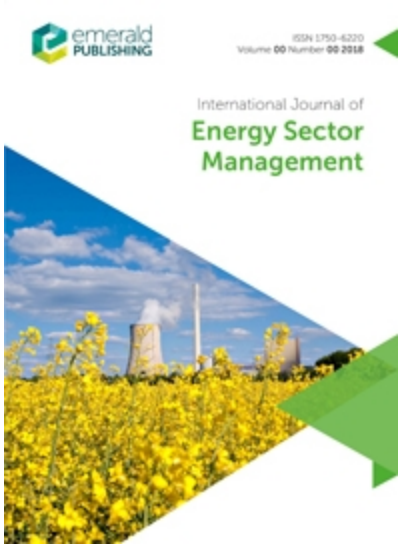

Utility-Scale Solar Projects in the Rural Midwest: An Assessment of Knowledge Flows

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Purpose

Solar photovoltaic (PV) systems have become one of the fastest-growing electricity generation assets across the United States (U.S.), and utility-scale solar has particularly become an increasingly notable deployment type. However, compared with smaller-scale, distributed PV systems, relatively less is known about the impacts of these large-scale projects, which are often sited in rural communities. Debates have ensued regarding the potential pros and cons of these projects, including local ecosystem, economic, and property value impacts, among others. The purpose of this paper is to better discern how information and knowledge of utility-scale solar projects flows across rural communities.

Design/Methodology/Approach

We conducted 45 semi-structured stakeholder interviews across the Great Lakes region (U.S.). We spoke with local officials, landowners, solar developers, electric utilities, the media, and others to better comprehend how individuals in rural areas are learning about new utility-scale solar projects, who they are learning about projects from, how they are engaging with these projects, and what desires and concerns they have.

Findings

Our findings illuminate existing patterns and gaps in the flow of knowledge surrounding utility-scale solar projects in the rural Midwest. The timing of initiation of the knowledge flows is also an important factor for how citizens and government officials feel about the reliability of a project, developer, or information.

Originality

This paper fills a gap in how we identified stakeholders who disseminate vital introductory information, and examine how that information is shared, which can prove useful in the eventual decision making and approval process of utility-scale solar projects.

Keywords: solar energy, knowledge flows, decision making, interview research, Midwest

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Conflicts of Interest

The authors have no conflicts of interest to declare with respect to this article's research, authorship, and publication.

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Data Availability

The more comprehensive coding data is available on request of the corresponding author. Individual interview transcripts cannot be published or shared, as that would violate the guidelines of the funder.

1. Introduction

Solar energy in the United States (U.S.) has grown by an average annual rate of 24% over the last decade, and newly installed solar capacity exceeded that of wind for the first time in 2022 (Solar Energy Industries Association, 2023; University of Michigan Center for Sustainable Systems, 2023). At the end of 2023, the U.S. had a total of 160 gigawatts (GW) of installed solar photovoltaics (PV) (Solar Energy Industries Association 2023), with roughly 1,000 additional GW of solar in interconnection queues (Lawrence Berkeley National Laboratory 2023). These solar projects are projected to bring forth more short and long-term jobs, increased tax revenue, and reduced greenhouse gas emissions (Dreveskracht 2012; Hernandez et al. 2014; Hernandez et al. 2015; Michaud 2020a; Pitt and Michaud 2015; Trandafir et al. 2023; Turney and Fthenakis 2011; Wiser et al. 2016), yet knowledge of what these projects may mean for communities remains in its relative infancy.

Traditionally, utility-scale solar facilities are built by solar developers to function like a power plant to provide electricity to the grid, either selling the output to utilities or to companies as part of a Power Purchase Agreement (Jain 2022). These solar projects are very large (i.e., cover hundreds of acres), typically with a capacity of at least 5 megawatts (MW), and often upwards of 100 MW, the latter of which can provide enough electricity to power 100,000 homes (National Renewable Energy Laboratory 2022). In the Midwestern U.S., these projects are usually sited on agricultural land as large and relatively clear areas that possess high solar irradiation (Ahed et al. 2019; Moore et al. 2022; Uebelhor et al. 2021). Farmers often lease their land to solar developers at prices that are greater than the profit that they could have made by selling crops grown on that land, especially due to changing and uncertain economic and environmental conditions of agricultural practices (Carroll 2023; Hoffacker et al. 2017).

Against this background, in this paper, we first review the literature surrounding solar siting in the six Great Lakes states (i.e., Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) of the U.S. Midwest, specifically around approval, knowledge flows, and social acceptance. We then outline the methods that we used to identify and interview solar-related stakeholders, including how we coded the interviews. In our analysis, we present recurring themes and trends observed throughout the interviews, as well as differences across stakeholder categories. We conclude with a final discussion and thoughts regarding engagement and information dissemination about utility-scale solar projects in rural communities in the Great Lakes region.

1.1 Solar Siting and Approval

Due to the difference in state-level incentives and approval processes for solar development, states are seeing a disparate amount of large solar facilities. To illustrate, in Minnesota and Ohio, only solar projects that are 50 MW or larger are required to be reviewed by state officials, and, in Wisconsin, only projects larger than 100 MW are required to have public hearings (Minnesota Commerce Department 2023; Ohio Power Siting Board 2017; Public Service Commission of Wisconsin 2024). In late 2023, the Michigan state government passed a bill that gave the state authority over large-scale solar projects, where previously each project was subject to local approval (Michigan Townships Association 2023).

However, some states, such as Illinois, explicitly give the ability to site solar projects to counties or townships (Illinois Power Agency 2020). Others, like Indiana, do not explicitly discuss who is responsible for solar approval and default to localities to take initiative (Greene et al. 2020). Proponents of a state-level approach to approving large solar projects argue that local governments may not have the technical knowledge to understand the benefits and costs of these

projects nor how to effectively implement them (Uebelhor et al. 2021). Conversely, proponents of a local approach argue that regional actors know the needs and suitability of a utility-scale energy project in their area better than the state does (Davis 2015).

Relatedly, local zoning ordinances often have a significant impact on whether or not a large solar project is approved. If a locality's ordinance allows renewable energy development, it usually has specific requirements on the size of a project and where it is allowed to be built (Bronin 2022). However, many communities do not have zoning ordinances that mention utility-scale solar; for example, in 2021, only 20% of the communities in Michigan had zoning for utility-scale solar (Fierke-Gmazel et al. 2021).

1.2 Knowledge Flows & Social Acceptance

The successful build-out of a solar project is also heavily determined by stakeholder engagement and public perception (Bessette et al. 2024; Dokyi and Sharifi 2024; Dunlap et al. 2024; Essa et al. 2021; O'Neil 2020; Uebelhor et al. 2021). Public perception of energy infrastructure is dependent on context, both of the type of installation and the project's host community (Fast 2016; Rountree et al. 2022). Local stakeholders' trust in solar developers also impacts project approval. Prior literature has suggested that renewable energy projects in communities with greater than average opposition are more likely to be denied or retracted (Sward et al. 2021).

Rural communities rely mainly on interpersonal relationships and informal means of acquiring information, such as word-of-mouth or local news, rather than scientific papers or information provided by outsiders such as developers (Anderson 2013; Fast and Mabee 2015; Fergen et al. 2021; Reimer and Brett 2013). Personal stories and anecdotes from constituents are often most convincing for local decision-making. Information transfer through local social

networks not only conveys the information itself, but also signifies the level of trust a recipient has in the information given its direct source (Reimer and Brett 2013).

The development of large, utility-scale solar in rural communities is still a relatively new concept, and rural communities' lack of knowledge of solar PV in general can serve as a roadblock to project approval (Neij et al. 2017). The process of learning about utility-scale solar is unique in that it involves many professionals who do not specialize in solar (Neij et al. 2017). Community members often express frustration with the lack of transparency in the siting and implementation process, as well as the spread of misinformation (Foley et al. 2021). Cultural and spatial proximity play large roles in the dissemination of knowledge regarding solar projects (Neij et al. 2017), and information that does not tie directly to the challenges local communities face daily is more likely to be dismissed (Li et al. 2010). However, the more inter- and intra-community links there are in a system, the higher the average knowledge level for the agent (Li et al. 2010).

2. Materials and Methods

In this study, we specifically conducted 45 semi-structured interviews via Zoom and telephone between May 2022 and March 2023. Our sampling was purposive by stakeholder category, with a target of at least 15 local officials, 10 landowners, five solar developers, and three of each of the following categories: citizens, electric utilities, regulators, nonprofit representatives, and the media. These figures were chosen to proportionally represent local officials, landowners, and solar developers as primary decision-makers (i.e., our "central stakeholders," with the others being more "peripheral stakeholders"), and specifically suggested by our funder. These participants were from our six focus area states (see Figure 1), and had knowledge of, experience with, or proximity to a large solar project. Purposive sampling in this

context ensured heterogeneity across geography and stakeholder type (Buckley Biggs et al. 2022; Pascaris et al. 2021).

To identify participants, we populated a list with contact information (i.e., email addresses) for individuals in each of these stakeholder categories by researching rural solar projects in each state and looking at social media and news stories (e.g., in local newspapers). We only contacted individuals that had available email addresses online. We adopted the U.S. Department of Agriculture – Economic Research Service (2025) definition of rural, which includes all territories outside of areas considered urban, despite this being an over-simplistic classification (Khalaf et al. 2022). We then reached out to everyone on this initial list via email to request interviews. During the interviews, participants were also asked if they knew anyone else involved with, or knowledgeable about, utility-scale solar who would likely to agree to an interview, adding a secondary element of snowball sampling to the purposive sample, similar to Michaud (2020b), Moore et al. (2022), Pascaris et al. (2021), and many other scholars. A general list of interview questions was created for all participants, as well as additional, specific questions for each stakeholder category (see Table 4). The completed interview recordings were then transcribed for analysis. It should be noted that due to the inherently smaller sample size of subjects in interview research, results are, indeed, more challenging to generalize (Buckley Biggs et al. 2022; Moore et al. 2022; Pascaris et al. 2021).

Next, our interviews were coded based on the themes and trends identified in the transcripts. Particularly, four researchers went through three interviews, one each from a landowner, a local official, and a solar developer, and noted patterns in each interview. The researchers convened and discussed the themes observed in the interviews to form a preliminary codebook. The purpose of the codebook was to identify types of information flow common

across interviews. The researchers then went back and each coded the same three interviews with the preliminary codes, reconvened, and discussed and refined the codebook based on observations from this second analysis. A final codebook of 10 codes was created (see Table 1). Two researchers coded each interview (see Figure 4 for a representation of this process), and each pair met to discuss their interviews and come to consensus on the codes applied.

Table 1

Codebook Utilized for Interview Analysis

Code	Description
Pre-Project Feasibility	Knowledge from preliminary developer analysis (e.g., GIS, zoning)
Landowner Outreach	Knowledge gained from developers talking with landowners whose land may be included in solar projects
Direct Communication	Knowledge flow that includes communication that is verbal and face-to-face between two different stakeholder groups
Indirect Communication	Knowledge flow that includes communication that is not face-to-face and includes public outreach strategies (e.g., mailers, websites)
Within-Group Communication	Knowledge flow between the same stakeholder groups
Local Context	Knowledge gained by those outside of a community from local stakeholders about background relationships and interactions that are specific to the project's area (e.g., identifying a "project champion")
Independent Information Seeking	Knowledge gained by stakeholders conducting independent research using external resources such as the internet
Prior Knowledge Flows	Knowledge from prior interactions with utility-scale solar developments
Other Energy Industry	Knowledge from past experiences with renewables (e.g., large-scale wind, rooftop solar)
Future Wishes	Desires about changes/improvements to the current flow of knowledge and decision-making process

3. Results

We ultimately conducted these interviews across our six states (again, see Figure 1), with an average of 7.5 interviews completed in each state, as displayed in Table 2. Table 3

subsequently shows the quantity of codes that were applied to each type of stakeholder group interview, with direct and indirect communication being the most common type of knowledge flow occurring.

Table 2

Stakeholder Group Interviews Conducted per State

	Stakeholder Group								
State	Local Officials	Landowners	Solar Developers	Nonprofits	Media	Regulators	Utilities	Citizens	**Grand Total**
Illinois	2	1	1		1	1			**6**
Indiana	4	1		1		1	1	1	**9**
Michigan	1	2	1	1		1			**6**
Minnesota	2	1	1		1			1	**6**
Ohio	2	3	1	1	1			1	**9**
Wisconsin	4	2	1				2		**9**
Grand Total	**15**	**10**	**5**	**3**	**3**	**3**	**3**	**3**	**45**

Note. Two interviewees were from tribal nations (local government officials from tribes in Minnesota and Wisconsin). Due to tribal sovereignty, tribes are not necessarily subject to the same regulation around (utility-scale) solar as the rest of the state.

Fig. 1. Map of the Study Area.

Table 3

Quantity of Knowledge Flows Coded by Stakeholder Group

Code	Stakeholder Group								
	Local Officials	Landowners	Solar Developers	Nonprofits	Media	Regulators	Utilities	Citizens	**Grand Total**
Direct Communication	46	2	25	14	16	11	7	9	**130**
Indirect Communication	12	4	13	2	13	8	6	7	**65**
Prior Knowledge Flows	26	8	14		3	2	1	1	**55**
Within-Group Communication	17	12	4	7			2	7	**49**
Other Energy Industry	14	11	3	4	4	1	4	8	**49**
Local Context	18	1	12	2	7		3		**43**
Independent Information Seeking	12	6	1	8	6	4	1	3	**41**
Future Wishes	14	6	3	3	3	1	3	1	**34**
Landowner Outreach	3	7	11	3		2		1	**27**
Pre-Project Feasibility	3		15	1					**19**
Grand Total	**165**	**57**	**101**	**44**	**52**	**29**	**27**	**37**	**512**

We then leveraged a Social Network Analysis (SNA) to create a diagram of how knowledge of solar energy flowed across our stakeholder groups. SNA is an analysis method that works to explain social network theory, particularly describing the tendency for individuals to create societies through relationships. In SNA, individuals form "nodes," and interactions form the "edges" or lines that connect nodes to form networks. In our study, stakeholders acted as the "nodes" and individual codes represented "edges." Each "edge" code was assigned a "source node" stakeholder and "target node" stakeholder based on the content of the coded interview. Applying matrices of codes between source nodes and target nodes in Ucinet 64, we yielded such a diagram that displayed the degree and strength of stakeholder relationships, as offered in Figure 2.

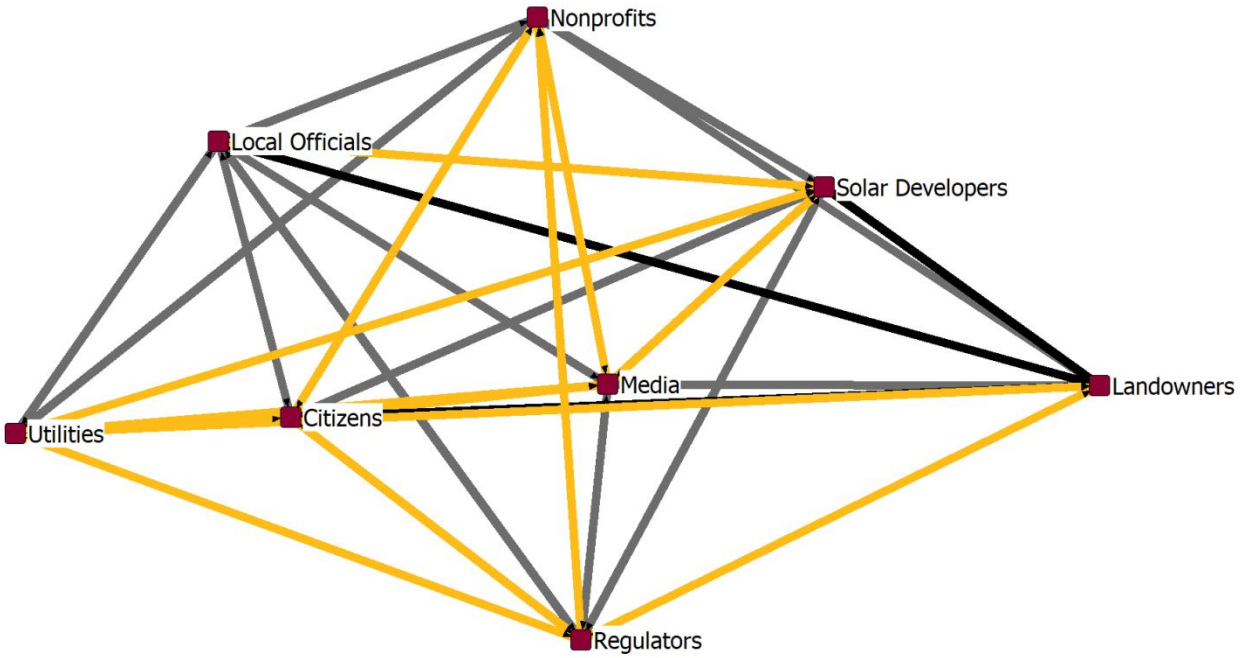

Fig. 2. Social Network Diagram of Stakeholder Relationships and Interactions by Knowledge Flows.

Here, we observe that Local Officials have the most direct communication flows (grey), whereas Citizens have the most indirect communication flows (yellow). Black represents our landowner outreach variable, suggesting that Solar Developers are largely starting the process by doing outreach to Landowners. Notably, Media and Citizens are central to all flows of knowledge with the highest number of edge connections. For a more granular representation of these interactions, please see Figures 6, 7, and 8 in the Appendix.

We next offer observations and exemplary quotes from our interviews, as organized by our central and peripheral stakeholders.

3.1 Central Stakeholders

3.1.1 Solar Developers

In their preliminary assessments of project development, solar developers consider factors of site suitability and permitting to evaluate feasibility. One solar developer mentioned developing materials on a project area's value and viability before entering a community, whereas others discussed existing land codes and landowner receptivity preceding land campaigns.

"We're maybe not in a position where we need to introduce ourselves to the community [yet], because that might lead to a bunch of different other questions, and we really don't even know if this project is feasible. So what we want to do is make sure that the project itself has 'legs.'" (Solar Developer #4).

We found that solar developers initiated nearly all occurrences of landowner outreach (see Figure 6). Their reported priorities included conducting an initial land prospecting push, gathering knowledge on community interest, establishing trust with landowners, and communicating the longer-term benefits of the projects.

"If we're able to get an anchor landowner—we'll consider those our larger landowners—they'll hopefully be a 'project champion' for us. If that person has been in the community for their entire life, and they're like, 'before you sign another piece of land, we know this county commissioner is going to want to know about this,' we'll go talk to that person today. We, as the developer, need to recognize…that we are not the experts in local politics, so I need to defer to those experts there on what they suggest and what they think is appropriate because maybe what works for one project will not work for another." (Solar Developer #1).

Nearly all of the solar developers we interviewed (i.e., 80%) found physical media like newspapers and door hangers effective, in addition to a project website. However, one solar developer told us that they also develop a project Facebook page to directly engage with community groups, and prepare informational one-pagers about utility-scale solar project benefits for public distribution. However, regarding mail, one developer mentioned that even letters can be overlooked and lead to communities feeling insufficiently informed.

"I think a lot of people don't see those letters. A lot of people don't really understand what it means, and then people feel caught off-guard like they don't know about [the project] because they don't remember reading the letter we sent to them, or people just don't open their mail." (Solar Developer #5).

In face-to-face communication, solar developers reported first seeking out local officials—including permit-issuing authorities, economic development coordinators, taxing beneficiaries, and county commissioners—to discuss initial development details. Interviewees noted holding informational sessions and having a personalized approach with landowners.

"I think one way that [our company] differentiates ourselves is that we really do try to take an extremely proactive approach to outreach on these projects. By the time we are ready to file permits in these communities, we will have attempted to meet with every single neighbor of the project." (Solar Developer #1).

Some solar developers advocate for state-level action to ease jurisdictional barriers to solar development such as moratoriums, and further encourage community outreach to combat exaggerated claims that lead to utility-scale solar opposition.

"Zoning on prime agricultural land has been a huge challenge because of the perception that you're taking valuable farmland out of production when in actuality you only need like 1% of farmland out of production, of prime agricultural land, to power 100% of the country." (Solar Developer #3).

3.1.2 Landowners

Developers initiated all of the landowner outreach observed in our study. Many instances of within-group communication reported by landowners were conducted either among personal acquaintances or via Facebook groups. After local officials, landowners were the most frequent group to report discussing solar projects amongst themselves. Of the direct communication reported by landowners, the exchange of knowledge was largely limited to word-of-mouth interactions. Of the indirect communication reported by landowners, information was received through conventional television and paper news outlets.

We also found that landowners often seek information independently, both to begin learning about solar, and to supplement or corroborate existing knowledge. All but one of our interviewees noted their commitment to online research. However, one landowner said that the information their community provides skews toward opposing solar.

"Solar is cheaper, but… in our country, there's political divide, and it often makes people skeptical. Or, one source of information says solar doesn't work, it is not a good thing, it has lots of bad things about it…there are some people that listen to those sources, so they aren't excited or don't think objectively about solar systems." (Landowner #1).

One landowner noted that adverse experiences with a wind farm in their county set a precedent for a lack of trust in renewable energy developers.

"That was malpractice on part of the developer, because they thought they were going to be smart and they went into secret agreements with the town chair and put a bunch of wind towers on his farm. Kind of [upset everybody] when they found out about it." (Landowner #2).

3.1.3 Local Officials

Local officials' first awareness of utility-scale solar project proposals typically coincides with developers doing landowner outreach. Local officials frequently engage in within-group communication; over half reported that officials from adjacent counties commonly share project and policy knowledge. Regarding word-of-mouth knowledge flows within communities, a large majority of local officials identified citizen and landowner mistrust of solar as an obstacle, and engagement as an important condition of project development.

"While solar has a lot of benefits, that's a decision that each community needs to make for themselves, and there's a lot of diverse points of view on the value of solar among tribal and other communities. So sharing information with people, getting buy-in, and understanding what the community wants is really important." (Local Official #7).

Local officials also pursue independent knowledge sources, including newspapers, industry contacts, and reports.

"I've read articles about how [opposition] is occurring in other places, and I'm like, wow, this is common. This is exactly what we're experiencing." (Local Official #11).

Two officials noted negative feedback in their township when their community learned of a solar project through the media. Citizens often felt deceived by their government due to insufficient project information dissemination.

However, occurrences of *direct* communication by local officials centered around two-way communication: they both provided and received information with most parties with which they interacted. They consulted solar developers on the initial stages of land acquisition,

conferred with local opposition to solar projects, and implemented public engagement strategies. Over half of the local officials we interviewed gain initial knowledge of solar projects directly from the developer.

"Typically we will hear from developers or their consultants that they're working with to find viable sites. We'll get a call, 'Hey, we're looking at a project in this general area. Can you tell me what the rules are?' That's the majority of how we learn about these potential projects." (Local Official #11).

One local official partially attributed solar opposition's prominence to the availability of online content, much of which they observe to be false or misleading. They instead encourage community members to approach the developer or local government directly for information. To address opposition, local officials commonly report prioritizing quality public education and community inclusion in the project's process. When a solar developer contacted one official's county about local ordinances, the officials first approached their communities to discuss potential for a solar project and ordinance adoption.

"We…educate them and ask questions about how much or how little they want the [solar developer] company to be involved in this. We organized open houses and workshops… The company had different posters about why they're here, what it's going to look like, economic benefits, the amount of jobs that are going to be there, and then they ultimately have reps there to answer questions. I think after that meeting, a lot of the community, the people that had concerns and questions, [their questions] were addressed." (Local Official #3).

We also found that some counties provide an opportunity to email the planning director with comments that the local government will pass onto the solar developer to be addressed on the meeting's record. Local officials discuss education and community engagement as valuable strategies to employ in future approaches to expand utility-scale solar development. One local official that we spoke with promoted the collaboration of diverse perspectives on solar development during the decision-making process.

"One of the big things that I try to pride myself on is the collection of individuals on [ordinance amendment] committees. We actually had a couple of members that were pro and a

couple of members that were against the technology and the use itself, which led to a lot of great conversations in order to come to essentially a compromise and what would be best for the community moving forward." (Local Official #8).

Below, in Figure 3, we illustrate the relative magnitude of our codes for these three central stakeholders.

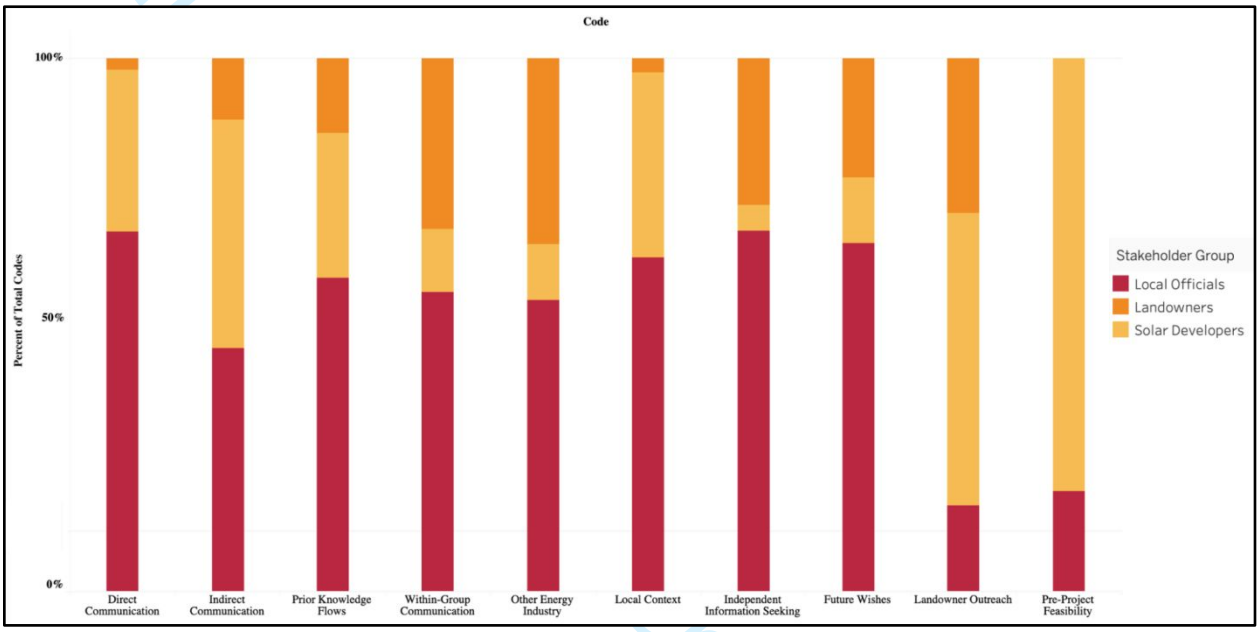

Fig. 3. Relative Magnitude of Central Stakeholder Knowledge Flow Codes.

3.2 Peripheral Stakeholders

Each peripheral stakeholder group in our study (i.e., nonprofits, media, regulators, utilities, or citizens) only had three interviewees. As such, we cannot make generalizations about these groups. However, these perspectives allowed us to supplement the observations made of the central stakeholders from a different angle.

3.2.1 Nonprofits

Nonprofit interviewees generally learned about utility-scale solar projects in their early stages of development, largely from press releases and draft ordinances, internal contacts, and independent research.

"The main source is that the [public utility board] tracks each development, so when a new project comes in, they file a pre-application letter, so I look at that all the time, just to see what's moving and shaking." (Nonprofit #3).

Nonprofit stakeholders also centered direct methods of communication with other stakeholders to advance energy conversations. One interviewee mentioned mediating communication between local officials and community members, while another spoke of ensuring that both industry accountability and its communication barriers are addressed.

"One of the things that an opposition group felt was that developers weren't communicating upfront, and if they were communicating, that they weren't communicating the full truth, that they are only communicating half truths about certain things, and I found that very interesting." (Nonprofit #2).

In one specific nonprofit's experience, the opposition group's vocality resulted in a disproportionately large presence. From polling results and local observation, this interviewee suggested that the opposition is a minority, yet assertive, opinion in their area.

"It's a very loud opinion, but it's also people who are very, very local to the project in terms of right across the street. So they're having, like, an outsized voice in calling themselves 'the community' when, really, it's just like a small band of brothers that are going out and being real loud. So it's just another thing that I'm thinking about in terms of 'how does the community feel about this?' versus 'how do the people who live across the street from the project feel about it?'" (Nonprofit #3).

In another nonprofit interviewee's opinion, communities commonly misunderstand the long-term benefits of utility-scale solar projects and would benefit from both larger awareness campaigns, as well as from the language of project benefits being personalized to their locality.

3.2.2 Media

Media members in our study facilitate indirect communication with the public through providing knowledge via news articles, press releases, newscasts, etc. Our media interviewees reflected that much of their readership consists of individuals already invested in solar energy, though stories do gain visibility in the general public.

"I think that [readership] is a mix of specific projects, people who are going to be directly impacted by that project, and then people who are just clean energy curious and interested, broadly speaking." (Media #2).

Through contact networking, word-of-mouth, and knocking on doors—direct communication—media members report gathering information on both regulatory proceedings and stakeholders' insights on solar project development.

"Generally, where I'm hearing about [utility-scale solar projects] initially is through the grapevine. I'm hearing from landowners, from my former colleagues at [environmental organization], from those kinds of people in that network in the very early phases when companies are having salespeople go and try to get leases on land." (Media #1).

During their independent gathering of information, media members discussed gaining knowledge from checking public utility dockets, seeing properties signed up for solar leases on county auditor websites, engaging with energy newsletters, and reading public comments in public proceedings. Some media members also obtained local testimony by attending public meetings.

One interviewee observed similarities in utility-scale solar project benefits and local resistance across geographical boundaries. Media stakeholders advocate for accessibility and genuine outreach on behalf of solar developers.

"It does seem like the developers aren't that accessible, even as a reporter. I feel like they're not doing a lot of outreach, and they're not necessarily that friendly or transparent. I mean, those are just subjective thoughts. But if I get that impression, I'm sure regular people don't feel like they're getting a voice or getting information from the actual companies." (Media #3).

3.2.3 Regulators

Regulators typically engage with community members by regularly requesting input on their agency processes. They first connect with developers when projects are bid into their procurement. One regulator interviewee reported being contacted by landowners and local officials for assistance with details of solar ordinance drafting.

"If the ordinance doesn't exist, a lot of times I will be asked to work with the local authorities to create an ordinance that can govern what the requirements are." (Regulator #2).

This same regulator characterized solar developers' landowner outreach as business-driven and minimally communicative. This contrasts with solar developer interviewees' claims to an interpersonal approach and contributions to community benefit.

"Most of the time, the landowner will receive from this land agent…they put in front of them a lease, and they say, 'We'd like you to consider signing this lease, and that lease gives us the right to come onto your land for an exploratory phase of time, and then if conditions are right and the project goes forward, that exploratory phase will convert into a long-term, many, many years lease.'" (Regulator #2).

3.2.4 Utilities

Utility stakeholders center their information dissemination on indirect methods such as a website, most often used by the general public, and reports, most often read by local officials. One utility representative talked about offering workshops with local officials, cooperation with local universities, and integration of citizen feedback in utility considerations, in addition to recommending transparent dissemination of project resources by the government.

"Essentially, a trade association and governments making sure that [solar project] information is available and promulgated by those entities is probably going to go a long way to helping." (Utility #3).

This same utility representative further reflected that online responses to large-scale solar projects are largely oppositional, and criticize the intentions of solar developers.

"One of the perceived negatives that I keep hearing is that these are out of town, out of state, investors or developers who don't know and don't care about the community, the local culture, and the local values…whether or not that's actually the case…I really can't say, but I can say that some of the statements and actions of some of the developers lend that perception to. They don't go out of their way to refute it." (Utility #3).

A different interviewee reported valuable collaboration with another electric cooperative currently advancing both utility-scale solar and energy storage. This interviewee was able to tour this cooperative's facilities and discuss their experiences.

3.2.5 Citizens

Finally, our citizen interviewees reported indirect communication occurring via the media, which tend to either summarize public reports or discuss opposition for utility-scale solar projects. One interviewee noted that land mapping in initial community engagement meetings for projects are overwhelming to citizens, and that developers must simultaneously navigate the project's intricacies and the constituents' dissent. Thus, this citizen recommended that their public utility board be intentional about hosting community engagement meetings early enough in the project's development where citizens feel there are still initial decisions to be made.

"I don't hear about new solar projects until somebody has a problem with it and it ends up in the media, and part of that has to do with the [public utility board]'s process of requiring maps at the first public engagement meeting." (Citizen #1).

While some citizens experience face-to-face engagement with solar developers during public meetings and with landowning community members, others tend to gain knowledge from personal contacts and local officials.

"I feel like I hear things from different developers differently, if that makes sense. Like, I know some of the developers, so they tell me if there's a project going on." (Citizen #3).

All three of our citizen interviewees have had conversations within their stakeholder group among neighbors, friends, and colleagues about solar development. One reported observing developer efforts to win local favor through citizens' within-group communication by recruiting "local elites" to scout community attitudes.

"It's kind of interesting because you'll have a solar developer go in, and, you know, start scouting out, speculating, on different land, and they'll ask landowners, 'Hey! Would you talk to your neighbors about this, too, and, like, ask them what their feelings are?' and so they're kind of telling people to go out and scout out how acceptable this will be because we don't want to upset other people." (Citizen #3).

Figure 4 quantitatively synthesizes the total amount of codes seen across our interviews by stakeholder group.

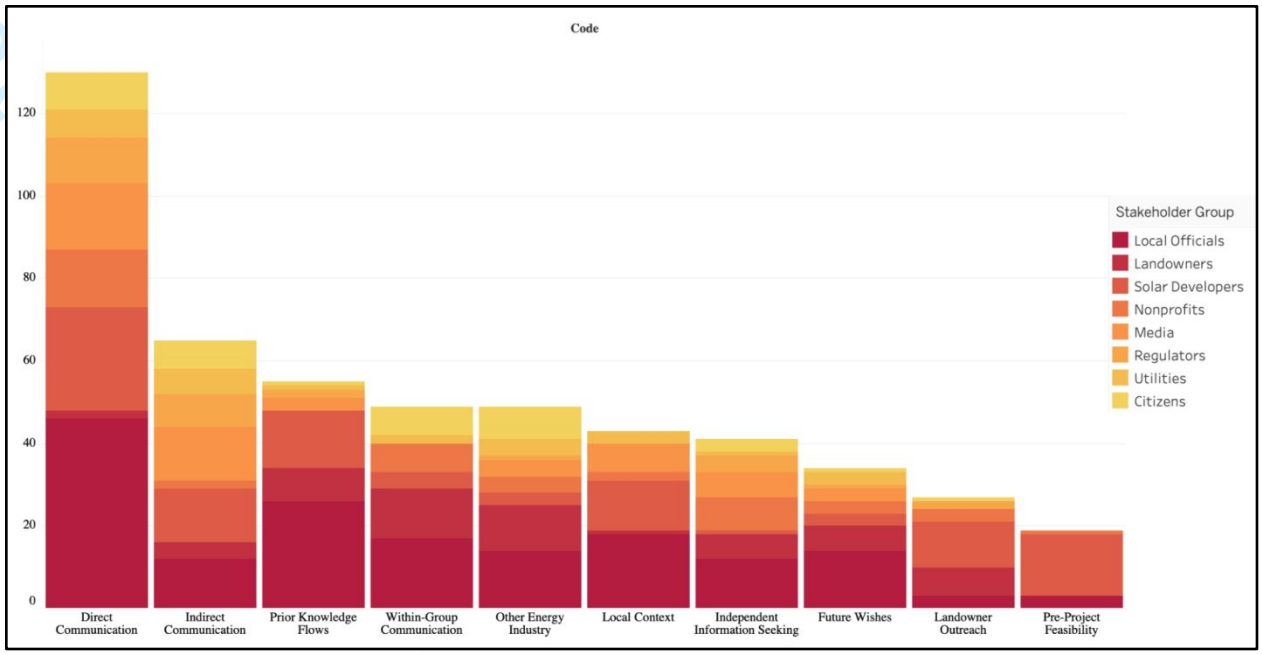

Fig. 4. Composition of Knowledge Flow Code Results by Stakeholder Group.
Relative to their interview sample, solar developers led code categories regarding knowledge sourcing (i.e., prior knowledge flows, landowner outreach, and pre-project feasibility), while media and nonprofits led code categories regarding knowledge exchange (i.e., direct, indirect, and within-group communication).

4. Discussion

Our findings illuminate existing patterns and gaps in the flow of knowledge surrounding utility-scale solar projects in the rural Midwest. Local government officials appear to be the center or conduit of information. They provide a connection point for many of the stakeholder groups in our study, specifically by forwarding questions from citizens onto developers, coordinating with developers to host meetings for citizens, bringing in nonprofits to help educate their citizens about solar, and connecting media representatives to prospective interviewees in the community. Local officials also reach out to government officials in other regions to learn about solar from others' experience, and to give or get advice on creating zoning ordinances.

While solar developers are the originators of the project and the source of most technical and project-specific information, their focus is primarily on landowners and local officials (and, secondarily, citizens, after they have secured land and zoning information). Moreover, in most

cases, the majority of the knowledge in the developers' networks of communication is outreach on the part of the developer, rather than receiving knowledge from the community. Among local officials, a sentiment that arose across interviews is the goal to "do our absolute best to try to help educate" (Local Official #8) in order "to make sure that we're doing right by everyone to the extent we can" as public servants (Local Official #3). Officials help to give the developers' information social and political relevance as they connect it with other stakeholder groups, and they receive other stakeholders' information in return, thus placing them central to flows of knowledge in this complex system.

It is also interesting to observe that while local officials in our sample discuss opposition from their community towards solar, they do not often indicate that this hostility is aimed at themselves. While this study did not measure trust per se, this omission on the part of the local officials could indicate that their position as intermediaries or liaisons between parties is trusted, or that the local officials do not consider hostility at themselves the most notable interaction that they have with regard to solar. However, it is also possible that local officials are unaware of or did not disclose any disapproval directed towards them. Despite these potential limitations, the role of local officials at the center of knowledge flows, especially in connecting developers and citizens and providing education, is an angle worth considering or pursuing in further research. If local officials can indeed serve as a trusted mediator or nexus between developers and citizens, this could be valuable information for approaches to future large-scale solar development efforts. While many developers pride themselves on direct, face-to-face engagement with the community, our research suggests that facilitating that contact with another trusted party (especially a local one) could improve relationships and the quality of information exchanged.

Due to the sample size of this study, findings should not be generalized to an entire population, including within the Great Lakes region, and especially outside of it. The study had a small sample size per stakeholder group, especially for media, citizens, utilities, nonprofits, and regulators, which each had three interviewees. While these peripheral stakeholders were interviewed to supplement the comments of the central stakeholders (i.e., solar developers, landowners, and local government officials) and their comments are valuable, it is important to keep in mind that they are the experiences of a very few individuals.

5. Conclusion

The purpose of our study was to identify how stakeholders in the Great Lakes region learn about utility-scale solar projects. While prior literature has investigated communication networks surrounding energy infrastructure, especially among local community members (Anderson 2013; Fast and Mabee 2015; Fergen et al. 2021; Reimer and Brett 2013), our study differed because it focused on this particular region of the U.S. with a focus on the flow of knowledge about large-scale solar projects specifically.

Prior literature has investigated community opposition to energy siting, including utility-scale solar, and found that unfamiliarity can precipitate opposition movements (Carlisle et al. 2016; Larson and Krannich 2016; Nilson and Stedman 2023; Susskind et al. 2022). By identifying gaps in communication networks around utility-scale solar siting in the Great Lakes region, our study can help identify areas to target in conveying information to and among local communities to decrease opposition.

The timing or order of knowledge flows is also an important factor for how citizens and government officials feel about the reliability of a project, developer, or piece of information. Solar developers want to make sure a project has feasibility and momentum by talking to

landowners and local officials before taking it to the broader community members. However, citizens may perceive developers as secretive or untrustworthy. Additionally, if developers wait too long to start engaging with citizens, more citizens engage in independent information seeking, which could result in higher frequency of misinformation in a community, especially once citizens start sharing information among themselves. Several interviewees view this as a problem that is difficult to fix. Future research could look more closely into the correlation between timing and trust.

Across stakeholder groups, the most common comment under the "future wishes" code (i.e., what interviewees wish would change about the way knowledge flows around large-scale solar) is an increase in community education, especially earlier in the process, offering intrigue for policy and project approval processes moving forward. Stakeholders generally identified confusion surrounding the development process, a failure to share information within the project community, and conflict management during conversations regarding solar development as areas for improvement. This supports prior literature about the importance of community engagement in large-scale solar projects (Crawford et al. 2022; Essa et al. 2021; O'Neil 2020; Uebelhor et al. 2021). Moving forward, future researchers should consider including other states, gathering information from a larger number of stakeholders via survey research, or perhaps even consider field research through public meeting observations. Using other means to better understand local communication around utility-scale solar projects, especially with landowners and opposition groups, may shed light on how large local groups have the power to change the outcome of solar projects. Nevertheless, as this area of inquiry continues to expand, our paper offers value in furthering the knowledge on communication and interaction in communities with utility-scale solar.

Appendix

Table 4

Stakeholder Interview Questions

Stakeholder	Questions
All Stakeholders	*To introduce the interview:* 1. What is your job title (if applicable), and where do you live (e.g., specific township/county)? 2. Please describe the nature and extent of your knowledge of solar energy. *To ask non-solar developer stakeholders:* 3. Where do you typically hear about new utility-scale solar project proposals? What do you typically learn about them? 4. What are your views of the pros and cons of these solar projects? 5. What is your knowledge of local zoning regulations for these solar projects? *To conclude the interview:* 6. What is your perspective on the future of utility-scale solar development in your state? Across the entire Great Lakes region? 7. Do you have any additional/final thoughts on utility-scale solar?
Solar Developers	a. How do you first connect with a community in which you're interested in building a utility-scale solar project? Who do you reach out to first? b. Moving forward from that, what is your broader outreach and education process about new solar projects in a community? c. What kind of materials do you distribute in these areas, and where do you distribute them? d. What are the key factors regarding site selection when it comes to developing a new project? e. What role does local zoning for solar play, if any, with your development processes?
Landowners	a. Do you share your own opinions on utility-scale solar with anyone? If so, how? b. What are your thoughts on how/if your local/state government officials should approve these types of projects in rural communities? c. Have you leased or sold your own land for a solar project? 1c. If 'yes,' what led you to that decision? 2c. If 'no,' have you been approached by a developer? What factors would you consider, if approached?
Local Officials	a. Do you have zoning ordinances in your area for utility-scale solar? 1a. *[If they do have zoning]* What led you to adopt this zoning ordinance?

	1b. *[If they do not have zoning]* What information might you need if you were to consider adopting a zoning ordinance for utility-scale solar? b. What role do you play, if any, in approving/regulating utility-scale solar projects in your community? c. Are you disseminating any information about these projects? If so, how/where?
Nonprofits	a. What role, if any, do you play in the outreach and education about these solar projects? b. *[If applicable]* What types of stakeholders do you engage with the most, and why?
Media	a. What articles have you written related to utility-scale solar in rural communities, and what did they entail? b. What types of stakeholders do you usually interview for these articles? c. How do you find people to interview? What types of questions do you ask them? d. Who are your readers/viewers?
Regulators	a. What role do you play, if any, in approving/regulating utility-scale solar projects in your community/state? b. Are you disseminating any information about these projects? If so, how/where? c. How do citizens, developers, and others typically engage with you about new solar developments? What types of stakeholders engage with you the most, and why?
Utilities	a. How are you involved, if at all, with these projects? b. Do you receive questions from your ratepayers about utility-scale solar development? If so, what types of questions are they asking?
Citizens	a. Do you share your own opinions on utility-scale solar with anyone? If so, how? b. What are your thoughts on how/if your local/state government officials should approve these types of projects in rural communities?

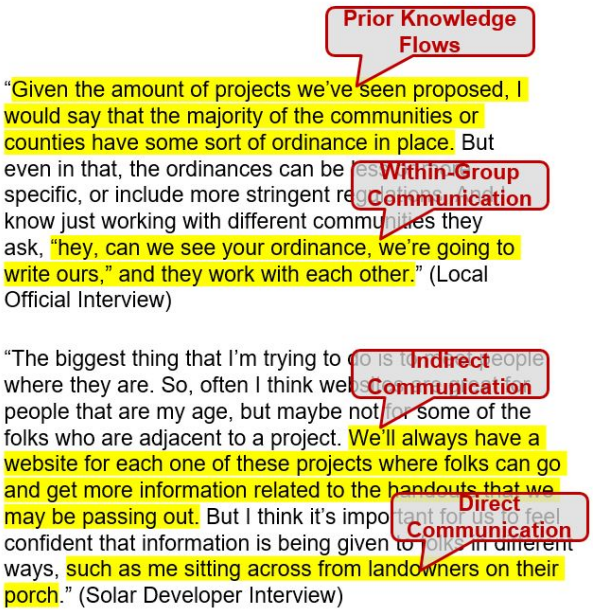

Fig. 5. A Representation of Our Coding Process.

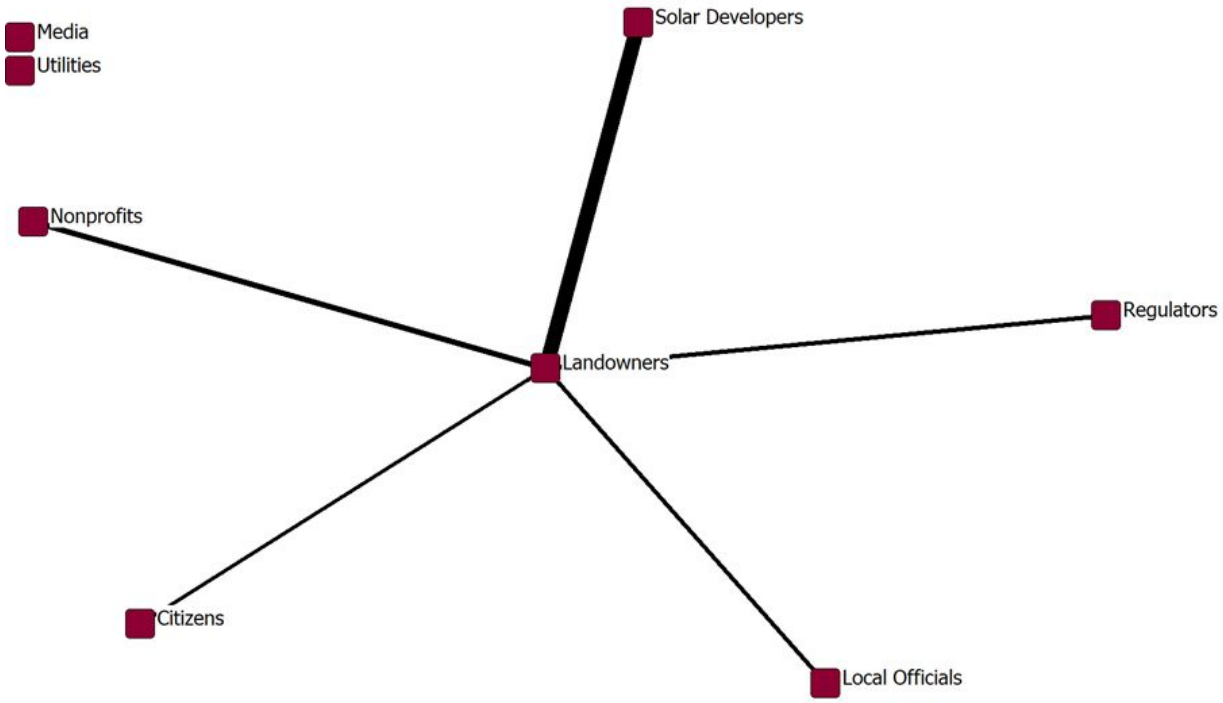

Fig. 6. Social Network Diagram for Landowner Outreach.

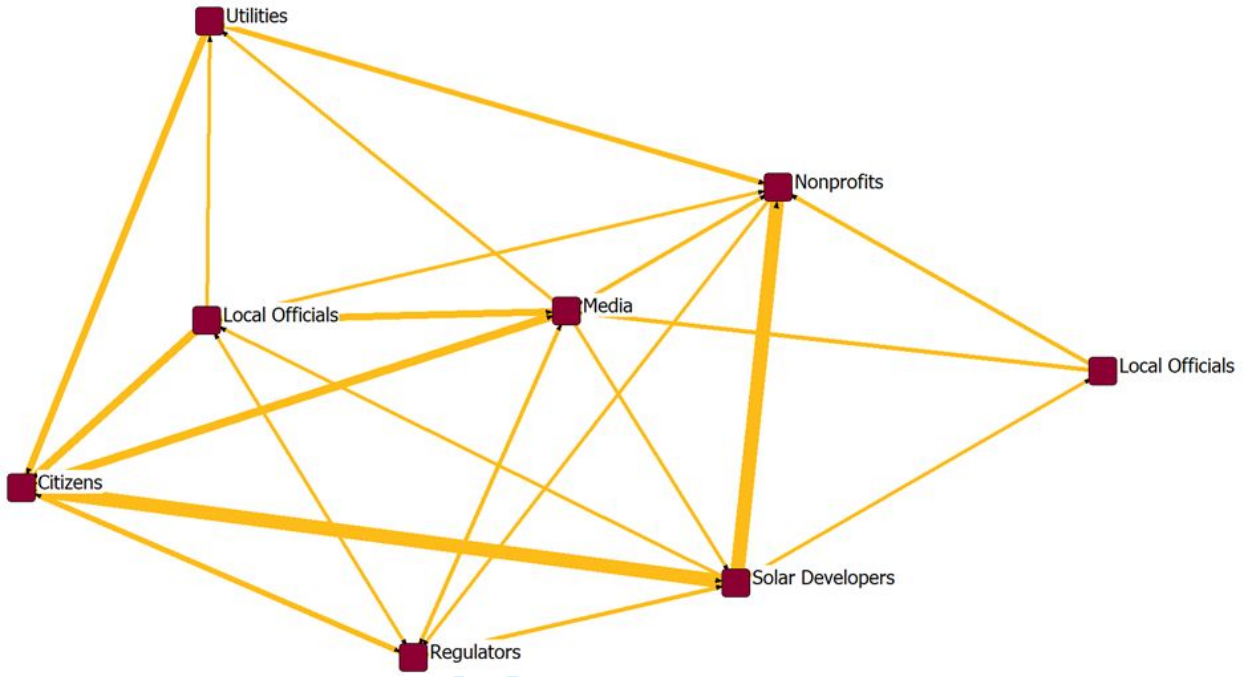

Fig. 7. Social Network Diagram for Indirect Communication.

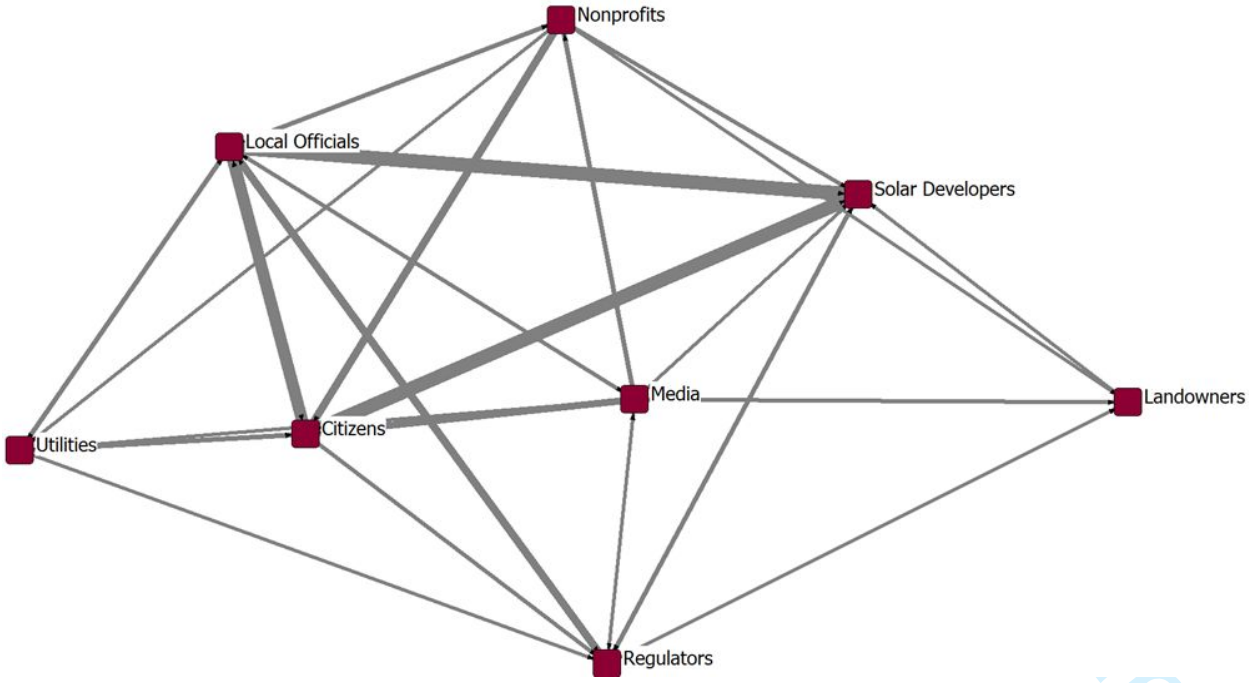

Fig. 8. Social Network Diagram for Direct Communication.

References

Anderson C (2013) The networked minority: How a small group prevailed in a local windfarm conflict. Energy Policy 58:97–108. https://doi.org/10.1016/j.enpol.2013.02.048

Bessette DL, Hoen B, Rand J, Hoesch K, White J, Mills SB, Nilson R (2024) Good fences make good neighbors: Stakeholder perspectives on the local benefits and burdens of large-scale solar energy development in the United States. Energy Research & Social Science 108:103375. https://doi.org/10.1016/j.erss.2023.103375

Bronin S (2022). Zoning rules stifle urban clean energy. Can the rules be rewritten? Kleinman Center for Energy Policy. https://kleinmanenergy.upenn.edu/podcast/zoning-rules-stifle-urban-clean-energy-can-the-rules-be-rewritten/. Accessed 12 January 2025

Buckley Biggs N, Shivaram R, Acuña Lacarieri E, Varkey K, Hagan DJ, Young HE, Lambin E (2022) Landowner decisions regarding utility-scale solar energy on working lands: A qualitative case study in California. Environmental Research Communications 4:055010. https://doi.org/10.1088/2515-7620/ac6fbf

Carroll M (2023) Considerations for transferring agricultural land to solar panel energy production. Craven County Center, North Carolina State Extension. https://craven.ces.ncsu.edu/considerations-for-transferring-agricultural-land-to-solar-panel-energy-production/. Accessed 12 January 2025

Crawford J, Bessette D, Mills S (2022) Rallying the anti-crowd: Organized opposition, democratic deficit, and a potential social gap in large-scale solar energy. Energy Research & Social Science 90:102597. https://doi.org/10.1016/j.erss.2022.102597

Davis S (2015) Renewable electricity generation and transmission expansion: A federal, state or regional approach? The Electricity Journal 28(4):28–35. https://doi.org/10.1016/j.tej.2015.04.005

Dokyi KAN, Sharifi A (2024) Identification and analysis of barriers to the implementation of utility-scale solar photovoltaic technology in Ghana. Energy for Sustainable Development 83:101547. https://doi.org/10.1016/j.esd.2024.101547

Dreveskracht RD (2012) Economic development, native nations, and solar projects. The American Journal of Economics and Sociology 72(1):122–144. https://doi.org/10.1111/j.1536-7150.2012.00866.x

Dunlap AA, Sovacool BK, Novakovic B (2024) "Our town is dying:" Exploring utility-scale and rooftop solar energy injustices in Southeastern California. Geoforum 156:104120. https://doi.org/10.1016/j.geoforum.2024.104120

Essa E, Curtiss K, Dodinval C (2021) Solar siting authority across the United States. Center for Local, State, and Urban Policy (CLOSUP), University of Michigan. https://closup.umich.edu/research/working-papers/solar-siting-authority-across-united-states

Fast S (2017) Assessing public participation tools during wind energy siting. Journal of Environmental Studies and Sciences 7:386-393. https://doi.org/10.1007/s13412-016-0419-0

Fast S, Mabee W (2015) Place-making and trust-building: The influence of policy on host community responses to wind farms. Energy Policy 81:27–37. https://doi.org/10.1016/j.enpol.2015.02.008

Fergen JT, Jacquet JB, Shukla R (2021) "Doomscrolling" in my backyard: Corrosive online communities and contested wind development in rural Ohio. Energy Research & Social Science, 80, 102224. https://doi.org/10.1016/j.erss.2021.102224

Fierke-Gmazel H, Gould MC, Neumann B, Reilly M, Beyea W, Derry J, Gilbert E, Mills S, Smith H (2021) Planning and zoning for solar energy systems: A guide for Michigan local governments. Michigan State University. https://www.canr.msu.edu/resources/planning-zoning-for-solar-energy-systems-a-guide-for-michigan-local-governments

Foley RW, Pollack CC, Barrella E, Wilkins R (2021) How public values theory can influence energy infrastructure planning: Exploring values articulation, time horizons, and substitutability through the Atlantic Coast pipeline. Energy Research & Social Science 72:101836. https://doi.org/10.1016/j.erss.2020.101836

Greene J, Ross B, Wyatt J (2020) Siting utility-scale solar and wind in Indiana. Great Plains Institute. https://solarformasoncounty.com/wp-content/uploads/2021/03/in-renewable-energy-guide.pdf

Hernandez RR, Easter SB, Murphy-Mariscal ML, Maestre FT, Tavassoli M, Allen EB, Barrows CW, Belnap J, Ochoa-Hueso R, Ravi S, Allen MF (2014) Environmental impacts of utility-scale solar energy. Renewable and Sustainable Energy Reviews 29:766-779. https://doi.org/10.1016/j.rser.2013.08.041

Hernandez RR, Hoffacker MK, Murphy-Mariscal ML, Wu GC, Allen MF (2015) Solar energy development impacts on land cover change and protected areas. Proceedings of the National Academy of Sciences 112(44):13579–13584. https://doi.org/10.1073/pnas.1517656112

Hoffacker MK, Allen MF, Hernandez RR (2017) Land-sparing opportunities for solar energy development in agricultural landscapes: A case study of the Great Central Valley, CA, United States. Environmental Science & Technology 51(24):14472–14482. https://doi.org/10.1021/acs.est.7b05110

Illinois Power Agency (2020) Long-term renewable resources procurement plan: Final revised plan. https://illinoisabp.com/wp-content/uploads/2020/05/Revised-LTRRPP-updated-from-ICC-Order-20-April-2020.pdf

Jain S (2022) Exploring structures of power purchase agreements towards supplying 24x7 variable renewable electricity. Energy 244(A):122609. https://doi.org/10.1016/j.energy.2021.122609

Khalaf C, Michaud G, Jolley GJ (2022) Toward a new rural typology: Mapping resources, opportunities, and challenges. Economic Development Quarterly 36(3):276–293. https://doi.org/10.1177/08912424211069122

Lawrence Berkeley National Laboratory (2023) Queued up: Characteristics of power plants seeking transmission interconnection. Electricity Markets and Policy Group. https://emp.lbl.gov/queues. Accessed 12 February 2025

Li Q, Cui W, Lin J, Sun X (2010) Knowledge dissemination on community networks. Proceedings of the 2010 International Conference on Management and Service Science 1–4. https://doi.org/10.1109/ICMSS.2010.5576185

Michaud G (2020a) Examining renewable energy transitions: A tool to enhance workforce development. Center for Local, State, and Urban Policy (CLOSUP), University of Michigan. https://closup.umich.edu/sites/closup/files/uploads/repi/REPI-Michaud.pdf

Michaud G (2020b) Perspectives on community solar policy adoption across the United States. Renewable Energy Focus 33:1–15. https://doi.org/10.1016/j.ref.2020.01.001

Michigan Townships Association (2023) Renewable energy siting and permitting. https://michigantownships.org/renewable-energy-siting-and-permitting/. Accessed 17 January 2025

Minnesota Commerce Department (2023) Energy environmental review & analysis. https://mn.gov/commerce/energy/eera/. Accessed 11 January 2025

Moore S, Graff H, Ouellet C, Leslie S, Olweean D (2022) Can we have clean energy and grow our crops too? Solar siting on agricultural land in the United States. Energy Research & Social Science 91:102731. https://doi.org/10.1016/j.erss.2022.102731

Mulvaney KK, Woodson P, Prokopy LS (2013) Different shades of green: A case study of support for wind farms in the rural Midwest. Environmental Management 51(5):1012–1024. https://doi.org/10.1007/s00267-013-0026-8

National Renewable Energy Laboratory (2022) Utility-scale PV. Annual Technology Baseline. https://atb.nrel.gov/electricity/2022/utility-scale_pv. Accessed 12 December 2024

Neij L, Heiskanen E, Strupeit L (2017) The deployment of new energy technologies and the need for local learning. Energy Policy 101:274–283. https://doi.org/10.1016/j.enpol.2016.11.029

O'Neil SG (2021) Community obstacles to large scale solar: NIMBY and renewables. Journal of Environmental Studies and Sciences 11:85-92. https://doi.org/10.1007/s13412-020-00644-3

Ohio Power Siting Board (2017) Standard application process. https://opsb.ohio.gov/processes/standard-process. Accessed 12 November 2024

Pascaris AS, Schelly C, Burnham L, Pearce JM (2021) Integrating solar energy with agriculture: Industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. Energy Research & Social Science 75:102023. https://doi.org/10.1016/j.erss.2021.102023

Pitt D, Michaud G (2015) Assessing the value of distributed solar energy generation. Current Sustainable/Renewable Energy Reports 2(3):105–113. https://doi.org/10.1007/s40518-015-0030-0

Public Service Commission of Wisconsin (2024) Electric major cases. https://apps.psc.wi.gov/APPS/dockets/majorcase.aspx?srvc=ele. Accessed 19 December 2024

Reimer B, Brett M (2013) Scientific knowledge and rural policy: A long-distant relationship. Sociologia Ruralis 53(3):272–290. https://doi.org/10.1111/soru.12014

Rountree V, Baldwin E, Hanlon J (2021) A review of stakeholder participation studies in renewable electricity and water: Does the resource context matter? Journal of Environmental Studies and Sciences 12:232-247. https://doi.org/10.1007/s13412-021-00726-w

Solar Energy Industries Association (SEIA) (2023) Solar industry research data. https://www.seia.org/solar-industry-research-data. Accessed 10 November 2024

Sward JA, Nilson RS, Katkar VV, Stedman RC, Kay DL, Ifft JE, Zhang KM (2021) Integrating social considerations in multicriteria decision analysis for utility-scale solar photovoltaic siting. Applied Energy 288:116543. https://doi.org/10.1016/j.apenergy.2021.116543

Trandafir S, Thomas P, Bidwell D, Rezendes R (2023) Community benefit agreements for solar energy: Examining values, preferences and perceived benefits in the United States using

a discrete choice experiment. Energy Research & Social Science 106:103305. https://doi.org/10.1016/j.erss.2023.103305

Turney D, Fthenakis V (2011) Environmental impacts from the installation and operation of large-scale solar power plants. Renewable and Sustainable Energy Reviews 15(6):3261–3270. https://doi.org/10.1016/j.rser.2011.04.023

Uebelhor E, Hintz O, Mills SB, Randall A (2021) Utility-scale solar in the Great Lakes: Analyzing community reactions to solar developments. Sustainability 13:1677. https://doi.org/10.3390/su13041677

University of Michigan Center for Sustainable Systems (2023) U.S. renewable energy. https://css.umich.edu/sites/default/files/2023-10/Renewable%20Energy_CSS03-12.pdf

U.S. Department of Agriculture – Economic Research Service (2025) Rural classifications – What is rural? https://www.ers.usda.gov/topics/rural-economy-population/rural-classifications/what-is-rural. Accessed 13 February 2025

U.S. Energy Information Administration (2023) Wind, solar, and batteries increasingly account for more new U.S. power capacity additions. https://www.eia.gov/todayinenergy/detail.php?id=55719. Accessed 29 December 2024

Wiser R, Millstein D, Mai T, Macknick J, Carpenter A, Cohen S, Cole W, Frew B, Heath G (2016) The environmental and public health benefits of achieving high penetrations of solar energy in the United States. Energy 113:472–486. https://doi.org/10.1016/j.energy.2016.07.068