

Project Management Challenges and Control Strategies in Grid-Connected Solar Photovoltaic Projects: A Scoping Review (2015–2025)

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Abstract

Grid connected solar photovoltaic (PV) projects are expanding rapidly, yet project managers continue to report delays and cost overruns linked to permitting, interconnection and procurement processes. This paper reviews studies over the last decade on project management challenges and associated control strategies for grid-connected PV projects worldwide, with an emphasis on utility-scale plants, while also considering distributed PV projects where the delivery processes can be broadly applied. A scoping review approach was adopted in this study. IEEE Xplore, ScienceDirect, Springer and other major publisher and repositories were searched for publications from 2015–2025 using structured search strings. The included literature reveals four recurrent challenge clusters: (i) utility interconnection timelines and grid-integration processes; (ii) permitting, environmental licensing procedures and policy approvals; (iii) land-use, siting governance and stakeholder acceptance and (iv) procurement and supply chain risks. Reported control strategies include digital application portals and improved screening tools, clearer technical and regulatory guidance, early stakeholder and land use engagement, diversified sourcing and inspection checklists. Based on these findings, this study synthesizes practical control strategies and identifies research gaps related to quantitative evidence on the schedule and cost impacts of specific controls in varying economic and regulatory conditions.

Keywords

Solar photovoltaic, project management, grid interconnection, permitting, procurement

Nomenclature and Abbreviations

EPC - Engineering, Procurement, and Construction

GW - Gigawatt

IEEE - Institute of Electrical and Electronics Engineers

MW - Megawatt

NGT - Nominal Group Technique

NREL - National Renewable Energy Laboratory

PJM - PJM Interconnection LLC

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PRISMA-ScR - PRISMA Extension for Scoping Reviews

PTO - Permission to Operate

PV - Photovoltaic

RQ - Research Question

SLR - Systematic Literature Review

USD - United States Dollar

1. Introduction

Grid-connected solar photovoltaic (PV) projects have increased quite fast over the last decade as different nations looked forward to decarbonize power systems. It has also been made possible due to supportive policy frameworks and growing commitments to net-zero targets (Keen et al, 2022). These improvements have seen a significant rise in both utility-scale and distributed PV installations worldwide (Gorman et al., 2025). As the technology and module costs also have declined over the years, the importance of non-technical delivery processes have increased. Despite this change in momentum, project managers are reporting persistent delays, cost overruns, and uncertainty during project delivery, particularly for grid-connected PV systems. The challenges are arising not only from core generation technology, but also from complex interactions among regulatory, organizational, and social processes that deals with project implementation. Project schedules gets uncertain due to these challenges which comes with additional transaction costs and, in some cases, cancellations of the entire project (Cruce et al., 2022). While there is a large body of technical and economic literature available on PV systems, there is comparatively less consolidated studies on project-delivery challenges and the control strategies used to mitigate them (Babu et al., 2025; Abdulla et al., 2024). Utility interconnection is one of the frequently cited constrictions in PV project delivery and multiple studies have reported that an increasing number of interconnection applications, along with limited network visibility have resulted in congested interconnection queues and extended engineering study timelines (O'Shaughnessy et al., 2022; Johnston et al., 2023). Steep and uncertain interconnection costs further result in project withdrawals prior to construction, reducing completion rates for these PV projects (Johnston et al., 2024).

1.1 Problem Statement

Existing work often lists solar PV project deployment challenges as “barriers” such as policy uncertainty, grid constraints, or social acceptance, without systematically linking these barriers to concrete delivery processes and project management actions (Gadzanku et al., 2025). Different other studies have examined the technical aspects of grid integration, power electronics, and resource assessment without a detailed project management inclusion. Consequently, project managers and decision-makers lack a structured synthesis of what tends to go wrong and what process controls have been proposed or implemented in grid-connected PV projects. This study addresses this gap through a scoping review of studies published between 2015 and 2025 that explicitly discuss project delivery challenges for grid-connected PV projects. The primary focus is on utility-scale projects, but distributed PV projects are also included where their delivery processes are discernible.

1.2 Research Questions

We are focusing our review on following research questions:

RQ1: Which project-management challenge clusters are reported for grid-connected solar PV projects?

RQ2: Which control or mitigation measures are proposed or adopted to each cluster of challenges?

RQ3: How do these control strategies and challenges differ in various regions and with project scales?

RQ4: What do the existing literature still lack, especially in terms of the quantitative evidence about the schedule and cost changes?

2. Methodology

A scoping review design was chosen to map the breadth of project-management challenges and control strategies reported for grid-connected PV projects. The review followed PRISMA-inspired stages such as identification of records, screening, full-text eligibility assessment and inclusion criteria. Given the diversity of study designs and qualitative emphasis, a narrative synthesis was undertaken without meta-analysis.

2.1 Eligibility Criteria

In order to find and filter potentially relevant literature systematically, a process of study selection was used based on guidelines to conduct a scoping review. Several bibliographic databases and institutional repositories were searched to identify peer-reviewed articles and high-quality reports dealing with the problem of project management in deploying grid-connected solar PV. The selection was performed in stages of identification, screening, eligibility and inclusion, and predetermined inclusion and exclusion criteria were used at each level. Table 1 provides a summary of the study selection criteria and exclusion criteria.

Table 1. Inclusion and exclusion criteria for study selection

Category	Inclusion Criteria	Exclusion Criteria
Publication period	Published between 2015 and 2025 (inclusive)	Published before 2015
Scope	Addresses grid-connected solar PV projects	Focuses on off-grid/stand-alone PV where grid-connection processes are not considered
Study focus	Includes techno-economic analysis only if it also discusses delivery processes	Pure techno-economic optimization/LCOE studies
Source type	Peer-reviewed journal or conference paper, or technical/policy report from recognized institutions	Non-credible/non-recognized sources or sources without institutional/peer-review standing.
Language	English and full text accessible	Non-English or inaccessible full text

2.2 Information Sources and Search Strategy

IEEE Xplore, Google Scholar, were used as primary search tools. To broaden coverage beyond only engineering journals, the search was extended to publisher databases such as ScienceDirect, SpringerLink, MDPI and institutional repositories. For each source, combinations of PV-related terms and project-delivery concepts were applied. Search strings were iteratively refined but followed a consistent structure.

Examples:

- i. (“solar PV” OR photovoltaic) AND (“interconnection process” OR “interconnection timeline” OR “grid code” OR “interconnection requirements” OR “utility approval”)
- ii. (“solar PV” OR photovoltaic) AND (permitting OR “environmental licensing” OR “land acquisition” OR stakeholder OR “public acceptance”) AND (“project development” OR construction OR EPC)
- iii. (“solar PV” OR photovoltaic) AND (“supply chain” OR procurement OR “lead time” OR logistics OR modules OR inverters OR transformers)
- iv. (“solar PV plant” OR “solar farm”) AND (“quality assurance” OR documentation OR handover OR “as-built records”) AND (grid OR utility)

For each database, the timeframe filter was set to 2015–2025 (inclusive). Search strings were adapted to platform-specific syntax (for example, field filters in IEEE Xplore). Reference lists of key articles and reports were screened to identify additional studies that met the eligibility criteria. All records were exported into a single spreadsheet prior to de-duplication and screening.

2.3 Study Selection Process

Searches across IEEE Xplore, Google Scholar, ScienceDirect, SpringerLink, and additional sources (e.g., MDPI outlets and institutional reports such as NREL) identified approximately 6,388 records published between 2015 and

2025. After removing approximately 1,200 duplicate records, 5,188 unique records remained for title and abstract screening. Title and abstract screening excluded 4,928 records that were out of scope, leaving 260 records for retrieval.

A second-stage rapid check that included keywords/abstracts and where needed, a brief skim, removed 180 records prior to full-text eligibility assessment, primarily due to mismatch with grid-connected PV scope, lack of project-development focus, off-grid focus, or inaccessible full text. Full texts were then assessed for remaining 80 studies. Fifty full-text reports were excluded for not meeting the eligibility criteria (e.g., power-electronics focus without delivery-process implications, purely techno-economic analyses without permitting/interconnection/procurement discussion, off-grid systems, or non-English/inaccessible full texts). In total, 30 studies met all inclusion criteria and were included in the final qualitative synthesis. The selection process is summarized in Table 2.

Table 2. Study selection counts and included-study sources

Criteria(s)	IEEE Xplore	Google Scholar	ScienceDirect	SpringerLink	Other sources	Total
Records identified	192	1,230	2,466	300	≈2000	6,388
Duplicate records removed	≈40	≈240	≈470	58	≈200	≈1,200
Records screened (title/abstract)	150	990	≈2,000	242	≈1,800	5,188
Records excluded (title/abstract)	142	940	≈1,900	230	≈1,700	4,928
Reports sought for retrieval (shortlisted)	8	50	100	12	100	260
Reports removed before eligibility assessment	4	35	70	8	60	180
Full-text reports assessed for eligibility	4	15	32	4	40	80
Studies included in final review (by source)	4	*	8	2	16	30

**Google Scholar was used as a supplementary discovery tool for the research studies. Papers identified via this medium largely overlapped with items indexed in the publisher databases and institutional sources such as MDPI, NREL etc. and the included studies were therefore attributed to their primary source databases.*

Figure 1 uses a PRISMA flow diagram of the paper selection process for the review.

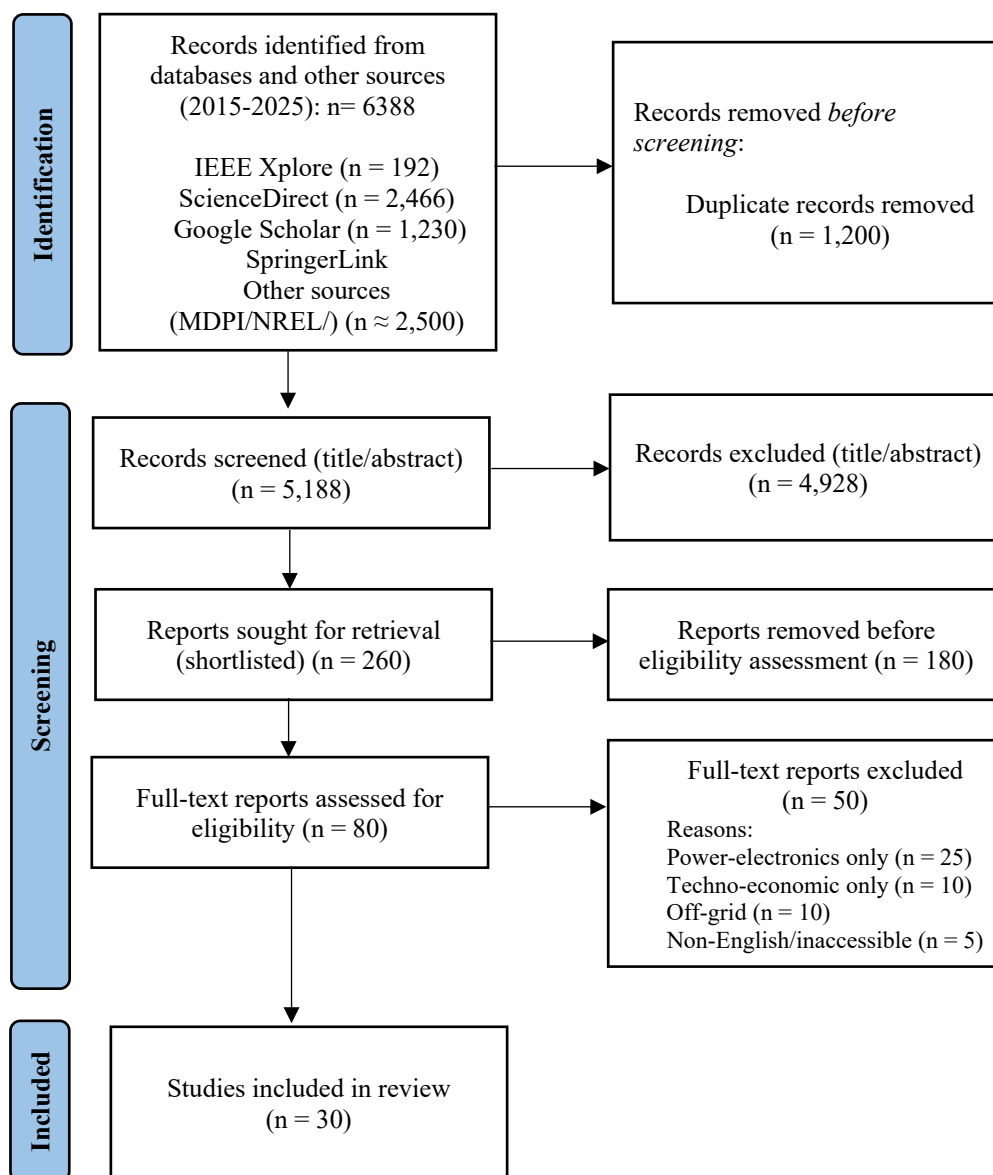


Figure 1. PRISMA-ScR flow diagram of study identification

2.4 Data Extraction and Clustering

Data from the studies were extracted manually through structured fields from each included study. These extracted fields are:

- Title
- Authors and year
- Summary and main findings
- Methodology or study design (e.g., case study, policy analysis, technical report, review)
- Region or country context (where reported)
- Study objectives and research question (if stated)
- Limitations
- Policy or project-management recommendations

The extracted data then were exported to a csv file and checked manually against the original documents where necessary. Each study was also assigned to one or more challenge clusters based on their primary focus:

- a. Interconnection timelines and grid compliance processes
- b. Permitting, licensing and policy risk
- c. Land-use, siting governance and stakeholder/community acceptance
- d. Procurement and supply-chain risk

Thematic synthesis was conducted by comparing main findings and recommendations across studies within each cluster. Descriptive counts of studies per cluster were compiled to characterize the distribution of emphasis.

2.5 Ethical Considerations

The review is based solely on previously published, publicly available literature. No human subjects, confidential data or experimental interventions were involved. Formal institutional ethics approval was therefore not required. The study adheres to standard publication ethics principles (IEOM), including accurate citation and avoidance of plagiarism.

3. Results and Discussion

Table 3 summarizes different characteristics from the included studies. For each study, their time period, geographic context, study design, and the solar PV project scale is taken into account. The results cover diverse nations, including the United States, India, Brazil, Ecuador, Kenya, Greece and broader multi-country analyses. Most studies are qualitative or mixed-methods, such as case studies, policy and regulatory analyses, technical reports, and multi-criteria impact assessments.

Table 3. Characteristics of the included studies

Reference(s)	Study type	Geographic focus	Project scale	Time period
Adithya (2016)	Empirical analysis	United States	Residential	2017–2019
Ghosh and Rahman (2016)	Empirical analysis	Bangladesh	Utility-scale	Not specified
Da Silva et al. (2019)	Literature review	Brazil	Utility-scale	Contemporary
McAllister et al. (2019)	Empirical analysis	United States	Residential and commercial	Not specified
Da Silva et al. (2020)	Literature review and modeling	Brazil (global examples)	Utility-scale	Not specified
Maqbool et al. (2020)	Empirical analysis (survey)	Pakistan	Small and medium-sized	Not specified
Cruce et al. (2022)	Empirical analysis	United States	Residential / small commercial	Not specified
Keen et al. (2022)	Empirical analysis	United States	Utility-scale	Not specified
O'Shaughnessy et al. (2022)	Empirical analysis	United States	Residential / small commercial	Not specified
Shojaimehr and Rahmani (2022)	Literature review and expert interviews	Iran	Utility-scale	Not specified
Beshilas et al. (2023)	Case studies and stakeholder engagement	United States (Tribal lands)	Distributed to utility-scale	2020–2023
Codemo et al. (2023)	Empirical analysis	Europe	Utility-scale	Not specified
Inayat et al. (2023)	Empirical analysis	Global	Utility-scale	Not specified

Reference(s)	Study type	Geographic focus	Project scale	Time period
Mulvaney and Bazilian (2023)	Literature review / conceptual analysis	Global	Utility-scale	Not specified
Fekete et al. (2023)	Literature review	Global	Utility-scale	Not specified
Gorman et al. (2025)	Empirical analysis	United States	Utility-scale	2000–2023
Johnston et al. (2024)	Empirical analysis (dynamic model)	United States (PJM region)	Utility-scale	2008–2020
Li (2024)	Mixed-methods (survey and SLR)	Ecuador	Not specified	Recent
Longden and Clapin (2024)	Empirical analysis	Australia	Utility-scale	2000–2023
Mogrovejo-Narvaez et al. (2024)	Hybrid methodology	Not specified	Utility-scale (~50 MW)	Not specified
Nilson et al. (2024)	Survey	United States	Utility-scale	2016–2023
Rocha et al. (2024)	Case study (action research)	Portugal	Utility-scale	2021
Abdulla et al. (2024)	Literature review	Global	Distributed and utility-scale	2010–2023
Amayo et al. (2025)	Mixed-methods	Global	Utility-scale	Not specified
Babu et al. (2025)	Empirical analysis	India	Utility-scale	Not specified
Gadzanku et al. (2025)	Systematic literature review	Primarily U.S. and Europe	Utility-scale	2000–2024
Hess et al. (2025)	Empirical analysis	United States	Utility-scale	Not specified
Shafiullah et al. (2022)	Literature review	Global	Multiple scales	Not specified
Erol et al. (2024)	NGT and literature review	Türkiye	Not specified	Not specified
Zhang et al. (2024)	Empirical analysis	China	Utility-scale	Not specified

To assess how the included studies satisfies our review objectives and overall quality assessment, each paper was mapped to determine whether it explicitly satisfies RQ1–RQ4 based on its stated research question. The results are summarized in Table 4.

Table 4. Mapping of included studies to the research questions (RQ1–RQ4)

Reference Paper	RQ1	RQ2	RQ3	RQ4
Adithya (2016)	Satisfies	Does not satisfy	Does not satisfy	Satisfies
Ghosh and Rahman (2016)	Satisfies	Satisfies	Does not satisfy	Satisfies
Da Silva et al. (2019)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
McAllister et al. (2019)	Satisfies	Does not satisfy	Does not satisfy	Does not satisfy
Da Silva et al. (2020)	Satisfies	Satisfies	Satisfies	Does not satisfy
Maqbool et al. (2020)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Cruce et al. (2022)	Satisfies	Does not satisfy	Does not satisfy	Does not satisfy
Keen et al. (2022)	Satisfies	Satisfies	Does not satisfy	Satisfies
O'shaughnessy et al. (2022)	Satisfies	Satisfies	Satisfies	Does not satisfy
Shojaimehr and Rahmani (2022)	Satisfies	Satisfies	Does not satisfy	Satisfies
Beshilas et al. (2023)	Satisfies	Satisfies	Does not satisfy	Does not satisfy

Reference Paper	RQ1	RQ2	RQ3	RQ4
Codemo et al. (2023)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Inayat et al. (2023)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Mulvaney and Bazilian (2023)	Satisfies	Satisfies	Satisfies	Does not satisfy
Fekete et al. (2023)	Satisfies	Satisfies	Satisfies	Satisfies
Gorman et al. (2025)	Satisfies	Satisfies	Satisfies	Does not satisfy
Johnston et al. (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Li (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Longden and Clapin (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Mogrovejo-Narvaez et al. (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Nilson et al. (2024)	Satisfies	Does not satisfy	Satisfies	Does not satisfy
Rocha et al. (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Abdulla et al. (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Amayo et al. (2025)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Babu et al. (2025)	Satisfies	Satisfies	Satisfies	Does not satisfy
Gadzanku et al. (2025)	Satisfies	Does not satisfy	Does not satisfy	Does not satisfy
Hess et al. (2025)	Satisfies	Satisfies	Satisfies	Does not satisfy
Shafiullah et al. (2022)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Erol et al. (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy
Zhang et al. (2024)	Satisfies	Satisfies	Does not satisfy	Does not satisfy

Here, “satisfies” indicates if the study explicitly addresses the research question based on its stated objectives, methods, findings, or recommendations. The category “does not satisfy” indicates that the study in context does not address the particular research question. “Not mentioned” indicates the extracted data did not provide enough information to determine any connection. RQ1–RQ4 correspond to the review’s research questions defined in Section 1.2. Subsequently, Figure 2 shows the number of included studies by the primary challenge clusters adopted in the review.

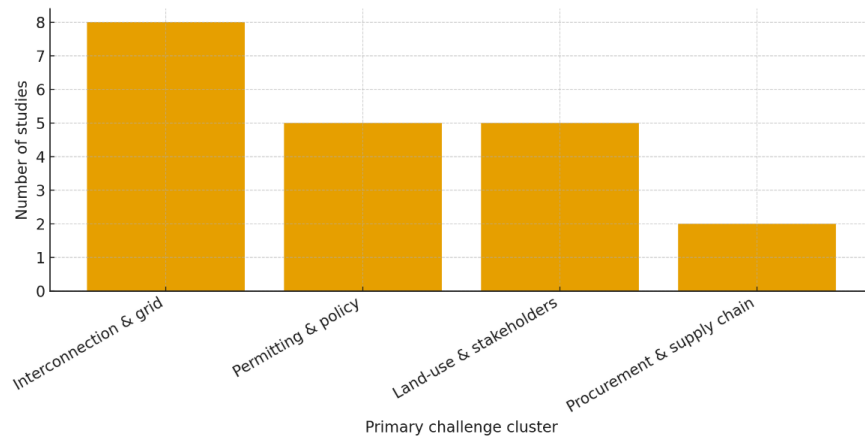


Figure 2. Number of included studies by primary challenge clusters

To complement the qualitative synthesis above, Table 5 below summarizes some quantitative evidence reported in the included studies. The metrics were sorted according to different challenge clusters.

Table 5. Quantitative evidence highlights from included studies

Challenge cluster	Key Metrics	Context	Reference
Interconnection and cost	<ul style="list-style-type: none"> Interconnection timelines have lengthened substantially (reported increase ~70% over the 2010–2023 period) Interconnection costs show wide dispersion (median \approx USD 0.05 million/MW; 90th percentile \approx USD 0.41 million/MW) 	Utility-scale PV, United States (PJM)	Gorman et al. (2025), Johnston et al. (2024)
Interconnection reform	Policy reform simulations suggest that queue-design changes such as entry-fee mechanisms could increase completed capacity (reported effect \approx +6.9 GW under modeled assumptions)	Utility-scale PV, United States (modeled)	Johnston et al. (2024)
Permitting	Local permitting pathways are associated with measurable reductions in approval duration (reported median reductions \approx 2.6 days for online/instant approval and \approx 1.2 days for over-the-counter permitting).	Residential PV, United States	O’Shaughnessy et al. (2022)
Distributed PV delivery	A substantial share of signed residential PV contracts did not convert to installations (reported \approx 51%), with measurable cost impacts (reported average \approx USD 0.20/W).	Residential PV, United States	Cruce et al. (2022)
Project lead time	Regulatory reform packages were associated with large reductions in project development lead times (reported reduction from \sim 83 to \sim 41 months).	Utility-scale PV, Australia	Longden and Clapin (2024)

3.1 Findings by Challenge Cluster

Interconnection proves to be a continually appearing critical path uncertainty for both large and smaller-scale solar interconnection and delivery, where project delays are perpetuated by congested queues, the need for multiple study reviews, and a lack of clarity regarding network limitations. Evidence for this is observable and identifiable in U.S.-based projects for which research suggests that congestion in the queue and engineering studies could appreciably prolong project timelines for solar interconnections, while uncertainties and variability in network upgrades and expenses could adversely affect project completion prior to financial closure and construction completion (Gorman et al., 2025; Johnston et al., 2024). Studies analyzing smaller and residential solar interconnection also reveal that project-specific procedural specifics regarding screening processes and local information needs become directly transferable to discernible project duration differences between interconnections, and that “soft” procedural factors are therefore demonstrably equivalent to hard technical project barriers (Fekete et al., 2022). Regarding mitigation techniques and alternatives to address interconnection barriers for solar energy integration and delivery, the most active existing solutions exist in procedural and technical advancements for improved screening and heightened transparency through the provision of hosting capacity-type information to decrease unnecessary study rework and iterations (Keen et al., 2022; McAllister et al., 2019).

Delays in permitting and licensing are uniformly described as multi-party problems of coordination, rather than challenges that are primarily or exclusively the responsibility of single agencies or sectors. The literature makes clear that local patterns of permitting and licensing processes and requirements can move the timing of installation and approvals in predictable and measurable ways, and that administrative design, such as online permitting and streamlined approvals, can decrease review time without sacrificing, or indeed often improving, review quality (O’Shaughnessy et al., 2022) In utility-scale developments, licensing complexity correlated with the fragmentation of mandates, a lack of uniform interpretation at the local level, and a sequencing of environmental and land-related approvals that, when inadvertently aligned with financial decisions, could increase the risk associated with project timelines (Da Silva et al., 2020). In contexts where changes to licensing complexities have been enabled, the best

evidence will necessarily originate from more traditional changes to work processes that rationalize work flows, increase clarity, and minimize rounds of dialogue between applicants and licensing bodies, with more comprehensive proposals for rationalization remaining more understudied relative to similar ends (Da Silva et al., 2019).

Land use issues of acceptance seem to be prominent in more governance or social science-focused literature, indicating that dissent cannot be easily or adequately explained by aesthetics, often being more visibly linked with procedural justice, trust, cost/benefit distribution, and local control over siting. Studies focusing on large solar installation siting practices indicate that acceptance and attitude are functions of consultation quality and governance, with project postponement and conflicts potentially increasing when consultation happens later in the process or perceived more symbolically than in participatory form (Gadzanku, et al., 2025). Finally, studies that investigate siting authority or decision frameworks indicate that institutional frameworks can impact either approval process or level of resistance, potentially conditioning planning of stakeholder consultation more as an activity of developers that can be managed within delivery workstream considerations rather than being an external principle (Hess, et al., 2025).

Procurement and supply chain risks are discussed within the context of the articles included as market-exposure risks (price variability, lead times, and ability to obtain critical elements) and management risks (risk sharing and timing that interact with the timing of permits and interconnections). On the topic of global procurement and supply chains for solar power, the volatility and management risks impacting procurement decisions and the feasibility of projects are represented particularly for those experiencing compliance risks and reputational risks (Mulvaney and Bazilian, 2023). Developers prefer not to commit until the last minute to avoid the risk of redesign but are then vulnerable to market risks from late procurement decisions for project lead times and prices and endure the trade-off (Rocha et al., 2024). Control from the literature verifies that critical equipment identified early and the focus on diversification and coordination of procurement and permit timing are reduced reworks and renegotiations (Erol et al., 2024).

3.2 Control and Mitigation Strategies

Throughout the included studies, a range of regulatory and procedural control strategies have been advised or implemented to mitigate recurring project delivery challenges in grid-connected solar PV projects. These strategies vary in scope and governance level, ranging from fully implemented administrative reforms to conceptual or early-stage policy mechanisms. Table 6 synthesizes the key control and mitigation strategies found in the literature, which addresses the challenges tackled, the context of implementation, and the reported evidence of effectiveness.

Table 6. Control and mitigation strategies reported in the literature for grid-connected solar PV projects

Strategy	Primary challenge addressed	Governance / implementation level	Implementation status	Evidence of effectiveness	Key references
Instant online permit approvals	Permitting delays	Local / utility	Implemented	Median approval time reduced by ~2.6 days	O'Shaughnessy et al. (2022)
Over-the-counter / expedited permitting	Permitting process duration	Local / state	Implemented	Approval duration reductions of ~1.2 days at median	O'Shaughnessy et al. (2022)
One-stop-shop planning approvals	Administrative fragmentation	State (Australia)	Implemented	Associated with substantial reductions in project lead times	Longden and Clapin (2024)
Designated single points of contact	Process navigation complexity	Utility	Implemented	Median PTO duration reduced by ~0.4 days	O'Shaughnessy et al. (2022)
Mandatory response-time targets	Approval delays	State / utility	Implemented	Median process intervals reduced by ~4 days	O'Shaughnessy et al. (2022)

Strategy	Primary challenge addressed	Governance / implementation level	Implementation status	Evidence of effectiveness	Key references
Hosting capacity maps	Interconnection uncertainty	State / utility	Implemented	Reduced need for detailed studies; improved screening efficiency	Keen et al. (2022), McAllister et al. (2019)
Interconnection entry fees	Queue congestion	Federal / utility	Proposed / modeled	Simulations indicate increased completed capacity (~6–7 GW)	Johnston et al. (2024)
First-ready, first-served queue prioritization	Interconnection inefficiency	Federal / utility	Planned	Modeled improvements in queue throughput and environmental outcomes	Johnston et al. (2024), Gorman et al. (2025)
Strategic environmental assessment	Fragmented licensing	Federal	Proposed	Not quantitatively evaluated	Da Silva et al. (2019), Da Silva et al. (2020)
Supplier diversification and contract flexibility	Procurement risk	Developer / EPC	Implemented	Reduced exposure to price volatility and delivery delays	Mulvaney and Bazilian (2023), Babu et al. (2025)

4. Research gaps and Future Directions

Even though the studies included give an excellent insight on the common bottlenecks in delivering grid-connected PV projects, the evidence base still contains critical limitations that limit the conclusion one may make about what works in the field. One of the key gaps is the lack of causal evidence that can be used to correlate the particular project-management controls with quantifiable delivery outcomes (time, cost, completion or withdrawal). A number of studies report interconnection delays and queue behavior and demonstrate how congestion and uncertainty can influence the course of a project, but only a small fraction of them assess the efficacy of specific reforms or project-level controls in similar ways across continents (Gorman et al., 2025; Johnston et al., 2024; O'Shaughnessy et al., 2022). In a similar vein, fragmentation and administrative complexity have been frequently cited as permitting permissible and policy discussion areas, but strong comparisons of alternative permitting models, including one-stop pathways, templates, or process digitalization, have not been well-developed and often context-specific, which restricts generalizability (Da Silva et al., 2020; Mulvaney and Bazilian, 2023; Riad et al., 2025). This adds to a more general methodological gap: the literature contains descriptions and suggested controls in abundance, but remains scant in terms of standardized metrics and similar outcome reporting across geographical areas and project size (Abdulla et al., 2024; Shafiullah et al., 2022). The second gap is the issue of cross-phase and cross-actor integration. Most literature studies interconnection in isolation of other workstreams, such as permitting or stakeholder acceptance, or procurement, but fewer follow up how these risks interact throughout the lifecycle, such as how interconnection uncertainty can influence procurement timing and contracting exposure or how delayed community opposition is worsened by permitting (Keen et al., 2022; Mulvaney and Bazilian, 2023; Rocha et al., 2024). Similarly, the fact that utility-scale and distributed PV studies differ is also recognized, but cross-scale synthesis has not yet been fully developed; residential and small-commercial delivery issues (e.g. cancellations and soft-cost dynamics) do not always relate to the control mechanisms considered in utility-scale research (O'Shaughnessy et al., 2022; Cruce et al., 2022; Nilson et al., 2024). The literature is acknowledging governance, procedural fairness and benefit distribution as determinants of acceptance on the stakeholder side, but there is yet to be established consistency in empirically testing which engagement methods mitigate delay risk at various land-use regimes and community settings (Gadzanku et al., 2025; Belletto et al., 2025; Fekete et al., 2023). Risk themes are also well known in the context of procurement and supply-chain work, yet there is a lack of evidence on how specific contracting structures (e.g., indexation, flexibility, multi-

sourcing) can be used in the context of variable combinations of regulatory and interconnection uncertainty (Keen et al., 2022; Shojaimehr and Rahmani, 2022).

Future studies thus should not involve much identification of challenges but rather testing and comparing controls with designs that can give greater inference. Priorities directions encompass: constructing and distributing structured datasets that interconnect and allow timelines to project outcomes; longitudinal and comparative interjurisdictional studies to assess permitting streamlining, queue reforms and digital tools under varying institutional circumstances; and analysis of combinations of controls instead of individual ones, as review indicates failures in delivery tend to arise due to cascading interactions across approvals, stakeholder processes and procurement choices (Johnston et al., 2024; Da Silva et al., 2020). The lack of evidence is also observed in underrepresented regions and in situations with a lower institutional capacity, where the risk drivers and workable controls might differ considerably compared to North America and Europe (Abdulla et al., 2024; Amayo et al., 2025). Finally, one of the potential ways to improve comparability between studies would be to use more consistent definitions and reporting of what was implemented, at what level, and with what measurable outcome, which would strengthen future synthesis and offer more powerful action-oriented recommendations to project managers and policymakers (Maqbool et al., 2020; Shafiullah et al., 2022; Erol et al., 2024).

4.1 Strengths and Limitations

This review contributes by bringing together literature that is often scattered across technical, policy and practice-oriented domains, and by framing findings in terms of project-management challenge clusters and control strategies. Our data extraction helped structure key fields e.g., summary, methodology, limitations and recommendations across a set of 30 studies. Despite of the extended research, several limitations must be acknowledged:

- a. The number of included studies is modest and limited to English-language sources, which may omit important experiences in other regions.
- b. Most detailed interconnection process studies originate from North American and African contexts; evidence from low and middle-income countries are relatively thinner.
- c. Heterogeneity in study design and reporting means that quantitative comparison of schedule and cost impacts was not feasible.
- d. Screening and extraction were performed by human reviewer, which can introduce subjective bias even with explicit criteria. These limitations suggest that the findings should be interpreted as indicative patterns rather than exhaustive or globally representative conclusions.

5. Conclusion

This scoping review synthesized project-management challenges and control strategies for grid-connected solar PV projects, based on 30 studies published between 2015 and 2025. Four main challenge clusters were identified. The literature emphasizes that these challenges often interact, leading to compounded schedule and cost risk. Across clusters, common control strategies are process-oriented, including digitalization and standardization of interconnection and permitting workflows, early coordination with utilities and authorities, structured stakeholder engagement and community benefit mechanisms, diversified sourcing and schedule contingency for key equipment, and improved documentation. While the review is limited by dataset size, language and regional skew, it highlights the importance of integrating regulatory, social and supply-chain considerations into PV project management from the earliest stages. Future research should quantify the effectiveness of specific controls, explore under-studied regions and commissioning practices, and improve empirical understanding of how project-management strategies can reliably reduce delays and cost overruns in the rapidly evolving PV sector.

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