WTP for a Community Solar Program (N=2910)

4.1.2 Values and Beliefs

Four of the values were significant at a 5% level of significance. Human altruism, altruism toward nature (biospheric altruism), self-interest , and openness to change all had a statistically significant positive influence on WTP.[5] That is, higher levels of human altruism, nature altruism, self-interest, and openness to change resulted directly in a higher willingness to pay for the community solar program on the margin. These findings still hold when considering interactions between values and NEP. The interactions between Human altruism, altruism toward nature (biospheric altruism), and openness to change were all statistically insignificant, suggesting only a direct effect of these values on WTP. The interaction between self-interest and NEP was statistically significant and negative. That is, NEP mitigates the effects of self-interest, assuming a one-way causal relationship suggested in the literature (Sanderson et al., 2017). For a given level of NEP, the interaction suggests that those with high self-interest had an overall reduced effect when mitigated by NEP and those with lower values of self-interest (negative) had

[5] We do not interpret the magnitudes of the coefficient estimates on WTP, given they are factor indices. A potential way to assess the magnitude would be to estimate the elasticity of a factor with respect to WTP.

a stronger overall marginal effect from lower self-interest on WTP. The interaction between NEP and self-interest shows that pro environmental beliefs may not positively interact with values that motivate personal gain. Our result for self-interest being positive does not align with the findings in Wolske et al. (2017) or the expectations of Stern et al. (1999). The results for human altruism, nature altruism (biospheric altruism), and openness to change align with our expectations and prior literature. Both Wolske et al. (2017) and Stern et al. (1999) find a strong positive relationship with human altruism and willingness to support solar and pro-environmental efforts. Results for openness to change are contrary to findings in Wolske et al. (2017) but agree with Stern et al. (1999) who found a positive relationship with pro-environmental behavior. Traditionalism had a statistically significant negative marginal effect on WTP. This shows that traditionalism is significant and higher levels lead to a lower willingness to pay for community solar. Furthermore, the interaction between traditionalism and NEP was positive and statistically significant. For a given level of NEP, the interaction indicates that higher traditionalism (positive) tends toward having a relatively overall lower WTP on the margin. A lower traditionalism score (negative) tends to result in a likely overall higher WTP on the margin, though the effects in both cases can go the other direction, given the sign and magnitude of NEP. Fundamentally this may make sense, as having traditional values does not necessarily limit support for pro-environmental actions when paired with strong environmental beliefs. In our sample we see that respondents with high levels of both traditionalism and NEP showed a higher willingness to pay, meaning that ecological concern can work with the traditional values to drive pro environmental actions. Results align with previous literature, including Stern et al. (1999) and Wolske et al. (2017), both of which found traditional values have a negative relationship with solar adoption and pro-environmental behaviors.

NEP had a statistically significant and positive marginal impact on WTP. This finding suggests those with a more oriented environmental worldview have a higher willingness to pay for the hypothetical community solar program. This aligns with our expectations and findings from Wolske et al. (2017), who found NEP to be a strong and positive factor in interest in adopting solar technologies.

Overall, results from the values and beliefs provide evidence that the VBN framework can help to explain variation in willingness to pay and support for community solar. The linkages found between values and environmental beliefs to willingness to pay reinforces the conceptual framework laid out.

4.1.3 Energy situation

For a household's energy situation, we found that energy burden, having electric heating in the home, and relying on someone else to help cover your electric bill (e.g. an energy assistance program) had a statistically significant influence on WTP. A higher monthly electric bill relative to monthly household income (energy burden) tends to result in a reduction in WTP by respondents for a community solar program. This marginal effect (or coefficient estimate) though should be interpreted with caution. If energy burden is 1 then all of a respondent's monthly income would be devoted to their electric bill. In our sample, the mean energy burden was 0.05, meaning the marginal effect would be 0.05*$32 = $1.59. As a respondent's electric bill begins to require more of their monthly income, not being willing to pay for a green energy program may not be a consideration. In addition, small saving on their electric bill may not be enough to overcome any cost uncertainty of the program (as written into the question to be incentive compatible). Having someone else pay for the electric bill resulted in a positive $7.01 increase in WTP. Finally, for respondents with homes with electric heating were willing to pay $3.70 more for a community solar program.

4.1.4 Household Characteristics

Of the household characteristics, household size and structure were the only statistically significant effects. Household size had a positive relationship with willingness to pay. That is, for each additional person in the household, WTP increases by $1.45. Thus, larger households are more likely to participate in the community solar program. At the 10% significance level, household structure (i.e. living in a townhome, condo, apartment, or other non-single house structure) had a positive marginal effect of $2.92 on WTP. This may represent interest in a community solar program for households they may not be able to install traditional rooftop solar.

4.1.5 Demographics

Of the demographic variables, four were statistically significant. Respondents with someone in the household with a college education were willing to pay $4.79 more for the community solar program. Respondents in a non-MSA county (i.e. less than 50,000 population) were WTP -$8.86 less on the margin, suggesting that rural respondents may be less supportive or may perceive fewer benefits from participating in community solar. As mentioned in Chapter 2, this finding is interesting, as many of the community solar programs in non-MSA counties talked about are fully subscribed, but these programs may not be big enough to fully meet even existing demand. Respondents who designated themselves as a non-White household, were willing to pay $6.99 less for the community solar program. From the state indicators, Kansas respondents were significantly more willing to pay compared to the base group Iowa ($7.19).

4.2 WTP for Community Solar Between MSA and Non-MSA Counties

To look at how willingness to pay (WTP) may vary between urban and rural areas, we estimated the same regression model twice using the household data from Metropolitan Statistical Area (MSA) respondents for one model and data from non-MSA respondents for a second model. Table 4.2 shows the model results from both groups and Figure 4.2 shows the distribution of WTP across households predicted from each model. The average WTP of Non-MSA respondents was -1.99 and the average WTP of MSA respondents was -0.21.

Table 4-2 MSA and Non-MSA Interval WTP Regression Model Results

	MSA		**Non-MSA**	
Variable	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Values				
Human Altruism	4.454***	1.455	2.524	1.668
Nature Altruism	2.504*	1.465	2.348	1.778
Self Interest	4.348***	1.067	0.161	1.292
Traditionalism	-3.950***	1.0852	0.063	1.376
Openness to Change	1.24	1.090	2.421*	1.333
Beliefs				
NEP	4.229***	1.197	5.549***	1.472
Values and Beliefs Interactions				
NEP : Human Altruism	-0.104	1.126	1.351	1.440
NEP : Nature Altruism	1.876*	1.166	-1.81	1.483
NEP : Self Interest	-0.959	0.991	-2.400**	1.149
NEP : Traditionalism	1.308	0.890	3.463***	1.153
NEP : Openness to Change	0.006	0.969259	-0.18	1.145794
Demographics				
Age	0.084	0.069	0.079	0.086
Income	1.29E-06	2.19E-05	-2.88E-06	3.62E-05
College Education	2.938	2.151	7.283***	2.759

Non-white	-2.911	2.972	-15.787***	4.347
Hispanic Latino	1.37	2.990	-6.741	5.361
Household Characteristics				
Female Headed	-0.406	2.115	-4.450*	2.561
Household size	1.845***	0.514	0.268	0.661
House structure	2.714	2.286	3.64	2.806
Rent	-0.491	2.434	3.245	5.196
Energy Situation				
Energy burden	-21.37	16.648	-41.934**	17.433
Energy insecure	4.245	4.266	0.92	4.487
Heat electric	4.693**	2.002	1.894	2.437
Bill paid by else	9.177*	5.249	5.384	7.033
(Intercept)	-21.627***	7.367	-8.524	9.719
Log (Scale)	3.646	0.020285	3.592	0.026736
Fit Statistics				
Log-Likelihood		-4789.941		-2683.673
AIC		9643.882		5431.345
N		1861		1049

Note: *** , ** an * indicate statistical significance at the 1, 5 and 10 percent levels

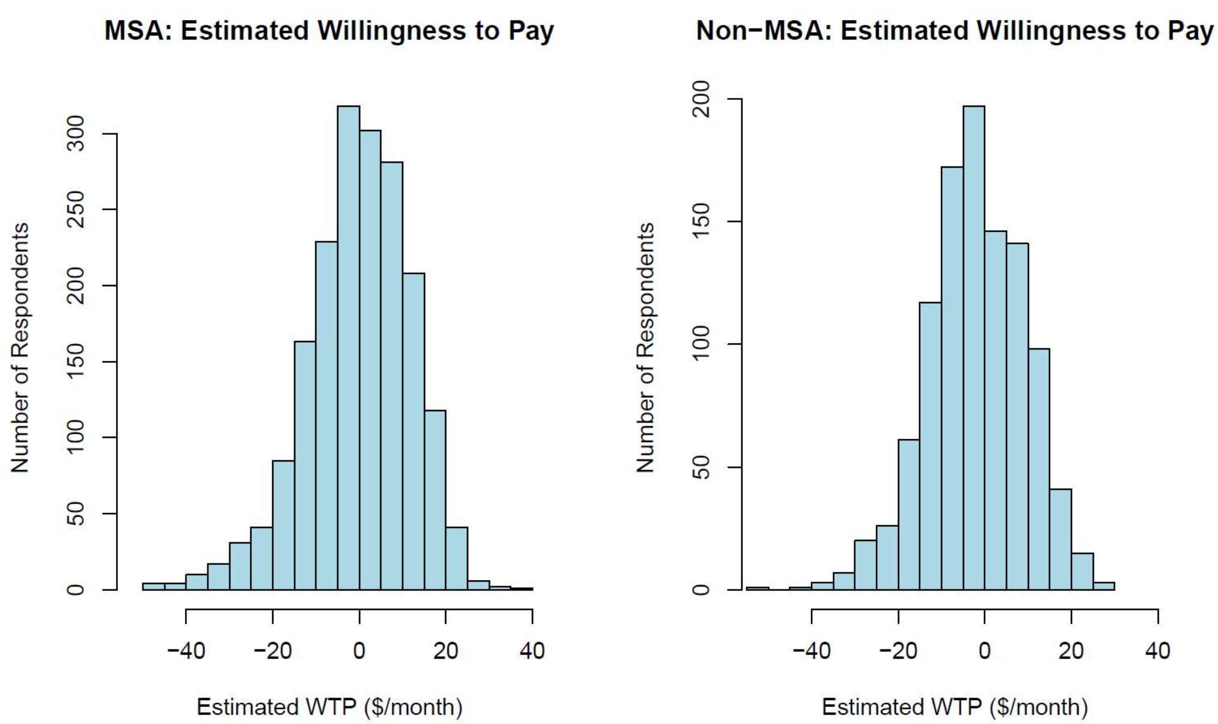

Figure 4-2 Histogram of WTP for MSA (N = 1861) and Non-MSA (N = 1049)

4.2.1 Values and Beliefs

In the MSA model, human altruism, nature altruism, self-interest, and traditionalism all show statistically significant effects on household WTP for community solar, like the full model. We see that higher levels of human altruism, nature altruism, self-interest, and openness to change resulted in a higher willingness to pay in MSA counties. Some of the biggest differences from the pooled model are that self-interest and traditionalism are both more impactful. Unlike the pooled model, the only significant interaction between beliefs (NEP) and values was NEP and nature altruism.

In our Non-MSA model most of the values are not significant. Only openness to change was significant at a 10% level of significance. All of the value's effects were lessened except for openness to change, where the effect was almost double that in the pooled model. Of the interaction terms, NEP interacting with self-interest and traditionalism were significant, but in opposite directions from the pooled model. These results show a positive impact from traditionalism interacting with NEP, meaning respondents with more pro-environmental beliefs were less likely to be influenced by traditionalist values.

The New Ecological Paradigm or NEP scale was highly significant in both models with impacts similar to the pooled model. Between the two models the non-MSA model showed a greater impact on the margin, suggesting that in more rural areas, pro-environmental beliefs lead to higher WTP for community solar programs.

4.2.2 Energy Situation

Variables looking into a household's energy situation show strong differences between MSA and non-MSA counties. In MSA counties, respondents using electric heating and having their bill paid by someone else were willing to pay more for community solar options. Similar to the pooled model, having electric heating is significant at the 5% level and having their bill paid by someone was significant at the 10% level. Energy burden was no longer significant in the MSA model.

From the Non-MSA model the only significant variable was energy burden at a 5% level of significance. This result may indicate that rural households with higher relative energy costs are significantly less willing to pay for community solar. Neither using electric heating or having their bill paid by someone else were significant in the non-MSA model.

These contrasts help us look at which parts of the overall model may be driven by regional effects. The significance of electric heating and bill support in MSAs and the dominant role of energy burden in non-MSA counties, suggest that urban and rural households prioritize different energy-related considerations when evaluating participation in renewable energy programs like community solar. It should be noted though that the marginal effect for energy burden in MSA counties, while not statistically significant, was still large and potentially economically meaningful.

4.2.3 Demographics

In the non-MSA model, having a college education was statistically significant and positive, with a larger effect than in the pooled model. In the MSA model, college education was not significant, but the direction of the effect remained positive.

Being a non-white household was significant and negative in the non-MSA model, with a larger magnitude than in either the MSA or pooled model. This may show that in rural areas, non-white respondents are less likely to support or have access to a community solar program. In the MSA model, the effect was still negative but not statistically significant.

The other demographic variables of age, income, and Hispanic/Latino, were not statistically significant in either model. This matches results from our pooled model and suggests that these factors may not play an influential role in willingness to pay for community solar.

4.2.4 Household Characteristics

Household-level characteristics also show differences between the two models. In the MSA model, household size was significant and positively related to WTP. This is similar to the pooled model for both significance and magnitude. In contrast, household size was not significant in the non-MSA model. For the non-MSA model being part of a female-headed household had a statistically significant and negative association with WTP. Other household-level characteristics, such as rent status and structure type, were not statistically significant in either model.

4.3 Solar Perceptions WTP

A final assessment of interest was the affect of solar perceptions and knowledge on willingness to pay based on how respondents answered a set of solar perception questions related to solar energy costs relative to fossil fuels, as well as impacts on property values and agricultural production. Table 4.3 provides estimates of the average WTP for solar perception/knowledge question across the different response types provided. As expected, respondents with greater knowledge that agree with the statements have higher WTP values for consumer solar than those that do not or disagree. The gap between respondents that already new and agreed with a statement and those that disagreed was around $9 for all of the questions.

Table 4-3 Solar Perception Questions with Average WTP for Community Solar

	The cost of energy produced from utility-scale solar projects has dropped significantly over the past two decades	**Solar power can be cheaper than power generated from coal**	**Solar power projects do not affect neighboring property values**	**Solar power projects would not significantly impact agricultural production in your area**
I already knew this	Avg=2.64 N=777	Avg=2 N=1538	Avg=3.68 N=722	Avg=3.04 N=836
I just learned this	Avg=0.22 N=896	Avg=-0.41 N=577	Avg=0.4 N=635	Avg=0.37 N=662
I do not know about this	Avg= -2.74 N=826	Avg= -4.81 N=391	Avg= -2.01 N=770	Avg= -2.44 N=727
I disagree with this	Avg= -6.81 N=263	Avg= -11.01 N=254	Avg= -5.06 N=635	Avg= -5.43 N=533
		Total N = 2,762		

Chapter 5 - Conclusion

5.1 Summary

The thesis aimed to estimate willingness to pay (WTP) and participate in a community solar program to understand what factors may influence support and participation in such programs in states across the Great Plains of the U.S. Community solar programs are a growing and potentially promising business model for solar in rural and urban communities. We hypothesized that social cognitive factors, like the Value-Belief-Norm (VBN) framework, and household energy situation would play a significant role. We collected primary survey data and estimated interval censored regression models from data on a hypothetical community solar choice task in the survey. We also examine the difference between urban and rural populations using MSAs and impact of solar perceptions and knowledge on WTP for community solar.

We found that values and beliefs, based on the VBN framework, were significant predictors and impacted respondents' willingness to pay and participate in a community solar program. We also found that values, such as self-interest and traditionalism, were mitigated by environmental worldviews, which also played a significant role. We found that demographic, household characteristics, and energy situation were significantly related to WTP, as well. These factors included having a college education, being in a non-MSA county, identifying as non-white, residing in Kansas, household size and structure type, level of energy burden, if their bill was paid by someone else, and if they used electric heating. Influential factors varied in MSA and non-MSA counties across the study region.

Some of our most interesting findings were the unexpected directions of the influence of some of the factors. We found that self-interest had a positive impact on our overall model, which was contrary to expectations, which may be a sign that energy independence may play a role in community solar adoption. Such findings may suggest that there are complex relations between values and beliefs across our area of study that could be further explored.

5.2 Policy & Program recommendations

The results from this thesis may have applications for both policymakers, power companies and solar providers. For solar providers, while the average estimated willingness to pay (WTP) was slightly negative, it was close to zero, and a substantial portion of respondents had a positive WTP. These results indicate that there exists a number of respondents in both urban and rural areas that are willing to pay to participate in a community solar program. That is, demand for such programs exists. These estimates may be used to establish a reasonable rate or charge that allows and encourages participation in community solar program based on projected impacts on consumers monthly energy bills in different regions and population segments. Solar providers can use these results to see if a community solar program would be viable in their area with their respective costs and value of energy. Additionally, providers can also use this information to identify high value potential markets and consider different marketing strategies for their consumers with altruistic and biospheric values compared to their consumers with egoistic & hedonic values. This in action may look like a solar provider targeting messaging for their community solar program by emphasizing the "green" aspects of the program and energy independence. Many of the community solar programs reviewed in Chapter 2 are currently at capacity, suggesting they could be expanded and brought into new areas. Additionally, using our split models between urban and rural, this study may offer insights that allow providers to tailor their program designs and marketing strategies to the characteristics and preferences of different regions, improving outreach and enrollment.

Policy makers can also use the results from this thesis to make more informed decisions about community solar programs. As programs may not be tied to profit but to access and equity, policy makers can use our model to understand the full range of WTP that may exist in a community. Since our model included variables that were used in Reames (2016) to describe more vulnerable groups. Policy makers may be able to better tailor situations to the community's specific makeup and needs. For respondents that had an estimated negative willingness to pay, our results may show the amount of assistance they would need in order to be willing to participate in a community solar program. The significant percentage of people with positive WTP values does indicate a demand for the programs, even if it increases their average monthly electric bill. The difference in willingness to pay for solar informed groups and solar misinformed can be a motivator for investment into educational initiatives for solar projects. This may allow for beneficial solar projects to be better accepted and benefit a wider range of consumers.

5.3 Limitations

Limitations to the study do exist. Data quality for online surveys is a challenge, as indicated by the number of surveys that were dropped due to potential quality issues and not meeting established quality criteria. In addition, we did not fully take care of the uncertainty built into the question format but do suggest ways to improve model estimation and capture such uncertainty in the future. Without the inclusion of more specific beliefs, as well as, personal/social norms in the VBN framework, we are not able to examine the linkage between values and beliefs with more specific beliefs and norms on behavior. This is an area for future research.

5.4 Future research

In the future, research could benefit from the inclusion of personal and social norms, providing the entire VBN framework. In addition, other social cognitive factors could be included, such as the theory of planned behavior and diffusion of innovation, following Wolske et al (2017). Including personal norms and social norms could help improve the model's ability to explain additional factors influencing WTP. Additionally, further research could include field studies in actual community solar programs and test our estimates with real world behavior.

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