Title
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Publication Date
2025-02-01

DOI
10.1016/j.erss.2024.103893

Energy Research & Social Science 120 (2025) 103893

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

What to expect when you're expecting engagement: Delivering procedural justice in large-scale solar energy deployment

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ARTICLE INFO

Keywords:
Energy justice
Procedural justice
Solar energy
Public perception
Community engagement
Scale

ABSTRACT

Community engagement in the planning process to build large-scale solar (LSS) projects can win local support and advance procedural justice. However, an understanding of community engagement in current LSS development is lacking. Using responses from a U.S. nationwide survey ($n = 979$) of residential neighbors living within 3 miles (4.8 km) of completed LSS projects (i.e. "solar neighbors") and project details from the U.S. Large-Scale Solar Photovoltaic Database (USPVDB), this study seeks to answer the following questions: How are solar neighbors' perceptions of community engagement associated with their attitudes toward their LSS projects? How do solar neighbors' perceptions of community engagement compare to their expectations? And, how do neighbors explain what they perceived about the planning process? We answer these questions using mixed methods, including regression modeling, a new gap analysis technique, and qualitative coding. We find that higher perceived engagement is associated with more positive attitudes toward the project, even when controlling for respondents who acted in opposition. Supporters and opponents alike expect more engagement than they perceived and information about projects both before construction and after operation is lacking. Awareness and engagement expectations increase at certain project size and proximity thresholds. However, most neighbors expect the public to offer input during engagement, but not make decisions. We contextualize these findings with explanatory comments from respondents.

1. Introduction

Rapid decarbonization of the global energy sector is necessary in avoiding worst case global warming and climate destabilization scenarios [1]. In the U.S., the Biden Administration has set a goal of decarbonizing the power sector by 2035 and achieving a net-zero economy by 2050 [2]. Most solar deployment in the coming decades, in terms of generating capacity, will come from large-scale solar (LSS) (defined as ground-mounted systems with a minimum of 1 MWdc installed capacity) [3]. At the end of 2023, LSS installations comprised 89 gigawatts (GW) (7 %) of overall installed capacity in the U.S. [4,5] and that amount is expected to grow to between 500 and 800 GW by 2050 [6].

Among the projected growth of LSS in the U.S. there is an ongoing debate about the appropriate role of community engagement in siting and permitting [7,8]. Resistance to LSS is growing as increasing numbers of counties and townships enact siting moratoria or restrictive ordinances which can slow or de facto ban LSS development [9,10]. Intending to speed up the process, some states have responded to this opposition by superseding local control of renewable energy siting decisions with state-level authority [11]. A recent report by the National Academy of Sciences acknowledges that no process is likely to convince the most strident opponents of renewable projects, however, it cautions that "shortcutting public engagement can lead to far longer delays" by alienating publics [12]. Beyond delay, favoring expediency over fairness in process can power imbalances and marginalization, replicating injustices embedded in the fossil fuel energy system [13,14].

Discussions about the appropriate role of community engagement in

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https://doi.org/10.1016/j.erss.2024.103893
Received 7 August 2024; Received in revised form 4 December 2024; Accepted 10 December 2024
Available online 20 December 2024

large-scale renewable energy development are not unique to the United States. Studies in Europe, Asia, Australia, and North America have repeatedly demonstrated the importance of process to positive community attitudes, lessened annoyance and overall acceptance of wind and solar developments [15–23]. Despite this research, an understanding of the current level of community engagement as perceived by neighbors of LSS projects is lacking.

Beyond its role in influencing the pace of LSS deployment, community engagement is an essential element of procedural justice in the energy transition. As the industry has reached meaningful penetration across the United States [24,25] and is poised for rapid growth, now is an opportune time to evaluate community engagement in existing projects through the lens of procedural justice. Toward this aim, we endeavor to answer the following research questions:

- What is the association between solar neighbors' perceptions of community engagement and their attitudes toward LSS projects in their communities?
- How do solar neighbors' perceptions of community engagement compare to their expectations?
- How are neighbors explaining what they perceived about the planning process?

The remainder of this paper is organized as follows. Section one continues with a review of the literature on procedural justice and renewable energy. Section two explains the quantitative and qualitative methods used to answer the three research questions. In section three we report the results for each research question. Section four includes a discussion of the results, limitations of this study, and policy implications. The paper concludes in section five.

1.1. Literature review

Energy justice is a concept which seeks to apply human rights to all phases of the energy lifecycle, from extraction to consumption to disposal [26]. The concept has grown to include five common principles: distributive, procedural, restorative, recognition and cosmopolitan justice [27]. Respectively, these principles are concerned with the fair distribution of energy benefits and burdens, how energy decisions are made, responding to past injustices, recognizing who is affected, and connecting these impacts across borders to encompass the entire energy lifecycle [27]. In the context of LSS, each principle plays a role, however procedural justice is often cited as one of the most important factors in the attitudes and acceptance of renewable energy host communities [20,22,23,28,29].

Procedural justice in renewable energy planning concerns access to information, opportunities to participate in the decision-making process, and an ability to affect outcomes [30–33]. These factors contribute to perceptions of whether the overall process was fair and the decisionmakers were trustworthy. Although in the energy justice literature articles featuring procedural justice are the most common among the five principles [27], metrics for procedural justice in energy decision making are comparatively underrepresented [34].

1.1.1. Procedural justice in renewable energy

Thirty years of research on wind energy have revealed the importance of resident perceptions of the siting process in determining acceptance and attitudes toward the project [35]. This has been demonstrated through early case studies of land-based wind energy development in Australia [15] and England, Wales and Denmark [16] and through later case studies of on-shore [36] and off-shore wind in the United States [37]. Factorial survey experiments reveal preferences for hypothetical projects that incorporate fair participation in planning in Germany and Poland [38]. U.S. state- [39], Canadian province- [17], and South Korean county-level [18] surveys of neighbors of completed wind projects suggest that perceptions of process fairness, including opportunities to impact decisions, are associated with more positive attitudes, community acceptance, and alleviated annoyance. This association has been further demonstrated through a U.S. national survey of wind neighbors [40].

Similar research on attitudes and acceptance of LSS is less common, though increasing. In the U.S., survey research has found generally favorable public attitudes toward *hypothetical* LSS development [41–43]. Local opposition at the project level, however, suggests LSS is prone to social acceptance gaps, similar to large-scale wind [44–46]. An early survey of residents in contact with an LSS system in Germany suggested procedural justice elements, such as transparency, access to information and opportunities to participate were important factors influencing acceptance [19]. More recent interview-based case studies of LSS in India [23], Mexico [20], Portugal [21], and the UK [22] further confirm the relationship between perceived procedural (in)justice and community acceptance of local projects.

In the U.S., research on the role of procedural justice and LSS acceptance is unfolding in the context of state-level policy changes which are alternatively supporting or limiting solar development. In Ohio, a 2021 state law gave counties the ability to create zones to exclude solar; a power that increasing numbers of counties are exercising [47]. At the same time, in New York, Illinois and Michigan, state laws intending to spur solar development limit local authority to approve or deny projects. Nilson and Stedman (2023) showed via a survey of residents in a region of upstate New York experiencing significant LSS development that perceived distributional and procedural injustices were significant factors contributing to opposition [48]. Nilson and Stedman situate these perceived injustices in the context of *rural burden*, the concept that rural people and places are unfairly obligated to provide renewable energy to support increasing urban demand. Anderson and Johnson (2024) explore rural burden and justice through the implementation of recent energy transition legislation in Illinois. The legislation, which frames reduced local participation in energy decision-making as a necessity for speeding decarbonization and advancing environmental justice for urban communities, may increase procedural injustice for rural communities forced to accept renewable development [49].

It is in this context of shifting state-level policy landscapes and increased federal support for renewable development that an evaluation of procedural justice through a nationally representative survey of LSS neighbors is so critical. Our survey and its approach to evaluating procedural justice is informed by previous studies yet breaks ground in many ways. The three most related studies, Walker and Baxter (2017), Firestone et al. (2018), and Nilson and Stedman (2023), each use a survey to evaluate perceptions of the process through commonly accepted elements of procedural justice such as access to information, opportunity to participate, and ability to affect the outcome [33]. To answer our first research question we develop an index of community engagement consisting of similar variables, and like Firestone et al. (2018) we emphasize participants who were aware of the project prior to construction [40]. Our study is set apart from Nilson and Stedman (2023) and Walker and Baxter (2017) by the scope of our sample (national versus state or province) and from Firestone et al. by the renewable energy system (solar versus wind). Our second and third research questions further differentiate this study by providing additional metrics from which to evaluate procedural justice.

1.1.2. Public participation

For our second research question, we operationalize procedural justice through respondent perceptions and expectations on a scale of overall community engagement. The theoretical underpinnings of this linkage date to Arnstein's "Ladder of Citizen Participation" [50]. The now famous ladder has been modified for many different planning contexts in the 55 years since its publication, including direct applications for community energy planning (González, 2020; Ross & Day, 2022) and evaluations of LSS developer engagement practices [10].

Underpinning these measures of engagement is the idea that as one moves from the more basic forms of engagement (merely informing the public) to power sharing (collaboration or decision making) more just procedural outcomes will ensue.

The longevity of Arnstein's ladder is a testament to its ability to denounce faux forms of engagement, but it is not without critique. The ladder oversimplifies power, overlooking instances where engagement does not achieve formal decision-making, but can yet influence outcomes [53]. Engagement in planning can involve formal and informal policy-making, influenced by formal and informal powers [54]. Moreover, decision-making can and should occur at multiple stages throughout a planning process [53,55]. This underscores the challenge of establishing metrics of procedural justice as outcomes of engagement can be highly context dependent [34]. Engaging multiple metrics as we do in this study of procedural justice is one way to mitigate the challenges of context dependency.

1.1.3. Gap analysis

We employ the scales of perceived and expected community engagement in a gap analysis approach as a novel procedural justice metric. Gap analysis is a process by which respondents' expectations (beliefs about what they think should happen) are measured against their perceived experience[2] (beliefs about what they understand has happened) [56]. This conceptual mode, established within the service management literature by [57], has been replicated to assess quality in airline service [58], banking [59], medicine [60], and retail shopping [61]. Experiences of community engagement are comparable to experiences of service in that they can be subjective and highly context dependent. Thus, a measure of the distance between respondent *perceptions* and *expectations* of engagement can provide an additional understanding of procedural justice.

1.1.4. Qualitative data

While our gap analysis allows for a quasi-quantitative comparison of process experience and expectation, Simcock (2016) used a similar comparative frame though strictly qualitative, involving case study interviews of a community wind farm in the UK. These interviews validate the importance of comparing expectations of process with experiences when evaluating procedural justice [62]. The qualitative analysis of Simcock (2016), like the numerous interview-based case studies relating to large and community-scale renewables and procedural justice, contributes significant explanatory power [20–23,63,64]. The use of qualitative methods is essential to understand nuanced social interactions which arise in contentious energy projects [65,66]. Though it is impossible to replicate interviews with a paper-based survey, we provided extensive open-ended comment space to allow our respondents to provide additional explanation. These comments, coded for relevance to procedural justice, in combination with the project-level data and quantitative survey responses, constitute our third metric for procedural justice.

2. Methods

This study represents one part of a larger five-stage research program exploring various aspects of LSS development. The greater research program design is both an exploratory sequential and a convergent parallel design [67,68]. Qualitative methods involving case study interviews in the initial stages informed aspects of this project which involve a mix of quantitative and qualitative methods (exploratory sequential). At the same time, during survey collection and analysis, project level data and nationwide mapping of LSS projects was being collected and merged with our survey data (convergent parallel). Within this greater mixed-method context, our study is itself a mixed-method study employing explanatory sequential design (beginning with quantitative methods and explaining them through qualitative analysis). Through this balance of methods we have sought to avoid the marginalization of qualitative methods which can occur in mixed method studies that often overemphasize quantitative data [69]. The multiple mixed methods design not only adds rigor to the study, but is better able to address the complexity of real world energy challenges [70].

2.1. Sample design

For this study and in the survey "large-scale solar" (LSS) is defined as a commercial solar project with a minimum capacity of 1 MWdc. The stratified, random invited sample included 4846 residential addresses located within three miles (4.8 km) of one of 782 LSS projects completed in the years 2017 through 2021 (summary statistics available in Supplement 2). We intentionally oversampled residents near innovative site types (agrivoltaic or previously disturbed land projects), living within a ½ mile (0.8 km) of the projects, near the largest projects and in some U.S. regions. Oversampling was necessary to achieve sufficient statistical power to identify associations related to these variables. Where appropriate we apply analysis weights to undo the effect of the oversampling so that the results are representative of the population of residents within 3 miles (4.8 km) of LSS. Additional details about when we apply the analysis weights are available in Supplement 3.

2.2. Questionnaire design

Questions were adapted from existing surveys,[3] created to fill gaps in the literature[4] and targeted to themes identified through case studies interviews conducted in previous stages of this work[5] [63].

The questionnaire was designed to gather respondent perspectives on a specific LSS project nearest their home, not LSS in general. Moreover, some residents within the sample lived within 3 miles (4.8 km) of more than one LSS project. To ensure that respondents would answer based on their experience with the specific LSS project associated with their ID number, we included a map of the project and a label indicating its year of completion with the letter which accompanied the survey (see Fig. 1). The maps were prepared by staff at the United States Geological Survey (USGS) and optimized to include identifying landmarks, such as street names, near the project.

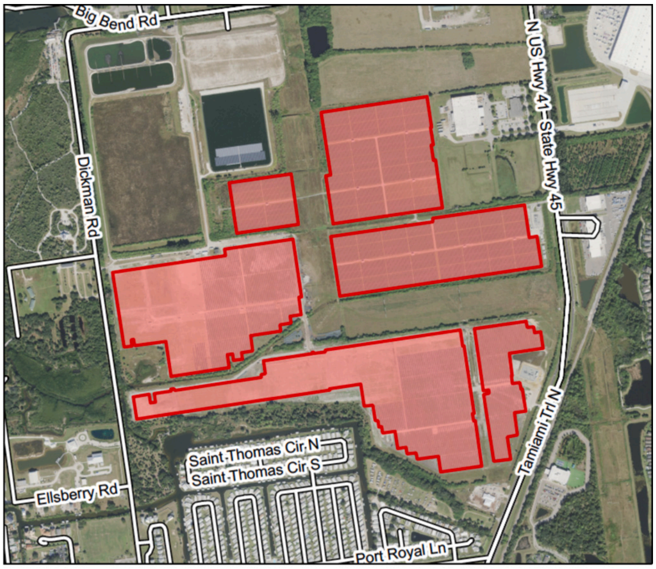
After the initial draft of the questionnaire had been reviewed by a technical advisory committee (TAC) and the University of Michigan Institute for Social Research (ISR) it was pretested with six residents living within 3 miles (4.8 km) of an LSS facility. These residents completed the surveys over the phone and were instructed to "think out

[2] We use the term "perceived experience" here as opposed to simply "experience" because we want to emphasize that respondent beliefs about what they understand has happened are subjective. That is, we are not comparing an expectation to a neutral observation, but rather an expectation to a perceived observation that could be interpreted differently by different parties.

[3] While the review gave emphasis to surveys examining renewable energy infrastructure, its scope included studies of fossil fuel infrastructure and public policy at the local and state level. For example, a question from a survey of local government officials about priorities in their community was adapted for our survey to ask respondents whether they 1. believe that the items listed should be priorities for their local government and 2. whether they perceived the LSS project to have helped or hindered those priorities.

[4] For example, to understand if respondents felt their community was bearing a disproportionate burden, they were asked whether they believed their community hosted more (less) than its fair share of energy infrastructure before (after) the LSS project was completed.

[5] Some case study interviewees expressed frustration about the electricity from the local project going to another state instead of meeting local needs. To test the generalizability of this sentiment, survey respondents were asked about their level of agreement with the statement "The power from future solar projects should be used in my community instead of another community."



Installation Year: 2017

Fig. 1. These maps, personalized for each respondent, were included on the backside of the letter accompanying the surveys mailed to potential respondents.

loud" so that the researchers could learn about respondent thought processes when interpreting the questions. An invitation, in Spanish, to take a Spanish translation of the survey was included at the bottom of the letter accompanying the survey for the final sample.[6]

2.3. Data collection

We followed Dillman et al.'s "Tailored Design Method" to increase response rates through carefully timed, frequent communication with sampled households [71]. Data collection began in April 2023 and continued through September 2023. Households were first sent a letter of introduction letting them know that a survey would be mailed in the next week. Next, they received the survey packet which included the survey letter with the accompanying map of the solar project near their home, the 12-page printed survey booklet, and a stamped return envelope. Affixed to the survey letter was a crisp $2 bill with a handwritten "thank you" label. To encourage a diverse representation in responses, households were instructed to have the adult with the most recent birthday complete the survey. A week after the survey packet was mailed, a reminder postcard was sent to the entire sample. A second reminder postcard was sent two weeks later to any households who had not yet responded. Both reminder postcards included a link to an online version of the survey. Finally, the largest subset of our sample received a fifth mailing which included a letter and a second copy of the paper questionnaire. Overall, we received 979 usable responses out of 4861 delivered invitations for a response rate of 20.5 % (see Table 1). A pdf of the full survey is available in Supplement 1.

2.4. Measures

To understand resident perceptions of what engagement occurred and how that engagement is associated with their attitudes about the project near their home, our study uses two unique and complementary measures of engagement: i) an index of community engagement comprised of ten Likert-scale questions about different aspects of the planning process and ii) an engagement scale in which respondents indicated the level of engagement they perceived to have occurred and the level of engagement they think should have occurred. A third set of measures, qualitative codes of open-ended comments, provide additional context to respondent perceptions of engagement.

[6] Only one household requested a survey in Spanish, however after receiving the link to the Spanish translation they did not submit a response. Spanish speakers may have been deterred by the fact that the invitation to request a Spanish translation of the survey was only included at the bottom of the survey letter. Perhaps in the future to appeal to more Spanish speakers that invitation should be moved to the top of the letter and/or included on all mailings.

Table 1
Overall response rate. Note: 90 % of full/usable responses were mail surveys; only 10 % responded via web survey.

Total invitations sent	4974
Undeliverable, ineligible	(−128)
Eligible invites	4846
Unusable partial completion (<50 %)[a]	30
Usable partial completion (50–80 %):	33
Full completion (>80 %)	946
Full + Usable Responses:	979
Response rate: sum/eligible	20.2 %

[a] Completeness was determined based on American Association for Public Opinion Research (AAPOR) Standard Definitions wherein, respondents who answered greater than or equal to 80 % of asked questions were considered complete, respondents who answered between 50 % and 79 % of asked questions were considered partially complete, and respondents who answered fewer than 50 % of asked questions were considered incomplete. The number of questions asked of each respondent depended on the skip logic involved. The fewest questions a respondent could be asked was 60 (if they didn't know the solar project existed) and the maximum number was 147 (if they participated in the planning process and were aware of the project prior to construction).

2.4.1. Measures for RQ1

Our first research question explores the association between community engagement and solar neighbors' attitudes toward their local project. We ran both ordered logit and linear (ordinary least squares) regressions with the index of community engagement as the explanatory variable. Both versions performed similarly and generated similar intuitions and outcomes. For ease of interpretation, we present only the linear regression results here but include the ordered logit results in Supplement 7. We report the results in two models: i) engagement and respondent-level controls, ii) engagement, respondent-, project- and community−/regional-level controls.

2.4.1.1. Dependent variable. Our dependent variable is the respondent's current attitude toward the project on the map. Respondents indicated their attitude on a 5-point Likert scale from "very negative (-2)" to "very positive (+2)."

2.4.1.2. Independent variables

2.4.1.2.1. An index of engagement. Participants who learned about the project near their home *prior to construction*[7] were asked about their perceptions of the planning process through a battery of ten questions (see Supplement 4) with a 5-point Likert scale from "strongly disagree (-2)" to "strongly agree [2]". Responses to these ten questions were combined into a single average engagement index. This new engagement index has a mean of −0.39, standard deviation of 0.82 and an

[7] Respondents who indicated that they learned about the project "after construction began," "once the project was operational," or "didn't know," were instructed to skip questions related to the planning process. Some of these respondents answered the planning questions anyway, but their responses have been removed from the models.

alpha of 0.93.[8] The fact that the mean value of the index is below 0 suggests an overall level of disapproval with the engagement that occurred during the planning process.

2.4.1.2.2. Respondent-level controls. We included a control to account for actions taken in the planning process. Respondents were first asked whether they had taken any of nine possible actions in the planning process (e.g. attended a public meeting, donated to groups active on the issue, signed a petition, etc.) Respondents who indicated they participated in at least one action were asked whether their actions were generally supportive, neutral, or opposed to the project. Our model includes three dichotomous control variables for the type of action taken: [1] actions in support vs. (0) no action, [1] neutral actions vs. (0) no action, and [1] actions in opposition vs. (0) no action. These controls allow us to understand if there is an association between increased engagement and attitude when controlling for the type of action (or lack thereof) a respondent took during the planning process.

We also controlled for whether the respondents owned or rented their home, attained a higher education degree (associates or more), and the distance from the respondent's home to the project in meters (min (9.3), max (4825.9), mean (1532.4)). In the model, we log transform the distance to account for the non-linearity of this variable. Additionally, we include controls for familiarity with the project (how often respondent sees it) in comparison to the reference "I see it nearly every day."

2.4.1.2.3. Project-level controls. In our second model we controlled for the size of the project with a log of the project area in square meters. Project areas varied from 8241 m^2 to 9,490,164 m^2. However, because smaller projects were more likely to be in urban centers with more nearby residents, the data was skewed toward smaller projects (see Supplement 5), so we use the log transformation of project area. We also controlled for the age of the project as of 2023. In so doing we found that project size and project age were confounding, so we included an interaction between project age and project size. This relationship is further illustrated in Fig. 3 in Section 3.1 below. Additional project level controls include a dichotomous variable for if the project was on previously disturbed land and two controls for two different types of agrivoltaic sites, environmental services or grazing, with non-agrivoltaic as the reference category.

2.4.1.2.4. Community-/region-level controls. Our second model also controls for if a community has been identified as a "disadvantaged community" as defined by the Justice40 initiative [72]. It also controls for the region of the country in which the project is located.

2.4.1.2.5. Control rationale. Some concern was raised over the potential for multicollinearity between the controls for action taken during the planning process and the dependent variable. That is, were controls for action taken during planning essentially measuring the same thing as a respondent's current attitude? However, there is only a modest correlation between the action control variable (including no action taken) and the dependent variable attitude (correlation = −0.33). Additionally, the controls for type of action allow for temporal distinction, differentiating, as do Rand and Hoen (2017), "support = during planning" from "attitude = after operation" [35].

We controlled for distance, project size, prior land cover, agrivoltaic type, and region to account for the oversampling employed on these variables. Comparable studies control for project size and respondent distance from the project as a measure of respondent familiarity [17,35,40]. While distance from the project is an objective measure, we also include self-reported familiarity to control for the visibility of the project to the respondent. Project age is also included in comparable studies [40] and is relevant for its ability to control for potential changes in respondent attitudes over time [39].

Our choices for demographic controls were influenced by the size of our sample. Because our model was limited to respondents who indicated they were aware of the project before construction our n (230) was one fourth of the total sample. Consequently, we were limited in the number of controls we could include. Some respondents skipped demographic questions such that inclusion of age, race/ethnicity, and income would each reduce the relatively small n of 230 by an additional 10–15 respondents. We include home ownership and higher education attainment because these controls did not reduce the size of the n. Supplement 6 contains tests of correlation for the control variables. Supplement 7 includes an additional OLS model with race/ethnicity, income and age for comparison to the model presented above.

2.4.2. Measures for RQ2

2.4.2.1. Direct perceptions of engagement. Two questions, not included in the index described above, ask respondents to rank engagement after thinking about the entire process. First, what they perceived *occurred* in the planning process "Which one of the following best describes the way members of the public were engaged in decisions about the solar project?" and second, what level of engagement they thought *should* occur, "In your opinion, which is the most appropriate way to engage members of the public in decisions about solar energy projects proposed in their community?" To make it clear to respondents that the answer choices represented a scale of engagement, an arrow between "no engagement" and "high engagement" was included above the five answer choices (see Fig. 2).

These two questions were developed to correspond to levels of citizen engagement originating from Arnstein's ladder and further contextualized in community energy planning [10,17,50–52]. In both questions, higher values relate to higher levels of perceived or desired engagement. Because Question 26, shown above, required knowledge of community engagement involved in decision-making for the project, it was only asked of respondents who indicated they knew about the project prior to construction and took some form of action during the process ($n = 78$). Question 27, which correspondingly asks respondents about their expectations of engagement, was asked of all respondents. Our results in Section 3.2 further compare expectations of respondents who acted during the planning process to expectations of respondents who took no action.

2.4.3. Measures for RQ3

For our third research question we use descriptive statistics from additional survey questions as well as text analysis of open field comments from the survey respondents. Our survey concluded with a blank page to allow participants to share any additional thoughts with the researchers. Additionally, some respondents included annotations alongside questions throughout the survey. Research staff cataloged each of these comments and annotations while redacting personal identifying information. In total 337 surveys included some form of additional comment, with some as short as a brief addendum to a question and others covering the whole back page and supplemental attachments. We used an initial set of themes informed by the literature to identify comments which specifically mentioned aspects of procedural justice. These themes included "access to information," "opportunity to engage," and "ability to affect outcome." These themes have been identified as common elements of procedural justice [33], linked to rungs of Arnstein's ladder in energy planning contexts [17,52], and used to comprise indices of procedural justice [40,48]. We also coded for comments which elaborated on the perceived level of engagement overall which further contextualize responses to the survey questions about perceptions and expectations of engagement in RQ2. Additional codes were added iteratively, as procedural justice comments were identified, and new themes emerged. These included references to the role of local, state and federal governments in the process and perceptions of local benefits. Two researchers from our team coded all

[8] A Cronbach's alpha coefficient of 0.93 is well above the range for acceptable reliability (Vaske, 2008). Respondents who answered six or fewer of the ten questions were dropped from the index.

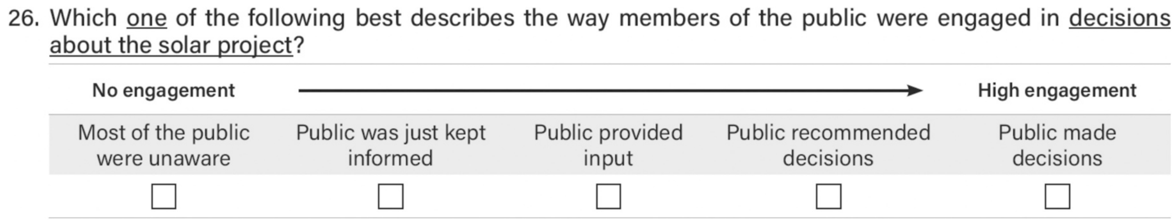


Fig. 2. One of two questions which asks respondents to directly rate how members of the public *were* engaged in the planning process or how they *should be* engaged.

comments individually using the agreed upon themes to determine if a comment was "procedural" or not. The researchers identified 71 and 72 comments, respectively, as "procedural," however there were differences among 15 of the identified comments. The lists were reconciled for a total of 78 comments. Finally, we matched these coded comments with project and individual level data to provide further context.

3. Results

3.1. What is the association between solar neighbors' perceptions of community engagement and their attitudes toward LSS projects in their communities?

Table 2 displays the OLS regression models of the association between respondent attitudes toward the solar project built near their home and the index of engagement. Across both models, the engagement index has a highly significant positively correlated association with attitude. In the second model, the coefficient for the engagement index is 0.80. A (1/5) or 20 % increase in perceived engagement is associated with a (0.80/5) or 16 % increase in attitude. Caution should be taken to avoid interpreting this association as causal and one-directional. That is, a neighbor's current attitude toward a project may also shape their perceptions of the engagement that occurred in the past [73].

Both models control for the type of action a participant took during the planning process with "no action taken" as the reference category. Interpreting these coefficients in model two suggests that respondents who took actions *in support* of the project, were associated with attitudes that were 0.32 *higher* than respondents *who took no action*. Likewise, respondents whose actions were *opposed* to the project, were associated with attitudes that were 0.70 *lower* than respondents *who took no action*.

Model two controls for project-level characteristics including size, age, land and agrivoltaic characteristics. The interaction between size and age, shown in Fig. 3, demonstrates that respondents of older projects have more positive attitudes than those near more recently built projects, and this relationship is more pronounced for smaller projects than larger ones. Although the coefficient for the Project Age (1.0) appears quite large relative to the other variables, it must be interpreted along with the coefficient for the interaction term (Project Size X Project Age).

The type of land on which the project was built and incorporating environmental services in the design of the project were not significantly associated with attitudes. Agrivoltaic grazing was negatively associated with attitude at a highly significant level. This is surprising as agrivoltaics are often proposed as a means of increasing local support.

Community and regional controls are also included in the second model. Projects built in disadvantaged communities are associated with more positive attitudes but not significantly. Likewise, compared to projects built in New England, projects built in the other regions of the United States are associated with more positive attitudes, especially in the Middle and South Atlantic regions where the associations are highly and moderately significant, respectively.

Table 2
The Ordinary Least Squares (OLS) regression of the dependent variable attitude, which measures respondents' current attitude toward the solar project nearest their home.[a]

	(1)	(2)
Variables	Attitude	Attitude
Engagement Index	**0.84*****	**0.80*****
(Likert scale 1–5)	(0.08)	(0.09)
Respondent-level controls		
Supportive Action	**0.45****	**0.32***
(no action = reference)	(0.18)	(0.18)
Neutral Action	**−0.21**	**−0.08**
(no action = reference)	(0.16)	(0.15)
Opposition Action	**−0.66*****	**−0.70*****
(no action = reference)	(0.18)	(0.18)
Owns Home	**−0.83**	**−0.85**
(1 = owner, 0 = renter)	(0.59)	(0.57)
Higher Education	**−0.14**	**−0.14**
(1 = associates or more)	(0.12)	(0.12)
Sees Project Occasionally	**0.04**	**−0.15**
(sees everyday = reference)	(0.14)	(0.14)
Rarely Sees Project	**0.41***	**0.35***
(sees everyday = reference)	(0.22)	(0.20)
Didn't Know Project Existed	**−0.46****	**−0.15**
(sees everyday = reference)	(0.20)	(0.23)
Distance from project (meters)	**0.03**	**0.08**
(log transformed)	(0.06)	(0.06)
Project/region-level controls		
Project Size (meters^2)		**0.18***
(log transformed)		(0.10)
Project Age		**1.00*****
(as of 2023)		(0.31)
Project Size X Project Age		**−0.06****
(interaction)		(0.02)
Prior Land Cover		**0.06**
(1 = disturbed, 0 = greenfield)		(0.25)
Agrivoltaic-Environment Services		**0.13**
(non-agrivoltaic = reference)		(0.19)
Agrivoltaic-Grazing		**−0.78*****
(non-agrivoltaic = reference)		(0.24)
Disadvantaged Community		**0.14**
(1 = dac)		(0.13)
Central Region		**0.30**
(New England = reference)		(0.23)
Middle Atlantic Region		**0.82*****
(New England = reference)		(0.29)
Mountain West Region		**0.44***
(New England = reference)		(0.25)
Pacific Region		**0.37**
(New England = reference)		(0.26)
South Atlantic Region		**0.62****
(New England = reference)		(0.24)
Constant	**−1.25***	**−4.40*****
	(0.64)	(1.57)
Observations	230	230
Adjusted R-squared	0.51	0.57

[a] Robust standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

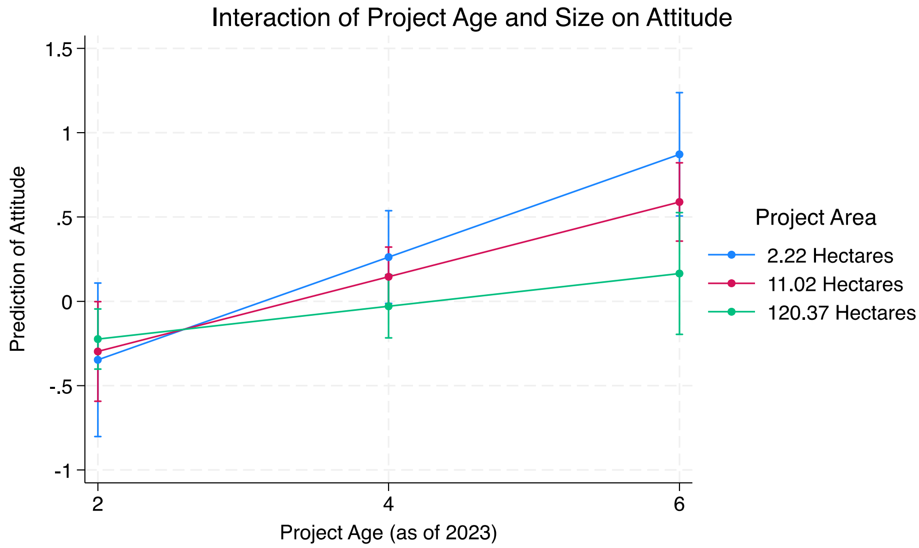


Fig. 3. The relationship between the size of the project (in hectares representing the 25th, 50th, and 75th percentiles of project area) and the age of the projects (years in operation as of 2023) reveals that the association between attitude and size is different depending on the age of the project.

3.2. How do solar neighbors' perceptions of community engagement compare to their expectations?

When asked "Which one of the following best describes the way members of the public were engaged in decisions about the solar project?" 70 % of respondents who knew about the project prior to construction and were active in the planning process ($n = 73$)[9] indicated "the public was just kept informed" or "most of the public were unaware." Sixty-seven percent of these same respondents, when asked "which is the most appropriate way to engage members of the public in decisions about solar energy projects proposed in their community?" responded "the public should provide input" or "the public should recommend decisions" (see Fig. 2 above). In Figs. 4 and 5 below, responses to the two questions are further categorized by the type of action the respondent indicated they took during the planning process (supportive, neither supportive nor opposed, opposed). All three groups of respondents who were active in the planning process indicate that they believe there should be higher levels of engagement than they perceive occurred for the project near their home (note the absence of blue in Fig. 5 and the increase in green, yellow and purple). The differences between expectations and perceptions grow as the actions taken move from supportive to oppositional.

Figs. 4 and 5 chart responses to two questions of overall engagement in decision making (perceived – Fig. 4 and expected – Fig. 5) separated by the types of action taken by the respondent during the planning process.

The perceptions (Fig. 4) and expectations (Fig. 5) of respondents who were aware of their local project before construction began and were active in the process can be compared to the responses (or lack thereof) of the larger sample (see Figs. 6 and 7).

Figs. 6 and 7 provide a comparison to Figs. 4 and 5, respectively, by revealing relevant responses from the broader sample. Figs. 6 and 7 are weighted values and Fig. 6 excludes individuals who moved to their residence after the project was completed. See Supplement 3 for additional information about weighting.

First, only 10 % of respondents[10] knew about their local project prior to construction (orange bar, Fig. 6). This means that 90 % of respondents indicated they were unaware during the planning process, much more than even the 57 % perceived by those who acted in opposition above (Fig. 4). Second, we asked the entire sample (926 respondents) for their opinion of the most appropriate way to engage the public in decisions about solar projects; nearly half (46 %) responded "the public should provide input." Indeed, the distribution of responses in Fig. 7 is most like the group of individuals who took actions generally in support of the project (Fig. 5).

In Figs. 8-9, we break down the mean distance from the project and the mean project size (both logged), by when respondents found out about the project and whether they were active in the planning process.

The results in Figs. 8-9 suggest a statistically significant difference in the distance from the respondent's home to the project among those who acted in the planning process and those who didn't (superscript "a" and "b"). Among these two groups there is not a significant difference in the size of the project near their homes (superscript "e"). However, there are significant differences in project size among the respondents who found out when construction began, after operation and those who didn't know about the project until receiving the survey. In short, the bigger the project, the more likely an individual was to find out about it before construction and the shorter the distance, the more likely to be active.

Moreover, there is one statistically significant difference when we break down the average distance and project size by the expected level of engagement (Figs. 10-11). The average project size for a respondent who believes that the public should *make* decisions (superscript c) is significantly different ($p < .05$) than the average project size for respondents who expect less engagement (superscript b). There is no statistically significant difference among the other four categories for size (superscript b Fig. 11) nor for any distance (superscript a Fig. 10).

[9] 5 respondents that were active and had prior knowledge answered question 26 but skipped Question 27. One additional respondent answered both questions but did not indicate whether the actions taken were supportive, neither, or opposed. Thus, the discrepancy between the n of active respondents who were aware of the project prior to construction [78], who answered both engagement questions [73] and the n of respondents who indicated the nature of their activity (72, Figures 4 and 5).

[10] 10 % is the weighted estimate for the number of respondents who indicated they knew about the project prior to construction excluding those who indicated they moved to the community after the project was operational. For an explanation of when we use weighted and unweighted numbers, see Supplement 3.

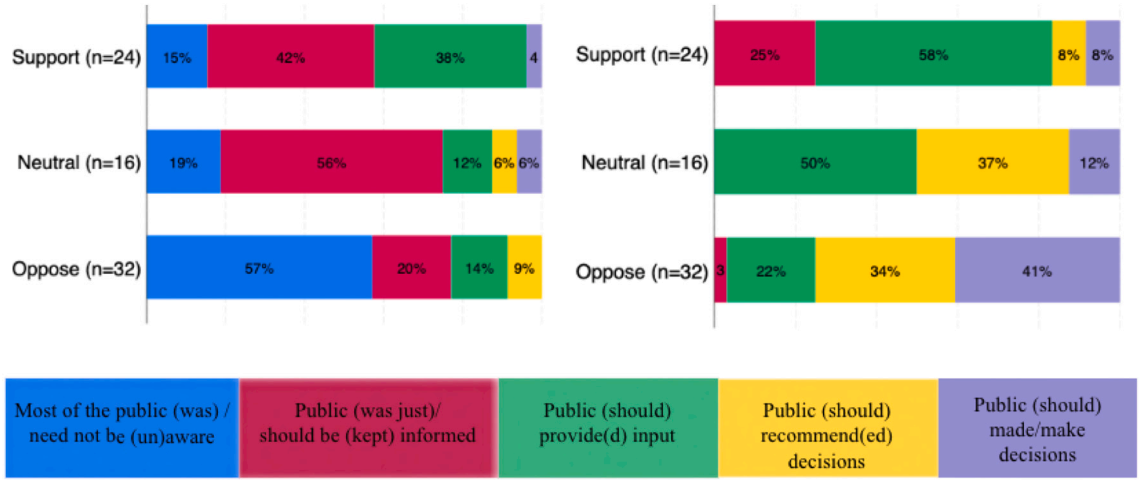


Fig. 4 & 5. Fig. 4. How were the public engaged in decisions about the project?
Fig. 5. Which is the most appropriate way to engage the public in decisions about solar projects?

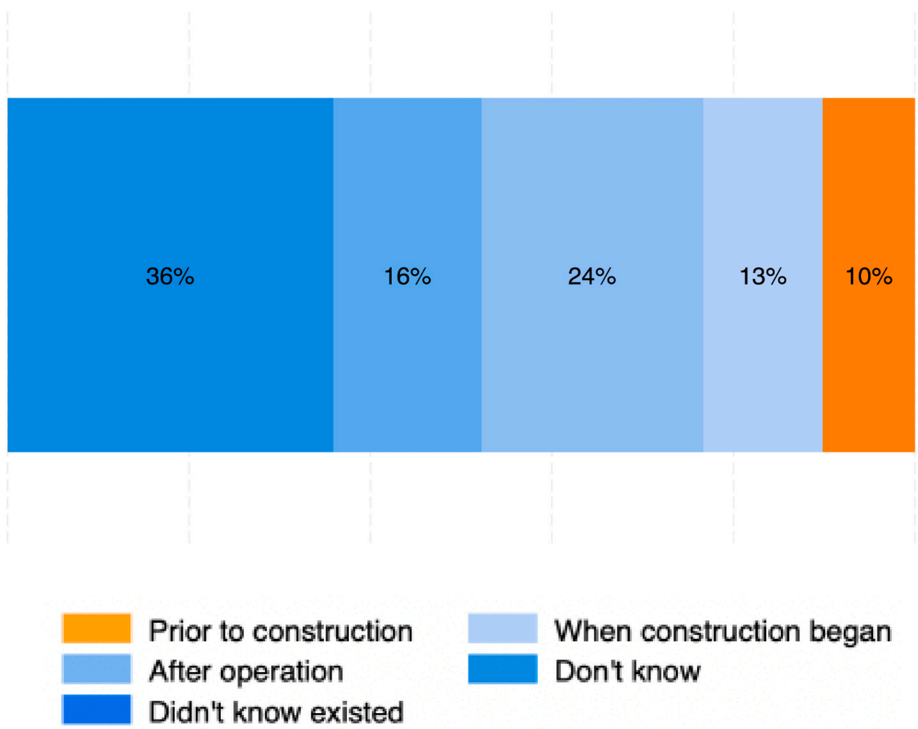


Fig. 6. When did you first learn about the solar energy project on the map? (n = 864).

3.3. *How are neighbors explaining what they perceived about the planning process?*

Out of the entire sample of 979 surveys, 326 contained at least one additional comment. We identified 77 of those comments as relating in some way to elements of the planning process. In Table 3 we briefly compare the project characteristics, attitudes, and involvement in the planning process of respondents who commented on the process to the whole sample.

It is important to note that these findings should not be perceived as representative of the average project neighbor, but rather, those who provided comments tend to live slightly closer to the project, were slightly more likely to be aware of the project and active in the planning process and were nearly 50 % more likely to have a "negative" or "very negative" attitude toward their project.

These findings are presented in order from lowest to highest level of engagement. The section concludes with comments which reflect on the overall level of engagement and experiences dealing with developers.

3.3.1. *Awareness – "All of a sudden it was there! Surprise!"*

Comments about project awareness provide additional context to our results showing that 90 % of respondents were unaware of the project before construction (including 36 % who were unaware it existed before receiving the survey). Feelings associated with low awareness range from frustration to ambivalence to positive attitudes about the project. Some expressed support for solar but desired more communication: "I'm all for solar projects, however living very close to the referenced project, I wasn't aware of any of the details surrounding it. More public

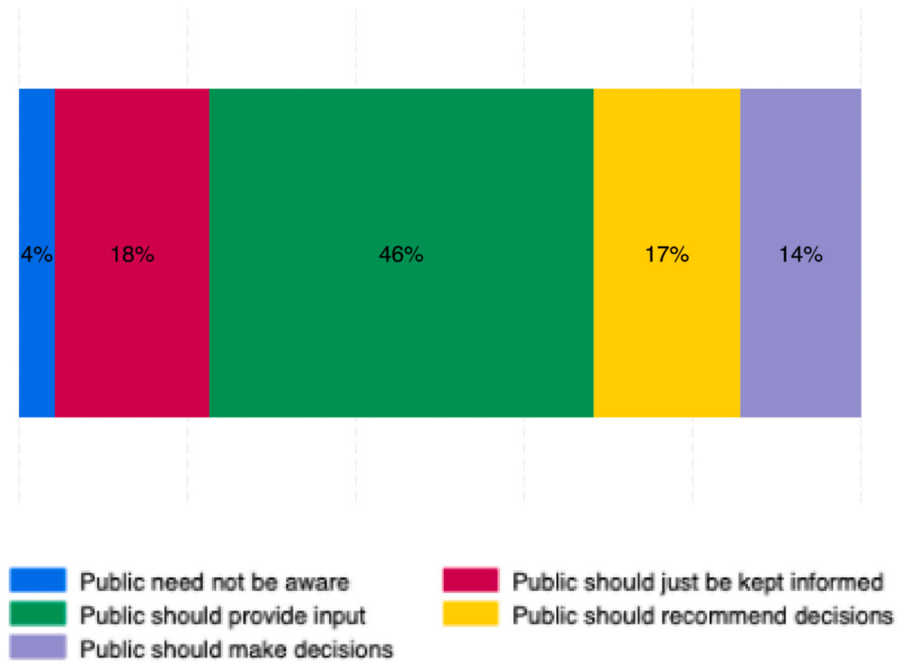
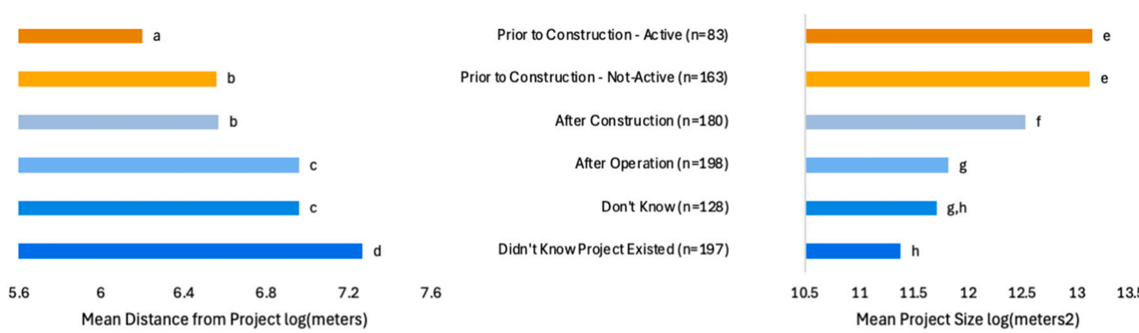
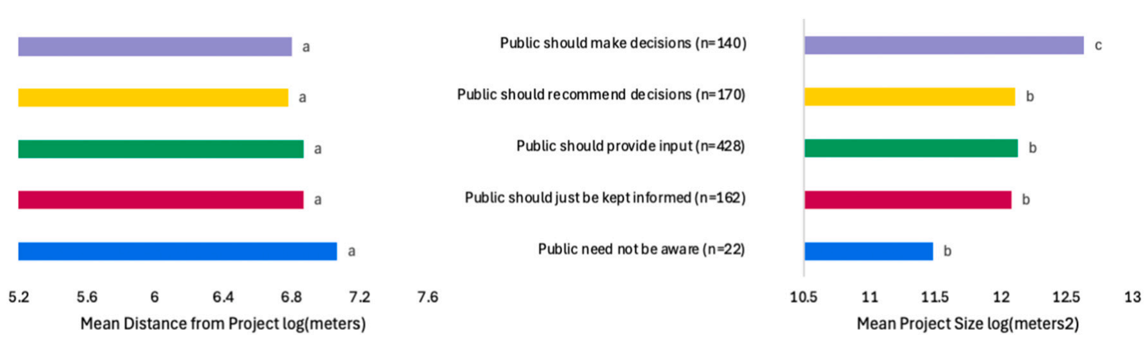


Fig. 7. Which is the most appropriate way to engage the public in decisions about solar projects? ($n = 926$).



Figs. 8-9. When did you first learn about the solar project on the map?
Mean distance from project is the log of distance in meters from respondents' home to the project. Project size is the log area of the solar project near respondent's home in meters^2. Means that share superscripts (shown at end of bars) indicate values that are not significantly different at $p < .05$ (means with different superscripts are statistically significant). For example, "a" signifies that the average distance for respondents who knew about the project prior to construction and were active (top bar, Fig. 8) was statistically different from the average distance from the project of respondents who knew prior but were not active "b" (2nd bar, Fig. 8) and found out when construction began "b" (3rd bar, Fig. 8). Values for mean distance and mean project size are unweighted, but log transformed. See Supplement 3 for additional information about weighting. Respondents who indicated they "Don't know" when they first learned about the project had earlier indicated at least some familiarity with the project. Respondents who indicated "Didn't know it existed" were unfamiliar with the project until they received the survey in the mail.



Figs. 10-11. Which is the most appropriate way to engage the public?
Mean log distance and project size by expected level of engagement in decisions about solar projects. Means which share superscripts indicate values that are not statistically different at $p < .05$. That is, there is no significant difference in average distance from the project among the levels of expected engagement. Further, only the mean of the log of project size for respondents who selected "the public should make decisions" is statistically different from each of the other four engagement options. Values are log transformed but unweighted in this table. See Supplement 3 for additional information about weighting.

Table 3
Comparison of the unweighted sub-sample of respondents who provided additional comments on their survey to those who did not comment (t-tests for differences of means columns B and C). **p < .05, *** $p < .01$. Sample sizes range within the columns due to some questions being skipped.

	(A) Full sample (n = 773–979)	(B) Commented on process (n = 69–77)	(C) Did not comment on process (n = 795–902)
Avg. project capacity (MWdc)	61.26	57.4	61.59
Avg. project size (meters^2)	1,057,249	981,473.6	1,063,718
Avg. distance from project (km)	1.39	1.1**	1.41**
Knew prior to construction	25.12 %	37.66 %***	24.06 %***
Active during planning	26.74 %	47.62 %***	23.84 %***
% Attitude negative or very negative	19.66 %	33.82 %***	18.3 %***

communication would be nice" (R1070). Others, found their lack of awareness to be a positive aspect of the project, explaining that the survey prompted them to seek it out, "the site is basically out of sight of most people" (R1304), "…hidden by trees and corn fields" (R3533), "out of sight, out of mind" (R1294). Moreover, some expressed their preference for the solar project over other potential land uses, "All of a sudden it was there! Surprise! But it's far better than more high-rise apartments!!!" (R750).

3.3.2. Access to information – *"I have no issue with solar… I have issues with the lack of communication…"*

> Even among those who were aware of the project, lack of information from developers and officials was an oft-cited complaint. "Communications are key…there was a billboard in front… [it] wasn't really informative" (R1565). "No information provided to us about the project" (R2742), "little to no communication…" (R3493) "None. No info."
>
> (R3546)

Even neighbors whose property abutted the project complained about receiving no information. These information disparities contributed to conflict between neighbors, "I wasn't told anything about it… no person came to my house to fill me in. I'm pissed that my neighbor was one of the owners of the fields and he couldn't even come TALK to me" (R855) [*emphasis respondent*]. Others sought a better explanation of the benefits, "there is a lot of work to be done in educating residents as to the benefits of locally generated solar power. No one seems to be doing that now" (R1601). "[I] generally support them, but … benefits of solar energy projects need to be continuously reported to [the] local community… showing… economic benefits" (3337). Even respondents who had leased land for development expressed a desire for better communication,

> "We have leased 6 acres of unused farmland … To my knowledge the developer has not been required to keep lines of communication accessible to neighbors. This would be preferable. Once the county required notifications went out, they disappeared."
>
> (R4777)

3.3.3. Opportunity to engage – *"Local had no say…"*

Beyond access to information, the ability or lack thereof to engage in the planning process represents a significant aspect of procedural justice. Some responses suggested that the late timing of information provision specifically limited their ability to participate in the process. "The only state meeting we were told about we had less than a week's notice to attend or watch virtually. This project was already approved before it could have been stopped" (R3698). Others described the planning meetings as a "big government steamroller" in which neighbors were confused, "Order was called – 'Sworn statements only!' 'No Questions!'" (R4208).

Some respondents connected limited engagement opportunities to the jurisdictional scale at which solar siting decisions were made. "There were no public meetings and no information ahead of time… [The] state is forcing solar on people without any input" (R4338). One respondent blamed pro-solar state legislation which limited the input of solar neighbors for triggering a lamentable [to the respondent] rise in anti-solar activism.

"Many laws were written to encourage solar and reduce the input of abutters… what happened next was predictable – lots of money came in from out-of-state to snap up the easiest…sites for industrial-scale projects … Ten years later, we have anti-solar activists in the state government actively blocking all renewable projects" (R2455).

On the other hand, at least one respondent perceived that their small town was incapable of fully engaging in the process due to a lack of capacity. "Small towns do not have [the] state to monitor what developers do! So, developers get away with what they want" (R3033). Yet, another respondent mentioned a failure to engage communities of interest, at the sub local level. The solar project was constructed alongside a well-established nature trail. The community of interest, the "runners, bikers, and walkers along the trail [respondent included] … resent having not been previously consulted or… included in the discussion" (R2800).

3.3.4. Ability to affect outcome – *"They pretended to address my concerns, then just didn't do anything"*

Respondents shared perceptions that the input neighbors contributed during the process fell on deaf ears. "I felt that the attitude of the city was, 'this project is going in. We are just gonna listen to these yokels from the boonies spout off until they're done and then push this baby through" (R869). Respondents explained their inability to affect change via power imbalances, sometimes legal power. "Neighbors signed a petition against this solar farm. We received a letter threatening a lawsuit if we fought the plan" (R2862).

A lack of opportunity to affect outcomes may arise after project completion. One respondent indicated that the site design had resulted in significant erosion and flooding for project neighbors. However, "meetings with [the power company] and developers have not changed anything" (R3694). For some, developer inaction in response to neighbor feedback moved beyond apathy to duplicity. "They pretended to address my concerns, then just didn't do anything" (R2573).

3.3.5. Level of engagement – *"The decision was made for us"*

Respondent comments about perceived and expected levels of engagement reveal significant contrasts, even within supporters and opponents. Some supporters cited the need for expediency in renewable energy deployment as a reason for limiting community engagement. "The less bureaucracy (and the less input from the community) involved, the better" (R604). Others went further,

"I believe it is no one's business where or who does solar projects. It's between the landowner and the supplier. If a company buys land that is for sale, it's their land. I don't think anyone need[s] to say what can and can't be done with the land they own or rent" (R4349).

The solution for some was for the government to limit engagement, though they did not always specify at which level. "The government needs to step up and make changes for the long-term… rather than appeasing uninformed/selfish voters" (R704).

While one respondent credited local support for getting their local solar project approved and decried state leaders who were "anti-science assholes" (R2209) another indicated that "if the local government had any veto, [the project] probably wouldn't have been built" (R3392).

Others who wished to see more LSS believed the solution was not less community engagement, but more. "Resolving local opposition needs to actively involve local residents and businesses" (R3337).

Many lamented the low levels of community engagement which resulted in the approval of unwelcomed projects or limited benefits.

> "The community gave input, wrote letters, read EIRs [Environmental Impact Reports], had petitions, and made an appeal (that took raising money). The community… recommended that all community homes affected by the project have the benefit of solar on them [yet] no decision[s] [were made] by the community… the decision was made for us. Now we have to live with it"
>
> (R3546)

4. Discussion

Increasing local opposition slows the pace of LSS deployment and increases uncertainty for project developers. To curtail local opposition many states have preempted local siting authority, moving decisions to the state level. There is a risk that such a move could further antagonize opposition and inadvertently slow deployment. This is a debate about the appropriate role of just energy decision-making in the context of the climate crisis. Here we engage with this discussion by evaluating the results of three distinct methods for understanding the relationship between engagement and attitudes toward a local LSS project.

4.1. Analysis of results

Our results indicate a positive association between respondents' perceptions of engagement and their attitudes toward their local project, consistent with previous work examining wind [17,40]. This finding is noteworthy in that it demonstrates this association for residents living near recently developed LSS across the US, affirming what Nilson and Stedman (2023) found within a single state.

By controlling for the type of action (supportive, neither, opposed, no action) taken by respondents who were aware of the project prior to construction, we can demonstrate that more engagement does not mean all participants will ultimately be supportive. Yet where there is more engagement, the attitudes of both supporters and opponents alike are more positive than in places where there is lower engagement. As state-level energy policy debates weigh the potential expediency gains of siting reform against increasing local opposition, the fact that more engagement equals better attitudes for everyone is meaningful. However, it is revealing that the negative coefficient for respondents who acted in opposition to their project (−0.70) was nearly equivalent to the positive outcome of engagement (0.80). This echoes one conclusion of the National Academy of Sciences that "even the most creative and robust public engagement is unlikely to sway ardent opponents of projects" [12]. There are likely many factors contributing to such opposition including demographic differences and opinions about climate change. While we have sought to control for some of these, many remain outside of the scope of this work.

It is noteworthy that the interaction of the size and age of the project and project age itself were significant factors influencing attitude,[11] but distance was not, even as it increased the likelihood of foreknowledge of the project. The contrasting significance of these factors seems to underscore the overall importance of process in shaping project attitudes; however, there is significant context which is obscured in the engagement index and the OLS regression. Results from RQ2 and RQ3 allow for more nuanced analyses.

In answering RQ2 we find that, on average, respondents who were active and aware prior to construction perceived less public engagement than they expected should occur. This is true regardless of whether respondents were active in support of, in opposition to, or neutral on the project. Given the regression findings from RQ1, the fact active participants perceive an engagement deficit is significant. That is, engagement is associated with more positive attitudes and yet, across the board, the engagement that is occurring is perceived to be less than desired. This result is also meaningful because complaints about a lack of engagement or requests for ever-more opportunities to voice dissent are often tactics of vocal (and ardent) opponents of solar. It is sometimes difficult to know if these complaints represent meaningful suggestions for improving decision-making processes or are simply strategies to slow or stall development. Here we show, consistent with Elmallah and Rand (2022) with respect to wind development, that even supporters and ambivalent residents who participated in action, expect more and better opportunities for engagement.

Still, the differences between expectations and perceived engagement varied among the three active groups, with deficits growing alongside increased opposition. This finding expands upon the case study of Simcock (2016) which explained divergent resident attitudes toward a community wind project as resulting from differing normative expectations of a just process. Indeed, the engagement expectation-perception gap analysis underscores the challenge of delivering a process that is widely accepted as just [62]. Rather than straightforward, stakeholders may hold contrasting definitions of what "justice" is and they may vary by geographical or cultural context [74–76]. The fact that expectations of engagement vary may be a reason (or an excuse) among policymakers and developers for why more engagement, in general, has not or should not occur. Nevertheless, there are three clear engagement lessons evident from the results.

First, the vast majority (90 %) of respondents were unaware of their project prior to construction. This contrasts with the perceptions of those who knew about the project prior to construction. Even among the respondents most likely to perceive a low-level of engagement, those who were active in opposition, only 57 % perceived that the public was unaware. Lack of awareness may be attributable to insufficient public notice requirements [63] or developer decisions to try to keep a low profile in the community, often referred to as "decide-announce-defend" [10,77,78].[12] Regardless of the cause, as has been articulated in recent case studies [36] and surveys [79] of large-scale wind development, there is clearly work to be done in increasing information and awareness of proposed LSS projects.

Second, although 75 % of respondents who acted in opposition ($n = 32$) expected higher levels of engagement, 50 % or more of the supportive ($n = 24$), neutral ($n = 16$) and non-active respondents (the vast majority, $n = 843$) expect only that "the public should provide input" or less. This suggests that although the general level of engagement ought to increase, most respondents do not expect the public to make decisions, or even recommend them. This mid-level expectation by non-active respondents addresses calls by some researchers to explore the perceptions of residents who remain silent during the planning process [44,62]. No matter how effective the effort to engage a community, many residents will be unable to participate or choose to stay silent. Meanwhile, the engagement process provides a platform for the strongest voices in support of or opposition to a project. The fact that the non-active majority expects that the public should provide input but not ultimately make decisions, may reflect an awareness of the need to balance contrasting desires of vocal minorities. Further, this could be an implicit recognition of engagement barriers, such as the time cost of

[11] When project age is excluded from the model size becomes significant at $p < .01$. When it is included, size is no longer significant, but the interaction between the two is.

[12] In a survey of wind and solar developers, Nilson et al. (2024), found that in considering their most recently canceled project, most developers wish they had started community engagement earlier in the process, but two believed early engagement backfired and the project may have succeeded if engagement had occurred later.

participating or the capacity to intervene in seemingly technical discussions. Alternatively, it could suggest a desire for the non-active to justify their own level of engagement or lack thereof. This may explain why, among respondents who knew prior to construction, 65 % of those who were not active, compared to 52 % of those who were active, expected only to provide input or less.

Third, it is noteworthy that the average project sizes of respondents who expect the public to make decisions are significantly larger than respondents who expect less engagement. Moreover, there is an approximately linear trend in which increasing average project size is associated with earlier project awareness. This may suggest that there is a size threshold at which the largest projects trigger earlier awareness, more action, and higher expectations of engagement. This is consistent with Campos et al. (2023) who found a link between project scale and the importance of citizen participation [80]. It may also be simply that in some jurisdictions there are different notification requirements based on project size. Further research into the intersection of project size and perceptions of procedural justice may help to elucidate whether a clear threshold can be isolated. On the contrary, while respondents closest to the projects were more likely to learn of them prior to construction, they were not more likely to expect high levels of engagement.

Ultimately, our study illustrates the argument of Stedman (2016) that, "people behave according to what they believe the system is, what they wish for it to be, and the magnitude and nature of the gap between the two." Non-active respondents expect less overall engagement and respond accordingly. In contrast, those who were more active may have been active in part because they believe the system should be one that welcomes community engagement.

Finally, the analysis of open-ended comments for RQ3 reveals a desire for earlier, more, and continued information even after projects are operational. In particular, community-members here and in previous studies [63] have expressed concerns about notification requirements regarding projects' environmental compliance, storm water runoff, and maintenance. Frustrations with communication disparities (R855) echo findings that the use of non-disclosure agreements in LSS landowner communications are at times even more restrictive than comparable fossil fuel developments [81]. Additionally, the avenues provided for local communities to engage project operators to ameliorate concerns or rectify complaints after operation require financial resources and technical expertise that may be lacking in rural communities [82–84] (R3033). These comments echo the finding from RQ2 that all active participants, regardless of their opposition or support of the project, expect more engagement than they experienced.

On the other hand, comments add nuance to the discussion about mid-level engagement in RQ2. While limited engagement decried by some commentators meant an inability to stop a project, others characterized the high engagement process as one that afforded "selfish voters" too much opportunity to oppose projects. The conflicting nature of these comments exemplify the challenge of balancing competing expectations of engagement.

4.2. Limitations and future work

We only surveyed respondents who lived near completed projects. Respondents living near projects that were not completed would likely have had different perceptions of the planning process and/or different engagement expectations. Future studies which incorporate canceled projects would provide a deeper understanding of engagement perspectives in these contexts.

The screening question about the list of actions that a respondent could have taken during the planning process did not include an "other" option. It is possible that some respondents who would have considered themselves active during the planning process did not do any one action from our list. While there was a benefit to ensuring that all who answered questions about their perceptions of the planning process were active and aware of the project prior to construction, the relatively small sample who met these two criteria limited the statistical power of our regression in RQ1 and lowered the n of our gap analysis in RQ2.

We would have liked to include additional controls in our model, especially regarding community ownership and local versus state siting authority. While some data was available for each of these variables, it was too nuanced for meaningful inclusion in the model.

There are many important questions to be answered about how various demographic factors are associated with different expectations of engagement. In this study, we primarily limited our analysis to distance from the project and project size. However, race/ethnicity, income, education and region all likely play a role in the level of engagement expected. These should be explored further in future work as they will be helpful in informing developers, policymakers and community members about best practices for engagement. Likewise, the role of renewable energy precedence within a locality should be investigated to better understand at which point solar neighbors may perceive an excessive burden of development.

4.3. Policy relevance

This study informs the debate on the balance of state- versus local-government control in siting LSS. Advocates for local control argue, as did one survey taker (R2455), that state laws reduce the ability of neighbors to provide input, which may stoke increased opposition, a warning echoed by the National Academy of Science [12]. On the other side, advocates for state control suggest state-level governments have higher capacity to provide for effective engagement. There are opportunities for the sort of mid-level engagement that solar neighbors prefer in both contexts, and developers and policymakers could work to ensure public feedback is considered in proposed projects and siting decisions made, respectively. These opportunities for engagement could occur early and often at various stages in the development process to promote trust and transparency between residents and developers [85]. Most importantly, the purpose of these engagement opportunities could be clearly communicated to residents beforehand so that their expectations are aligned with the purpose of the meetings [86].

A bigger implication is that there may be higher expectations of engagement for larger projects. Specifically, though only a small (15 %; 140/926) proportion of respondents prefer that "public should make decisions" (i.e., through a public vote or other process), this sentiment is more often associated with neighbors living near larger projects than small projects. What is striking in the context of the siting authority debate is that in most states, state-level control typically only applies to the largest projects. This is not unique to the United States, as in the United Kingdom, large projects labeled "Nationally Significant Infrastructure Projects" (NSIPs), are sited at the national level instead of by local officials [22,87,88]. If such a move is seen to diminish engagement, rather than increase it, this would fly in the face of public preferences. For example, in our survey, when asked about preferences for future solar projects in their community, the number of respondents in support of putting decisions to public referenda or vote outnumbered opponents by a ratio of four to one. Further, opponents of state government having more decision-making power for solar development outnumbered proponents two to one.

5. Conclusion

The transition toward a decarbonized energy system necessitates trade-offs. The benefits of decarbonization are global and diffuse. While decarbonization from the energy transition will benefit the residents who live near LSS projects, these benefits may be challenging for them to reconcile with their perception of salient impacts of solar development. Having a say in the transition process can have meaningful impacts on attitudes toward projects. Indeed, though engagement may seem to initially slow development, it may accelerate the transition by avoiding reactionary moratoria on solar development. Moreover, engagement does not necessarily require ceding decision-making power to the public. Transparent and consistent communication about the purpose of engagement opportunities can help to better inform resident expectations and thereby decrease gaps between perceived and hoped-for processes.

CRediT authorship contribution statement

Karl W. Hoesch: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sarah B. Mills:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis. **Joseph Rand:** Writing – review & editing, Project administration, Formal analysis, Data curation. **Robi Nilson:** Writing – review & editing, Software, Methodology, Formal analysis. **Douglas L. Bessette:** Writing – review & editing, Conceptualization. **Jacob White:** Writing – review & editing, Data curation. **Ben Hoen:** Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

This study was created and conducted, and article completed without the use of artificial intelligence. Its content is 100 % human.

Acknowledgement

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number DE-38419. The views expressed herein do not necessarily represent the views of the U.S. Department of Energy or the United States Government. We would also like to thank members of our Technical Advisory Committee.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103893.

Data availability

Data will be made available on request.

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