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Public support for community microgrid services

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ABSTRACT

Utility-owned community microgrids can provide communities with decentralized grid access to distributed energy resources and improve reliability and resiliency. However, the feasibility of installing microgrids requires rigorous cost-benefit analysis, which should incorporate social values. Currently, the gap in our understanding of ratepayers' preferences for community microgrid services leaves stakeholders guessing. Using a survey-based contingent valuation method, with a referendum-style elicitation format, this paper provides evidence of public support for community microgrid installations in Arizona, Colorado, New Mexico, and Utah (the Four Corners). The Four Corners region is unique in its potential for renewable electricity capacity as well as heterogeneous state policy objectives regarding the transition to clean energy. A split-sample survey of 4783 Four Corner's ratepayers resulted in between 40 and 45% of respondents voting to support a community microgrid installation (after controlling for hypothetical bias) with a median willingness-to-pay (WTP) of $25.44 (divided among 24 months) if the ratepayer received direct benefits, or $13.92 if they received indirect benefits. Ratepayers in Utah were willing to pay the most relative to the other states. Results highlight the impacts of ideological, institutional, and socioeconomic factors on public support and WTP.

1. Introduction

Grid modernization efforts in the United States (US) stem from broader policy objectives to update, decentralize, and de-carbonize the electric grid. The American Society of Civil Engineers estimates that the current level of underinvestment in the electric grid will lead to nearly $3 trillion in total output being lost by 2039 (EBP US, 2020). However, there is considerable nuance in the implementation of technology capable of utilizing distributed energy resources (DERs) to increase their level of penetration, while also increasing the resiliency and reliability of power to the end user. Conceptually, microgrids allow for the use of intermittent DERs, and can operate either alongside or separate from the centralized electric grid. While microgrids are common in security or critical infrastructure cases such as military installations, laboratories, or university campuses, extensions are being realized for residential customers in tandem with critical infrastructure, which are referred to as community microgrids (Warneryd et al., 2020; Gui et al., 2017). While the exact definition of a community microgrid is still under debate, this paper adopts the perspective of Warneryd et al. (2020) where *'A community microgrid is technically a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries which acts as a single controllable entity with respect to the grid. A community microgrid can connect or disconnect from the grid to enable it to operate in both grid-connected or island-mode. Moreover, a community microgrid is connected with its community through physical placement and can be owned by said community or other part' (pg. 2)*. For the purpose of this article, I assume the community microgrid is under public utility control and operation – the most likely scenario in the US due to the lowest barrier of entry belonging to utilities who can easily take advantage of their existing infrastructure.

Community microgrids serve the end users with market and non-market benefits. Examples of market benefits include a lower cost of production for distributed energy generation, financial benefits from avoiding outages, or general returns on investment. Non-market benefits are more difficult to evaluate but could include the value of outage avoidance and the subsequent loss of agency for end users to continue with daily activities. These two types of benefits will be collectively referred to herein as microgrid services.[1] One pervasive difficulty associated with energy infrastructure, but more so with respect to the utility adoption of community microgrids, is the relative assessment of benefits and costs used for determining the feasibility of investments.

Community microgrids often include a utility partner as to utilize already existing infrastructure. With the inclusion of a utility partner, there is a direct link between ratepayers and the cost recovery of

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[1] For an exhaustive list of community microgrid goals and their benefits, see Gui et al. (2017).

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infrastructure investments. Therefore, it is imperative that the ratepayers' perspective is fully accounted for when determining the feasibility of a community microgrid installation. This includes fully accounting for both market and non-market values. Electric utilities commonly use the interruption cost estimate (ICE) framework to determine the economic cost of disruptions and the subsequent value of resilience investments, but previous literature finds that this framework is not adequate in measuring the full economic benefit (Mukhopadhyay and Hastak, 2016). While the ICE framework incorporates customers' willingness-to-pay (WTP) to avoid outages, damages are concave over the duration of the outage, they do not compound over the duration of the outage, and do not estimate the economic loss due to business disruptions. Critically, this approach treats all customers within their class homogenously when valuing resilience investments. In reality, customers' WTP will vary depending on the distance of the resilience investment to the customer and the level of benefits received from said investment. Yet a paucity of peer-reviewed evidence exists on ratepayers' support and WTP for community microgrid services in the US. While there is a guidebook for electric utilities to perform WTP studies in regards to estimating economic costs of outages and reliability upgrades (Sullivan et al., 2018), a gap remains in how to use WTP studies to measure community microgrid services specifically – especially when these microgrid services can be vague or difficult to quantify for customers.

To address this gap, the present article provides novel evidence for the public support and WTP for such community microgrid services in Arizona, Colorado, New Mexico and Utah (Four Corners). The Four Corners was chosen as the study region due to the heterogeneity across the four states in installed renewable generation capacity, distributed generation potential (Prăvălie et al., 2019), and regulatory frameworks such as renewable portfolio standards (RPS). The research question pursued is whether ratepayers in the Four Corners region support the installation of a community microgrid that passes along some level of costs to ratepayers in the form of an increased monthly surcharge, and how that support changes across different levels of microgrid services to the ratepayer. To answer this research question, the survey-based contingent valuation method (CVM) is employed, with a large split-sample web-based convenience survey of electric ratepayers across the Four Corners. The decision to utilize a CVM largely revolves around the market and non-market aspects of microgrid services that are otherwise difficult to determine with revealed preference techniques. The survey collected ratepayer characteristics on electricity use, electric provider relationship, ideology, household, and sociodemographics. With the use of a referendum-style elicitation format, and maximum likelihood econometric framework, median household WTP estimates are provided for determining overall support of community microgrid services across two levels of benefits to the ratepayer.

The resulting econometric findings suggest that ratepayers' support varies with the level of benefits received by the proposed microgrid installation. Those who are in the direct benefits sample are more likely to vote for a referendum, which would increase their electric bills by a surcharge for a microgrid that manages their local community and its critical infrastructure than those who are in the indirect group. Those in the indirect group were voting to install a microgrid in their provider's broader service region but not directly in their community. This two-benefit design highlights the ambiguity faced by ratepayers when considering their support for microgrid services since quantifiable results such as percent or likelihood changes to reliability and resilience metrics are not often possible or realistic. After controlling for hypothetical bias, respondents in the direct group have a total median WTP for the installation of $25.44 spread across 24 months of bill surcharge increases ($1.06 per month). Those in the indirect group had a total median WTP of $13.92 ($0.58 per month). This paper provides the consumer preference evidence for community microgrid services in the study region, an example of how CVM can be used by public utilities to better assess the value of microgrid services, and a critical evaluation that remains largely absent from the grid modernization literature.

The Four Corners includes electric providers that operate in different states, have different ownership structures (and thus different incentives), are subject to heterogeneous regulations, and service a wide range of customers. To further narrow differences in WTP across these sources of heterogeneity, analysis of state-specific WTP estimates are presented. Findings suggest that Arizona, Colorado, and New Mexico have similar median WTP estimates but Utah has significantly higher estimates. This emphasizes the need for electric utilities considering community microgrid services to conduct original surveys specific to their service region.

The rest of this paper is structured as follows: Section 2 provides background on community microgrid benefits, the changing regulatory climate that incentivizes community microgrids, and how utility decisions are made regarding resilience investments in the US. Section 3 provides an overview of the CVM and the survey instrument used in this study. Section 4 provides the results of the survey and finally, discussion of the results, policy implications, and conclusions are presented in Section 5.

2. Background

The use of microgrids to further decentralize electricity grids improves resiliency and reliability by mitigating the detrimental effects of natural disasters, cyber-attacks, intermittency, and peak demand (Hussain et al., 2019; Mishra et al., 2020; Zia et al., 2018). While the US has the largest global share of microgrid capacity, microgrid end-use varies widely from commercial, institutional, military, and community applications (Mordor Intelligence, 2021). The development of a microgrid is often the result of several confounding factors. Ajaz and Bernell (2021) performed a multi-level perspective analysis of California, New York, and Oregon, and found that several factors lead to policy changes that may result in the development and deployment of microgrids. They find landscape, regime change, and other state-specific dynamics to be catalysts for these policy changes. For California and New York, landscape pressures such as grid-impacting natural disasters offer a window of opportunity for policy change and can pave the way for microgrid development and adoption. While the article outlines factors which have contributed to microgrid adoption in those states, there is a lack of perspective on public/consumer-side demand for the systems and the associated financial cost to ratepayers.

Electric utilities are continuously entering the microgrid space at the community and public utility level given their ability to use existing distribution infrastructure and relationship to end-users (Lenhart and Araújo, 2021). When considering a community microgrid, utilities assess both private and social value when determining the feasibility of a microgrid installation. These values can be difficult to determine fully, without information about public preferences, due to the combination of market and non-market values associated with community microgrid services. Microgrids provide a number of services and are often associated with increases in reliability and resiliency, and it is well known that residential customers have a demand for them. For example, residential customers have expressed a range of positive WTP values for the avoidance of power outages, a commonly cited benefit of community microgrids (Carlsson and Martinsson, 2008; Morrissey et al., 2018; Hussain et al., 2019; Reichl et al., 2013; Kim et al., 2019; Niroomand and Jenkins, 2020). In a more general sense, contingent valuation literature also suggests that consumers are willing to pay for higher quality of service through grid improvements (Kennedy et al., 2019), green energy (Roe et al., 2001; Andor et al., 2018; Xie and Zhao, 2018; Ntanos et al., 2018), and backup generation (Baik et al., 2018). These contingent valuation studies provide generalized estimates of consumer WTP for resiliency and reliability upgrades but are not specific to microgrids as the mechanism for providing those benefits. This distinct difference creates a branch in the literature as microgrid services extend far beyond simple outage avoidance due to their physical presence in communities, ability to optimize DERs, and unique set of services supplied during grid stress events.

There are studies that investigate ratepayers' WTP for microgrid services in particular. Hotaling et al. (2021) assessed New York ratepayers' WTP for community microgrid services during an extended power outage. They find that WTP for community microgrid services was positive – even when the ratepayer was not receiving direct supply to their residence. This provides direct evidence of consumers WTP for microgrids that provide indirect benefits. The authors employed a discrete choice experiment to determine ratepayers' WTP for specific community microgrid services such as providing supply to hospitals, emergency services, potable water, etc. The paper focuses on WTP valuation for critical services but does not evaluate WTP for community microgrids outside of an outage event. The present paper differs by investigating ratepayers' WTP for community microgrids without the presence of an outage and contingent on whether the installation directly benefits them and their community or not. Graber et al. (2018) also used choice experiments to determine the WTP for rural solar-powered microgrid attributes in India. They find that WTP is most impacted by the amount of power generated by the microgrid, the reliability, and the price. They also find that satisfaction is higher for these rural microgrids than the electric grid itself. The two above studies employ discrete choice experiments to identify the WTP for attributes associated with community microgrids. The DCE approach is beneficial when the research question focuses on the specific attributes of community microgrids such as services following power outages, types of buildings being supplied critical load, type of DER penetration, etc. Each attribute receives its own WTP estimate. Since microgrids are engineered for their specific use case, the fuel mix, composition, and effectiveness of the microgrid is non-standardized. This vagueness most accurately reflects the decision-making problem faced by consumers. In the context of this paper, the goal is to estimate the support and WTP for a microgrid given two levels of consumer benefits. It is for these reasons the contingent valuation method (CVM) is used.

This paper aims to contribute evidence of public support for such services similar to Hotaling et al. (2021) and Graber et al. (2018), but uses a different elicitation format to evaluate the microgrid installation as a whole, and in a study region with different climate, income levels, and ideological and political views. The Four Corners is prone to grid destabilizing events. Burillo et al. (2016) predicts that rising average temperatures in Arizona will result in 30 times more power outages and a higher probability of cascading failures for each Celsius degree increase in ambient air temperature. The authors cite smart grid power flow controls as a potential mitigation tactic for these adverse effects from climate change. Fortunately, the Four Corners has "excellent" to "outstanding" levels of renewable electricity potential (Prăvălie et al., 2019), and a heterogeneous set of state-level policy directives regarding the future of renewable generation (National Conference of State Legislators, 2021). Each state has a widely different approach to renewable portfolio standards. These standards are self-enacted legal requirements that each state must fulfill by a deadline to produce a portion of their electricity from renewable sources. Arizona is requiring 15% of electric supply to be renewable by 2025. Colorado is 100% by 2050 for utilities serving 500,000 customers and more, New Mexico is requiring 100% by 2045, and Utah has a voluntary goal of 20% by 2025. As a result of these goals, generation capacity is expected to become more intermittent as solar and wind generation become more prevalent. Given the potential that community microgrids have in decentralizing the electric grid, allowing better access to distributed energy generation, and increasing reliability and resilience, it is imperative that research into the public demand for community microgrids be conducted to better inform utilities who are considering these investments.

3. Methods

To determine the economic value of community microgrids, a stated-preference survey was designed and deployed across the Four Corners from August 2020 to January 2021. The survey resulted in 4783 responses and was conducted using the web based Qualtrics XM™ platform and their accompanying research services. To elicit a representative sample of households, Qualtrics was supplied with fulfillment quotas based on census estimates for each state in the region. The state-specific quotas include population share, sex, age, race, Hispanic origin, household income level, urban/rural classification, and whether the respondent obtained a college degree. The census data came from the 2017 American Community Survey (ACS) 5-year estimates, except for the urban/rural classification coming from the 2010 Census (not asked during the ACS). Qualtrics filled quotas and rejected participants that did not meet remaining sample requirements. In the above categories, the sample matches the 2017 ACS estimates almost perfectly, with the sample being slightly more educated and of less Hispanic origin than found in the ACS estimates. The comparison between the sample and the ACS estimates can be seen in Table A1 in Appendix A. Fig. 1 shows the distribution of responses by county in the Four Corners region.

Respondents were asked a series of questions about their electricity use habits, relationship with their electric provider, general attitudes and preferences, ideology regarding electricity and politics, and various socioeconomic identifiers. The survey included a referendum-based valuation exercise to determine the general community-level preference and median willingness-to-pay (WTP) for microgrid services.

3.1. Valuation exercise

The valuation exercise is the focal point of this analysis. As part of the contingent scenario, survey respondents are given substantial information on community microgrids. Respondents are presented with information on the need for community microgrids, what a community microgrid is, benefits and costs of the microgrid, why their opinion matters, and finally, examples of community microgrids currently in use.

Respondents were then asked to participate in a closed-ended referendum style valuation exercise, the design of which follows previous literature (Boyle et al., 1985; Cameron and James, 1987; Carson et al., 1998). The referendum style elicitation format used in this paper is considered an incentive compatible approach to reducing hypothetical bias commonly associated with contingent valuation, but this survey is not entirely incentive compatible since the good being evaluated is excludable (Arrow et al., 1993; Johnston, 2006; Landry and List, 2007; Carson et al., 2004; Zawojska and Czajkowski, 2017; Champ et al., 2002). Respondents were initially asked a referendum style question on whether they would vote for the installation of a community microgrid by their electric provider, contingent on their level of benefits, at no cost to them:

> *Assume that your electric provider held a referendum style vote of its customers on whether to add a microgrid to your community at no upfront cost to you. If >50% of respondents vote yes, your electric provider would install this microgrid.*
> *Taking into consideration your desire for the microgrid installation, would you vote for the referendum to install the microgrids?*

Respondents were allowed to respond with a Yes, No, or Not Sure. Under the no cost to respondent scenario, adoption rates for the microgrid referendum reflected a majority, with 58.43% of respondents answering Yes, 16.35% saying No, and 25.22% saying they are not sure.

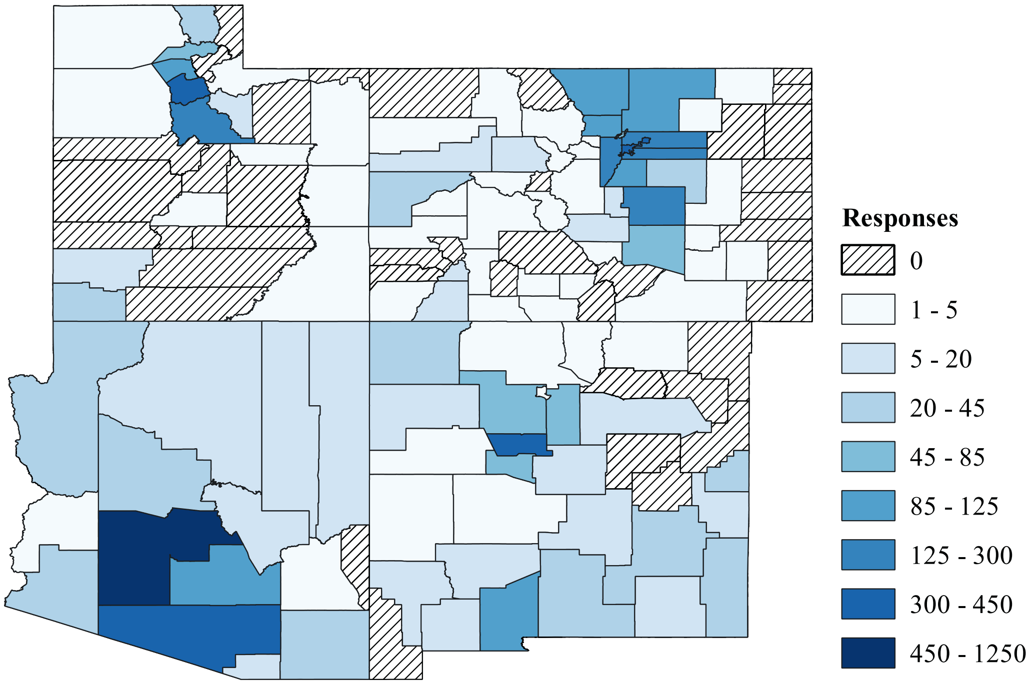

Fig. 1. Survey responses by county ($n = 4783$).

The follow-up to this question was a similar split-sample valuation exercise except the respondent was tasked with voting contingent on an increase to their baseline customer charge (surcharge) and some level of benefits provided by the microgrid on which they were voting. Respondents were separated into two categories – receiving direct or indirect benefits from the microgrid that they were voting on. Respondents who were presented with direct benefits were asked to "Assume that the electric provider guaranteed that the microgrid would directly benefit your community by providing electricity to the community and support for critical infrastructure during stress events". Those who were presented with indirect benefits were asked to "Assume that the electric provider stated that the microgrid would be installed in a nearby community, but in times of grid stress, this microgrid could reduce the probability of outages to your community". The difference between direct and indirect benefits is qualitative in nature as no numerical values are associated with improvements. This most reflects the reality of community microgrid installations as each installation will provide different levels of benefits depending on the underlying reliability and resilience of the respondent's local grid. This is referred to as a form of qualitative nesting that allows researchers to measure how WTP changes across levels of qualitative microgrid benefits (Carson and Mitchell, 1995).

As previously mentioned, respondents were presented with a randomly assigned increase to their electric bill that would manifest in their customer charge. These increases in the respondent's customer charge are based off the monthly average electricity bill in the Four-Corners. A respondent could see an increase to their electric bill ranging from $0.10 to $17. The average monthly electric bill in the Four-Corners is $86.97 based off the Electricity Information Administration's (EIA) Low-Income Energy Affordability Data Tool (LEAD Tool) as of 2020. Eight different payment levels were derived from an exponentially increasing percent of the average monthly electric bill and rounded to an even number for simplicity: 0.1% ($0.10), 0.5% ($0.50), 1% ($1), 3% ($3), 5% ($5), 10% ($9), 15% ($13), 20% ($17). The respondent was randomly assigned a payment level from a random discrete uniform distribution of these surcharge increases. Below is the valuation exercise respondents faced when contingent on costs and level of microgrid benefits received.

Now assume that your electric provider held a referendum style vote on whether to add a surcharge to your electricity bill for a duration of 2 years (24 billing cycles). This surcharge would pay for the installation of a microgrid. [Insert Level of Benefits]. If >50% of respondents vote yes, your electric provider would install this microgrid and increase your electric bill (the amount is listed in the question below).

Taking into consideration your desire for the microgrid installation as well as your current disposable income, would you vote for the referendum to install the microgrids if the electric provider added a surcharge of $[Assigned Payment] to your monthly electric bill for 24 billing cycles?

It is assumed there is a direct negative relationship between the amount a respondent is asked to pay and their likelihood to vote in favor of the referendum. This relationship is clearly presented in Table 1 which is the result of this public referendum by each payment level.

It is also common to experience upward hypothetical bias in regards to stated-preference questions, regardless of elicitation format (Little and Berrens, 2004; Li et al., 2009). A cheap talk script was used to remind the respondents of their disposable income and the potential for hypothetical bias in the survey (Cummings and Taylor, 1999; Penn and Hu, 2019). To help mitigate hypothetical bias, respondents were asked to rank their level of certainty in their valuation question response on a scale of 0 through 10. This numerical certainty scale is used widely as a method to mitigate hypothetical bias (Akter et al., 2008; Li and Mattsson, 1995; Morrison and Brown, 2009). Several recoding schemes were implemented in which Yes votes are recoded to No votes if they do not surpass certainty levels. The YES*X* scheme recodes Yes responses to No if the respondent reported a confidence below *X*%. For the purposes of this study, three different certainty thresholds were used, 60% as YES6 (Poe et al., 2002), 70% as YES7 (Ethier et al., 2000), and 80% as YES8 (Champ and Bishop, 2001). The voting behavior for these certainty thresholds is also included in Table 1.

From the voting behavior in Table 1, it is apparent that the percentage of respondents voting for the referendum declines as they are asked to pay more. This finding is consistent across the raw sample for the direct and indirect groups as well as their subsequent certainty recoding schemes. Additionally, the proportion of respondents who voted Yes in the direct group was consistently higher than their indirect

Table 1
Voting behavior by payment level and certainty recoding scheme.

	Indirect Group ($N = 2397$)				Direct Group ($N = 2385$)			
Payment Level	% Raw	YES6	YES7	YES8	% Raw	YES6	YES7	YES8
$0.01	0.64	0.49	0.46	0.36	0.66	0.54	0.44	0.36
$0.50	0.64	0.56	0.48	0.38	0.68	0.58	0.49	0.38
$1.00	0.63	0.53	0.47	0.37	0.69	0.59	0.53	0.42
$3.00	0.58	0.43	0.38	0.28	0.59	0.48	0.44	0.34
$5	0.48	0.39	0.34	0.26	0.59	0.47	0.40	0.31
$9	0.41	0.31	0.27	0.21	0.43	0.34	0.29	0.21
$13	0.38	0.29	0.26	0.19	0.39	0.29	0.26	0.18
$17	0.27	0.21	0.18	0.12	0.39	0.29	0.25	0.16
Total	0.50	0.40	0.35	0.27	0.55	0.45	0.39	0.30

Note: All figures are the percent who voted Yes. For each group (YES6, YES7, YES8, YES9), Yes responses were kept if they matched a certainty level of that number or higher, the rest were recoded as No responses.

group counterparts. To provide additional evidence of this, a Mann-Whitney Rank Sum test was used to determine whether the distribution of voting is same across both levels of benefits. The null hypothesis that the distribution is the same across both groups is rejected with a z-score of -3.021 (p-value of 0.0025).[2] This provides further evidence that voting behavior across the two groups is not statistically the same, and that further analysis is needed to determine whether the observed ratepayer characteristics influence voting behavior.

3.2. Determinants of participation and willingness-to-pay

Voting behavior is influenced by external factors other than the information provided in the valuation exercises. These external factors amass in the form of institutional and environmental perspectives, attitudes, and sociodemographics. An exhaustive list of observed characteristics used in this analysis are presented in summary statistic form in Table 2. There are several categories of observable characteristics that may impact voting behavior. A combination of electricity use, provider relationship, ideological, household, and sociodemographic characteristics were chosen carefully for this analysis to reduce the potential for correlation. Additionally, since the survey was conducted during the COVID-19 pandemic, a control for self-reported pandemic related income shocks is included as this may impact a respondent's disposable income, and thus their willingness to accept an increased financial burden.

Survey respondents where allowed a Not Sure response, but following the conventional and conservative approach of Carson et al. (1998), Not Sure responses are recoded to No responses. This limits the survey responses to a binary indicator of support for the referendum, where a respondent is either a Yes vote or a No or Not Sure vote. This dichotomous choice (DC) framework combined with the take it or leave it approach of presenting a single payment level makes the "closed-ended" contingent valuation (CECV) methodology of Cameron and James (1987) optimal. Respondents in support of the referendum are in essence willing to pay for microgrid services through surcharges on their electric bill. It is assumed that the underlying WTP function for these services is exponential as follows:

$$WTP_i = e^{x_i'\gamma + \sigma\varepsilon_i} \tag{1}$$

where a respondent's WTP for microgrid services is a function of a vector of their observable characteristics, $\boldsymbol{x}_i$, the associated parameter estimates, $\boldsymbol{\gamma}$, an unknown error term that is logistically distributed, ε_i, and a variance parameter, σ. Assuming an exponential form for the WTP function imposes a mathematical lower bound on the distribution of 0 which is consistent with the logic that a respondent who does not support the referendum has an implied WTP of $0. A latent class variable, Y_i, is implemented which is equal to 1 if the respondent voted for the referendum and 0 if else. The following probability statement outlines the decision process of voting subject to the natural log of the payment level that a respondent was randomly assigned and their underlying WTP function (Eq. 1).

$$Pr(Y_i = 1) = Pr(WTP > ln(t_i)) \tag{2}$$

The probability that a respondent votes in favor of the referendum is then determined by the probability that their WTP for the microgrid services is higher than the amount assigned to them. Assuming that the error term is logistically distributed with a mean of zero, Eq. 2 is expanded to include the cumulative density function and incorporated into a log-likelihood equation, which is used to calculate the maximum likelihood estimates via the Newton-Raphson method,

$$ln(\mathscr{L}) = \sum_{i=1}^{n} y_i ln\left(1 - \left(1 + exp\left(-\frac{\boldsymbol{x}_i'\boldsymbol{\gamma} - \beta t}{\sigma}\right)\right)^{-1}\right) + (1 - y_i) ln\left(\left(1 + exp\left(-\frac{\boldsymbol{x}_i'\boldsymbol{\gamma} - \beta t}{\sigma}\right)\right)^{-1}\right) \tag{3}$$

The inner product of $\left(-\frac{\beta t + x'\gamma}{\sigma}\right)$ can be rewritten as $-(t, x')\begin{bmatrix} -\beta/\sigma \\ \gamma/\sigma \end{bmatrix} = -z'\delta^*$. In this paper, the median WTP is estimated using $MD(WTP) = \exp\,[-\boldsymbol{z}'\boldsymbol{\delta}^*]$. Where $\boldsymbol{\delta}^*$ are the averages of the covariates. The median WTP is used to mitigate the skewness that may occur from fat tails and outliers and is consistent with the median voting hypothesis associated with the referendum voting format (Li et al., 2009). The median WTP estimates in this paper represent the median amount the average ratepayer is willing to pay for the microgrid services, irrespective of the level of benefits. In this study, it is important to measure the difference in median WTP across both the direct and indirect benefits group. To account for these differences, the sample is split among direct and indirect benefit groups and regressed separately.

[2] Additionally, a rank sum test was used to determine there is no statistical difference in the distribution of payment levels across the two groups of microgrid benefits, to ensure one group did not see systematically higher/lower payment levels than the other.

Table 2
Summary statistics for observable characteristics.

Variable	Description	Coding	Mean	S.D.
Electricity Use and Provider				
Tracking	How carefully a HH tracks electricity use	1 = Not carefully at all, 5 = Very carefully	3.33	1.19
Ownership Structure	Knowledge of ownership structure	0 = Does not know, 1 = Knows the ownership structure	0.46	0.5
Best Interest	Does respondent think provider has their best interests in mind	0 = No, 1 = Yes	0.51	0.5
Confidence	How confident respondent is that provider will make correct decisions	1 = Not at all confident, 5 = Completely confident	3.49	1.02
Outage Length	Length of most recent outage	Categorical, varying timesteps range from never having an outage to outage lasting more than a month	1.76	1.74
Attitudes and Preferences				
Importance of Supply	"It is important to have as much electricity as I need when I need it"	1 = Strongly disagree, 3 = Neither agree nor disagree, 5 = Strongly agree	3.98	0.98
Pollution	Concern for pollution from electricity generation	1 = Not at all concerned, 5 = Very Concerned	3.76	1.11
Ideological				
Political Ideology	Report political ideology	1 = Strongly liberal, 4 = Middle of the Road, 7 = Strongly Conservative	4.11	1.74
Household				
Average Bill	Average monthly summer electric bill	Incremental by $50. 1 = Less than $50, 3 = $100–$150, 6 = More than $250	3.56	1.88
Efficiency Upgrades	Ever made efficiency upgrades?	0 = No, 1 = Yes	0.53	0.5
Sociodemographic				
Income	Household income before taxes	Incremental, varying steps.	4.16	1.93
Covid Impact	Has HH income been affected by COVID	0 = No, 1 = Yes	0.43	0.49
Female	Respondent identifies as female	0 = No, 1 = Yes	0.51	0.49
Age	Age of respondent	Discrete: 18–93	46.84	17.8
Rural	Is household in rural environment?	0 = No, 1 = Yes	0.13	0.34

4. Results

4.1. Median WTP across the four corners

Table 3 provides the estimation of Eq. 3 and is presented as marginal effects evaluated at the Four-Corners means. The median WTP is estimated for each specification in the lower panel.[3,4] Monthly fixed effects are included to account for the duration of the data collection which encompassed holidays that impact disposable income.

In the case of this study, the non-recoded median WTP estimates contain an upward bias as they include respondents who are 50% certain and less – which can be debated as a not sure response since these respondents cannot be relied on to say Yes in a real-world referendum scenario. It is for this reason, that median WTP estimates in the YES6–8 recoding schemes are more reliable as noted earlier. For the recoded responses, the indirect group's monthly median WTP estimates range from $0.04–$0.58 depending on the certainty threshold (higher threshold correlating with a lower estimate). All of these indirect group estimates are statistically different from zero in their point estimates at the 95% confidence interval or higher. For the direct group, monthly median WTP estimates range from $0.03–$1.06 depending on the certainty threshold. More interestingly, as the certainty threshold increases, the gap between the indirect group and the direct group shrinks to becoming almost identical in their point estimates as seen in the YES7 and YES8 recoding schemes. This indicates that the more certain a respondent is, the less likely their response is driven by the variation in benefits and more so by unobserved factors.[5] Additionally, the extremely low point estimates for median WTP at high certainty thresholds may be driven by a correlation between a respondent's certainty and the payment level they were exposed to, as higher financial burdens are correlated with uncertainty (correlation coefficient between the payment level and certainty score is −0.0220). Additionally, it is possible that respondents who are confident in their answers may be voting ideologically rather than truly considering the valuation scenario. This phenomenon results in decreases in total program median WTP. For the non-recoded data, the total median WTP for the indirect group is $69.36 and the direct group is $141.84 over a two-year period. These results are significantly lower than those found in Hotaling et al. (2021) which find a mean WTP of $168.60 for the year for their most inclusive scenario which includes many critical infrastructure attributes. The difference between our results and theirs may be the result of the vagueness associated with the term "critical infrastructure" as part of the valuation exercise as well as differing sociodemographic and ideological characteristics. It is likely that specifying specific critical infrastructure components anchors the respondent to a higher WTP.

With the controlling of hypothetical bias, the total for the indirect group ranges from $0.96–$13.92 and $0.72–$25.44 for the direct group. There is no consensus in the literature on what the appropriate level of

[3] All regressions include monthly fixed effects and the variables listed in the summary statistics (Table 2). To measure the impact that adding various covariates may have on the regression, Table A2 in Appendix A shows four separate model specifications for the non-recoded data with stepwise integration of covariates. Point estimates are largely consistent across specifications and insensitive to the inclusion of additional covariates. The preferred model (specification 4 – all covariates) is used in Table 3 and the rest of the study.

[4] Median WTP estimates are sensitive to their assumed empirical distribution. The most common types are linear and exponential distributions. The linear distribution has an infinite lower and upper bound that allows for negative WTP. The exponential distribution restricts the lower bound to zero which aligns with the theoretical limit of the good being provided in this study. For completeness, both exponential and linear median WTP estimates using non-recoded data are calculated and presented in Table A3. Results indicate that the exponential model greatly decreases the median WTP amount. For the indirect group, median WTP ranges from $6.25–$6.34 in the linear model and $2.81–$2.88 in the exponential model depending on the number of included covariates. For the direct group, median WTP ranges from $8.75–$8.85 in the linear model and $5.87–$6.07 in the exponential model.

[5] It is possible that highly confident responses could be driven by ideological bias rather than the level of benefits presented to the respondent. In this case, it would be expected that the share of respondents who voted Yes would be similar between the benefit groups as the certainty recoding increases. Table 1 shows that for recoding scheme YES7 we see 35% and 39% for indirect and direct benefits respectively. For scheme YES8, we see 27% and 30% for indirect and direct benefits respectively. Given that there is a difference in the share of Yes votes between the direct and indirect benefits groups even at the higher tier, it is unlikely that ideological bias is the primary factor causing the price premiums to dissipate between benefit tiers.

Table 3
Logit and WTP estimation with certainty recoding.

	Non-Recoded		%60		%70		%80	
	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct
Logged Payment Level	−0.085***	−0.075***	−0.071***	−0.071***	−0.064***	−0.054***	−0.051***	−0.046***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
Income	0.025***	0.026***	0.022***	0.027***	0.015**	0.025***	0.009	0.017***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.006)	(0.006)
Tracking	0.015	0.000	0.016	0.004	0.010	0.015	0.013	0.024***
	(0.010)	(0.010)	(0.010)	(0.011)	(0.009)	(0.010)	(0.008)	(0.009)
Ownership Structure	0.078***	0.060**	0.023	0.013	0.033	−0.011	0.016	−0.026
	(0.025)	(0.024)	(0.024)	(0.025)	(0.023)	(0.024)	(0.020)	(0.021)
Best Interest	0.054**	0.062**	0.021	−0.007	0.004	−0.009	0.027	−0.029
	(0.027)	(0.026)	(0.026)	(0.027)	(0.025)	(0.026)	(0.022)	(0.023)
Confidence	0.043***	0.044***	0.071***	0.080***	0.067***	0.073***	0.043***	0.071***
	(0.013)	(0.013)	(0.013)	(0.014)	(0.013)	(0.013)	(0.011)	(0.012)
Outage Length	0.000	0.025***	0.001	0.020***	−0.004	0.012*	0.000	0.008
	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.006)	(0.006)
Importance of Supply	0.064***	0.090***	0.084***	0.117***	0.086***	0.121***	0.083***	0.108***
	(0.012)	(0.013)	(0.012)	(0.013)	(0.012)	(0.013)	(0.011)	(0.012)
Pollution Concern	0.062***	0.035***	0.067***	0.062***	0.061***	0.058***	0.055***	0.057***
	(0.012)	(0.011)	(0.012)	(0.012)	(0.011)	(0.011)	(0.010)	(0.010)
Political Ideology	−0.013*	−0.026***	−0.008	−0.028***	−0.004	−0.029***	−0.002	−0.009
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
Average Bill	−0.003	−0.005	−0.005	−0.006	−0.007	−0.009	−0.010*	−0.003
	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.005)	(0.006)
Efficiency Upgrades	0.055**	0.095***	0.011	0.067***	0.016	0.054**	0.017	0.045**
	(0.024)	(0.025)	(0.024)	(0.025)	(0.023)	(0.024)	(0.020)	(0.021)
COVID-19 Impact	0.048**	0.001	0.040*	−0.018	0.026	−0.002	0.008	0.010
	(0.024)	(0.025)	(0.024)	(0.025)	(0.023)	(0.024)	(0.020)	(0.021)
Female	−0.068***	−0.025	−0.055**	−0.041	−0.071***	−0.040	−0.053**	−0.049**
	(0.026)	(0.026)	(0.025)	(0.026)	(0.024)	(0.025)	(0.021)	(0.022)
Age	−0.003***	−0.004***	−0.001	−0.001	0.000	−0.000	0.000	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Rural	0.020	−0.023	0.055	−0.003	0.022	0.006	−0.015	−0.006
	(0.036)	(0.036)	(0.034)	(0.037)	(0.033)	(0.035)	(0.030)	(0.032)
Monthly Median WTP	2.89	5.91	0.58	1.06	0.24	0.24	0.04	0.03
Total Median WTP	69.36	141.84	13.92	25.44	5.76	5.76	0.96	0.72
[95% CI]	[2.20, 3.80]	[4.33, 8.48]	[0.36, 0.84]	[0.70, 1.50]	[0.12, 0.38]	[0.10, 0.42]	[0.01, 0.09]	[0.01, 0.07]
Observations	2349	2336	2349	2336	2349	2336	2349	2336
(−2*LL)	2684.16	2623.01	2606.00	2585.80	2519.22	2527.17	2255.52	2275.36

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All columns include monthly fixed effects. Point estimates presented here are marginal effects evaluated at the sample mean. WTP confidence intervals calculated using Krinsky-Robb method with 5000 repetitions.

certainty is for a valid WTP estimate (Akter et al., 2008). The results of this study indicate that the aggregation of a public's median WTP will always be subject to levels of uncertainty accounted for and levels of uncertainty recoding greatly affect the valuation to be used for benefit-cost analysis. For the remainder of this paper, the YES6 or 60% recoding scheme will represent the preferred specification. Additionally, using the preferred specification from Table 3, the predicted probabilities of a Yes vote is calculated and plotted against payment levels following Maddala (1983) and Rollins and Dumitras (2005) and is presented in Fig. 2. This graph indicates that the likelihood of voting in favor of the referendum is higher when respondents were faced with a lower payment level. Additionally, the difference between both groups is minimal at low payment levels but separates and declines substantially as the payment level increases.

An additional area of interest is in the point estimates of the covariates themselves for the preferred specification. The point estimates in Table 3 are presented as marginal effects evaluated at the sample means. Across both the direct and indirect groups, the natural log of the payment level is negatively associated with the likelihood of voting for this referendum. For each log-dollar of payment level from the mean that a respondent saw, their likelihood of participation decreased by 7.1%. Intuitively, this indicates that the more financial burden a customer is asked to accept, they are less likely to support the infrastructure investment, a sentiment which is mirrored in Fig. 2. Additionally, there is a positive relationship between a respondent's income and their likelihood to participate. The underlying mechanism is assumed to be a higher level of disposable income and a lower sensitivity to price increases. This may indicate that electric providers whose customers are above average in income are more likely to successfully gather support and the funds necessary for a community microgrid project. In this sample, increases in income category are associated with a 2.2–2.7% increase in the likelihood of voting in favor of the referendum. Given the limited increments a respondent could select their income level from, this magnitude is a relatively small part of predicting support, even at the highest level of income.[6]

Many consumer characteristics were also collected and used to control for the heterogeneity in perspectives across the sample (see Table 2 for descriptions). Only a handful of characteristics proved to be significant. In an attempt to elicit the impact of customer-provider relationship on the willingness to support the referendum, respondents were asked if they thought their provider had their best interests in mind. The point estimate was not statistically different from zero, but an additional question about the level of confidence the customer has in their providers financial and investment decisions had a large and statistically significant impact. Higher levels of reported confidence were associated with increases of 7.1–8.0% in the likelihood of supporting the referendum. This represents the importance of a positive customer-

[6] For example, the average income in the indirect sample is 4.125 (categorical scale, see summary statistics). Since there are eight possible income categories, a respondent who is in the highest category (more than $200,000) would be approximately 10% more likely to vote for the referendum than those with an average income.

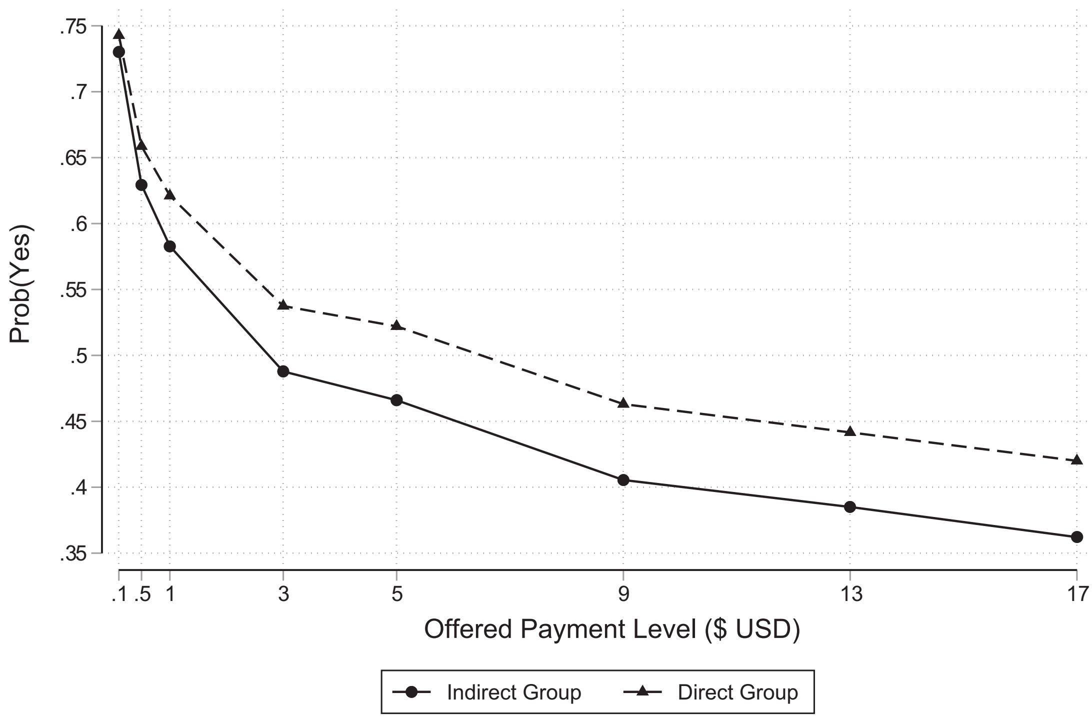

Fig. 2. Probability of a yes response by offered payment level (YES6 recoded).

provider relationship, specifically in infrastructure and business decisions, in garnering public support for community microgrid investment projects.

Respondents were also asked the duration of their most recent power outage. This proved to only be statistically different from zero for the direct benefits group. Respondents in the direct benefit group are 2% more likely to support the program for each increment above the average outage duration across the Four-Corners. Several ideological questions were asked as well. Respondents who more strongly desired adequate and sufficient on-demand electric supply are 8.4–11.7% more likely to support the program. Respondents who are more concerned with pollution from electricity supply are 6.2–6.7% more likely to support the program. This is an interesting finding because respondents were informed of the percentage of microgrids that are fully renewable which is less than a majority. This finding may be explained by the high level of renewable generation investment in the Four-Corners potentially causing respondents to automatically associated new infrastructure with renewables – note that respondents presented with the share of renewable only microgrids during the survey which at the time was estimated to be 20%. Finally, respondents were asked to report their political ideologies on a scale from liberal to conservative. With the Four-Corners average being middle of the road, conservative leaning respondents in the direct benefit group were 2.8% less likely to participate for each point away from the mean. This association may be due to aspects of fiscal conservatism associated with political conservatism.

Respondents who make efficiency upgrades to their homes may also be positively associated with support for programs as they are more conscious of energy use and investments. Respondents who made efficiency upgrades in the direct group are 6.7% more likely to support the program. Additionally, the survey was sent out during the COVID-19 pandemic. This pandemic has resulted in financial shocks to many households. In order to control for the impact of the pandemic on disposable income, respondents were asked if they have been negatively impacted financially by the pandemic. Those in the indirect group who had been were 4% more likely to vote for the referendum, but the mechanism is unclear. One theory may be that these respondents are home more often, and thus rely on electric reliability more. Females were 5.5% less likely to support the program, but the impact is only statistically different from zero in the indirect benefits group. This finding is antithetical to the finding in Li et al. (2009) which showed that being female was positively associated with energy research and development. Finally, there is no statistical evidence that respondents who considered their home rural had different likelihoods of supporting the program than those who are urban. While all of these characteristics are useful in predicting outcomes across the Four-Corners, policymakers and electric providers may find more value in a state-specific analysis.

4.2. WTP estimates by state

A median WTP estimate across the Four Corners is valuable for generalized assessments of microgrid services by region, but higher resolution estimates allow for more specialized use-cases and account for the significant heterogeneity that exists between the states in the Four Corners. The state in which a respondent resides can impact their WTP through several mechanisms. States governments differ in general attitudes towards electricity which can be quantified through realized and legislative actions or inactions. Table 4 shows how the Four Corners states differ on renewable portfolio standards, average price of electricity, average electric bill, solar and wind generation, and utility generation requirement opinions.

Table 4 defines the differences that exist between states. While New Mexico and Colorado lead in renewable portfolio standards, Arizona and Utah have small or non-legally binding objectives. Additionally, Arizona and Utah enjoy low-cost electricity in the residential sector, while Colorado and New Mexico ratepayers have higher costs per kWh. This is mitigated by the low monthly electric bills for Colorado, New Mexico, and Utah, while Arizona has the highest. This is likely the result of climate as Arizona is significantly hotter than the other states in the Four Corners. Additionally, Colorado and New Mexico lead the pack in power sector renewable energy consumption while Arizona and Utah trail behind significantly. Arizona, Colorado, and New Mexico residents have between 63 and 65% support for requiring utilities to produce 20% of their electricity from renewable sources while that number falls to 58% for Utah. Finally, Arizona and Colorado rank relatively high in terms of

Table 4
Sources of state heterogeneity.

State	Arizona	Colorado	New Mexico	Utah	Data Source
Renewable Portfolio Standards	15% by 2025	100% by 2050 for utilities of 100 k + customers	100% by 2045	20% by 2025 (voluntary)	National Conference of State Legislators [a]
Average Residential Price per kWh (Annual)	11.3 cents	14.15 cents	14.62 cents	9.99 cents	2019 EIA-861 Schedule 4A, 4D, and EIA-861S [b]
Average Electric Bill (monthly)	$126	$83	$80	$76	2019 EIA-861 [b]
Renewable Power Sector Consumption	10.40%	23.20%	22.50%	10.40%	EIA State Energy Profiles [c]
Support to require utilities to produce 20% of electricity from renewable sources	63%	65%	63%	58%	Yale Climate Opinion Survey [d]
Power Grid Reliability Ranking	2nd	11th	33rd	24th	US News and World Report, 2019 [e]

[a] https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx (accessed Sep 9, 2021).
[b] https://www.eia.gov/electricity/data/eia861/ (accessed Sep 9, 2021).
[c] https://www.eia.gov/beta/states/overview (accessed Sep 9, 2021).
[d] https://climatecommunication.yale.edu/visualizations-data/ycom-us/ (accessed Sep 9, 2021).
[e] https://www.usnews.com/news/best-states/rankings/infrastructure/energy (accessed Sep 9, 2021).

power grid reliability, which is the average number of minutes power outage resident's experience in the year, while New Mexico and Utah fall to the middle of the pack. These differences across states are a significant source of heterogeneity and the institutional repercussions of them may impact WTP estimates by state. Table 5 provides state-level median WTP estimates.

Voting behavior by for non-recoded responses has some variation across states. The indirect group of Arizona would miss passage of the referendum by 1% as well as the direct group of New Mexico. Given the small range in which the referendum does not pass, random variation cannot be ruled out. Most notably, the direct group of Utah overwhelmingly would pass the referendum with 60% of responses in favor. When recoding responses to control for hypothetical bias using the preferred recoding mechanism, these numbers fall. These numbers are used to estimate the median WTP estimates seen in the table.

Findings suggest a wide range of median WTP estimates across the states. For Arizona, the indirect benefits group has a monthly median WTP of $0.47 and the direct group $1.08. These results are very similar to the Four-Corners monthly averages of $0.58 and $1.06 respectively. In comparison, Colorado has very similar estimates of $0.46 and $1.01 per month for the indirect and direct groups respectively. It is logical that these two states have similar estimates as they consistently rank high in terms of power grid reliability (2nd and 11th). The value added of a community microgrid is arguably less salient in states with more reliability on average. New Mexico has a monthly median WTP estimate of $0.89 and $0.56 for the indirect and direct groups respectively. The direct group is less than the indirect group and it is unclear why (it is the only state to experience this difference). Utah has the highest median WTP figures of the four states, with $1.17 for the indirect group and $1.77 for the direct group. This figure is driven by the larger than average vote in favor rates of the direct group for the state.

5. Conclusions

Community microgrid services have the potential to mitigate power disruptions by adding resiliency and reliability to the electric grid. These nodes provide both market and non-market benefits to the electric provider as well as the end-user. For electric utilities considering community microgrids as an option, it is imperative they fully understand the public support and WTP for these microgrid services, so they can accurately assess the economic benefits from a microgrid installation. Given the paucity of literature on WTP for microgrid services in the US, this paper serves to provide evidence for a growing body of literature on the topic in a region that has not been previously studied and provide a framework for utilities to design original contingent valuation surveys. In the Four Corners, the ratepayers' WTP is dependent on the ideological, political, and socioeconomic characteristics of the rate base.

The main contribution of this paper is the median WTP estimates for community microgrid services and how they differ by the level of benefits to the ratepayer and the state the ratepayer lives. Across the Four-Corners, ratepayers have a median WTP of $25.44 ($1.06 per month for 24 months) for a community microgrid that provides direct benefits to them. This figure is reduced to $13.92 ($0.58 per month) if the microgrid in question is not installed in their community but on their electric grid at large.

There are limitations to the contingent valuation methodology, specifically that the results presented here are specific to the hypothetical microgrid services shown to the ratepayer. In this study, the community microgrid presented did not include statistics on the mix of storage, fossil fuel, or renewable capacity and was meant to be general in nature. This emphasizes the need for electric providers to survey their ratepayers regarding specific community microgrids being planned along with explicit information on location, type, benefits, etc. Since microgrids are typically engineered for each specific use case, a ratepayers WTP or support the installation are likely to shift depending on

Table 5
WTP estimates by respondent state of residency.

	Arizona		Colorado		New Mexico		Utah	
	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct
Median WTP	0.47	1.08	0.46	1.01	0.89	0.56	1.17	1.77
[95% CI]	0.25–0.78	0.62–1.80	0.23–0.82	0.54–1.80	0.35–2.08	0.19–1.42	0.52–2.45	0.74–3.98
Vote in Favor (Original)	49%	55%	50%	55%	53%	49%	53%	60%
Vote in Favor (Yes6)	39%	45%	40%	44%	43%	40%	43%	48%

Note: All regressions use the YES6 certainty recoding mechanism and all covariates. Estimates for each state use state level averages for covariates during the estimation procedure. The regressions include a dummy variable for Colorado, New Mexico, and Utah. Inclusion or exclusion of point estimates for these dummy variables are used to generate WTP estimates by state. Confidence intervals are calculated using the Krinsky-Robb method using 5000 repetitions. Marginal effects from each regression are presented in Appendix A, Table A4.

the unique characteristics of the proposed microgrid. For example, installations utilizing entirely renewable energy may command a higher WTP than those that use fossil fuels exclusively or a mixture of the two. Additionally, the level of direct benefits to the ratepayer had significant impacts on the median WTP, this may indicate that it is beneficial to segment the costs of the microgrid to those customer classes receiving direct benefits from its installation. From the work that is presented here, policymakers, regulators, and electric providers in the Four-Corners will be more informed on the baseline demand for community microgrids as well as the feasibility of such installations. Future work that stems from this study may include the difference in support and WTP for community microgrids with different generation sources, geographical distance to the ratepayer, level of microgrid tie-in, and ability to utilize distributed energy resources for shared local consumption.

Declaration of Competing Interest

The authors declare no known interests related to their submitted manuscript.

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Appendix A

Table A1
Survey representativeness.

Quota	Levels	Arizona		Colorado		New Mexico		Utah	
		Census	Sample	Census	Sample	Census	Sample	Census	Sample
Sex	Male	49.7%	49.2%	50.2%	49.1%	49.5%	44.3%	50.3%	48.7%
	Female	50.3%	49.9%	49.8%	50.5%	50.5%	55.0%	49.7%	50.6%
Age	18–34	30.6%	28.0%	32.0%	29.0%	30.5%	31.1%	37.7%	34.6%
	35–54	32.4%	33.4%	34.7%	36.1%	31.7%	34.5%	34.0%	36.2%
	55+	36.9%	38.7%	33.2%	34.9%	37.8%	34.4%	28.3%	29.2%
Race	White	80.5%	77.5%	87.3%	82.6%	76.9%	78.8%	89.4%	85.5%
	Black or African American	5.4%	5.8%	5.2%	5.0%	2.8%	3.4%	1.7%	2.0%
	American Indian or Alaska Native	5.6%	3.6%	2.1%	2.2%	10.7%	7.2%	1.7%	1.4%
	Asian	4.1%	8.1%	4.1%	7.8%	2.3%	4.4%	3.3%	5.3%
	Native Hawaiian or Other Pacific Islander	0.4%	1.7%	0.4%	0.7%	0.2%	0.8%	1.4%	2.7%
	Other	7.8%	8.3%	4.8%	5.2%	10.7%	9.8%	5.6%	5.3%
Hispanic	Hispanic or Latino	30.9%	19.6%	21.3%	17.1%	48.2%	32.4%	13.7%	10.9%
	Not Hispanic of Latino	69.1%	80.4%	78.7%	82.9%	51.2%	67.7%	86.3%	89.9%
Household Income	<50 K	38.3%	38.0%	38.1%	37.6%	53.0%	52.0%	36.7%	36.6%
	50 K–100 K	31.6%	31.6%	31.7%	31.7%	28.0%	27.0%	35.9%	35.5%
	>100 K	30.3%	30.5%	30.3%	30.7%	19.0%	21.0%	27.4%	27.8%
Rural	Urban	89.8%	89.9%	86.2%	86.0%	77.4%	75.3%	90.5%	90.5%
	Rural	10.2%	10.1%	13.8%	14.0%	22.6%	24.7%	9.5%	9.5%
Education	No College	52.2%	46.4%	52.2%	44.1%	64.9%	52.1%	57.9%	48.3%
	College	47.8%	53.6%	47.8%	55.9%	35.1%	47.9%	42.2%	51.8%

Note: The data in this chart is collected from the 2013–2017 American Community Survey 5-year estimates with the exception of the Rural/Urban interface which comes from the 2010 Census. Educational attainment is calculated at the population that are 25 years and older.

Table A2
Median WTP estimations for increasingly level of covariates.

	Spec. 1		Spec. 2		Spec. 3		Spec. 4	
Covariate	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct
Logged Payment Level	−0.077***	−0.067***	−0.081***	−0.070***	−0.085***	−0.074***	−0.085***	−0.075***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Income	0.029***	0.029***	0.023***	0.026***	0.020***	0.021***	0.025***	0.026***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Tracking			0.023**	0.008	0.013	−0.003	0.015	0.000
			(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Ownership Structure			0.074***	0.050**	0.082***	0.057**	0.078***	0.060**
			(0.023)	(0.023)	(0.024)	(0.024)	(0.025)	(0.024)
Best Interest			0.051**	0.058**	0.064**	0.072***	0.054**	0.062**
			(0.025)	(0.025)	(0.026)	(0.026)	(0.027)	(0.026)
Confidence			0.052***	0.050***	0.038***	0.041***	0.043***	0.044***
			(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Outage Length			0.002	0.027***	0.004	0.032***	0.000	0.025***
			(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Importance of Supply					0.059***	0.084***	0.064***	0.090***
					(0.012)	(0.012)	(0.012)	(0.013)
Pollution Concern					0.065***	0.038***	0.062***	0.035***
					(0.012)	(0.011)	(0.012)	(0.011)
Political Ideology					−0.015**	−0.030***	−0.013*	−0.026***

(*continued on next page*)

Table A2 (*continued*)

	Spec. 1		Spec. 2		Spec. 3		Spec. 4	
Covariate	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct
					(0.007)	(0.007)	(0.007)	(0.007)
Average Bill					−0.001	−0.001	−0.003	−0.005
					(0.006)	(0.006)	(0.006)	(0.006)
Efficiency Upgrades					0.042*	0.069***	0.055**	0.095***
					(0.024)	(0.024)	(0.024)	(0.025)
COVID-19 Impact							0.048**	0.001
							(0.024)	(0.025)
Female							−0.068***	−0.025
							(0.026)	(0.026)
Age							−0.003***	−0.004***
							(0.001)	(0.001)
Rural							0.020	−0.023
							(0.036)	(0.036)
Observations	2396	2385	2386	2371	2353	2340	2349	2336
Monthly Median WTP	2.87	5.98	2.84	6.06	2.9	5.87	2.89	5.91
Total Median WTP	68.88	143.52	68.16	145.44	69.6	140.88	69.36	141.81
[95% CI]	[2.06, 3.67]	[3.86, 8.10]	[2.07, 3.61]	[3.96, 8.16]	[2.13, 3.67]	[3.91, 7.84]	[2.12, 3.65]	[3.95, 7.86]

Note: Standard errors in parentheses. All point estimates are marginal effects evaluated at the mean. All columns include monthly fixed effects. All WTP Estimates are different from zero beyond the 99% confidence interval. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3
Median WTP estimates by assumed distribution.

	Spec. 1		Spec. 2		Spec. 3		Spec. 4	
Median WTP	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct
Linear Model	6.31***	8.76***	6.28***	8.84***	6.36***	8.75***	6.35***	8.76***
	(0.48)	(0.59)	(0.46)	(0.58)	(0.46)	(0.57)	(0.46)	(0.56)
Exponential Model	2.87***	5.98***	2.84***	6.06***	2.90***	5.87***	2.89***	5.91***
	(0.41)	(1.08)	(0.39)	(1.07)	(0.39)	(1.00)	(0.39)	(1.00)

Note: All specifications include monthly fixed effects. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4
Marginal effects from state heterogeneity analysis.

	Indirect	Direct
Logged Payment Level	−0.072***	−0.071***
	(0.007)	(0.007)
Income	0.022***	0.027***
	(0.007)	(0.007)
Ownership Structure	0.023	0.015
	(0.024)	(0.025)
Tracking	0.018*	0.004
	(0.010)	(0.011)
Best Interest	0.022	−0.007
	(0.026)	(0.027)
Confidence	0.072***	0.080***
	(0.013)	(0.014)
Outage Length	−0.001	0.020***
	(0.007)	(0.007)
Importance of Supply	0.084***	0.117***
	(0.012)	(0.013)
Pollution Concern	0.067***	0.062***
	(0.012)	(0.012)
Political Ideology	−0.009	−0.029***
	(0.007)	(0.007)
Average Bill	−0.003	−0.007
	(0.006)	(0.007)
Efficiency Upgrades	0.010	0.067***
	(0.024)	(0.025)
COVID-19 Impact	0.040*	−0.017
	(0.024)	(0.025)
Female	−0.057**	−0.039
	(0.025)	(0.026)
Age	−0.000	−0.001
	(0.001)	(0.001)
Rural	0.050	0.000
	(0.035)	(0.037)
Colorado	−0.007	−0.020
	(0.028)	(0.029)

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Table A4 (*continued*)

	Indirect	Direct
New Mexico	0.059	−0.027
	(0.040)	(0.042)
Utah	0.058*	0.008
	(0.034)	(0.036)
Observations	2349	2336

Note: Point estimates are presented as marginal effects evaluated at the four-corners means. Standard errors in parentheses. All regressions include monthly fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2022.106344.

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