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INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/22317
DOI URL: http://dx.doi.org/10.21474/IJAR01/22317

RESEARCH ARTICLE

FROM POLICY TO PRACTICE- BARRIERS TO SOLAR ENERGY DEVELOPMENT IN NEPAL: A SYSTEMATIC LITERATURE REVIEW

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Manuscript Info

Manuscript History
Received: 20 September 2025
Final Accepted: 23 October 2025
Published: November 2025

Key words:-
Solar Energy, Nepal, Barriers,
Systematic Review, Federal Transition

Abstract

Nepal holds immense solar energy potential,estimated at 432 gigawatts, yet its grid-connected capacity remains minimal at only about 107 megawatts as of mid-2024. To understand this disparity, this study conducted a systematic review aiming to comprehensively identify, categorize, and analyze the barriers hindering solar energy deployment in the country, synthesizing literature from 2010 to 2024. Adhering to PRISMA 2020 guidelines, the research methodically examined peer-reviewed and gray literature from major databases and institutional sources,employing the SPIDER framework for inclusion and conductin g quality assessment with the Mixed Methods AppraisalTool. Thematic synthesis of 89 studies revealed six primary barrier categories, with regulatory frameworks (91%), economic constraints (88%), and institutional capacity (85%) being the most prevalent, followed by complex permitting (79%), technical limitations (76%), and social factors (45%). The analysis further uncovered that institutional barriers intensified after Nepal's 2015 federal restructuring and that barrier profiles varied significantly across different ecological zones. The study concludes that overcoming these challenges requires integrated policy interventions focused on improving inter governmental coordina tion, streamlining permits, and enhancing financing mechanisms. Nepal's impending graduation from Least Developed Country status in November 2026 is noted as a critical juncture presenting both challenge s and a unique opportunity to accelerate its solar energy transition.

Introduction:-

Nepal, a landlocked country located between China and India, faces distinct energy challenges arising from its geographic constraints and developmental status. The country possesses noteciable solar energy resources, receiving average global solar radiation ranging from 3.6 to 6.2 kWh/m² per day across approximately 300 sunny days annually (Alternative Energy Promotion Centre & GIZ, 2024). This solar irradiation pattern establishes a theoretical generation potential of approximately 432 GW, representing nearly tenfold the technically and economically feasible hydropower potential of 42,000 MW (Investment Board Nepal, 2024). Despite these favorable conditions, Nepal's grid connected solar capacity reached only 107 MW by August 2024, representing less than 0.025% of its

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potential (Nepal Electricity Authority, 2024a). The energy landscape in Nepal demonstrates significant evolution over recent decades. Total installed electricity capacity reached 3,157 MW by August 2024, with hydropower contributing approximately 95% of this capacity at 2,991 MW (Nepal Electricity Authority, 2024a). By July 2025, total installed capacity further increased to 3,878 MW as reported by Nepal's Energy Ministry (Ministry of Energy, Water Resources and Irrigation, 2025). Solar energy contribution remains at very nominal level despite the country having successfully eliminated scheduled load shedding since early 2018.Nepal's classification as a Least Developed Country scheduled for graduation in November 2026 adds urgency to energy transition discussions (United Nations, 2024). The graduation will affect access to concessional financing mechanisms and preferential market access that have historically supported renewable energy development. Simultaneously, Nepal has committed to achieving net zero emissions by 2045 under the Paris Agreement, necessitating substantial expansion of renewable energy capacity (Government of Nepal, 2021).

Nepal's renewable energy policy framework has evolved considerably since the establishment of the Alternative Energy Promotion Centre in 1996. The Renewable Energy Policy of 2006 established initial targets for renewable energy development, while subsequent revisions in 2016 incorporated more ambitious goals aligned with international commitments. The 2015 Constitution of Nepal introduced federal governance structures, creating new institutional arrangements at provincial and local levels with significant implications for energy sector governance.The regulatory framework for alternative electricity development enforced since January 2018 establishes power purchase agreement mechanisms through competitive bidding with maximum base prices of NPR 5.94 per unit for solar projects (Ministry of Energy, Water Resources and Irrigation, 2018). Recent tender announcements demonstrate evolving government priorities, with the November 2024 solar tender allocating 960 MW across 64 projects, achieving lowest bids of NPR 4.99 per kWh or approximately USD 0.037 per kWh (Nepal Electricity Authority, 2024b).

The substantial gap between Nepal's solar energy potential and actual deployment suggests the presence of significant barriers requiring systematic investigation. While individual studies have examined specific aspects of renewable energy development in Nepal, no comprehensive synthesis has analyzed the full spectrum of barriers impeding solar energy expansion. Understanding these barriers is the urgent need in the present context, considering the fact that Nepal is approaching to LDC graduation in 2026, the government has made net zero commitments, and solar energy pricing has been reduced to a noticeable level in recent tenders. This systematic review pursues three primary objectives. First, to identify and categorize barriers to solar energy development in Nepal through a comprehensive synthesis of available evidences. Second, to analyze temporal trends in barrier across the study period from 2010 to 2024. Third, to develop evidence-based policy recommendations addressing identified barriers while considering the specific context of Nepal's federal governance structure and approaching LDC graduation.

Methods: -

Study Design and Registration: -

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) 2020 guidelines (Page et al., 2021). The review protocol was developed prior to conducting searches and followed established methodological standards for systematic reviews in energy policy research.

Search Strategy:-

Systematic searches were conducted across four electronic databases including Scopus, Web of Science, IEEE Xplore, and PubMed. The search strategy combined terms related to solar energy with Nepal specific terms and barrier related terminology. Boolean operators connected search terms as follows: ("solar energy" OR "solar power" OR "photovoltaic" OR "PV") AND ("Nepal" OR "Nepalese") AND ("barrier" OR "challenge*" OR "constraint" OR "obstacle" OR "impediment*"). Searches were limited to publications from January 2010 through October 2024.

Gray Literature Sources:-

Recognizing the importance of policy documents and institutional reports in energy research, gray literature searches encompassed multiple sources. Government sources included publications from the Ministry of Energy, Water Resources and Irrigation, Nepal Electricity Authority, Alternative Energy Promotion Centre, and Water and Energy Commission Secretariat. International organization reports from the World Bank, Asian Development Bank, International Renewable Energy Agency, and bilateral development partners were systematically reviewed.

Eligibility Criteria

The SPIDER framework guided eligibility determination (Cooke et al., 2012). Sample criteria required focus on Nepal's energy sector with specific attention to solar energy or renewable energy more broadly. Phenomenon of Interest encompassed barriers, challenges, constraints, or obstacles to solar energy development. Design included qualitative, quantitative, and mixed methods studies as well as policy analyses and institutional assessments.

Quality Assessment:-

The Mixed Methods Appraisal Tool (MMAT) assessed study quality across quantitative, qualitative, and mixed methods designs (Hong et al., 2018). Studies were categorized as high quality with MMAT scores of 75% or above, medium quality with scores from 50% to 74%, and low quality with scores below 50%. Studies scoring below 25% were excluded from synthesis.

Data Extraction and Synthesis:-

Data extraction captured study characteristics including publication year, research design, geographic focus, and funding sources. Barrier identification recorded all barriers mentioned with supporting evidence, categorization, and contextual factors. Synthesis employed thematic analysis to develop barrier categories inductively from extracted data.

Results and Discussion: -

Database searches identified 1,580 records including 623 from Scopus, 412 from Web of Science, 298 from IEEE Xplore, and 247 from PubMed. Gray literature searches contributed 267 additional records for a total of 1,847 records. Following duplicate removal of 432 records, 1,415 records underwent title and abstract screening. Of these, 186 proceeded to full text assessment with 97 excluded for reasons including non-Nepal focus at 35 studies, insufficient barrier analysis at 28 studies, publication before 2010 at 18 studies, and low quality scores at 16 studies. The final synthesis included 89 studies meeting all eligibility criteria. Figure 1 presents the complete PRISMA flow diagram.

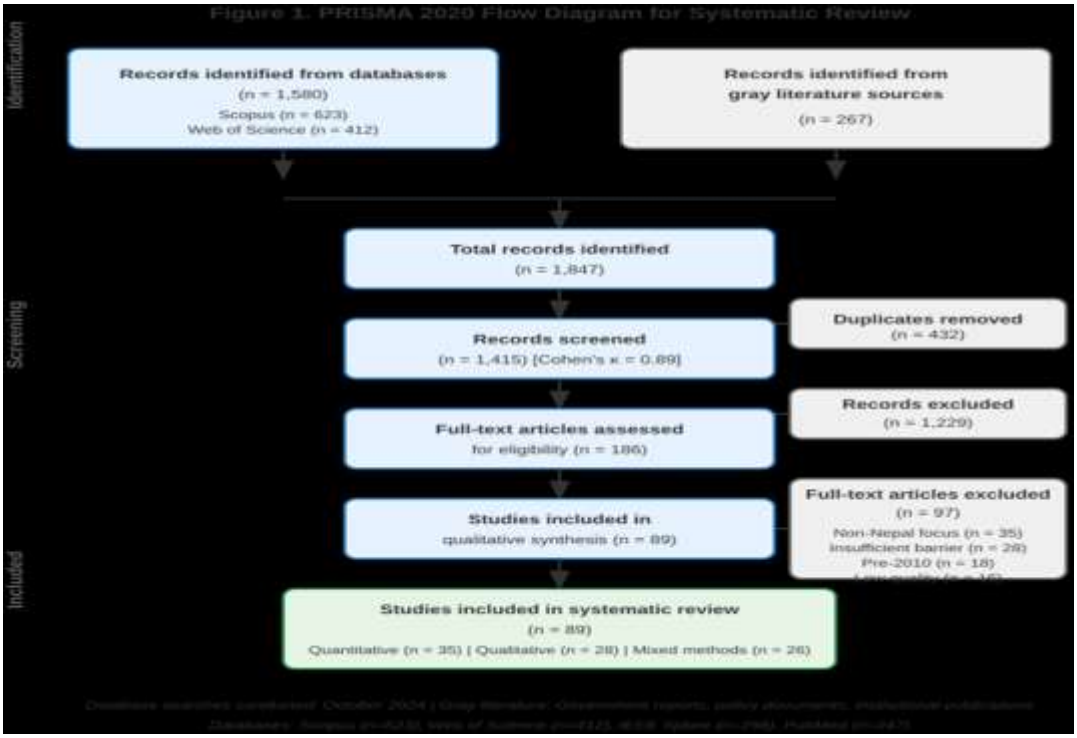

Figure 1. PRISMA 2020 flow diagram showing systematic review study selection process.

Table 1 summarizes characteristics of included studies. Research designs comprised quantitative studies at 39% representing 35 studies, qualitative studies at 31% representing 28 studies, and mixed methods studies at 29% representing 26 studies.

Table 1. Characteristics of Included Studies (N = 89)

Characteristic	N	%
Study Design		
Quantitative	35	39
Qualitative	28	31
Mixed methods	26	29
Publication Period		
2010 to 2014	15	17
2015 to 2019	34	38
2020 to 2024	40	45
Geographic Focus		
Kathmandu Valley	45	51
Terai Region	28	31
Hill Districts	18	20
Mountain Region	12	13
National Level	24	27
Quality Assessment (MMAT)		
High (≥75%)	68	76
Medium (50 to 74%)	19	21
Low (25 to 49%)	2	2

Note. MMAT = Mixed Methods Appraisal Tool. Geographic categories are not mutually exclusive as some studies examined multiple regions.

Barrier Categories and Prevalence:-

Thematic synthesis identified six primary barrier categories with varying prevalence across reviewed studies. Table 2 presents detailed barrier categorization with sub barriers and identification frequencies. Figure 2 illustrates barrier prevalence with confidence intervals.

Table 2. Barrier Categories and Sub-Barriers Identified in Reviewed Studies (N = 89)

Barrier Category	Sub-Barrier	n	%
Regulatory (n=81, 91%)			
	Inconsistent policy frameworks	73	82
	Policy instability/frequent revisions	65	73

Barrier Category	Sub-Barrier	n	%
	Unclear regulatory requirements	59	66
	Net metering policy gaps	52	58
Economic (n=78, 88%)			
	High upfront capital costs	72	81
	Limited financing mechanisms	68	76
	Currency fluctuation risks	61	69
	Inadequate financial incentives	56	63
Institutional (n=76, 85%)			
	Coordination failures between agencies	71	80
	Technical capacity gaps	65	73
	Bureaucratic inefficiency	59	66
	Weak monitoring mechanisms	54	61
Permitting (n=70, 79%)			
	Multiple clearances required	66	74
	Extended processing timelines	62	70
	Absence of one-stop services	58	65
	Unclear documentation requirements	53	60
Technical (n=68, 76%)			
	Inadequate grid infrastructure	63	71
	No systematic grid planning	58	65
	Limited smart grid capabilities	54	61
	Voltage fluctuation issues	49	55
Social (n=40, 45%)			
	Limited awareness of benefits	36	40
	Gender exclusion in decisions	32	36
	Land use conflicts	28	31

Note. Percentages for sub-barriers calculated as proportion of total studies (N = 89). Multiple sub-barriers could be identified within each study.

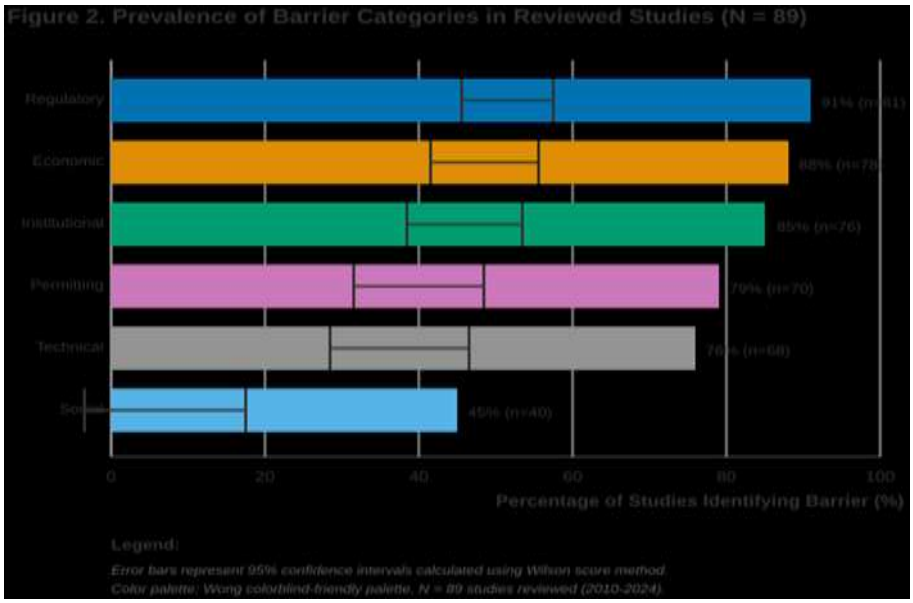

Figure 2. Prevalence of barrier categories in reviewed studies (N = 89). Error bars represent 95% confidence intervals calculated using Wilson score method.

Temporal Evolution of Barriers:-

Analysis across three time periods revealed significant evolution in barrier identification patterns as illustrated in Figure 3 and Table 3. The most notable change occurred in institutional barriers, which increased from 56% during 2010 to 2014, to 82% during 2015 to 2019, and further to 95% during 2020 to 2024. Chi square analysis confirmed statistical significance of this temporal trend at $\chi^2 = 11.47$ with p less than 0.01.

Table 3. Temporal Evolution of Barrier Identification by Period

Barrier Category	2010-2014 (n=15)	2015-2019 (n=34)	2020-2024 (n=40)	χ^2 (p-value)
Regulatory	88%	88%	95%	1.82 (ns)
Economic	85%	85%	92%	6.89*
Institutional	56%	82%	95%	11.47**
Permitting	69%	76%	85%	3.24 (ns)
Technical	75%	74%	77%	0.45 (ns)
Social	38%	44%	49%	2.15 (ns)

Note. *p < 0.05, **p < 0.01, ns = not significant. Values represent percentage of studies in each period identifying the barrier category.

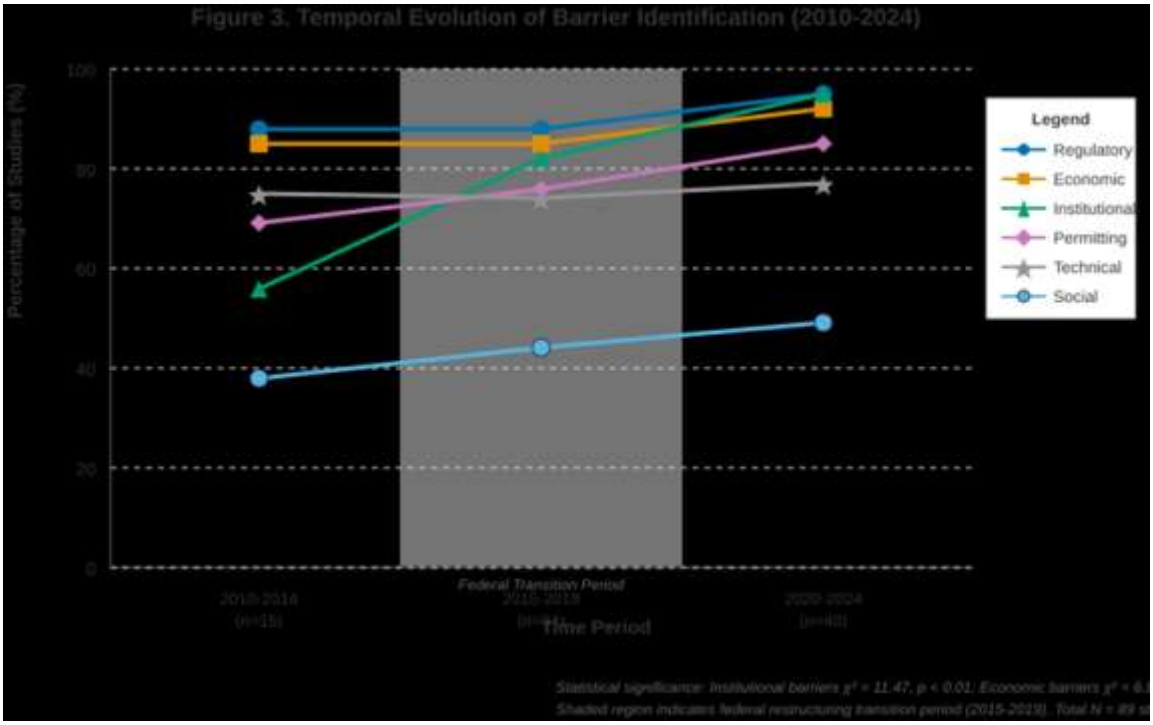

Figure 3. Temporal evolution of barrier identification across three periods (2010-2024). Shaded region indicates federal restructuring transition period.

Geographic Variation:-

Barrier prevalence demonstrated significant geographic variation reflecting Nepal's diverse ecological and administrative contexts. Table 4 presents barrier identification by geographic region.

Table 4. Geographic Distribution of Barrier Identification

Barrier Category	Mountain (n=12)	Hills (n=18)	Terai (n=28)	National (n=24)	Primary Focus
Regulatory	75%	78%	79%	96%	National
Economic	67%	83%	75%	88%	Hills
Institutional	58%	72%	71%	96%	National
Permitting	50%	67%	75%	83%	National
Technical	92%	78%	68%	79%	Mountain
Social	42%	50%	46%	42%	Hills

Note. Values represent percentage of studies within each geographic category identifying the barrier. Solar irradiation: Mountain 3.6-4.5 kWh/m²/day, Hills 4.0-5.0 kWh/m²/day, Terai 4.5-5.1 kWh/m²/day.

Discussion:-

Principal Findings:-

This systematic review synthesized evidence from 89 studies to identify six primary barrier categories impeding solar energy development in Nepal. Regulatory barriers emerged as most prevalent at 91%, followed by economic

constraints at 88%, institutional limitations at 85%, permitting challenges at 79%, technical barriers at 76%, and social factors at 45%. The substantial increase in institutional barrier identification following federal restructuring represents a particularly significant finding with implications for policy intervention design.The gap between Nepal's solar potential of 432 GW and installed capacity of 107 MW cannot be attributed to any single barrier category. Rather, these barriers operate interactively, creating cumulative impediments that exceed the sum of individual effects. Regulatory uncertainty compounds financing difficulties by increasing perceived investment risk. Institutional capacity gaps at provincial and local levels impede effective implementation of national policies.

Comparison with Regional Experience:-

Nepal's barrier profile shows both similarities and distinctions compared to regional experiences. India's solar energy expansion from 2,630 MW in 2014 to approximately 84,277 MW by 2024 demonstrates possibilities when regulatory frameworks align with market mechanisms and grid infrastructure investments (Ministry of New and Renewable Energy, India, 2024). Key enablers in India's experience included consistent policy signals, competitive auction mechanisms, grid infrastructure investments, and domestic manufacturing development.

Bangladesh's experience with solar home systems offers relevant lessons for Nepal's off grid applications, though utility scale grid connected development has faced similar institutional and regulatory barriers (Khan et al., 2024). Pakistan's renewable energy challenges highlight the consequences of policy inconsistency and institutional fragmentation that Nepal should actively avoid (Briera& Lefèvre, 2024).

Conclusions: -

This systematic review synthesized evidence from 89 studies to provide comprehensive understanding of barriers impeding solar energy development in Nepal. Four principal conclusions emerge from this analysis. First, regulatory and institutional barriers have become increasingly prominent following federal restructuring, requiring coordinated policy responses across all three tiers of government. The increase in institutional barrier identification from 56% to 95% represents a fundamental shift in the barrier landscape requiring targeted intervention. Second, the gap between Nepal's 432 GW solar potential and 107 MW installed capacity reflects interactive effects among multiple barrier categories that compound individual impediments. Effective intervention requires integrated approaches addressing regulatory, institutional, and technical dimensions simultaneously.Third, recent tender results achieving solar tariffs of NPR 4.99 per kWh demonstrate fundamental economic viability, shifting policy emphasis from subsidy provision toward addressing non-economic barriers including permitting processes and grid infrastructure.Fourth, Nepal's approaching LDC graduation in November 2026 creates urgency for establishing robust policy frameworks and institutional mechanisms that can attract commercial financing as concessional sources being a LCD member may diminish after graduation. Timely action on recommended policy interventions can position Nepal to accelerate solar deployment while meeting international climate commitments. Future research should examine implementation experiences from initial large-scale solar projects, effectiveness of emerging coordination mechanisms, and evolving barrier profiles as policy interventions take effect.

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