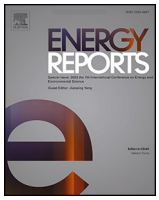
Energy Reports 15 (2026) 108988

Contents lists available at ScienceDirect

Energy Reports

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



Review article

Uneasy tensions in research on local responses to large-scale solar plants: A critical and integrative review

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ARTICLE INFO

Keywords:
Large-scale solar
Social acceptance
Energy justice
Institutions
Impacts
Perceptions
Conflict

ABSTRACT

Driven by the construction of new large solar power plants, recent years have seen a boom in solar PV energy, with global capacity tripling between 2018 and 2023. By the end of this decade, solar is set to become the largest renewable energy source, surpassing both wind and hydropower. However, the growing number and scale of solar projects are raising concerns about their socio-ecological impacts and energy justice implications. Conflicts at deployment sites are becoming more frequent, challenging long-held assumptions about solar energy's public acceptability. While research on social acceptance and energy justice has mainly focused on other technologies, there is now a growing body of social science work examining large-scale solar plants. Yet this literature remains fragmented: diverse methodologies, conceptual frameworks, and normative standpoints make it difficult to develop integrated understandings of why injustices and opposition occur, what solutions are being proposed, and how they are pursued. This article addresses these gaps through a critical and integrative review of 255 peer-reviewed studies that empirically examine large-scale solar deployment. We identify five overarching themes of research focused on institutions, perceptions, impacts, conflicts, and solutions. These themes are shaped not only by their research objects but also by distinct disciplinary knowledge and goals. By bridging these perspectives, we propose a critical and relational metatheoretical perspective that highlights new research directions and offers a basis for more holistic understanding and practice.

1. Introduction

The idea of a renewable energy transition is being promoted worldwide as key to addressing climate change. Solar energy is central to this vision and according to the International Energy Agency (2024) global capacity is projected to increase by over 4000 gigawatts by 2030, accounting for 80 % of the growth in global renewable capacity during this period. This rapid expansion is the backdrop to growing controversy over large-scale solar plants' socio-ecological impacts across global value chains and in multiple national contexts, leading to widespread socio-political conflicts and injustices (Stock and Sareen, 2024).

This raises questions about why and how exactly large-scale solar deployment is resulting in negative impacts and opposition. Energy social science offers valuable resources for addressing these questions and understanding the underlying dynamics of large-scale solar's acceptability and fairness. As a broad field encompassing diverse perspectives on energy production, distribution, and consumption, it provides tools for analysing the drivers, processes and implications of socio-technical change, including the deployment of large-scale solar projects.

However, Bidwell and Sovacool (2023) have recently highlighted the "uneasy tensions" between the two main research programs focused on the deployment of renewable energy technologies: "community acceptance" and "energy justice." They argue that the latter generally takes a more critical stance than the former, and that acknowledgement of the interrelated epistemological and moral tensions can improve scholarship and policy dialogue. So far, these two main research programs have been mainly applied to case studies of local opposition to wind farms in the Global North, but recent research on large-scale solar plants worldwide signals a shift and the need to critically reflect on if and to what extent these research programs contribute understanding to the socio-political conflicts generated by large-scale solar. Additionally, more critical research approaches have recently begun to be more mainstreamed – such as political ecology and environmental justice scholarship (Sovacool, 2021; Knuth et al., 2022).

To the best of our knowledge no comprehensive review has yet attempted to integrate these literatures with a view towards examining the social dynamics of large-scale solar deployment. In this paper, we address this gap by conducting an integrative review of 255 peer-

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https://doi.org/10.1016/j.egyr.2025.108988
Received 8 August 2025; Received in revised form 25 November 2025; Accepted 23 December 2025
Available online 10 January 2026

reviewed academic articles that focus on the social dimensions of large-scale solar energy plants. Based on the findings of this review, we aim to address the following research questions:

1. *Why and how does the deployment of large-scale solar energy plants result in local opposition?*
2. *What recommendations and solutions are proposed, and how are they being pursued?*
3. *How can these dynamics be theorized to better inform energy decision-making processes?*

Our critical and integrative approach relies on the notions of social acceptance and energy justice as points of departure for further mapping and integrating the social scientific literature on large-scale solar plants. In the following section, we introduce these key research programs in greater detail, outlining their primary contributions as well as their limitations. Section 3 presents the integrative methodology that guided our review and the results of our bibliometric analysis. Section 4 presents the integrative review of five key research themes identified in the literature. In keeping with the spirit of the integrative review, Section 5 proposes a critical and relational conceptual perspective that synthesizes insights across these themes, highlighting limitations and strength of current research and pointing to areas that warrant further empirical investigation. We conclude by summarising our findings and key theoretical, methodological and practical contributions.

2. Social responses to renewable energy deployment: overview of main approaches and concepts

In energy social science, research programs are oriented to questions such as how to accelerate low-carbon transitions (Sovacool et al., 2025), how to foster social acceptance of renewable energy technologies (Ellis et al., 2023), and how to institutionalize energy justice (Heffron, 2022). To address these questions, social scientists draw from a wide array of concepts and methodologies. These research approaches not only originate from different disciplines but also reflect fundamentally distinct ontological and epistemological assumptions and values (Skjølsvold, 2024); are shaped by specific geographic and historical contexts (Fast, 2013; Van der Horst et al., 2021); and address diverse research audiences with varying expectations for impact (Batel, 2020; Burawoy, 2005). Moreover, in energy social science just as in all social sciences, conceptual frameworks are never politically neutral: they carry assumptions about agency, power, and the pathways deemed legitimate for sustainability (Bidwell and Sovacool, 2023).

There are two main research programs that study the social dimensions of renewable energy deployment, typically in European and North American contexts (Rand and Hoen, 2017; Jenkins et al., 2021; Wüstenhagen et al., 2007). Research which focuses on "community acceptance," usually situated within the broader "social acceptance" research program, is grounded in the disciplines of geography and social psychology and aims to describe factors that contribute to support and opposition to renewable energy, mainly wind energy projects (Bell et al., 2005; Devine-Wright, 2009). The research program focusing on "energy justice" is grounded in philosophy, jurisprudence and sociology and mainly aims to examine the distributive and procedural fairness of renewable energy projects and associated institutions (Sovacool and Dworkin, 2015; Jenkins et al., 2016; Heffron and McCauley, 2017). Bidwell and Sovacool (2023) have argued that these research programs differ not only in terms of explicit goals and methods, but also in terms of more implicit ethics and normative visions of the energy future, namely in the orientation that researchers take towards questions of change (e.g. reform or transformation) and justice (e.g. instrumental or intrinsic).

There is an abundance of literature reviews dealing with these research programs, but rarely do scholars attempt to integrate them. One recent exception is Minadakis and Vega-Araujo's (2024) review of the interrelations between the concepts of social licence to operate, social acceptance and energy justice, in which they posit that energy justice has emerged as a powerful analytical tool for understanding and potentially measuring the social licence to operate. The broader analytical scope of energy justice, e.g. its attentiveness to value-chains, can help reveal factors that influence community acceptance beyond the particular geographical area where a project is sited. Yet in this approach it is still the local community which is viewed as the site where conflicts are shaped. The emphasis is therefore on how energy justice principles can be used instrumentally to increase legitimacy and trust in a developer in order to increase their reputational capital and secure consent for projects in a local community.

As for reviews focused only on social acceptance literature, these often aim to re-establish what exactly the research program is about (Wüstenhagen et al., 2007; Wolsink, 2018; 2019; Fournis and Fortin, 2017). To make sense of the changes in this field, Batel (2020) argues that social acceptance research has had three "waves" (Batel, 2020). The first wave framed local resistance in terms of NIMBYism, casting it as selfish or irrational. The second wave criticised this approach and moved toward psychological explanations, emphasizing place attachment, values, and perceptions of justice, which led to strategies such as community engagement and benefit-sharing. The more critical third wave turned its attention to how renewable energy projects are embedded in broader systems of political, economic, and ideological power – particularly neoliberal capitalism – and how they often reproduce patterns of inequality, exclusion, and dispossession. This shift reframes the central question from "how can we increase acceptance?" to "how are energy transitions conceived, legitimized, and implemented – and with what consequences?"

This third wave brings the social acceptance research program into closer dialogue with more critical approaches to environmental social sciences, such as political ecology and environmental justice (Avila, 2018; Knuth et al., 2022). The latter was developed in the United States in the 1970s and 80 s by grassroots activists, assisted by academics from sociology and other disciplines, with the aim of providing empirical support for claims that environmental hazards were being disproportionately located in areas with minority and disadvantaged populations (Holifield, 2015). Political ecology was developed at the same time but by radical geographers and anthropologists predominantly in rural "Third World" settings. Its central concern was with the agrarian question – the ways in which capital was transforming agriculture and peasant societies (Watts, 2015). From this perspective, conflicts over renewable energy are conceptualised as a response to changes in the "socionatural metabolism of capitalism" (McCarthy, 2015). Despite their differences, environmental justice and political ecology share an orientation to normative theories of social justice, political-economic analyses of environmental change and conflict; and a constructivist approach to social movements (Holifield, 2015).

While Bidwell and Sovacool (2023) position energy justice research towards this more critical pole, they sidestep the field's nuanced internal relations and its relationship with the more critical field of environmental and climate justice. In fact, scholars have noted that there are multiple competing definitions of energy justice with some being more critical and reflexive than others (Pellegrini-Masini et al., 2020; Sovacool et al., 2017). In addition to the aim of establishing conceptual and methodological clarity (Jenkins et al., 2016; 2020; 2021), a key theme in these reviews is the question of how to orient research towards policy impact and how to integrate energy justice principles into policy and institutional frameworks (Heffron, 2022; Heffron and Sokolowski, 2024). This again points to divergences with the research on community acceptance, which tends to focus more on "the community" and the particular project as the locus of the issue rather than the political and economic institutions which shape projects and the broader context,

When it comes to renewable energy deployment, the focus in energy justice research has been on the procedural, distributive and, increasingly, the recognition, injustices that large-scale projects create (although the concepts of procedural and recognition justice are often

conflated – Ramasar et al., 2022). More recent frameworks have attempted to integrate additional principles into this conversation, such as restorative justice (Heffron and Hazrati, 2024), as well as other theoretical frameworks such as the capabilities approach (Velasco-Herrejon, Bauwens, 2020) or associated pragmatist frameworks (Laes et al., 2023; Groves et al., 2021). There is also a growing recognition, especially from political ecological perspectives, that conceptualisations of energy justice are rooted in Eurocentric systems of political thought (Sovacool et al., 2023; Dunlap and Tornel, 2023). When applied in contexts such as the Global South, they run the risk of reproducing hegemonic power relations (Tornel, 2023).

The radical critique offered by environmental justice and political ecology perspectives has often revealed how large-scale energy projects are perpetuating colonial legacies and capitalist logics of extraction and enclosure (Avila-Calero, 2025; Knuth et al., 2022; Newell et al., 2022; Sovacool, 2021; Temper et al., 2020). Environmental justice also shares normative commitments with the associated research program of climate justice, with a distinct grassroots discourse highlighting local impacts and experiences of climate change, inequitable vulnerabilities, the importance of community participation, and demands for community sovereignty (Newell et al., 2021; Schlosberg and Collins, 2014). While these concepts diverge from those in the field of energy justice research, the boundaries are not clear-cut and there have been attempts to integrate them or view them as part of the same tradition (Heffron, 2022; Hess and Ribeiro, 2016; Boateng et al., 2023).

Reviews of the environmental and climate justice literatures have been less common, particularly regarding the deployment of wind and solar energy technologies. This perhaps reflects Bowen's (2002) contention that environmental justice's empirical foundations are "underdeveloped". However, this positivist critique fails to properly acknowledge the concept's origin in social movements and reframes political problems as economic ones. A key theme of the environmental justice literature is the consistency of its *critical* epistemology and its self-understanding as being oriented to both an academic and public audience (Schlosberg and Collins, 2014; Temper and Del Bene, 2016). Thus, even if the concept of environmental justice can be described as also undergoing a process of institutionalisation whereby it has become a "policy vocabulary" (Jenkins, 2018), its use in academia is still largely heterodox and deeply entangled with social movements and grassroots activism (Temper et al., 2015; Martinez-Alier, 2014).

It can thus be said that the "uneasy tensions" identified by Bidwell and Sovacool (2023) between different visions of change and between different approaches to justice are not only reflected in relations between the community acceptance and energy justice research programs. They are also essential to the internal dynamics of each of these research programs and their relations to other approaches in the social sciences. These tensions make interdisciplinary exchange difficult, leading to the prioritization of some dimensions (e.g. the "local community" or "the public") at the expense of others (e.g. institutions and markets). This highlights the need for critical reflexivity and cross-disciplinary debate throughout the research process, as well as the need to scrutinise underlying ontological and epistemological assumptions, values and visions of the future.

Moreover, as the deployment of wind and solar energy plants proliferates and accelerates around the world the growing diversity of empirical situations and technological arrangements makes it difficult to reconcile, or make sense of, different theoretical frameworks, objects of analysis and key research themes in a coherent way. For instance, it is entirely plausible that conceptual frameworks developed and refined for studying wind energy deployment in the Global North (e.g. social acceptance) are not well suited to the analysis of conflicts over large-scale solar deployment in the Global South. Likewise, it is plausible that not all recommendations and solutions proposed for conflicts over large-scale wind energy, will be useful or relevant for large-scale solar. It is clear then that, as the literature on large-scale solar plants develops, there is a need to explore the specificity of this form of energy generation and its implications for both acceptance and justice in different socio-cultural and socioecological contexts. Reviewing and integrating this literature will not only be useful to researchers for analysing specific conflicts over large-scale solar, it can also help achieve a more holistic understanding of the global political economy and power relations in which they are integrated.

3. Research design

To explore the existing body of research on large-scale solar plants, we employed a structured review methodology designed to systematically search for, evaluate, and synthesise relevant studies. Our goal was to bridge conversations emerging from different research programs and examine how, where, why, and by whom large-scale solar projects have been investigated. Given the wide array of disciplinary lenses, theoretical perspectives, and methodological approaches informing this body of work, conventional review methods often struggle to capture the full scope of relevant knowledge (Cronin and George, 2023; Devine-Wright and Peacock, 2024). To address this complexity, we adopted an integrative literature review approach (Cronin and George, 2023; Ofosu-Peasah et al., 2021). This method enabled us to combine systematic techniques – such as content and keyword analysis – with theory-driven interpretation, allowing us to draw insights from multiple communities of practice. By juxtaposing diverse perspectives, we aimed to identify new research directions, critically organise existing findings, and build a more comprehensive conceptual framework (Cronin and George, 2023; Torraco, 2005). The review process unfolded in three stages: selecting relevant studies, bibliometric analysis of publications to help identify patterns and key themes, integrative analysis of key themes to inform a theoretical perspective that can help explain how and why the deployment of large-scale solar plants can lead to conflict.

3.1. Selecting the articles

Searches were conducted using the Scopus database across a timeframe from 2014 – April 2025. This timeframe was chosen because it coincides with the rapid growth in large-scale ground-mounted solar PV around the world, with the very few publications prior to 2014 being less relevant to the scale and dynamics of current projects and conflicts. Initial searches used variations of the terms "(social/community/public) acceptance" and "(energy/environmental) justice," combined with variations of "large-scale solar" (e.g. "solar park") across title, abstract and keywords. The search was restricted to peer-reviewed journal articles in the English language, excluding conference proceedings, books and dissertation theses.

First searches returned a limited number of articles and so the search criteria were progressively widened, using terms such as "opposition," "resistance," and "conflict". This produced a total of 140 articles that were then subject to screening. Articles were excluded if they: a) did not relate to large-scale solar; or b) did not aim to analyse social dimensions relating to acceptance and justice. Additional relevant articles were identified through the reference lists of articles selected from these first database searches. This produced a corpus of 110 articles which were then read by the first author with the aim of outlining broad themes.

In a second stage, additional Scopus searches were performed to locate articles that could yield further insights into each of the identified themes that may have been less visible from earlier searches, e.g. legitimacy, land acquisition, environmental impacts and agrivoltaics. At this stage we also omitted the "large-scale" qualifier, using instead variations of "solar PV" but excluding keywords such as "decentralised" or "rooftop". This resulted in an additional 510 articles. We then read each abstract and excluded articles if they did not address either the social dimensions of large-scale solar or one of the already identified themes in relation to solar PV (e.g. agrivoltaics as a solution to land-use conflicts). Of these, 145 were deemed relevant to the review resulting in a final corpus of 255 articles (available from the corresponding author

upon request).

One of the main methodological challenges of the research was locating as many articles dealing with the social dimensions of large-scale solar as possible. In the first stage of searching, there were many articles only identified through reference lists because of: (a) unexpected terminological variation in keywords used to describe large-scale solar plants and the key issues of interest; or (b) a focus on multiple energy sources or scales of solar meant that solar (or variations) did not feature in the title, abstract or keywords. While we attempted to address this by identifying articles in reference lists and, in the second stage, through different criteria, it is still possible that relevant articles were not identified.

3.2. Analysing when, where and by whom large-scale solar has been studied

The general characteristics of each paper were then examined in terms of the following criteria: year of publication, national context of empirical research, publication journal and disciplinary affiliation of lead author. Articles were further classified based on the presence of a social acceptance and/or energy justice framing, identified through an analysis of their keywords, titles, and abstracts. While we acknowledge the possibility that the concepts of social acceptance or energy justice could have played a role in articles despite not featuring in these bibliographic categories, we believe this approach is suitable to identify if these concepts played a *key* role in an article. This analysis was conducted by entering data into Microsoft Excel manually.

3.2.1. Year of publication and change over time

As shown in Fig. 2, empirical peer-reviewed social research about large-scale solar deployment has increased significantly between 2014 and 2025 and is on track to increase again in 2025. Of the 255 studies in our corpus, more than half were published between 2022 and April 2025. While the low volume of articles in 2014 is surprising considering the much longer history of research on the social acceptance of renewable energy technologies, the increase is clearly in line with acceleration of solar deployment worldwide. We also examined here whether or not articles included "acceptance" and/or "justice" concepts in their keywords and how this changed over time.[1] While we acknowledge that these concepts can be used in studies without being included as keywords, we postulate that their inclusion as keywords signifies their status as important to the study's conceptual framing or analytical approach. The aim here was not to distinguish between different conceptualisations of acceptance and justice, but to analyse if authors use these terms to frame their articles and, thus, to gain a picture of the main ways that the problem of conflict over large-scale solar is being framed. Thus, Fig. 2 shows that there have been slightly more studies with only acceptance in their keywords than there have been with only justice. While there seems to be a large number of studies that take neither an acceptance nor justice framing, this gap closed in 2024 which possibly indicates growing conflict and controversy over large-scale solar.

3.2.2. Geographical distribution of research

Fig. 3 illustrates that the literature is global in scope, with the studies distributed across 57 countries. However, most of the literature focused on countries in the Global North (68 % of total n). While the United States was by far the single most studied country (n = 64, 22 % of total n), 35 % of the studies in our corpus were of European countries, with Germany having the most cases, followed by Portugal and The Netherlands (both n = 12, 4 % of total n). The second most studied country was India (n = 25, 9 % of total. n).

[1] For this, all keywords referring to acceptance (e.g. community, public acceptance, local acceptance) acceptability) and justice (e.g. energy justice, environmental justice, distributive justice) were coded as such.

It is also interesting to note the contrasting relevance of the concepts of energy justice and social acceptance in different regions. Overall, social acceptance (26 %) was favoured over energy justice (17 %) in the Global North, with the opposite being true in the Global South (energy justice = 20 %, social acceptance = 7 %). However, 73 % of studies in the Global South used neither framing (59 % for Global North). In the United States, 30 % of studies had a justice framing, while 18 % positioned themselves as oriented to acceptance. The situation was reversed in Europe, with 30 % of studies oriented to social acceptance and only 8 % prioritising the concept of energy justice.

3.2.3. Journal of publication and disciplinary affiliation

As can be seen in Fig. 4, the articles were published in 75 different journals, indicating a highly distributed and potentially fragmented body of literature. However, over one-third of the publications appear in just two journals: *Energy Research & Social Science* (28 %) and *Energy Policy* (9 %). Nearly half of the articles in *Energy Research & Social Science* explicitly engage with concepts of acceptance and/or justice. Additionally, 36 % of all energy justice-focused articles and 26 % of social acceptance-focused articles are published in this journal (compared to 4 % and 16 %, respectively, for *Energy Policy*). These patterns suggest that within the energy social science community, energy justice and social acceptance have emerged as the dominant frameworks for examining large-scale solar deployment. At the same time, the wide distribution of articles across other journals highlights that large-scale solar is being explored in a range of diverse fields, pointing to the presence of alternative conceptual lenses and issues. Notably, many of these journals are not centered on energy technologies but instead engage more broadly with environmental politics, and it is striking that those known for their radical or critical perspectives – such as *Capitalism, Nature, Socialism* and *Antipode* – included no articles employing the concepts of energy justice or social acceptance.

While many studies adopt interdisciplinary perspectives, authors come from a broad range of disciplinary backgrounds. Geography was the discipline with the highest number of lead authors (n = 61, 24 % of total n), followed by economics (n = 33, 13 % of total n), engineering and sociology (both n = 23, 9 % of total n) and political science (n = 21, 8 % of total n). Social acceptance literature was mainly constituted by economics (n = 14), political science (n = 7), engineering and planning science (both n = 6), and psychology and sociology (both n = 5). Energy justice literature was dominated by geography (n = 13), followed by economics (n = 5) and then STS, public policy and engineering (all n = 4).

3.3. Analysing how large-scale solar been studied

While energy justice and social acceptance are prominent themes in parts of the literature on large-scale solar, they represent only a portion of the broader research on its social dimensions. To gain a more integrated and comprehensive view of this landscape, we conducted a bibliometric keyword co-occurrence analysis using VOSviewer software. This method identifies how frequently pairs of keywords appear together within the same documents. Keywords have been shown to be useful indicators of themes, concepts, methodologies and research directions in systematic reviews, and analysing them can help reveal relations between these different dimensions (Devine-Wright and Peacock, 2024; Park and Nagy, 2018). VOSviewer constructs a co-occurrence matrix based on this data and uses clustering algorithms to group keywords into thematically related clusters. This generates a visualisation in which different colours represent distinct thematic clusters, the thickness of the lines indicates the strength of co-occurrence links between keywords, and the size of each node reflects the number of times that keyword appears in the dataset. More holistically, the spatial positioning of nodes reflects the overall network structure: keywords that are closer together tend to share similar co-occurrence patterns across the dataset, indicating broader thematic relationships, while more distant nodes

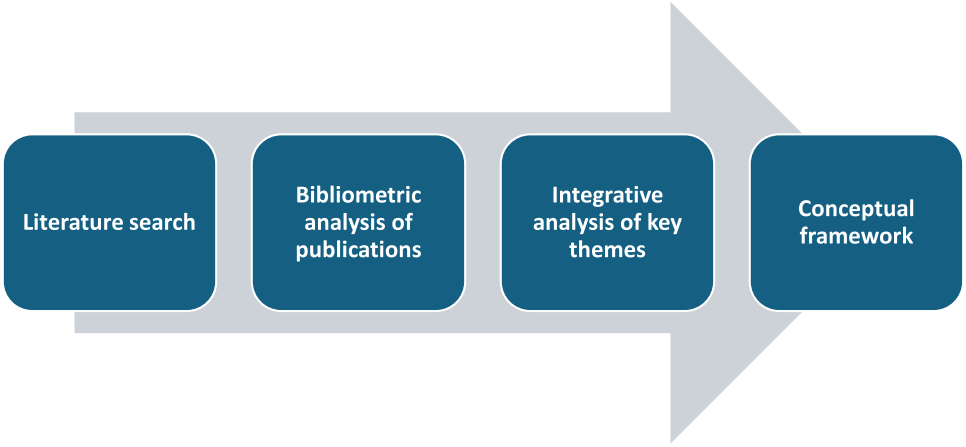

Fig. 1. Research methodology flow.

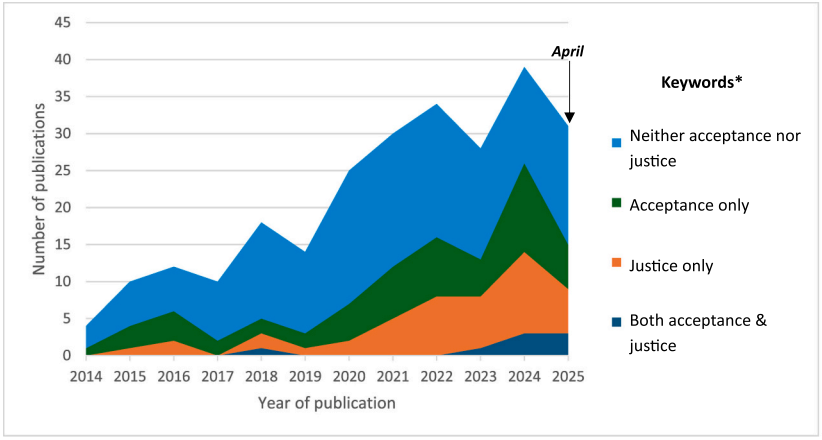

Fig. 2. Year of publication, change over time, and prevalence of acceptance and justice in article keywords (January 2014 – April 2025).

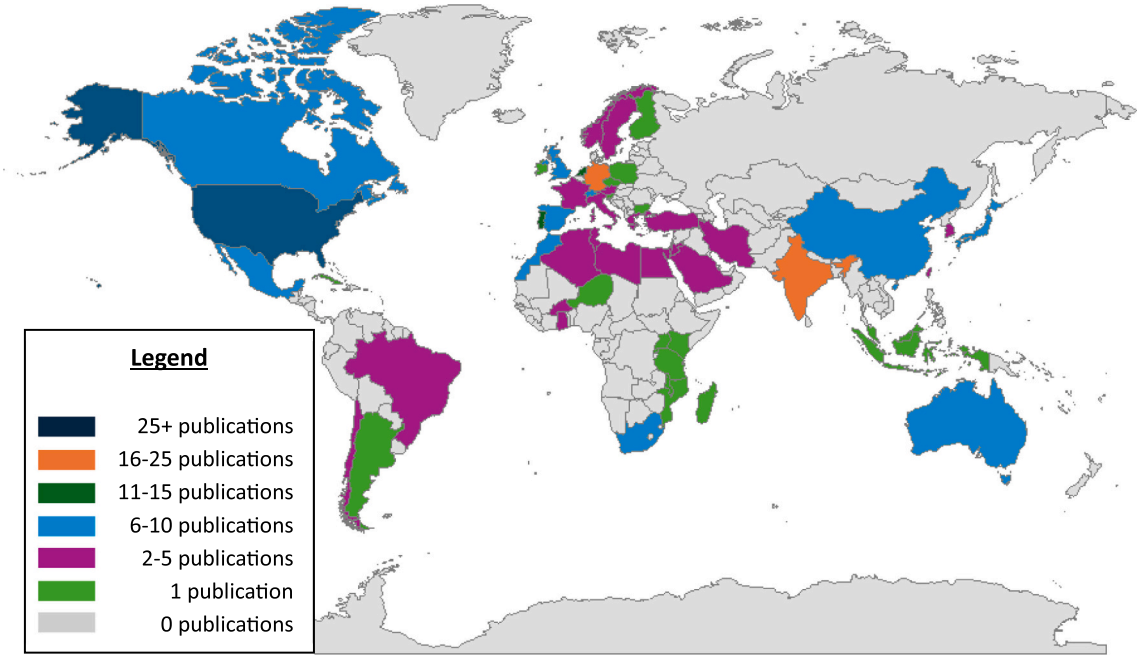

Fig. 3. Distribution of national research contexts within the literature corpus.

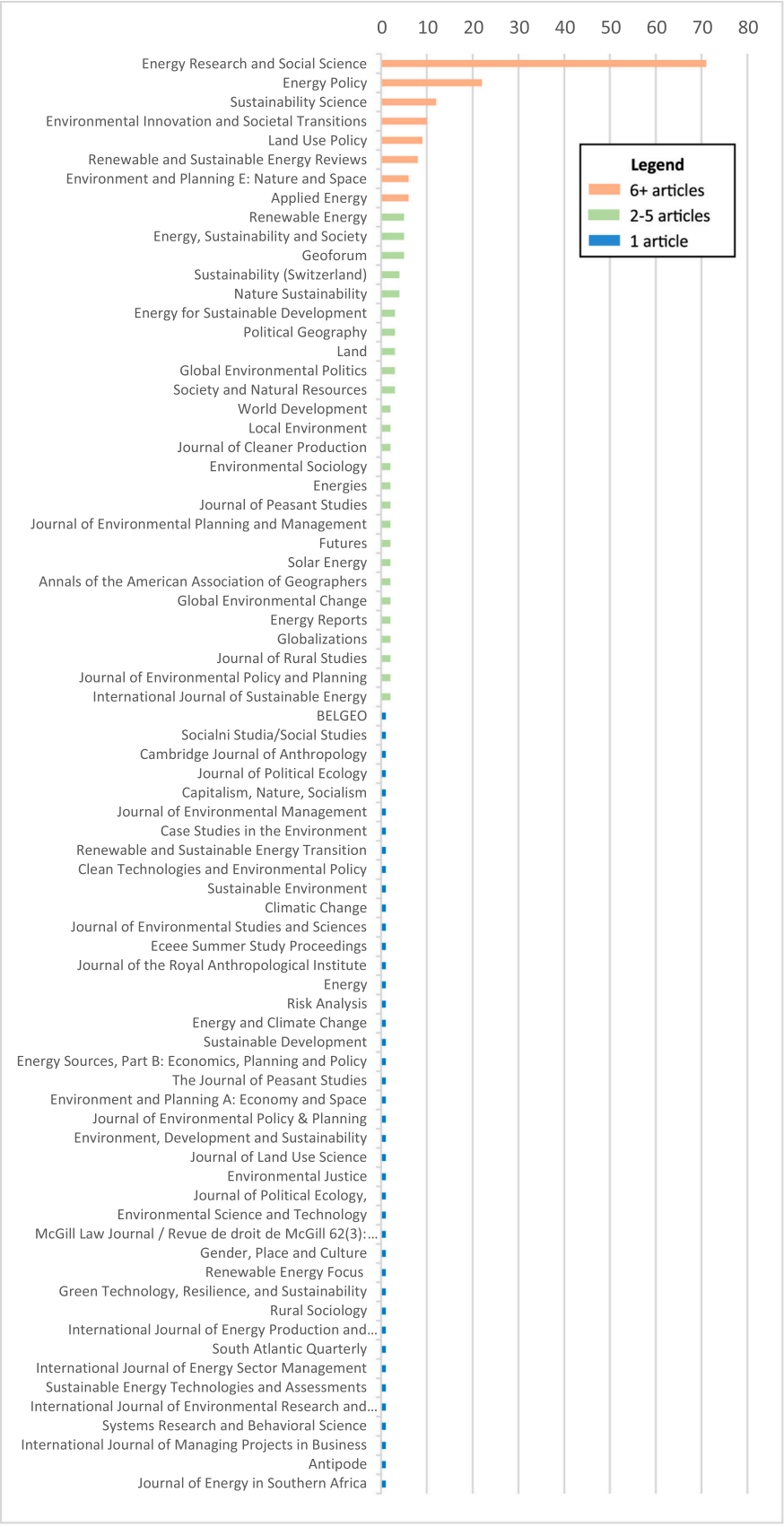

Fig. 4. Article Count by Journal of Publication.

represent more weakly related topics or distinct areas within the research field. Thus, using this tool allowed us not only to establish commonly used terms but to view the structure and interconnections of the research on large-scale solar more broadly. However, it should be remembered that this model is based upon the keywords chosen by authors and therefore should not be taken as absolute.

To reduce redundancy and improve conceptual clarity, we used VOSviewer's thesaurus function to merge synonymous or closely related terms. For example, combining "acceptability," "public acceptance," and "acceptance of solar energy" under social acceptance, and grouping "public opinion" with "public attitudes" as public perception. This helped to capture broader patterns and avoid fragmentation caused by variations in terminology. To manage network size and enhance readability, we applied different minimum occurrence thresholds to attain a balance between detail and clarity, settling on a threshold of 4. Lower thresholds (e.g., two) produced overly dense maps, while higher ones (e.g., five) excluded relevant but moderately frequent terms. In our analysis, we also omitted certain high-frequency keywords (e.g., "solar PV," "large-scale solar," "renewable energy," "energy transitions") to better highlight the relationships between different research programs. Lastly, for the visualisation we selected a minimum cluster size of 1 and VOSviewer's LinLog layout option, which emphasises the separation between clusters by drawing more strongly connected keywords closer together while pushing loosely connected groups further apart. This helps make the thematic structure of the field more visible and improves interpretability of the clusters. Again, the role of these methodological choices in shaping the data highlight that results should be taken only as a preliminary step towards more fine-grained analysis.

We ran two separate analyses. The first excluded the literature which focused on innovations because it often treated large-scale solar as a background problem and thus obscured the relations between key themes in the rest of the literature. As shown in Fig. 5, the analysis confirmed a distinction between the energy justice and social acceptance literatures, while also revealing a third cluster grounded in political ecology. Ideal-typical differences between these three research programs, based on the network analysis and further thematic analysis, are summarized in Table 1. In addition to revealing alternative concepts and issues (e.g. energy colonialism), the analysis highlights four distinct objects of analysis: opposition/resistance, policy and institutions, public perceptions, and impacts (e.g. dispossession and visual impact) – each occupying central but separate positions in the network.

The second network analysis aimed to visualise the relationships between four types of innovation identified in the literature: agrivoltaics, geographic information systems (GIS), community energy initiatives, and participatory methods. As shown in Fig. 6, these innovations tend to cluster with distinct research programs, reflecting differing conceptual framings. Research aligned with political ecology is particularly associated with agrivoltaics, which is framed as a response to tensions over land use and dispossession. In contrast, the energy justice literature exhibits a more fragmented relationship with innovation. However, participatory methods such as action research are linked to energy justice via the concept of procedural justice. As explored further in Section 4.5, this concept underpins proposals for including local communities in landscape design processes.

Energy justice is also connected to community energy initiatives, including benefit agreements and profit-sharing schemes, which address concerns of distributive justice in large-scale solar deployment. This innovation cluster overlaps with the concept of community acceptance, but the presence of choice experiments suggests ongoing tensions between top-down and bottom-up approaches to local involvement. Interestingly, while energy justice plays a central role in the broader conceptual map of the literature (see Fig. 5), in the context of innovation, that centrality is occupied by the concept of social acceptance. The latter is connected to all four types of innovation, but its strongest association is with GIS. The proximity of GIS and social acceptance to public perceptions suggests literature aiming to integrate the latter into top-down GIS based spatial planning tools which tend to privilege technoeconomic criteria (Sward et al., 2021) and there was no direct keyword connection between GIS and energy justice or environmental justice. There was, however, co-occurrence between GIS and public

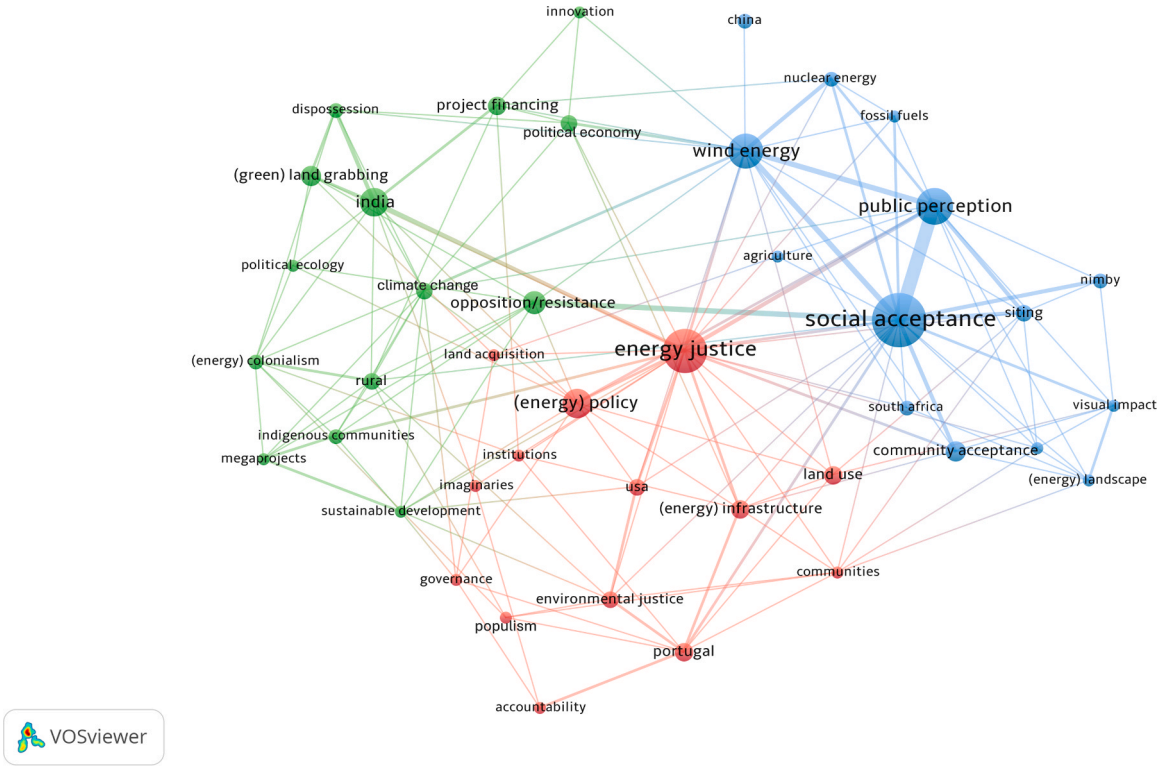

Fig. 5. Network visualisation of the corpus (excluding literature on innovations; n = 198).

Table 1
Ideal type differences between three research programs on the deployment of large-scale solar.

	Social acceptance	Energy justice	Political ecology
Objects	Siting processes, public opinion, attitudes, visual impact	Governance, accountability, project impacts, land acquisition	Land dispossession, resistance strategies, political economic processes
Concepts	Social gap, community acceptance, risk, nimby	Procedural justice, distributive justice, recognition justice	Green grabbing, energy colonialism, racial capitalism, enclosure
Main geographical focus	Global North (e.g. Australia)	Global North/South (e.g. Portugal)	Global South (e.g. India)
Subjects	The public, rural communities, stakeholders	Rural communities	Indigenous & peasant communities

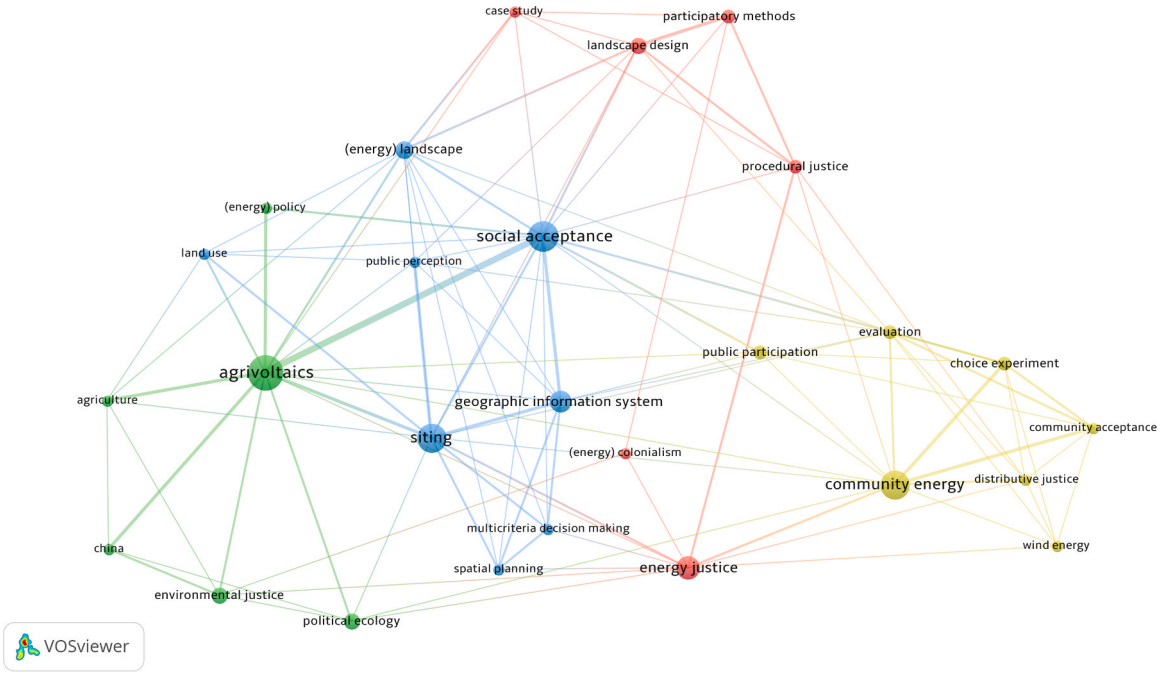

Fig. 6. Network visualisation of the relation between research programs, concepts, issues and innovations (n = 62).

participation, suggesting attempts to integrate procedural justice into spatial planning tools. Further analysis revealed that were two studies which implemented participatory approaches to GIS based multi-criteria decision making (Rösch and Fakharizadehshirazi, 2025; Wang et al., 2022) and there was another which aimed to apply the concept of spatial distributive justice to GIS based analyses of site suitability (Lehmann et al., 2024). This latter study was not picked up in the co-occurrence analysis represented in Fig. 6 because it did not contain GIS in its keywords. While this highlights the danger of drawing conclusions from keyword co-occurrences, it does not detract from its utility to map broad patterns that can serve as a starting point for more fine-grained analysis. It is this task that we turn to next.

4. Integrative review of five key research themes

The above analysis provides a broad overview of the social scientific literature on large-scale solar deployment. In addition to identifying distinct patterns in conceptual approach, location of research and disciplinary perspective, we identified five key research themes: institutions, perceptions, impacts, conflicts and solutions. Analysing the literature in terms of these themes allowed us to integrate insights from different research programs (see Section 5). In the following, we discuss each of these themes in detail.

4.1. Institutional drivers of large-scale solar deployment

In our corpus, 77 studies were classified as focusing on the institutional drivers of large-scale solar. Rather than examining specific deployment cases or public perceptions of solar energy, these studies explore the policies, regulations, and political-economic dynamics that shape why and how large-scale solar projects are developed. In the following, we shall examine how institutions shape three key stages in project development: planning and environmental permitting; land acquisition; and project financing.

4.1.1. Planning and environmental permitting

A central concern in the literature is how planning institutions assess social and environmental impacts, which varies across political cultures (Romov and Teschner, 2022; Schram et al., 2024). In the United States and Australia, ambiguous policies allow "vocal minorities" to obstruct projects (Alibašić, 2023; Hess et al., 2025; Martin and Rice, 2015), whereas European studies emphasize the lack of genuine participatory opportunities for local communities (Schram et al., 2024). This divergence, where much of the literature in the United States calls for more streamlined governance and planning procedures while, in Europe, we more often see calls for extensive public participation in decision-making suggests that political context is playing an important role in framing what is viewed as desirable and realistic energy futures.[2]

Indeed, critical scholarship highlights how institutional attitudes toward public input are shaped by political culture and dominant

[2] As is seen, for example, in the United States's renewed "abundance" agenda popularised by the recent bestselling book by Klein and Thompson (2025).

ideological discourses, which may portray local opposition as irrational or obstructive (Siamanta, 2017). Such framings precondition institutional responses and determine whether citizen concerns are taken seriously. However, institutions also often evolve in response to local resistance. In liberal democracies, institutional visions of the energy future can be influenced by public opinion and local opposition. In the United Kingdom, for instance, where there was considerable controversy about the development of wind energy projects in rural areas through the 2010s, planning regulations under the Conservative government restricted solar development on "prime agricultural land" (Roddis et al., 2018; Hussain et al., 2025). More recently, in South Korea and Japan, growing local opposition has led to increasingly restrictive zoning laws (Ko, 2023; Okazawa et al., 2025).

4.1.2. Land access and acquisition

Ground-mounted solar PV plants are more land intensive than other energy technologies and often monopolizes land, limiting alternative uses like agriculture (Capellán-Pérez et al., 2017; Daniels, 2023). Access to land is further complicated by existing grid infrastructure, which influences where solar developments can occur (Sareen, 2022). One of the main ways that developers gain access to land is by leasing it from landowners, providing the latter with new income streams (Spangler et al., 2024; 2025; Ghosh et al., 2023). In other countries, usually in the Global South, land access is facilitated in a more top-down way through the state acquisition of collective lands (Cantoni and Rignall, 2019; Stock and Birkenholtz, 2024). These examples highlight how different types of political economy legitimate land control and land-use change. In Global North contexts, the economy of contracts takes precedence whereas centralised political power shapes land access in Global South countries. In most cases, however, land acquisition processes invariably take place with low levels of public accountability, and without appropriate legal frameworks for expressing and managing conflict (Müller and Pampus, 2023).

The asymmetrical "capabilities" of different actors play a central role, with "the rules of the game" favouring those with greater legal and technical expertise (Spangler et al., 2025) or those with greater social status based on racialised, gendered and class-based hierarchies (Stock and Birkenholtz, 2024). Moreover, the legal frameworks governing land access are often inherited from past institutional regimes designed to enable fossil fuel extraction or colonial land transfer (Spangler et al., 2025; Cantoni and Rignall, 2019). The latter especially depend on discursively rendering land as "empty" and in need of "improvement" (Stock, 2021b), highlighting how renewable energy deployment is preceded by a process of social construction whereby the environment becomes an economic resource rather than socioecological wealth or common good (Müller and Pampus, 2023; see also Fontaine, 2020; Forget and Bos, 2022; McEwan, 2017). Scholars are increasingly using the term "green grabbing" to convey how the dispossession of common ecological resources is enacted through institutionalized processes that invoke environmental values and directives – such as on renewable energy or climate protection – to legitimize the continuing of imperial relations of extractivism in subaltern and peripheric territories, for the economic growth of core and elite territories and groups. (Rignall, 2016; Siamanta, 2017; Stock and Birkenholtz, 2024; Dunlap et al., 2025; Stock, 2022).

4.1.3. Project financing

Three major actor types drive large-scale solar development: energy firms, project developers, and asset management companies (Christophers, 2022). State policy has played a crucial role in shaping financing environments by introducing subsidies, feed-in tariffs, procurement auctions, and power purchase agreements (PPAs), all of which serve to "de-risk" investments for these actors (Rodríguez-Manotas et al., 2018; Christophers, 2022). Feed-in tariffs were vital to early deployment (Gerhardt, 2017), while recent procurement auctions have led to record-low prices in Portugal, Spain, and India (Thapar et al., 2018; Kitzing et al., 2020; Hochstetler and Kostka, 2015).

As subsidies have been phased out, corporate PPAs have emerged as dominant financing models, allowing firms like Amazon and Google to directly purchase energy from large-scale solar projects and thus drive deployment at scale (Christophers, 2022). However, this market-oriented shift has concentrated power among large corporations and financial actors, excluding smaller-scale or community initiatives (Ghosh et al., 2023; Girard and Sareen, 2024; Sareen, 2022). Comparative studies suggest that financing models are closely shaped by national state–business relations (Hochstetler and Kostka, 2015), while financial policies themselves are often influenced by entrenched fossil fuel interests (Haukkala, 2015; Fartash and Ghorbani, 2023). These dynamics underscore the political nature of ostensibly technocratic financing decisions.

4.2. Perceptions of large-scale solar deployment

Our analysis of 56 studies on public perceptions reveals a predominance of social-psychological frameworks examining attitudes and affective evaluations toward solar energy systems. While most research focuses on general populations (Carlisle et al., 2015; Roddis et al., 2019; Ruddat and Sonnberger, 2019), some investigate specific groups, such as technical experts (Frate and Brannstrom, 2017; Lucchi et al., 2023), environmental organizations (Hilker et al., 2024), and project developers DiPersio et al., 2021; Bessette et al., 2024).

4.2.1. Proximity and scale

Visual impacts have been a core concern in the literature on social acceptance of wind energy. Likewise, many studies in our corpus show that acceptance of large-scale solar is influenced by the location of the project, particularly its proximity to people's homes (Carlisle et al., 2016; Larson and Krannich, 2016; Keeley et al., 2022; Rodríguez-Segura et al., 2023; Zander et al., 2024). Yet, findings vary by context. Carlisle et al. (2016), studying public attitudes in California, find that proximity matters but that it is mediated by land use types. For instance, people prefer greater buffer zones between large-scale solar and wildlife habitats than between large-scale solar and residences. By contrast, Zander et al. (2024), in research on the world's largest solar farm in Australia's Northern Territory, find that residents closest to the site were most supportive, citing high levels of pride, hope, and trust in the developer. These differences suggest that proximity effects are context-dependent and should be followed up by qualitative studies.

Another increasingly studied variable is project scale. While earlier surveys often failed to differentiate between scales of solar PV, more recent studies distinguish perceptions of large versus small projects (Nilson and Stedman, 2022). Support tends to decline with increasing project size, especially when visible impacts are accompanied by strong emotional responses (Cousse, 2021). Yet, the relationship is not binary: many communities express support for medium-sized installations, particularly in areas of low ecological value (Rodríguez-Segura et al., 2023). This underscores the relational nature of public attitudes and highlights the importance of landscape context and place attachment (Roddis et al., 2020).

4.2.2. Place and landscape change

Beyond project-level variables, recent work explores psychosocial dimensions related to place and landscape. Qualitative studies reveal that large-scale solar projects are interpreted through locally specific value systems. For example, responses can be shaped by pastoral ideals, or by more pragmatic and utilitarian logics (Bevk and Golobič, 2020). In both cases, there is often support for "place-technology fit," i.e., solar arrays that integrate discreetly into the existing landscape (Lucchi et al., 2023; Vuichard et al., 2021). Despite broad agreement on ideal siting locations – such as rooftops – tensions persist between those seeking to preserve agricultural land and those open to its transformation for solar energy (Späth, 2018).

Place identity plays an increasingly central role in shaping responses to large-scale solar. While early work in California suggested that "sense of place" had limited influence (Carlisle et al., 2014), recent studies in post-industrial areas – especially in the United States – highlight its significance, particularly in regions with historical ties to coal (Crowe and Li, 2020; Gamper-Rabindran and Ash, 2024). Mayer (2025) finds that residents prefer siting large-scale solar on former industrial lands, reflecting changing local imaginaries. In Italy, where cultural heritage and land-use traditions are deeply valued by many communities, concerns extend beyond buildings to landscape practices and rural identities (Lucchi et al., 2023; Naspetti et al., 2016). Similarly, in the Czech Republic, fears of enclosing farmland are shaped by collective memories of socialist land management (Navrátil et al., 2021).

Political context also plays a critical role in shaping perceptions. In Portugal, for instance, attitudes are shaped by concerns over energy poverty and low trust in political institutions (Campos et al., 2023). In the United States, resistance to large-scale solar is increasingly driven by political polarization (Mayer, 2025). But there, as in many other contexts, it is also shaped by the economic and symbolic divide between urban and rural areas, with perceptions of large-scale solar often framed through narratives of "rural burden" (Nilson and Stedman, 2023; Batel et al., 2024). This underscores how landscape is not merely an aesthetic category, but one imbued with and in political, historical, and socio-cultural meaning and processes.

4.2.3. Benefits, risks, and justice

A major focus in this literature is how people perceive the benefits and risks of large-scale solar. These are typically framed in binary terms – e.g. economic benefits such as jobs or lower energy bills versus burdens such as health risks or loss of tourism-based income (Uebelhor et al., 2021). Linked to this is the notion of distributive justice and the question of whether people perceive that benefits and burdens are fairly allocated across affected communities (Nilson and Stedman, 2023). Procedural justice is also a key concern. In the United States, recent research shows that expectations around public participation strongly influence support, particularly for projects exceeding certain thresholds of scale or proximity (Hoesch et al., 2025). Improved engagement mechanisms, such as involving third-party facilitators, clarifying trade-offs, and ensuring transparency, can enhance trust and support (Bessette et al., 2024). Attempts have also been made to integrate broader justice frameworks into public perception studies. Jeon et al. (2024), for example, develop a typology of four ecological justice categories to assess public responses. Yet, one of the most underexplored dimensions remains recognition justice, including concerns around equity, identity, and epistemic inclusion (see Barragan-Contreras, 2022). This is a notable gap, especially given the increasing diversity of communities affected by solar development.

4.3. Impacts of large-scale solar deployment

Our corpus includes 37 studies examining specific cases of large-scale solar deployment, with a focus on describing, interpreting, and explaining their socio-ecological impacts. These impacts span four key domains: economic, environmental, social, and political. This typically *critical* perspective is often framed in new, interdisciplinary, research programmes and fields, such as political ecology and critical agrarian studies (Dunlap et al., 2025; Shokrgozar et al., 2025). Most of these studies analyse cases of large-scale solar deployment in the Global South and other countries that can be classified as either semi-peripheral or peripheral in the world system (Wallerstein, 1993), which suggests that it is in these countries where most of the negative impacts of large-scale solar are occurring.

4.3.1. Economic impacts

A frequently cited benefit of large-scale solar deployment is job creation. However, these are often projected rather than realized. For example, Almarshoud and Adam (2018) estimate that installing 16 GW of solar energy in Saudi Arabia by 2032 could create over 18,000 jobs, foster a domestic photovoltaic industry, and promote international-local collaboration. Other studies highlight the economic benefits to landowners, particularly when large-scale solar replace less profitable agricultural activities such as tobacco farming (Krishnan and Pearce, 2018). These macro-level analyses typically compare renewable scenarios to more carbon-intensive regimes, presenting large-scale solar as economically advantageous (e.g. Chapman and Fraser, 2019). However, negative economic impacts are more commonly observed. These are often preceded by processes of enclosure, whereby economic or political elites capture land, water, or mineral resources. For instance, water-intensive practices for panel cleaning can exacerbate regional water scarcity (Stock, 2021c), while large-scale solar development frequently involves the privatization of public lands (Mulvaney, 2017). Upstream impacts, such as the extraction of minerals for solar panel production, highlight broader global economic inequalities (Kramarz et al., 2021). Some scholars argue that these "resources" only become economically significant through social construction (Forget and Bos, 2022), emphasising the embeddedness of large-scale solar in broader economic and symbolic systems.

4.3.2. Environmental impacts

At the macro level, large-scale solar plants contribute to substantial reductions in carbon emissions, with associated improvements in public health by displacing fossil fuels (Luo et al., 2022; Chapman and Fraser, 2019). However, most studies emphasise potential negative environmental impacts, particularly on local eco-systems. For instance, large-scale solar plant construction usually involves vegetation clearance and fencing, which can fragment habitats and restrict wildlife movement. Installations also pose risks of direct wildlife mortality through collisions, while altered surface reflectivity can produce localized heat island effects and glare hazards for drivers and pilots (Mulvaney, 2017). In California, soil disturbance during construction has raised health concerns related to the spread of fungal spores (Mulvaney, 2017). Water use for maintenance has also raised alarms, particularly in arid regions, and is often framed as a process of *encroachment* on shared resources (Stock, 2021c; Sovacool et al., 2025). Geographical context is decisive here, with many case studies focusing on large-scale solar plants sited in desert landscapes, especially in the United States (Van de Graaf and Sovacool, 2014; Grodsky and Hernandez, 2020; Dunlap et al., 2024a). These areas are ecologically sensitive and institutionally shaped by frameworks that prioritize short-term economic returns over long-term sustainability (Kennedy and Stock, 2022).

Lastly, there is a striking lack of studies on the end-of-life management of large-scale solar plants and its relationship with community acceptance. This omission is particularly salient given that the impermanency of wind and solar plants has been promoted as a key benefit (Jaber, 2013). Moreover, perceptions about what happens when a renewable energy installation reaches the end of its operational life or planning consent can influence the dynamics of community acceptance, as has been shown in research on wind energy (Windemer, 2023). One notable exception in our corpus was Spangler et al. (2024) finding that farmers lease their land for solar power on the condition that the land will be farmable again after solar panels are removed. As more large-scale solar PV plants begin to reach their end-of-life, it will be important to investigate if such promises are kept and the temporal dynamics of acceptance, support and land-use more broadly.

4.3.3. Social impacts

Social impacts concern social relations and structures. Large-scale solar may generate positive outcomes if they empower historically marginalized groups through meaningful participation or benefits. Conversely, they may exacerbate inequalities when they displace livelihoods, as seen when agricultural income for landless labourers is lost

(Ghosh et al., 2023; Yenneti and Day, 2016). Sovacool (2021) refers to this dynamic as *entrenchment*, where existing social hierarchies are reinforced. Several studies highlighting entrenchment are set in India, where large-scale solar deployment is reproducing colonial patterns of dispossession (Shokrgozar et al., 2025). Similarly, in the United States, large-scale solar projects have led to the disturbance of Indigenous cultural heritage sites (Sovacool et al., 2025; Mulvaney, 2017). Gender relations are also affected, for instance when projects designed to empower women may unintentionally reinforce gendered hierarchies (Stock, 2021a; Stock et al., 2023; Stock and Birkenholtz, 2020). Many of these accounts focus on lived experiences near large-scale solar sites, revealing how racism, sexism, and classism can be perpetuated through energy transitions (Dunlap et al., 2024; Sovacool et al., 2021; Stock and Sovacool, 2024). Psychosocial dimensions of entrenchment such as stigmatisation and social alienation remain underexplored but are significant. Importantly, social impacts often intersect with other domains. For example, water enclosure can deepen rural marginalization (Stock, 2021b), while exclusion from planning processes is often shaped by entrenched disparities in cultural capital, where technical expertise overrides local knowledge (Dunlap et al., 2024).

4.3.4. Political impacts

The political impacts of large-scale solar deployment are caused by the exclusion of local stakeholders, particularly through inadequate consultation. This is especially visible in rural contexts, where communities often feel already politically and economically marginalized (Batel et al., 2024). Exclusion is both procedural and psychosocial, closely linked to the entrenchment processes discussed above. This is exemplified by the dominant "scientific-bureaucratic" model of energy governance which prioritizes technical over local knowledge, producing procedural injustices (Dunlap et al., 2024; Yenneti and Day, 2015). Exclusion also arises in more subtle ways, such as unresolved stakeholder conflicts or limited community engagement (Van de Graaf and Sovacool, 2014). Spatial injustice is another concern: large-scale solar plants are often located in areas with low electricity consumption, raising questions about who ultimately benefits (Huang et al., 2025).

While exclusion is common across both the Global North and South, studies in the latter reveal deeper forms of political and material exclusion (Stock and Sovacool, 2024; Stock and Birkenholtz, 2020). In some countries, communities adjacent to large-scale solar remain without reliable electricity (Cantoni et al., 2021; 2022). Cantoni et al. (2022) describe such communities as caught in a "scalar limbo," excluded from both rural and urban energy infrastructures. Political impacts are also shaped by spatial and institutional design. In South Africa, the creation of designated zones for solar deployment has led to an uneasy co-existence of competing interests, potentially forming new political entities (McEwan, 2017). Accountability is also a recurrent theme in this literature, with large-scale projects involving a multitude of actors – e.g. developers, utilities, asset managers – making it unclear who is responsible for ensuring community involvement or how sustained community participation would work in practice (Dunlap et al., 2024; Sareen et al., 2024).

4.4. Conflicts over large-scale solar deployment

While the previous section explored the socio-ecological impacts of large-scale solar, many of those studies did not focus on cases where community opposition emerged. This section draws on 26 studies from our corpus that explicitly examine such opposition. These cases often build on the earlier clusters by analysing how institutional drivers, public meanings, and experienced impacts interact to produce conflicts. Importantly, they also investigate how opposition evolves over time and the power dynamics that shape – and are shaped by – these responses.

4.4.1. From impacts to opposition

Whereas studies focusing on impacts identified structural processes like enclosure, encroachment, entrenchment, and exclusion, case studies on conflicts engage more explicitly with the subjective and sociopolitical dimensions of these impacts, often tracing how these processes trigger community perceptions of injustice that lead to organised opposition. For instance, Wilzing et al. (2023) show how residents in Spain's Vail d'Albaida expressed anxiety and opposition due to uncertainties around project impacts (see also Batel et al., 2024). Within this literature we can identify four key domains of community concern. Economic concerns typically involve fears of declining revenues from agriculture, tourism, or other land-based activities (Stock, 2022; Wallace et al., 2025). Environmental concerns centre on biodiversity loss, endangered species, and habitat destruction (Brás et al., 2024; Mulvaney, 2017; Shyu, 2025). Social concerns often revolve around place-attachment, cultural identity, and the erosion of traditional practices (Moore and Hackett, 2016; Pasqualetti et al., 2016; Rignall, 2016; Sánchez Contreras et al., 2024a, b). Political concerns relate to a lack of transparency and inclusive decision-making, often leading to or reinforcing a sense of "territorial resentment" rooted in long-standing spatial and historical inequalities (Jacroux and Freshour, 2024; Brás et al., 2024; Argenti and Knight, 2015).

The sociocultural context plays a pivotal role in shaping these responses to large-scale solar. In Greece, for example, Argenti and Knight (2015) describe how local resistance draws on a national identity shaped by memories of foreign occupation, with large-scale solar perceived as a form of "green colonization." Similarly, in Portugal, opposition often emerges through collective narratives of marginalization and lost autonomy (Batel et al., 2024; Wallace et al., 2025). In Mexico, (Barragan-Contreras, 2022) highlights how community mistrust is intensified by developers' use of terms like "consent" and "participation," which are seen as empty gestures used to legitimize projects (see also Ki and Yun, 2024). These insights reveal that community opposition is rarely based on misinformation or NIMBYism (Scott and Smith, 2017; O'Neil, 2021). Rather, it reflects awareness and understanding of the institutional drivers of large-scale solar deployment. As such, efforts to improve participation or communication without reforming the underlying institutional structures are unlikely to reduce opposition, especially in Global South or Indigenous contexts where notions of justice may differ from Global North paradigms (Barragan-Contreras, 2023; but see Nicholls, 2020).

4.4.2. Forms and strategies of opposition

Several studies go beyond identifying the reasons for opposition to explore how it takes shape and develops over time. Rather than treating community responses as static, these works emphasize the dynamic and strategic nature of opposition. Stock (2022), for instance, documents a range of resistance practices, from formal protests and lawsuits to blockades, acquiescence, and even suicide. However, there is a need for more research on the specific strategies that opposition movements take in different contexts (Sovacool et al., 2022).

Other studies show how opposition often evolves from diffuse concerns into more organized efforts centered on specific narratives or discourses (Crawford et al., 2022; Jacroux and Freshour, 2024; Wallace et al., 2025). In both Europe and North America, the notion of communities being turned into "sacrifice zones" has emerged as a unifying frame that connects various grievances. Similar to the notion that project opponent's often use an "insider-outsider" frame to mobilise opposition (Mulvaney, 2017), such discourses help mobilize local protest movements by linking community sentiment and interests to broader concerns of justice and governance (Brás et al., 2024; Wallace et al., 2025; Scott and Smith, 2017).

These movements often transcend political and social differences, forming coalitions that include rural landowners, Indigenous groups, environmentalists, and local business owners (O'Neil, 2021; Wilson, 2022). Solidarity based on shared feelings of anger, loss, or betrayal can help overcome divergent worldviews and politics, facilitating collective action (Jacroux and Freshour, 2024). In these cases, shared narratives

serve as a powerful resource for uniting disparate actors, even if only temporarily (Susskind et al., 2022). In contrast, Crawford et al. (2022) use the "social gap" framework (Bell et al., 2005) to argue that vocal opposition groups may not represent the broader community, contributing instead to a "democratic deficit."

4.4.3. The dynamics of conflict

Critical scholarship also examines how authorities, developers and other actors respond to community resistance. A common strategy is to ignore it, treating residents as illegitimate stakeholders and dismissing protests or petitions as irrational or obstructive (Brás et al., 2024; Wallace et al., 2025). These patterns of exclusion often reflect deeper institutional norms and policy frameworks that prioritize technical solutions over democratic accountability. When opposition escalates into broader public controversies, developers may respond with corporate social responsibility initiatives or minor project adjustments designed to pacify dissent (Stock, 2022; Wallace et al., 2025). While these strategies may appear responsive, they often function to reframe substantive concerns as technocratic issues that can be managed through expert intervention (Rignall, 2016; Barragan-Contreras, 2022; Shokrgozar and Girard, 2024). In doing so, they shift control of the narrative back to developers, marginalizing grassroots voices.

Policymakers and governmental actors may respond to or even anticipate opposition by reforming legal and spatial planning frameworks, for instance by increasing environmental protections and public participation requirements (Hess et al., 2025; Mulvaney, 2017; Shyu, 2025). But it has also been seen that in the context of conflicts over large-scale solar, policymakers have responded by declaring projects to be in the national interest, allowing their licencing and permitting processes to be streamlined (Wallace et al., 2025). These findings point to the increasingly contested and politicized nature of energy infrastructure and the risks of depoliticizing or decontextualising opposition by interpreting it as homogenous in its meaning and purpose, and also that opposition is an active force that can reshape the regulatory and discursive landscape of energy transitions.

4.5. Solutions for the problems of large-scale solar deployment

In our corpus there are 62 studies that focus on analysing or proposing solutions to the problems of community acceptance, energy justice and the multiple economic, environmental, social and political impacts that large-scale solar plants produce. These innovations suggest that innovative solutions can help bridge gaps between developers and communities, with the aim of fostering more sustainable and equitable deployment of large-scale solar. However, they also have their own challenges and limitations. In the following we shall examine three areas where various initiatives are proposed and analysed. First, there are studies which address issues of spatial planning, aiming to improve site evaluation and decision-making by using geographic information systems (GIS) or by mobilising local knowledge. Second, there are studies which focus on alternative business or organisational models and the actors that can help facilitate them. Third, there is a growing literature on the concept of "agrivoltaics" as a solution for tensions between agriculture and large-scale solar.

4.5.1. Spatial planning innovations

A prominent theme emerging from these studies is the role of spatial planning and multi-criteria decision analysis (MCDA), often facilitated through GIS, to identify optimal sites for utility-scale PV projects. Across diverse geographic contexts – from Portugal and Niger to Turkey and Taiwan – these tools are used to balance technical, environmental, and economic factors in site selection. For instance, Boubé et al. (2025) and Tercan et al. (2021) demonstrate how analytic hierarchy process (AHP – another structured decision-making method) weighted criteria (e.g., irradiance, slope, proximity to infrastructure) can help optimize solar farm siting.

What is significant here, however, is that several studies advocate the integration of participatory and justice-based frameworks in these spatial planning tools. Multiple case studies reveal that integrating public perception and spatial distributive justice into technical assessments can lead to more socially accepted and context-sensitive outcomes (Codemo et al., 2023; López-Bravo et al., 2024). Public Participation GIS and stakeholder-driven AHP have been proposed as tools to incorporate local knowledge, ensuring solar development respects ecological and social priorities (Rösch and Fakharizadehshirazi, 2025; Wang et al., 2022). Sward et al. (2021) critique conventional GIS-MCDA for neglecting social dynamics, advocating for place-based criteria (e.g., cultural landscapes, historical inequities) to address energy justice. Similarly, Lehmann et al. (2024) stress transparent spatial distributive justice frameworks, noting how varying principles (e.g., equality vs. benefit-based allocation) lead to divergent equity outcomes.

In addition to calls for deliberative democracy in planning processes (Fan, 2024; Nicholls, 2020), countermapping and participatory cartography are also proposed as decolonial tools to amplify marginalized voices and address spatial, procedural and recognition injustices, exposing how state-led projects "empty" territories of socio-ecological relations (Avila et al., 2022; Sánchez Contreras et al., 2024a,b). Similarly, Wilson (2022) critiques Alberta's solar projects for perpetuating extractivist paradigms, proposing "deep energy literacy" to center Indigenous reconciliation and intersectional justice. Others argue for collaboration and co-design with Indigenous communities to address root causes of energy injustices (Sankaran, McIntyre-Mills, 2022; Fan, 2024; Mawere and Mukonza, 2025). Hilimire et al. (2025) promote innovative educational programmes based on "relational teaching" to disrupt the historical pattern of environmental injustices inflicted on marginalized communities and bridge gaps between renewables development and Indigenous sovereignty.

The question of how solar PV plants should be designed and integrated into surrounding landscapes also emerges as a central problem, with participatory landscape design being promoted as a means for fostering both acceptance and procedural justice. Enserink et al. (2023, 2024) demonstrate that tangible prototypes and inclusive processes in Dutch solar projects can mitigate opposition by addressing local concerns, though economic priorities often override broader benefits like biodiversity. Moore and Hackett (2016) emphasize "place-making" in siting conflicts, arguing that early, values-based engagement, as seen in California's Ivanpah solar plant, can prevent polarization. Törnroth et al. (2022) extend this with "participatory utopian sketching," a creative method to align solar futures with community aspirations.

4.5.2. Community energy initiatives

Economic innovations such as community benefit agreements (CBAs), shared ownership models, and support for community-based organizations (CBOs) are increasingly recognized as useful tools for addressing issues of acceptance and justice in the deployment of large-scale solar. CBAs, when well-designed and locally tailored, can improve public support by aligning project benefits with community goals, particularly in areas with histories of disempowerment or neglect (Trandafir et al., 2023; van den Berg and Tempels, 2022). However, to avoid deepening distrust these benefits must be perceived as fair and contextually appropriate by the community.

Beyond benefits distribution, deeper forms of political and economic inclusion are also key. Shared ownership and participatory governance models have been shown to increase local support, especially when citizens are offered genuine stakes in both the process and outcomes of energy projects (Stadelmann-Steffen and Dermont, 2021; Azarova et al., 2019). CBOs play a vital intermediary role in this space, particularly in marginalized communities, by facilitating access, shaping local implementation strategies, and integrating community needs into projects (Knox-Hayes et al., 2023; Grimley et al., 2022; Lenhart et al., 2020). However, there is also a need for more research on such intermediaries in relation to large-scale solar projects.

While in the United States there is a growing literature on "community solar" and the role of community-based organisations, the European literature on community participation in solar PV plants is now dominated by the concept of "Renewable Energy Communities", which tend to be framed mainly in terms of decentralised rooftop systems in urban areas rather than as solutions to the negative impacts of large-scale solar plants in rural areas. However, there are several articles which frame community energy initiatives as a promising solution for these impacts, namely as an alternative model of ownership and governance that aligns with principles of energy justice and social acceptance. However, the extent to which RECs can play a role in large-scale solar deployment remains uncertain, requiring further research into their scalability. More radical, Indigenous-led initiatives such as those studied by Kinder (2021) exemplify decolonial alternatives, promoting solar projects for self-determination and resistance to extractivism. Meanwhile, hybrid models repurpose fossil fuel sites for solar, bridging labour and cultural divides in pursuit of a just transition (Egler and Barbieri, 2024).

4.5.3. *Combining solar plants with agriculture*

Agrivoltaic systems – the co-location of solar panels and agriculture – can offer technical and ecological benefits to the deployment of large-scale solar, improving land-use efficiency while simultaneously addressing energy and food production goals (Vezzoni, 2023; Rösch and Fakharizadehshirazi, 2024). Studies show that they can maintain or even increase crop yields in arid regions by reducing heat stress and conserving soil moisture (Barron-Gafford et al., 2019), while also minimizing water evaporation and boosting biomass productivity (Miskin et al., 2019). However, there is also evidence that in some contexts these systems can have a negative impact on agricultural cultivation (Ketzer et al., 2020).

Most significantly, by enabling dual land use agrivoltaics are seen as an innovation that can resolve land-use conflicts (Ketzer et al., 2020; Goldberg, 2023) and there is a growing literature which also frames it as a solution to the lack of social acceptance of large-scale solar more generally (Sirnik et al., 2024; Biró-Varga et al., 2024). Several studies argue that agrivoltaics can reduce local opposition to solar development, particularly when farmers benefit economically and agricultural traditions are preserved (Pascaris et al., 2021; 2022; Wagner et al., 2024). Hilker et al. (2024) analyse the views of nature conservation associations, finding that many view agrivoltaics as an innovative way to balancing renewable energy goals with biodiversity concerns.

Despite this promise, Biró-Varga et al. (2024) found that local communities remain concerned about wildlife impacts and the visual impact on the landscape, even while appreciating agrivoltaics' multifunctionality and economic benefits to farmers. Moreover, Ketzer et al. (2020) found that successful agrivoltaic projects themselves will require stakeholder participation to achieve local acceptance. Reflecting much of the literature on impacts and conflicts around large-scale solar, Seay-Fleming et al. (2025) argue that environmental benefits alone are not enough to create acceptance of agrivoltaics because of perceived injustices associated with local legacies of extraction and land financialization. Accordingly, research is beginning to emerge that explores the integration of energy democracy principles into agrivoltaic projects (Koga et al., 2025), advocating for participatory governance models that empower local stakeholders and ensure equitable decision-making. These findings suggest that beyond technological design, the legitimacy and sustainability of agrivoltaics depend on how well they align with local needs, engage communities, and distribute benefits fairly.

Like other technological and organisation innovations, the concept of agrivoltaics is not immune to being co-opted by incumbent actors and business-as-usual logics. In the United States, governing institutions are largely viewing agrivoltaics as a "technological fix" (Moore et al., 2022) and to discursively legitimise the acquisition of farmland (Seay-Fleming et al., 2025), while in China the more advanced deployment of agrivoltaics is dispossessing and marginalising rural communities via authoritarian land grabs (Hu, 2023; 2024; 2025). This again raises broader questions about the political economy of renewable energy transitions and cautions against assuming that solutions for the impacts of large-scale solar are inherently just or inclusive. Agrivoltaics may have potential to address many of the problems of large-scale solar but are themselves not immune to those same problems (Taylor et al., 2025; Sirnik et al., 2024; Goldberg, 2023).

5. Towards a critical and relational perspective on social responses to large-scale solar projects

The findings of this review affirm general insights from the social sciences and humanities, namely that the deployment of renewable energy technologies is not simply a technological matter but is fundamentally shaped by political and economic institutions on the one hand and by evolving forms of public knowledge and meaning on the other (Bridge et al., 2018; Walker, 1995). Faced with a plurality of socio-technical possibilities, institutions decisively influence why and how large-scale solar PV plants are planned and implemented through high-level political decisions about the energy mix, land use, grid infrastructure, financial incentives, and planning regulations. At the same time, public meanings – including general knowledge and perceptions of solar energy, views about specific projects, and broader historically embedded identities, cultural values, and place-based attachments – play a crucial role in shaping not only how different actors respond to large-scale solar plants, but also how they are envisioned, justified and communicated at the governance level. As a result, conflicts over large-scale solar plants play out over both the material or anticipated impacts that arise from the interaction of institutions and public meanings (see Fig. 7). This interaction can thus also lead to other responses, such as local support, acceptance, or willingness to cooperate with, or participate in, large-scale solar initiatives, for instance through community benefits agreements. Taken together, what this review emphasises, then, is that advancing a just transition in large-scale solar deployment requires research that critically examines how institutional arrangements and public meanings co-evolve and interact.

Yet despite decades of scholarship, much of the literature on the social acceptance of renewable energy technologies, including large-scale solar, tends to focus on community, socio-political and market dimensions of acceptance in isolation. In particular, the prioritization of "the community" and "the public" tends to reduce complex socio-political dynamics into managerial problems of communication or engagement, overlooking the deeper economic, political, and ideological structures at play. An exception to this is seen in Roddis et al. (2020) concept of "relational acceptance," which is used to account for how social, cultural, political, and economic factors interact over time. But much of this research remains shaped by non-critical approaches that often portray public opposition as irrational, misinformed, or as a barrier to technocratic policy goals that themselves often remain unscrutinised as visions of desirable and feasible futures. As a result, research adopting the concept of social acceptance frequently fails to engage with issues of power, justice, and agency that underpin public responses to changes in systems of energy provision.

Perhaps because of the rapid expansion of large-scale solar energy across the world – and especially in semi-peripheral countries in the Global North and peripheral countries of the Global South – these issues are now being addressed with alternative conceptual and methodological approaches (Shokrgozar et al., 2025; Dunlap et al., 2024). Such critical perspectives, grounded in energy justice, postcolonial theory, and political ecology, tend to emphasize how structure, context, and power shape both acceptance and resistance. They investigate how large-scale solar is entangled with broader systems of dispossession – land grabs, labour precarity, and environmental degradation – especially in rural or Indigenous contexts. Concepts like energy colonialism and racial capitalism help to historicize and politicize renewable energy development, situating it within longer trajectories of accumulation and

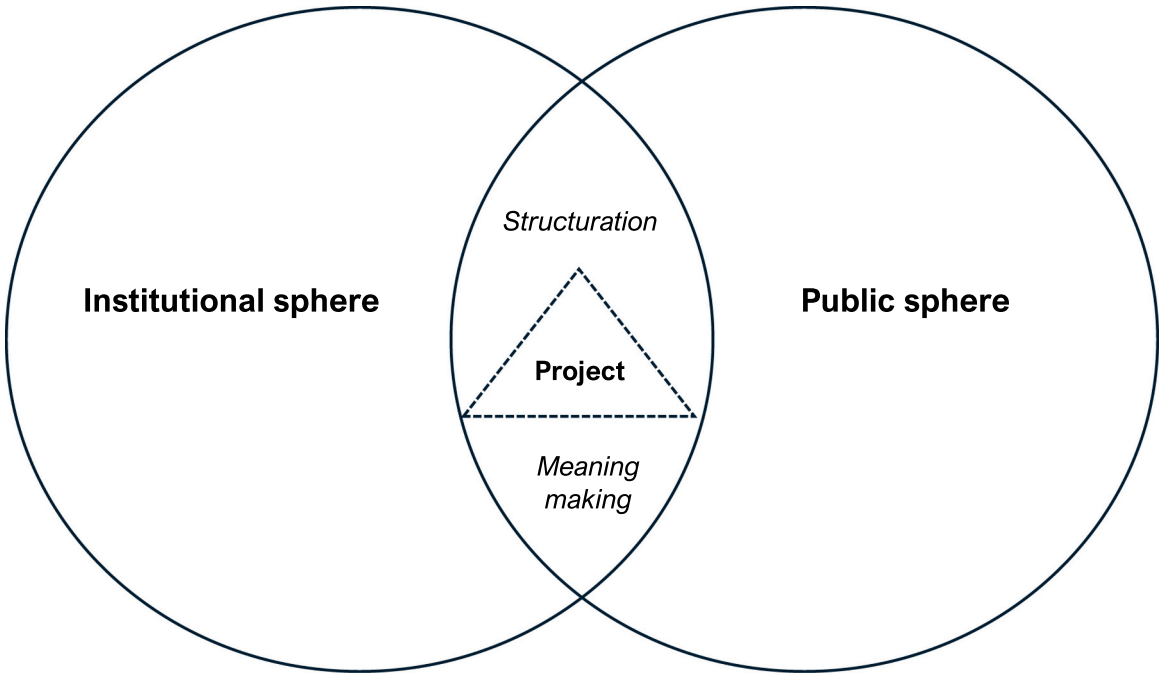

Fig. 7. Large-scale solar PV projects in the interaction of the institutional and public spheres.

control Batel, 2020; Sovacool et al., 2021; Sánchez Contreras et al., 2024a,b). Although much of this critical literature examines the interplay between institutions and public responses (e.g. Stock, 2022), further work is needed to illuminate how public responses are conditioned by institutional structures and to identify the conditions in which they can challenge and transform those structures.

What is clearly needed is a way of conceptualising the deployment of large-scale energy infrastructures which integrates multiple levels and objects of analysis. The conceptual model we provide in Fig. 7 distinguishes two intertwined processes – meaning-making (discursive) and structuration (extra-discursive) – through which the institutional and public spheres interact. In addition to the literature reviewed in this article, this model is inspired by critical and relational approaches to the study of social life, such as the social psychology of legal innovation (Castro, 2012) and cultural political economy (Jessop and Sum, 2022), which aim to analyse the interrelations between the institutional and public spheres (Batel and Castro, 2009; Batel et al., 2016; Jessop, 2020). By "institutional sphere" we mean the actors often associated with the nation state and other levels of governance (e.g. policymakers, regulatory bodies, planning authorities) and the systems of rules which they generate and which help structure social reality. By "public sphere" we mean the actors often associated with civil society, including citizens and NGOs, the heterogenous set of social relations that are not (yet) dominated by institutional orders, and the site of identities and interests that are generated by people's experiences and "lifeworld" (Jessop, 2020). These spheres are not fixed or autonomous but continually reconfigured through interaction of structuring and meaning making practices. Many energy actors, such as community cooperatives or local development agencies, operate at their boundaries, which further illustrates the need for a relational analysis.

Meaning making is essential to social life because it allows people to reduce complexity or uncertainty and to act (Jessop and Sum, 2022). In our corpus, meaning making is evident in public or lay perceptions of solar energy, in shaping local responses to specific large scale solar projects, and in how developers, policymakers, and authorities represent projects and public responses. However, survey-based methods – while useful for gauging general sentiment – often reduce the complexity of meaning making by sacrificing key structuring dynamics such as power relations. Another issue is that studies often aggregate attitudes toward all forms of solar, blurring critical differences between rooftop and utility-scale systems. Underpinning this approach is the assumption that solar energy is inherently more acceptable than other energy technologies and infrastructures (see Dunlap et al., 2024). These approaches to the meaning making dimension struggle to capture the gap between individuals' support for a hypothetical renewable energy project and their lived experiences of its deployment – particularly when projects disrupt livelihoods, degrade ecosystems, or undermine cultural values. This methodological gap is especially acute in Indigenous and Global South contexts, where standardized instruments may misinterpret local epistemologies or erase critical concerns altogether (Hanger et al., 2016; Zander et al., 2024). Consequently, our framework highlights the need for methodological pluralism that can attend to epistemic, affective, and experiential forms of knowledge. A critical and relational approach can help bridge this gap by explicitly linking individual or collective perceptions to the institutional arrangements in which they arise.

Roos and Hornborg (2024, p. 80) recently point out that contemporary visions of solar power often reproduce a "Promethean" image of technology, that is as "simply an innovative means of harnessing energy, with no detrimental implications in terms of the social distribution of resources, i.e. as politically neutral." Another virtue of the critical and relational framework that we propose here is that it encourages researchers to examine how such visions circulate in society and become embedded in social practices and institutions. While approaches that incorporate narrative (Scovell et al., 2024), worldview (Sposato and Hampl, 2018), or social representations (Nilson and Stedman, 2022) offer promising alternatives to concepts such as attitude and opinion, researchers adopting them rarely examine how meanings are scaled up or embedded within institutional frameworks that influence project design or policy.

Several studies in our corpus do in fact examine the interaction between institutions and meanings by pointing to the significance of discourses and imaginaries in shaping both institutional choices and public support for large-scale solar, as well as their interrelations (Siamanta, 2017; Girard et al., 2025; Stock, 2021b; Haines et al., 2023). Imaginaries can be defined as semiotic ensembles that "frame individual subjects' lived experience of a complex world and/or guides collective calculation about that world" (Jessop and Sum, 2022, p.356) or, similarly, as "collectively held, institutionally stabilized, and publicly performed

visions of desirable futures, animated by shared understandings of forms of social life and social order" (Jasanoff and Kim, 2019 p.4). As such, imaginaries of large-scale solar energy are produced not only within institutional and expert domains – such as law, science, and engineering – but also in the public sphere, where local communities interpret, negotiate, and sometimes contest these visions. Some critical scholars have shown how, in institutional settings, large-scale solar is often framed through a techno-centric and globalized lens, emphasizing continuous economic growth, efficiency, and integration into broader energy markets (Jasanoff and Simmet, 2021; Dunlap, 2021). This global vision of "renewable energy" risks overriding locally grounded imaginaries, including forms of life that are socially and ecologically sustainable, yet do not conform to standardized notions of progress or productivity. Recognizing and engaging with these alternative imaginaries could open the way for energy transitions that not only achieve "sustainability" but do so in a way which supports social resilience and valued ways of life (Jasanoff and Simmet, 2021).

Structuration refers to the material or "extra-discursive" dimensions of social life (Jessop and Sum, 2022). In the context of the deployment of a large-scale solar project, structuration includes the biophysical resource and capital flows, modes of production and regulation, and the property relations and governance practices which enable and constrain it (Avila-Calero, 2025). At the macro-level, the effects of structure on the deployment of large-scale solar are seen in injustice associated with the global asymmetric flows of extracted materials, energy and labour (Alami et al., 2024; Brock et al., 2021; Hornborg et al., 2019). At the micro-level, the site of deployment is structured by solar's spatiotemporal profile as a "flow resource" (Avila-Calero, 2025). This is expressed in the relative horizontality of photovoltaic technology, with the need for vast amounts of land bringing projects into direct competition with agriculture, conservation, recreation, and other forms of land use which are the basis of local livelihoods (Huber and McCarthy, 2017). Structuring practices are seen when institutional orders and arrangements influence the distribution of benefits and burdens, often privileging national or regional interests while displacing negative impacts onto local communities – particularly those already socially or economically vulnerable, including rural communities, Indigenous populations, women, and precarious labourers (Stock and Birkenholtz, 2020; 2024; Fan, 2024; Sovacool et al., 2025). Crucially, publics do not merely receive these impacts – they also interpret, negotiate, resist, or accommodate them, potentially reshaping institutional practices in subtle ways. However, the range of possible social responses is conditioned by the relationship between structuration and meaning making.

Understanding social responses to large-scale solar deployment thus requires, as a first step, conceptualising how different structuring and meaning-making practices interact and with what consequences (Jessop and Sum, 2022). For instance, the relation between the institutional sphere and local responses to large-scale solar can be conceptualised as being mediated by structuring practices such as economic enclosure or political exclusion. This generates several empirically testable possibilities, such as a misalignment between structuring and meaning-making practices leading to local conflicts over large-scale solar plants. Alternatively, when socially shared meanings about solar energy fit with institutional rules and practices, might the deployment of large-scale solar be supported? Yet, because there are a range of responses to large-scale solar plants that go beyond saying yes or no, our model encourages examination of how alternative visions of solar energy futures, such as agrivoltaics or community solar, emerge within the public sphere as "social innovation" and, through practices of structuration and contestation, eventually become embedded in institutions (Hewitt et al., 2019). Thus, as well as analysing how meaning-making practices and institutions align or misalign, it is also important to investigate how specific imaginaries and discourses, such as those based on concepts of energy justice or energy democracy, are embedded in institutions and how they result in specific structuring practices.

In our corpus it was spatial planning institution that was regarded as the most important in determining what happens in specific sites for large-scale solar projects. The importance of spatial planning has been highlighted in the research on social acceptance of wind energy (e.g. Cowell, 2010; Toke, 2005; Aitken et al., 2008; Van der Horst and Toke, 2010). In the research on large-scale solar it was seen how, within the specific rules around planning systems, social imaginaries are translated via discursive, bureaucratic, technocratic and financial "practices of legitimation" (Sareen, 2019; Spangler et al., 2025). As such, it is in these situations that relations between different values (e.g. development and conservation), interests (e.g. public and private), and forms of knowledge (e.g. expert and lay knowledge) are mediated (Fournis and Fortin, 2017; Ellis and Ferraro, 2016). The model we propose thus can be described as taking a "metatheoretical" position insofar as it allows for and promotes the generation of concepts such as practices of legitimation which bring together the discursive and extra-discursive moments of institutional processes such as spatial planning.

Particularly interesting was the different ways that public participation in planning institutions was represented as a problem across different geographical contexts. In the European Union, several of the studies concluded that the deployment of large-scale solar plants would be both fairer and faster if the public had more say in their planning and design (Brás et al., 2024; Schram et al., 2024). In contrast, most studies in the United States were more cautious in their stance towards decentralising governance, often associating local opposition with climate denialism and right-wing populism (Alibašić, 2023; Hess et al., 2025). These differences are perhaps indicative of deeply ingrained and culturally specific political imaginaries. That public participation is a central tenet of land use and development decisions in most European countries is informed, as Ellis and Ferraro (2016) point out, by "a strong normative idea that members of the public should have some involvement in the decisions that shape the places where they live" (Ellis and Ferraro, 2016, p.40).

This normative idea is by no means the same everywhere, as is reflected in our corpus by calls for scholars not to impose concepts of energy justice outside of their Global North contexts of production (Barragan-Contreras, 2022; Sankaran, McIntyre-Mills, 2022). Some issues associated with this were seen in Hanger et al.'s (2016) study of a large-scale solar project in Morocco, when local survey respondents misinterpreted questions about public engagement and participation as about whether they would like to be employed by the project. Such a configuration of structuring and meaning-making practices may also help explain why in these contexts injustice often co-exists with acceptance. In Ghana, for instance, Stock et al. (2023) found that even when a solar project dispossessed locals of land and livelihood, communities expressed acceptance and optimism about the future, revealing the colonial internalization of these projects as symbols of progress and economic growth (see also Batel et al., 2024).

What was common across most contexts, however, was that the practice of public participation rarely lived up to its normative aspirations. Several cases highlighted the structuring and meaning making practices by which lay knowledge was "rendered technical" (Shokrgozar and Girard, 2024; Cantoni and Rignall, 2019). Another widely observed issue was that project developers are often not legally obliged to engage with relevant communities (Brás et al., 2024; Bessette et al., 2024). This is associated with the "announce and defend" approach to policy, much criticised in the social acceptance of wind energy literature (Pepermans and Loots, 2013). A key lesson from the literature on the social acceptance of wind energy is that speeding up decision-making processes at the expense of due process and public participation can lead to the suppression of conflict, breed resentment and undermine long-term legitimacy (Ellis and Ferraro, 2016). This suggests that, despite the specificities of large-scale solar and the tendency of social acceptance research to overlook critical and relational perspectives, there is much that can still be gained by being attentive to research on the social acceptance of other energy technologies.

The critical and relational framework we are suggesting provides a

vantage point to integrate insights from different research programs. But beyond this, it also suggests avenues for future transdisciplinary research on the deployment of large-scale solar and other energy technologies. Namely, it calls for a critical analysis of the interaction between the structuring practices emanating mainly from the institutional sphere and the meaning-making practices emanating mainly from the public sphere. This seems necessary to us since much of the literature on large-scale solar deployment tends to privilege one over the other. On one side are analyses that foreground meaning making insofar as they treat perceptions, values, beliefs and goals as the main drivers of conflict (Kitzing et al., 2020; Trandafir et al., 2023; Busch and McCormick, 2014; Crawford et al., 2022). On the other side are more structuralist perspectives that view the deployment of large-scale solar plants, and conflicts over them, as embedded in global value chains and markets, capitalist accumulation processes, and geopolitical relations (de Souza and Cavalcante, 2016; Baker and Sovacool, 2017; Christophers, 2022; Alami et al., 2024; Delatin Rodrigues and Grasso, 2025) or, more conceptually, as a response to the growth and changes in the socio-natural metabolism, i.e., the flows of energy and materials in the economy (Temper et al., 2018; Roos and Hornborg, 2024). This division also points to the importance of reflecting upon underlying epistemological categories such as the relations between agency and structure, and between micro and macro in social research on energy transitions (Foulds et al., 2025). In addition to these methodological reasons, there is a normative need to reconcile these perspectives for a democratic, decolonial and ecological deployment of solar power plants.

6. Conclusion

Research on the social dimensions of large-scale solar deployment has expanded markedly over the past decade. Yet this body of work is characterised by diverse theoretical and methodological approaches, often grounded in contrasting normative perspectives and problem framings. We began by noting that social acceptance and energy justice constitute two of the main lenses through which scholars examine renewable energy deployment, but that more critical traditions, such as political ecology, also exist. To make sense of this heterogeneous landscape, our critical and integrative review combined a bibliometric analysis with thematic synthesis. The bibliometric analysis demonstrated that research trajectories are shaped not only by conceptual choices but also, more fundamentally, by disciplinary knowledge and geographical contexts. We then identified five cross-cutting themes – institutions, public perceptions, impacts, conflicts, and solutions – and synthesised their associated sub-themes within a perspective that views conflicts over large-scale solar projects as emerging through interactions between institutional arrangements and public meanings. Our relational model, which is metatheoretical in spirit (Sovacool et al., 2021), encourages researchers to interrogate opposition at every stage, from policy formulation through planning and implementation, and to trace the connections between micro-level dynamics and broader structural forces. Its explicitly critical orientation, with a dual focus on discursive meaning and material structures, enables inquiry into how responses to large-scale solar are shaped over time, by whom, and with what consequences.We also highlighted several conceptual and methodological limitations in the existing literature. Many of these can be addressed through multi-method research designs attentive to the epistemic, affective, and experiential dimensions that shape public responses to energy infrastructures, but that also situate these responses in relation to different levels of analysis. Understanding contestation over large-scale solar therefore requires closer attention to how institutions and public meanings interact and co-produce conflict. This calls for analytical frameworks foregrounding meaning, practice, power, and justice – approaches that recognise communities and other civil society actors not merely as stakeholders but as active agents in shaping energy futures. In this sense, opposition to large-scale solar should not be dismissed as a barrier to be overcome but understood both as signalling deeper contradictions in capitalist political economy (McCarthy, 2015) and as a constitutive feature of democratic social life (Barry and Ellis, 2014).

Our review also offers insights for researchers, policymakers, and practitioners seeking to develop more just and socially acceptable large-scale solar projects. First, project design and governance should be grounded in deep and authentic engagement with what Batel (2018) terms "communities of relevance," challenging assumptions that those living near renewable energy infrastructures are merely "affected communities" rather than actors with prior interests, knowledge, and capacities to shape the issues at stake. In the large-scale solar literature, such engagement is reflected in ideas like "deep energy literacy" Wilson, 2022) as well as in models of collective economic and political participation.

Second, projects should address multiple impacts and principles of energy justice by embracing the concept of multifunctionality. While often discussed in relation to agrivoltaics, multifunctionality applies to solar projects more broadly, highlighting their potential to simultaneously deliver social, economic, and environmental benefits – for example through local economic participation or the provision of ecosystem services (Oudes et al., 2022). Although studies increasingly explore the multifunctionality of solar infrastructures and its links to acceptance (Biró-Varga et al., 2024), further research is needed to understand these dynamics across diverse contexts and scales.

Finally, although many innovative approaches are oriented toward energy justice, they remain susceptible to power imbalances and can be co-opted by corporate or state actors, reducing local knowledge to inputs within technocratic decision-making. This underscores the need for critical reflexivity not only in research but also in the financing, planning, design, and implementation of large-scale solar projects. It also highlights the importance of interdisciplinary collaboration, policy innovation, and long-term engagement with communities of relevance. Participatory interventions such as counter-mapping can help unsettle dominant spatial logics and enable grassroots actors to articulate alternative energy imaginaries (Avila et al., 2022), positioning communities as sites of resistance, creativity, and transformation rather than obstacles to technological progress (Del Bene et al., 2018). Addressing the challenges associated with large-scale solar deployment therefore requires more than improved communication or consultation. It demands rethinking how projects are conceived, planned, and governed in ways that challenge entrenched political-economic structures. An important step toward this is the adoption of a critical and relational approach to social acceptance and energy justice that conceptualises institution-public interactions through meaning-making and structuration.

CRediT authorship contribution statement

Susana Batel: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ross Wallace:** Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ross Wallace reports financial support was provided by Research Foundation for Electricity and Mobile Communication. Susana Batel reports financial support was provided by Research Foundation for Electricity and Mobile Communication. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by FSM - Swiss Research Foundation for Electricity and Mobile Communication, Switzerland [grant number B2023–01].

Data availability

Data will be made available on request.

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