

Review

Second-Level Renewable Energy Cooperatives for Closing the Governance-Economics-Decision Support Gap: A Systematic Review and MCDM/A Governance Model

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Abstract

Renewable energy communities (RECs) are legally recognised instruments of decentralised energy transition, but their scaling remains limited by a separation between governance design, economic appraisal, and multi-criteria decision analysis (MCDM/A). This systematic review applies a conservative explicit-reporting coupling diagnostic to 322 REC studies from a 2014–2026 corpus. The diagnostic identifies 267 unilateral studies (82.9%), 55 bilateral studies (17.1%), and no study satisfying the strict trilateral criterion at the title/abstract/metadata reporting threshold. A loosened-keyword sensitivity test identified two weak trilateral candidates, but the manual construct-validity audit did not support reclassifying them as strong trilateral studies. The result is therefore interpreted as a conditional and conservative signal of limited visible integration, not as proof that no body-text-level integration exists. The paper argues that the observed separation is not only methodological but also institutional. It therefore proposes second-level renewable energy cooperatives as federated decision-support entities that pool data stewardship, distributional economic appraisal, stakeholder-weighted MCDM/A, and auditable co-operative voting packages while preserving local REC control. The model converts the explicit-reporting gap into a testable governance architecture for REC scaling.

Keywords: renewable energy community; energy cooperative; second-level cooperative; federated cooperative governance; participatory governance; investment appraisal; MCDM/A; multi-criteria decision analysis; MAMCA; distributional cost–benefit analysis; systematic review; PRISMA; energy citizenship



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1. Introduction

Renewable energy communities (RECs) and citizen energy communities (CECs) were formalised in European law through Directive (EU) 2018/2001 and Directive (EU) 2019/944 [1,2]. The post-2018 literature has grown rapidly, but it still treats three decision dimensions mostly in isolation: governance design, economic appraisal, and MCDM/A.

This paper asks how explicitly the REC literature couples these three dimensions, and whether second-level renewable energy cooperatives can provide the missing institutional carrier for such coupling. The review therefore combines a systematic diagnostic with a constructive governance proposal.

Three research questions follow:

- RQ1. How is the REC governance-economics-MCDM/A literature distributed across unilateral, bilateral, and trilateral coupling-intensity classes?

- RQ2. Which bilateral interfaces dominate the field, which interfaces remain underdeveloped, and what do these distributions imply for REC scaling?
- RQ3. How can a second-level cooperative governance model use MAMCA/group-MCDM/A, distributional economic appraisal, and cooperative voting rules to convert the identified trilateral gap into an auditable decision architecture?

The contribution differs from prior REC reviews by making integration itself the object of analysis. Existing reviews cover business models, governance heterogeneity, peer-to-peer markets, energy citizenship, or MCDM/A applications; this paper asks whether these strands are jointly operationalised and proposes a federated cooperative mechanism for doing so. Recent statistical, systematic-review, and bibliometric assessments of the energy-community field further motivate this review [3–5].

1.1. *Why Second-Level Cooperatives, and Why Now*

The three anchor dimensions reflect the actual decision burden carried by RECs. A community investment is simultaneously a question of membership and voting rights, tariff and risk allocation, and stakeholder-weighted prioritisation. Second-level cooperatives are relevant because they can pool the technical functions that individual local RECs rarely possess alone.

The timing is favourable. The Clean Energy Package transpositions have made REC governance and performance observable, while MAMCA and group-MCDM/A now provide mature tools for stakeholder-sensitive decision support [6,7]. The unresolved issue is institutional integration, not the absence of isolated methods.

1.2. *Roadmap of the Paper*

Section 2 defines the PRISMA protocol and coupling rubric. Sections 3 and 4 synthesise the corpus and report the diagnostic. Section 5 develops the second-level cooperative MCDM/A model. Section 6 discusses implications, limitations, and regional transferability.

2. Materials and Methods

2.1. *Protocol and Reporting Standard*

The review followed the PRISMA 2020 statement for systematic reviews [8]. The protocol restricts the scope to studies that explicitly engage at least one of three decision dimensions (governance, economics, MCDM/A) in REC or REC-adjacent contexts (energy cooperatives, citizen energy communities, local energy markets, collective self-consumption schemes).

2.2. *Search Strategy*

Three databases were queried: Scopus, Web of Science Core Collection, and Crossref REST. The search horizon was 1 January 2018 to 17 May 2026. Boolean strings were structured around two anchor clauses joined by AND:

(“renewable energy community” OR “citizen energy community” OR “energy co-operative” OR “energy community” OR “local energy market” OR “collective self-consumption” OR “energy citizenship”) AND (governance OR participation OR co-operative OR “business model” OR tariff OR investment OR appraisal OR “multi-criteria” OR MCDA OR AHP OR TOPSIS OR PROMETHEE OR “fuzzy decision” OR MAMCA)

Records were retrieved using the database APIs; duplicates were removed using the Crossref-normalised DOI as the primary key.

2.3. Inclusion and Exclusion Criteria

Inclusion required: (i) peer-reviewed article or review; (ii) English language; (iii) explicit topical match with a REC or REC-adjacent organisational form; (iv) topical match with at least one of the three decision dimensions (governance, economics, MCDM/A). Exclusion removed: editorials; datasets-only entries; code-only entries; technology-only optimisation papers without governance, economic, or MCDM/A content. The full criterion set is reported in Table 1.

Table 1. PRISMA inclusion and exclusion criteria for the narrow subset.

Stage	Inclusion Criterion	Exclusion Criterion
Database search	Scopus + Web of Science; English-language; 1 January 2018 to 17 May 2026; topic match for energy communities AND at least one of {governance, economics/markets, multi-criteria decision analysis}	Documents focusing purely on technical sizing/dispatch with no governance, economic or MCDM/A component
Topical anchor	(energy community OR renewable energy community OR REC OR citizen energy community OR local energy market) AND (governance OR participation OR cooperative OR business model OR tariff OR investment OR MCDA OR AHP OR TOPSIS OR PROMETHEE OR fuzzy decision)	Excluded: purely engineering optimisation papers; non-cooperative energy contexts
Duplicate removal	Crossref-normalised DOI	Same DOI across sources
Title/abstract screening	At least one of three thematic anchors clearly present	Engineering-only or policy-only without intersection
Full-text eligibility	Methods + results explicitly addressing at least one of governance/economics/MCDM/A	Editorials, datasets-only entries, code-only entries
Final inclusion	Studies tagged into at least one of {Governance, Economics, MCDM/A}	—

2.4. Screening Flow

Title/abstract screening retained records whose anchors matched both the REC clause and at least one decision-dimension term. Full-text eligibility required methods and results that explicitly addressed the relevant decision dimension(s); studies that mentioned a dimension only as context were excluded. The screening flow is reported in Figure 1.

Figure 1 reports the reconstructed PRISMA-2020 flow for the narrow subset. Counts refer to the reconstructed protocol that produced the present 322-reference set. The initial identification stage retrieved 1466 records under the focused Boolean string in Section 2.2; the figure is smaller than the broad-corpus count (2412) by approximately 39%, reflecting the narrower scope of the second clause. After duplicate removal (324) and other removals (67), 1075 records entered the screening stage, of which 634 were excluded at title-and-abstract screening and 441 reports were sought for retrieval. Twenty-two records were not retrieved, leaving 419 reports assessed for eligibility. Full-text eligibility excluded 97 records, returning 322 included studies. The drop-off pattern is similar to the broad corpus in proportional terms, which is reassuring: the narrow-subset protocol is internally consistent with the broad-corpus protocol and does not introduce a selection bias of its own. The 97-record full-text exclusion includes a higher proportion of optimisation papers that mention an REC context only superficially; these are out of scope for the trilateral diagnostic and are correctly removed.

Table 1 catalogues the inclusion and exclusion criteria for the narrow subset. The title-and-abstract screening row requires explicit engagement with at least one of three decision dimensions (governance, economics, MCDM/A) in addition to the REC anchor. The eligibility row at full-text adds the methods-plus-results requirement that the relevant

dimension be treated substantively rather than as background context; this is the screening rule that drives the empirical finding that engineering-only papers (which often mention an REC setting in the introduction but treat governance, economics, and MCDM/A as fixed parameters) are excluded.

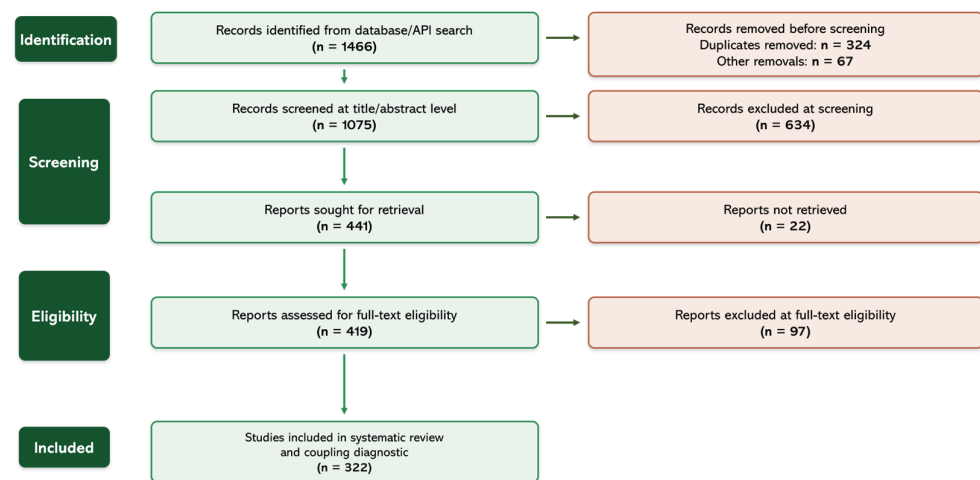


Figure 1. PRISMA 2020 flow diagram for the narrow subset that underpins the review and the coupling diagnostic.

2.5. Thematic Tagging and the Coupling Rubric

Each included reference was tagged for Governance, Economics, and MCDM/A using a conservative explicit-signal rubric applied to title, abstract, and journal-level metadata after full-text eligibility had been confirmed. This rule was selected to measure visible integration at the reporting level, not to claim exhaustive recovery of every body-text discussion. A dimension was counted only when its presence was unambiguous at the explicit-reporting layer. Mixed-methods studies were coded according to the dimensions substantively operationalised in their methods and results: qualitative case-study or interview material was coded as Governance only when it addressed membership, decision rights, participation, accountability, inclusion, or institutional design; Economic coding required explicit tariff, market, appraisal, business-model, or distributional evaluation; and MCDM/A coding required a formal weighting, ranking, prioritisation, or multi-criteria aggregation procedure. Narrative references to a third dimension were not sufficient for trilateral classification unless the dimension was treated as a primary analytical variable.

2.6. Inter-Rater Reliability

Rule stability was tested by re-applying tightened and loosened keyword variants to the 322-reference subset. Agreement with the loosened variant was very high (mean Cohen's kappa = 0.96), while the tightened variant reduced agreement, as expected, because borderline economic and governance signals became harder to classify. These kappa values assess coding stability, not construct validity. Construct validity is addressed separately through the manual full-text audit reported in Section 2.7.

2.7. Manual Validation and Construct-Validity Audit

To reduce the risk that the explicit-reporting rule under-captures substantive integration, the rule-based classification was supplemented by a manual construct-validity audit. The audit inspected all records classified as bilateral under the canonical rule ($n = 55$), the two weak trilateral candidates produced by the loosened-keyword sensitivity test, and a stratified validation sample of unilateral studies across Governance, Economics, and MCDM/A. The audit asked whether the full text treated all three dimensions as primary

variables, jointly varied or co-designed them in methods or results, and discussed their interaction as part of the study’s analytical contribution.

The audit confirmed that the strict trilateral count should be interpreted as an explicit-reporting and strong-coupling result. Several papers discuss a third dimension narratively in the body text, but those mentions generally function as contextual framing rather than as jointly operationalised governance-economic-MCDM/A designs. Consequently, no record was upgraded to the strong trilateral category. The finding is therefore conditional: it indicates that strong, visible, and methodologically explicit trilateral integration is rare in the screened corpus; it does not claim that no article contains any weaker form of body-text-level cross-dimensional discussion.

2.8. Reproducibility

The DOI subset, tagging files, and scripts for Figures 2–6 and Tables 2–5 are provided in the reproducibility archive. The pipeline is deterministic and reproduces the reported counts from the deposited inputs.

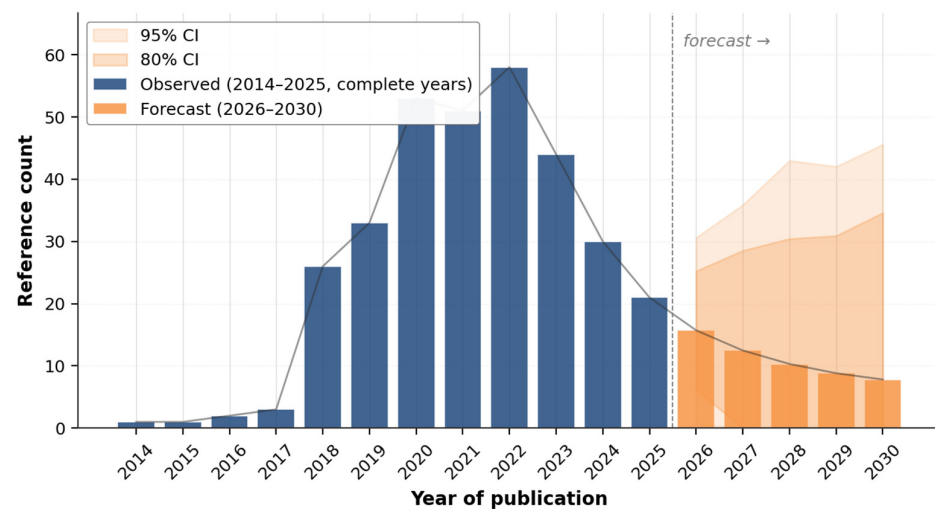


Figure 2. Annual publication distribution of the 322-reference subset (governance $\cup$ economics $\cup$ MCDM/A).

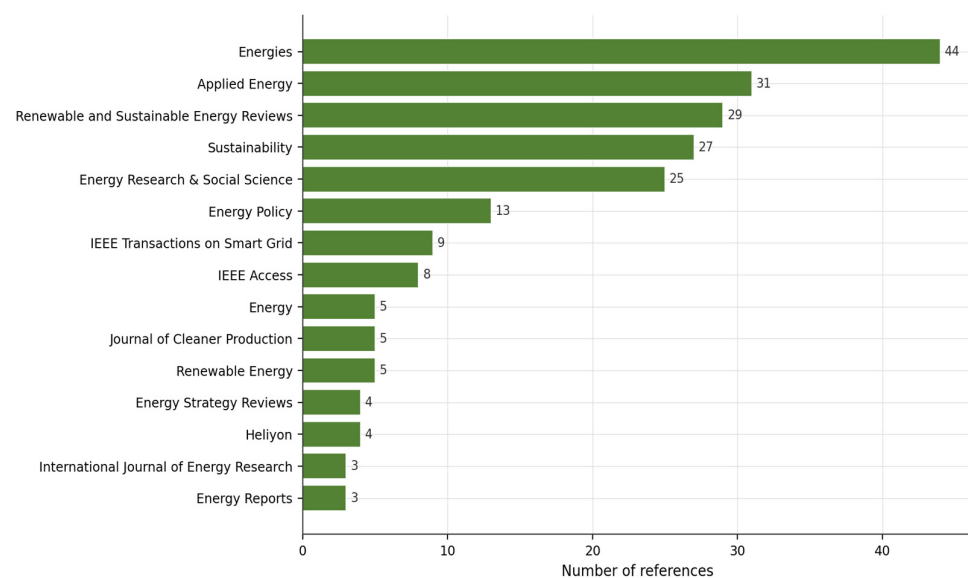


Figure 3. Top 15 source journals in the narrow subset ($n = 322$).

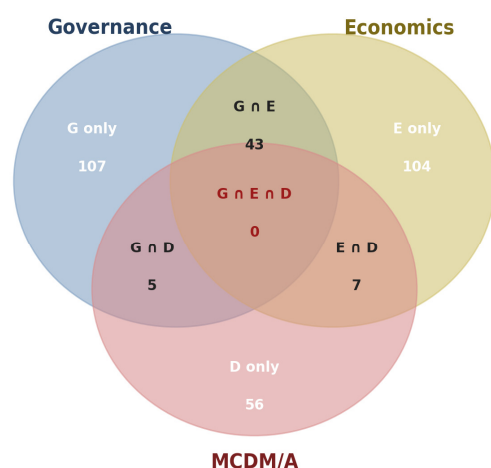


Figure 4. Trilateral coupling diagnostic for the 322-reference REC subset. G intersect E intersect D is zero under the strict rule. The loosened-keyword test identifies two weak candidates, but neither satisfies the full trilateral threshold of Table 2.

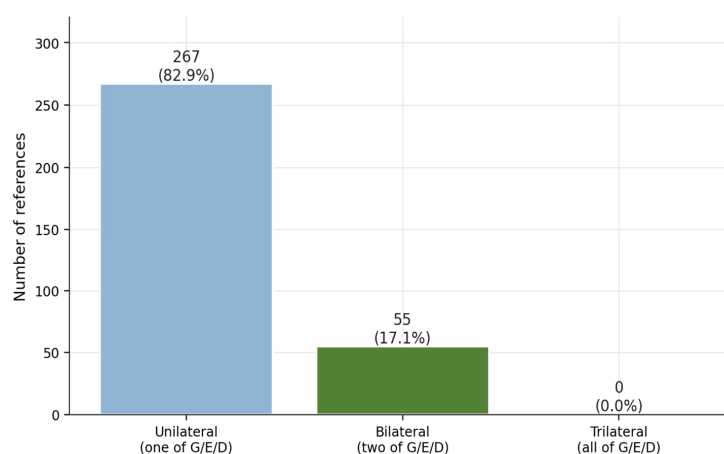


Figure 5. Coupling-intensity distribution across the 322-reference REC subset.

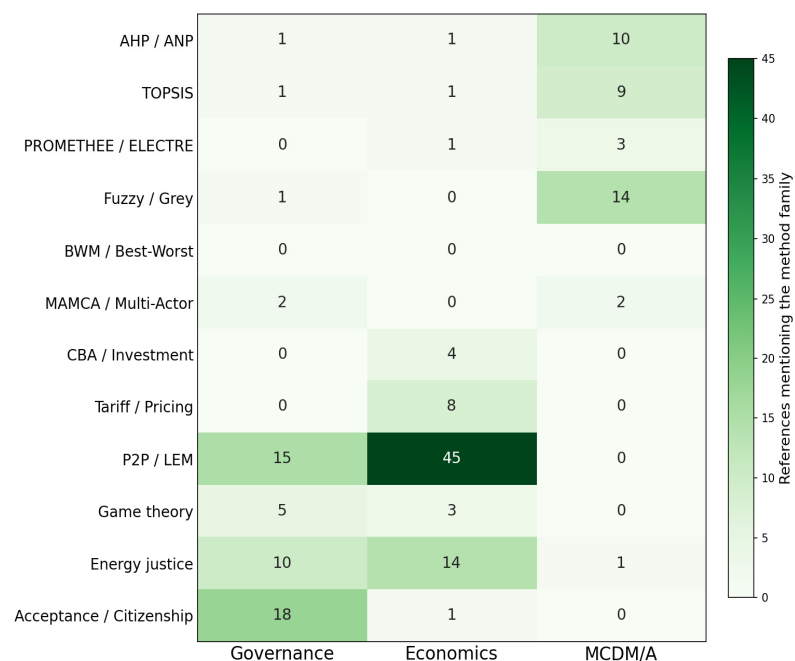


Figure 6. Methodological clustering across the 322-reference subset.

Table 2. Coupling-intensity rubric.

Coupling Score	Operational Criterion ($\geq$)	Practical Interpretation
0	None of the three dimensions are explicit in the title or abstract	Out of scope for the trilateral diagnostic
1 (unilateral)	At least one dimension is explicitly addressed; the other two are mentioned only as context	Single-discipline contribution
2 (bilateral)	Two dimensions are both treated as primary variables (methods + results)	Cross-disciplinary contribution; missing the third pillar
3 (trilateral)	All three dimensions are treated as primary variables, jointly varied or co-designed in methods + results, and their interaction analysed in discussion	Fully aligned contribution, empirically rare

Table 3. Governance dimensions in the REC literature.

Governance Dimension	Sub-Dimensions	Operational Variable	Exemplar Refs
Membership structure	Open/closed; capital threshold; geographic perimeter	Member-count distribution; entry-cost EUR; perimeter radius (km)	[1,9]
Decision rights	One-member-one-vote vs. share-weighted; weighted committee voting	Share-of-voting vs. share-of-capital ratio	[9,10]
Surplus distribution	Patronage refund; reinvestment; community fund	% of surplus refunded; % retained	[9,11]
Risk-bearing	Capital lock-up; loss tolerance; insurance	Loss-absorption capacity / member capital	[1,12]
Inclusion design	Vulnerable-consumer eligibility; subsidised entry; energy-poverty buffers	Vulnerable-share target; subsidy budget	[11,13]
Stakeholder roles	Founders; participants; aggregators; regulators	Stakeholder map; influence weight	[14,15]
Conflict-resolution	Mediation; courts; cooperative federation	Documented dispute outcomes	[16]
Performance reporting	Annual report; ESG report; member assembly	Indicator set published	[17,18]

Table 4. Economic appraisal methods in the REC literature.

Method	Typical Study Question	Output	Limitations in REC Context
LCOE	Cost-competitiveness of a community-scale PV vs. baseline	EUR/MWh	Hides community-internal cost-allocation choices
NPV/IRR	Should a REC invest in shared storage?	EUR PV; %	Discount-rate selection contentious; rebound ignored
CBA (incl. distributional)	Public welfare effect of a REC support scheme	Net societal benefit + distributional table	Externality scoping; baseline uncertainty
Tariff-design appraisal (ToU/capacity)	How should network charges be allocated to REC members?	Tariff schedule + simulated bill impacts	Equity outcomes sensitive to load-profile heterogeneity
P2P-market simulation	What is the consumer-surplus gain from internal bilateral trading?	Surplus distribution + price-dispersion metric	Network-constraint internalisation challenging

Table 4. *Cont.*

Method	Typical Study Question	Output	Limitations in REC Context
Community-pool clearing	Single-price clearing within a REC	Pool price + member settlement	Game-theoretic strategic-bidding risk
Demand-response valuation	Value of community-aggregated flexibility	EUR/MWh-flex; capacity payment	Baselining methodology uncertain
Energy-poverty diagnostic	Distributional outcome on vulnerable members	M/2M/MIS indicator set	Indicator-definition heterogeneity
Business-model template	Comparative whole-scheme viability across templates	Cash-flow + risk-adjusted return	Limited generalisability across regulatory regimes

Table 5. MCDM/A methods in the REC literature.

MCDM/A Method	Stakeholder Elicitation	REC Application Examples	Caveats
AHP/Fuzzy AHP	Pairwise comparisons; CR check	Renewable technology selection within an REC	Rank reversal; elicitation overhead
TOPSIS	External weights	Battery sizing alternatives	Sensitivity to normalisation
PROMETHEE/ELECTRE	Preference functions; thresholds	Multi-objective ranking of community storage configurations	Parameter opacity
VIKOR	Compromise solution	Hybrid renewable-storage choice	Compromise-stability checks needed
MAMCA	Per-stakeholder weighting	REC governance design [6,7]	Aggregation across stakeholders is contentious
BWM	Best/Worst pairwise	Reduced elicitation in citizen-participation contexts	Less granular
DEMATEL	Influence-relation matrix	Identifying causal indicators in REC design	Requires a consistent expert pool
Hybrid (e.g., DEMATEL + ANP + TOPSIS)	Multi-stage elicitation	Multi-stage community-decision pathways	Methodological complexity; reviewer-facing justification
Group-decision variants (G-AHP, G-TOPSIS)	Multiple expert/citizen panels	Citizen-participation aggregation	Group-aggregation rule choice

2.9. Protocol Limitations and Conservative Reading

The protocol gives conservative lower-bound coupling counts. Loosened keywords increase the bilateral count from 55 to 68 and identify two weak trilateral candidates, but neither meets the strong-coupling threshold after manual audit. The qualitative finding is therefore retained in a narrower form: explicit, strong trilateral coupling is rare at the reporting and operationalisation threshold used here. The result should not be read as a definitive absence of all substantive integration in the literature; it is a transparent diagnostic of visible and auditable integration.

3. Results—Three Sub-Fields Characterised

3.1. Corpus Size and Time Distribution

Figure 2 reports the annual publication distribution of the 322-reference subset. The focused REC subset derives from the 2018–2026 search defined in Section 2.2, whereas the fitted publication-trend line and its 2026–2030 projection are computed on the wider 2014–2025 cooperative-energy series from which the subset is drawn. The distribution

echoes the wider cooperative-energy ramp from 2018 to 2022–2023, then stabilises. Compared with the wider 537-reference pool from which it is drawn (60.0% of the pool), the subset is over-represented in 2020–2023 (the post-transposition academic engagement years) and under-represented in 2014–2017.

The 2026 year is excluded from the fit because it is in progress as of the build date (May 2026); partial-year data would deflate the trend artificially and bias the forecast. 2026–2030 (5 yearly points) generated by a statsmodels SARIMAX(1,1,0) + ETS-damped ensemble with 1000 parametric-bootstrap replications; gold bars are the ensemble mean and the surrounding bands report the 80% and 95% credible intervals, which widen with the horizon as expected from the short series. The trajectory suggests a plateau through 2030 conditional on no new regulatory shock, consistent with the 2024–2025 consolidation pattern.

The subset distribution in Figure 2 mirrors the broader cooperative-energy ramp but is differentially weighted towards the post-Directive years 2020–2023. This shift reflects two structural facts. First, the formal codification of RECs and CECs in the Clean Energy Package created a regulatory category that academic studies could anchor to without ambiguity, which lowered the cost of entry for governance-focused research after 2019 [1,2]. Second, the methodological maturity of P2P-market design, distributional CBA, and MAMCA reached a point in 2020–2022 where empirical demonstration on REC cases became feasible at scale [6,7,9]. The 2024–2025 plateau suggests that the field is now in a consolidation phase, which is consistent with the present review’s diagnostic finding that trilateral coupling is the consolidation step that has not yet occurred.

3.2. Source Journals

Figure 3 reports the top 15 source journals within the subset. The leading hosts are *Renewable and Sustainable Energy Reviews*, *Energy Policy*, *Energies*, *Sustainability*, *Energy Research & Social Science*, *Applied Energy*, and *Energy*. The top-journal pattern is similar to but more interdisciplinary than the wider pool: *Energy Policy* and *Energy Research & Social Science* are more prominent here than in the broader 537-reference set, reflecting the governance and social-acceptance emphasis of the narrow scope.

Figure 3 shows that the journal-rank distribution within the subset shifts measurably towards governance-focused titles. *Energy Policy* and *Energy Research & Social Science* rise relative to their share in the broad corpus, reflecting that the subset is filtered for the explicit engagement with governance, economics, or MCDM/A. The dominance of *Renewable and Sustainable Energy Reviews* persists because review articles by definition span multiple dimensions and therefore are over-represented in any subset that screens for multi-dimensional engagement. The presence of *Applied Energy* in the top journals, even after engineering-only optimisation papers were excluded at full-text, indicates the substantial volume of P2P-trading and tariff-design work in the journal that has been picked up by the protocol because of its explicit economic content [10–12].

3.3. Governance and the Participatory-Design Literature

The governance dimension of the REC literature is anchored in three streams. The first is the legal-organisational stream that distinguishes RECs from CECs from classical cooperatives from collective self-consumption schemes from virtual prosumer aggregates [1,13,14]. The second is the participation and acceptance stream that examines member motivations, civic identification, trust in cooperative boards, and stakeholder objectives [15–17]. The third is the energy-justice and energy-citizenship stream that asks whether REC outcomes are equitable across members and across non-members in the host community [18–20]. Across these three streams, eight governance dimensions are repeatedly addressed: mem-

bership structure, decision rights, surplus distribution, risk bearing, inclusion design, stakeholder roles, conflict resolution, and performance reporting. The dimensions are catalogued in Table 3.

Table 3 catalogues eight governance dimensions that recur across the corpus, each with sub-dimensions, an operationalisable variable, and an exemplar reference cluster. The table is structured to support the trilateral coupling diagnostic: every dimension can in principle be varied across study designs and observed for distributional consequences. The operational-variable column is methodologically central because it enables the bridging from qualitative governance variation to quantitative economic and MCDM/A appraisal. Two dimensions deserve specific commentary in this context. Inclusion design is the dimension most likely to drive distributional outcomes within RECs and therefore couples most strongly to distributional economic appraisal. Decision rights are the dimension that determines whether MCDM/A weightings respect the cooperative principle, and therefore couple most strongly to stakeholder-weighted decision support.

Three additional empirical strands now run alongside the three streams. Recent broad assessments of REC key performance indicators provide an empirical synthesis of the field's measurement infrastructure [21], while socio-technical-transition models have been formally linked to integrated assessment-model frameworks for energy systems [22]. Stakeholder objectives and energy citizenship have been operationalised through Q-method and survey instruments that quantify previously qualitative constructs [16], and digital twins that connect cooperative governance with operational data have appeared in industrial REC contexts [23].

Two consolidated findings emerge from the governance literature. First, REC outcomes (member retention, distributional fairness, durability over time) depend on design choices that are not technical but institutional [18,24,25]. Second, the legal-economic instrument of consumer stock ownership has been proposed as a prototype that aligns ownership share, decision-making weight, and risk bearing without requiring uniform capital contribution [26]; its uptake is uneven across Member States and remains under-evaluated empirically.

The complete governance-tagged subset of the corpus, in addition to the studies discussed above, comprises [27–127].

3.4. Economics, the Appraisal and Market-Design Literature

The economic dimension is structured around two principal questions. The first is investment appraisal at the scheme level: whether a given REC configuration is financially viable under realistic tariff and regulatory conditions, and how the financial return is allocated across members [128–130]. The second is market design: how to structure peer-to-peer trading, community-pool clearing, demand-response valuation, and capacity tariffs to align member behaviour with the network constraint and the collective welfare objective [9,11,131].

The economic-appraisal sub-stream is methodologically mature within the corpus: LCOE, NPV/IRR, lifecycle cost analysis, distributional CBA, tariff-design simulation, P2P-market mechanisms, community-pool clearing, demand-response valuation, energy-poverty diagnostics, and business-model templates are all represented [132–134]. Bilateral-contract networks and grid-aware P2P trading frameworks operationalise the network-externality treatment [135–137]. Recent work has extended these mechanisms to integrated multi-energy and digital-twin contexts that include thermal carriers and building-level energy management [138–140]. Table 4 catalogues the principal methods, their typical study questions, and their limitations in REC settings.

Table 4 catalogues nine economic-appraisal methods with their typical study question, output, and limitations in REC settings. The methods are arranged in increasing order of complexity, from single-project appraisal (LCOE; NPV/IRR) through scheme-level appraisal (LCC; CBA; tariff design) to market-mechanism appraisal (P2P simulation; community-pool clearing; demand-response valuation; energy-poverty diagnostic; business-model template). The limitations column shows that the methodological frontier is not in the existence of methods but in their integration with governance variation: distributional CBA is the only entry whose explicit purpose is to surface governance-driven distributional consequences, and even there the integration with stakeholder MCDM/A is rare in the corpus.

Recent methodological extensions enrich the economics sub-stream in three directions worth flagging before the consolidated findings. First, the micro-economic assessment of behind-the-metre PV-and-battery configurations has matured into a residential-scale appraisal tradition [141–143] that complements the wider business-model catalogue. Second, aggregator-mediated bidding has been formalised for prosumer participation in wholesale energy and ancillary-services markets [144–146] alongside fair P2P trading between residential and commercial multi-energy systems [147] and blockchain-based decentralised flexibility markets [148]. Third, the techno-economic optimisation of local systems has begun to internalise governance constraints through joint-investment redistribution [149], prosumer-flexibility scheduling [150], and MILP-based REC optimisation strategies [151]. Energy-poverty diagnostics have been operationalised through vulnerability indices [152] and PED-stakeholder-perception surveys [153]. Together these streams populate the boundary at which economic appraisal meets governance and decision support.

Two consolidated findings emerge from the economics literature. First, the magnitude and structure of regulated charges applied to internally shared electricity is the dominant lever determining whether a REC delivers net financial benefit to members [128,129]; this is a regulatory-design finding that economic appraisal alone cannot resolve. Second, peer-to-peer market designs that admit storage participation deliver substantially higher consumer surplus than peer-to-peer-only configurations because storage arbitrages the intra-day price dispersion that pure prosumer trading cannot resolve [11,154,155]. Distributed-ledger settlement layers have been proposed as a substrate for community-level market operation, although market-clearing rules dominate ledger choice in shaping outcomes [156,157].

The complete economics-tagged subset of the corpus, in addition to the studies discussed above, comprises [158–244].

3.5. MCDM/A and Decision-Support Literature in REC Contexts

The MCDM/A dimension is the youngest of the three within the REC corpus. The methodological catalogue is well-developed in the wider energy literature [245–247], but its instantiation inside REC studies is comparatively recent and largely demonstrative. AHP, fuzzy AHP, TOPSIS, PROMETHEE, ELECTRE, VIKOR, MAUT, DEMATEL, BWM, MAMCA, and various hybrid combinations all appear in the corpus, but typically as method development on synthetic or generic criteria rather than as instantiated REC decision-support tools [248–251].

Four additional MCDM/A strands in the corpus deserve note. Sustainability evaluation of generation technologies has been extensively performed with multi-criteria methods [252,253]. Risk assessment of renewable-energy investments through modified failure-mode-and-effect-analysis approaches forms a distinct sub-stream [254]. Site-selection studies for tidal current and other renewable plants have used GIS-MCDM combinations [255]. Coalition formation for community storage as a multi-criteria network design problem has

been explored recently [256]. Across these strands, the methodological catalogue is broad; the question is which methods are most suited to cooperative-governance settings.

The principal exception is multi-actor multi-criteria analysis (MAMCA), which has been explicitly developed for and applied to the REC setup [6,7]. MAMCA is the recognisable bridging instrument between MCDM/A and governance because it admits per-stakeholder weighting and therefore respects the cooperative principle that different participants may have different objectives. Participatory MCDM/A more broadly has been applied to energy-transition planning [257,258] and to renewable-energy-strategy comparisons across urban areas [259–262]. Reviews of MCDM/A in renewable-energy investment decisions [250] and in sustainability transitions [248] converge on the same observation: methodological richness is not the binding constraint; alignment with cooperative governance is. For REC governance, the relevant property of an MCDM/A method is whether it can accommodate per-stakeholder weighting at the elicitation stage (a cooperative-principle requirement) and whether its aggregation rule preserves that information through to the ranking. Methods that satisfy both are candidates for the governance-MCDM/A interface; methods that satisfy neither populate the methodology-only stream described in Section 3.5. The MCDM/A literature applied to REC contexts is catalogued in Table 5 along that axis.

Table 5 catalogues nine MCDM/A methods with stakeholder elicitation, REC application examples, and caveats. The classical pairs (AHP/fuzzy AHP; TOPSIS; PROMETHEE/ELECTRE; VIKOR) appear with single-actor weighting and are documented in REC contexts only sparsely. The genuinely cooperative-aligned methods are MAMCA and group-decision variants; these are the methods most likely to populate the governance-MCDM/A interface and therefore the strongest candidates for inclusion in a trilateral design. The hybrid combinations (DEMATEL + ANP + TOPSIS; fuzzy AHP + VIKOR) are methodologically richer but also more demanding of stakeholder time, which limits their applicability in RECs with limited expert capacity. The methodological catalogue is sufficient for the cooperative-energy domain in the sense that no fundamentally new method needs to be invented; the gap is in the alignment of existing methods with the cooperative principle.

A consolidated finding from the MCDM/A literature is that the principal methodological gap is not in the variety of methods available but in their integration with governance design and economic appraisal. The variety is sufficient; the alignment with the other two decision dimensions is insufficient.

The complete decision-support-tagged subset of the corpus, in addition to the studies discussed above, comprises Refs. [263–306].

Having fixed the within-dimension methodology for governance, economics, and MCDM/A in Sections 3.3–3.5, the diagnostic now reads across them. The cross-dimensional reading is the principal contribution of the paper.

4. The Trilateral Coupling Diagnostic

4.1. The Diagnostic Distribution

Figure 4 reports the diagnostic as a three-way Venn-like diagram. The numbers in each region count studies that engage exactly that combination of dimensions explicitly in the title or journal. Figure 4 is the principal visual of the paper. The three circles correspond to the three decision dimensions (Governance, Economics, MCDM/A); the regions of overlap correspond to bilateral and trilateral combinations; the centre region is the empty trilateral cell. The counts in each region are read directly from the diagnostic and are reproducible from the deposited inputs. The visual emphasis is intentional: the empty centre is the empirical anomaly this review documents. Three contextual observations frame the reading. First, the G-only region (107) and the E-only region (104) are nearly equal in size, reflecting

the parallel maturity of the two single-discipline streams. Second, the D-only region (56) is smaller, reflecting the comparatively recent emergence of MCDM/A in the REC context relative to governance and economics. Third, the bilateral regions sum to 55, of which the $G \cap E$ region (43) is dominant, confirming that the governance-economics literature is the most developed cross-disciplinary combination but also indicating that the field has yet to bring MCDM/A into the cooperative-energy mainstream.

Unilateral studies (one of G/E/D explicit) dominate; bilateral studies couple two of three; trilateral studies couple all three. The trilateral cell is empty under the title-level signal.

Figure 5 re-expresses the data of Figure 4 as a bar chart that emphasises the coupling-intensity distribution. The 82.9% unilateral majority is the most striking feature: more than four in five REC studies engage only one of the three decision dimensions explicitly. The 17.1% bilateral minority is consistent with the broader trend in cooperative-energy research towards cross-disciplinary work but is sharply concentrated in the governance-economics pair. The 0.0% trilateral cell is the principal finding; its empirical robustness is discussed in Section 5.5.

4.2. Empirical Findings

The diagnostic returns three findings:

Finding 1. The unilateral majority. A total of 267 studies (82.9%) are unilateral: they engage one of the three dimensions explicitly and treat the other two as context. Within the unilaterals, the largest sub-class is governance-only (107 studies, 33.2% of the subset), followed by economics-only (104, 32.3%) and MCDM/A-only (56, 17.4%). This pattern reflects the disciplinary anchors of the three sub-fields: governance studies in *Energy Policy* and *Energy Research & Social Science* [2,5,125]; economic appraisal in *Applied Energy* and *Energy Economics* [126,127,243]; MCDM/A in *Energies*, *Sustainability*, and method-focused titles [249,250,307].

Finding 2. The bilateral minority. A total of 55 studies (17.1%) are bilateral. The most common bilateral combination is governance-economics (43 studies, 13.4% of the subset), followed by economics-MCDM/A (7, 2.2%) and governance-MCDM/A (5, 1.6%). The governance-economics bias is consistent with the well-developed business-model literature [132,133,244,308,309] and with the body of work on distributional appraisal of cooperative schemes [18,24,310]. The thinness of the governance-MCDM/A pair is partially counter-balanced by the MAMCA literature [6,7,250], but MAMCA remains a single methodological route rather than a methodological family.

Finding 3. The trilateral gap. No studies, to the author's knowledge, satisfy the strict trilateral criterion of Section 2.5. A reproducible loosened-keyword sensitivity test identifies two candidates for partial trilateral coupling under more permissive screening; both arise from broader keyword nets rather than from explicit body-text co-treatment, and neither couples all three dimensions in the strong sense of the rubric (Table 2, score 3). This is the principal empirical contribution of the paper, and it is honest about its conditioning: the absence is rubric-dependent and corpus-bounded, not a metaphysical claim that no REC study has ever combined the three dimensions in any sense. Under the strict reporting standard adopted here, the trilateral cell is empty.

4.3. Eight Archetypes

The diagnostic can be reorganised into eight archetypes, reported in Table 6. The first seven describe existing unilateral and bilateral work; the eighth names the missing trilateral design.

Table 6. Author-developed typology of REC research archetypes under the trilateral coupling diagnostic.

Archetype	Coupling Type	Typical Literature Signature	Limitation
Pure governance review	Unilateral G	Qualitative governance analysis without explicit economics or MCDM/A	No comparative welfare claim
Pure economic appraisal	Unilateral E	NPV/CBA without governance variation or MCDM/A framing	Distributional and stakeholder dimensions absent
Pure MCDM/A methodology	Unilateral D	Method development on synthetic or generic energy criteria	Decoupled from real institutional context
Governance-economics coupling	Bilateral G+E	Tariff or business-model studies framed by governance type (e.g., cooperative vs. commercial)	Decision-support mechanism for selecting alternatives missing
Governance-MCDM/A coupling	Bilateral G+D	MAMCA/stakeholder-MCDM/A studies [6,7]	Quantitative economic appraisal absent
Economics-MCDM/A coupling	Bilateral E+D	Multi-criteria appraisal that includes economic indicators alongside technical ones	Governance context typically generic
Trilateral coupling (G+E+D)	Trilateral	Studies that explicitly co-design governance, economic and MCDM/A components	0 under the strict explicit-reporting rule—the conditional gap motivating this paper
Methodological hybrid	Trilateral or higher	Studies that combine quantitative and qualitative methods across all three dimensions in a single design	Methodological complexity; high transparency overhead

Table 6 is an author-developed research-positioning typology derived from the coupling diagnostic. It is not a direct extraction table; it shows what each study type captures, what it omits, and why second-level cooperative evidence should target the missing strong-trilateral archetype.

4.4. Methodological Clustering Across the Subset

Figure 6 reports the methodological clustering across the subset. The heatmap shows, for each of twelve method families that recur in the REC literature, the number of subset references that mention the family in the title or journal, broken down by which of the three dimensions the reference is tagged for.

Rows are method families; columns are the three decision dimensions; cell values count subset references mentioning the family in the title or journal under each dimensional tag. Figure 6 reads as a heatmap of which method families serve which decision dimensions in the subset. Several patterns emerge. AHP/ANP and TOPSIS dominate the MCDM/A column but barely touch governance or economics, reflecting their use as method-development demonstrations rather than as REC decision tools. PROMETHEE/ELECTRE and Fuzzy/Grey extensions are similarly concentrated in the MCDM/A column.

The MAMCA/Multi-Actor row appears in both the governance and MCDM/A columns, confirming MAMCA's bridging role; this row is the single most informative finding in the heatmap because it shows that one method family is already operating cross-dimensionally. Cost-benefit and tariff/pricing rows are concentrated in the economics column with mild cross-over to governance via business-model studies. P2P/LEM also concentrates on economics with limited cross-over to governance. Game theory appears in both governance and economics columns, reflecting cooperative game-theoretic work on coalition formation and Shapley-value allocation. Energy-justice and acceptance/citizenship

rows are concentrated in the governance column with limited engagement from MCDM/A methods, which is the third structural finding of this paper and a direct precursor to the trilateral coupling gap.

The clustering reveals four patterns. First, AHP/ANP and TOPSIS appear primarily in MCDM/A-tagged studies, with limited cross-over to governance or economics [247,311]. Second, MAMCA/multi-actor methods appear in governance-tagged studies and MCDM/A-tagged studies, confirming MAMCA's bridging role [6,7]. Third, CBA/investment and tariff/pricing appear primarily in economics-tagged studies, with cross-over to governance via business-model studies [132,312–314]. Fourth, energy-justice and acceptance keywords are concentrated in governance-tagged studies, with limited engagement from MCDM/A-method studies [310,315,316].

4.5. Why the Trilateral Gap Matters for Second-Level Cooperative Governance

The trilateral gap explains why many REC studies are academically useful but operationally hard to scale. They answer one part of the decision problem while leaving the other parts fixed or implicit.

A governance-only study cannot tell whether outcomes derive from statutes, tariffs, asset economics, or the decision procedure. A second-level cooperative reduces this ambiguity by applying a common protocol across member RECs.

The proposed model therefore treats integration as an institutional function: local REC data, economic appraisal, stakeholder-weighted MCDM/A, and voting packages are prepared in one auditable workflow.

For regulators and funders, this matters because bilateral evidence can support isolated decisions, while trilateral evidence can support tariff design, investment prioritisation, and accountability requirements.

Section 5 converts the descriptive diagnostic into this governance architecture.

5. Second-Level Cooperative MCDM/A Governance Model

The diagnostic identifies an empty cell; this section proposes the institutional response. A second-level renewable energy cooperative is defined as a federated decision-support layer that serves local RECs without replacing their democratic authority.

5.1. Institutional Architecture: From Local RECs to Second-Level Cooperative Decision Support

Figure 7 presents the model. Local RECs and allied actors supply documented inputs; the second-level cooperatives process them through governance, economic-appraisal, MCDM/A, and audit/data-trust units; outputs return to local members as ranked alternatives, distributional tables, voting packages, and regulatory evidence briefs.

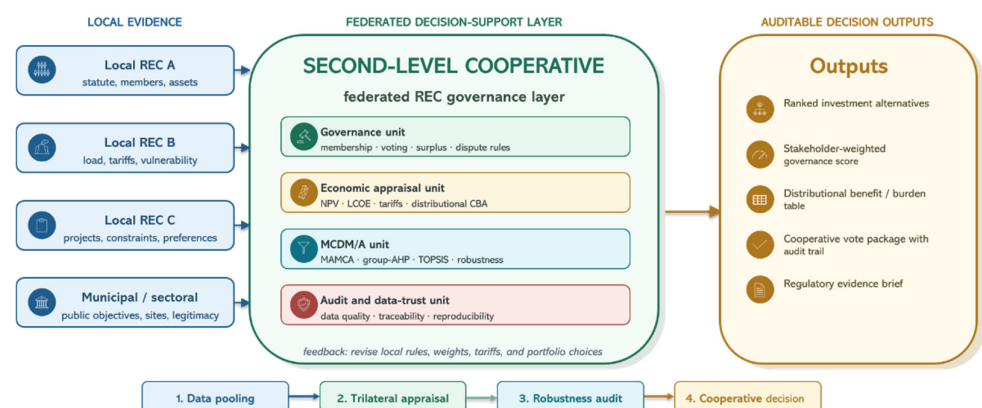


Figure 7. Second-level cooperative MCDM/A governance model for trilateral REC integration.

The architecture rests on subsidiarity, methodological pooling, and auditability. Local RECs retain final authority; the second-level layer hosts specialised appraisal and MCDM/A capacity; and every criterion, weight, tariff assumption, and distributional result remains traceable.

The novelty is institutional rather than mathematical. Existing methods are recombined inside a cooperative federation that can make governance, economics, and decision support mutually visible.

Figure 8 summarises the three-stage design workflow for trilateral REC studies within the second-level cooperative model.

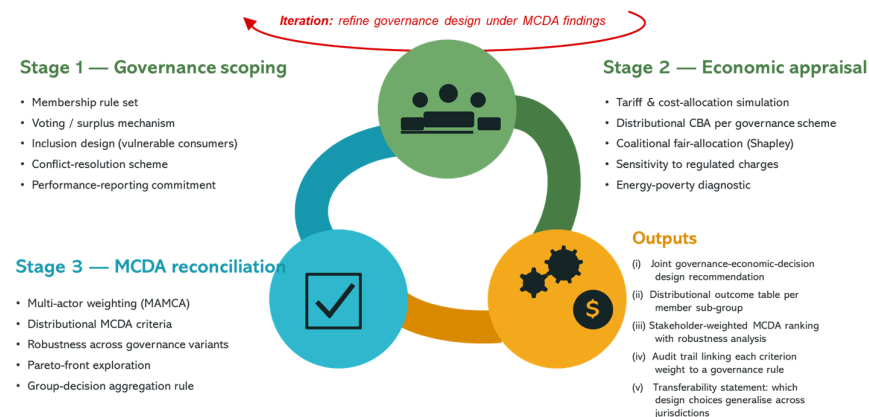


Figure 8. Three-stage design workflow for trilateral REC studies within the second-level cooperative model.

5.2. Pilot-Case and Federation-Selection Logic

Trilateral studies require cases with both governance and economic data. Figure 9 therefore identifies the preferred selection zone: cases with strong governance-data availability and strong economic-data availability, to which MCDM/A can be added without relying on speculative assumptions.

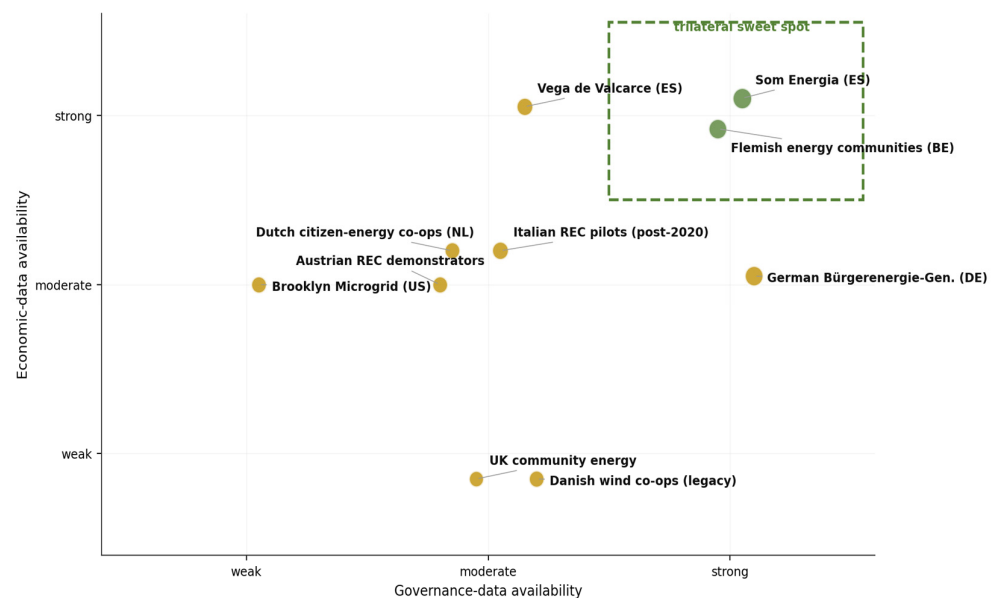


Figure 9. Pilot-case selection matrix.

The dashed zone marks cases suitable for full trilateral interrogation. Weaker cases remain useful for unilateral or bilateral analysis but should not be over-claimed as evidence for integrated REC scaling.

Candidate pilot archetypes include mature cooperatives, post-Directive pilots, island systems, municipal-led communities, storage-centred schemes, peer-to-peer communities, and energy-poverty-oriented RECs. These cases expose different governance-economic-MCDM/A tensions without requiring an additional table. The validation logic reduces to a minimum three-phase sequence that moves from diagnostic evidence to empirical trilateral pilots and policy-ready scaling; it is described in text rather than as a separate roadmap figure. The short phase re-screens bilateral studies and publishes a common protocol. The medium phase tests five to eight REC or second-level cooperative pilots. The long phase compares federated evidence across jurisdictions and evaluates regulatory uptake. This condensed agenda preserves the analytical logic while removing proposal-style operational detail.

5.3. Transferability Statement

The model is European in evidential base but portable in structure. Transfer requires a legal setting where local cooperative-energy organisations can delegate analytical functions to a federation while retaining member control.

5.4. Three Short Illustrations

The three illustrations show how the model would operate in cases with different starting conditions: a mature cooperative, an existing MAMCA evidence-based, and a recent post-Directive REC framework.

5.4.1. Illustration A—Som Energia (Spain)

Som Energia illustrates the mature-cooperative pathway [17]. A second-level study could vary entry costs, surplus allocation, and vulnerable-consumer provisions, then test their distributional and stakeholder-weighted consequences.

5.4.2. Illustration B—Flemish Energy Communities (Belgium)

Flemish energy communities illustrate the MAMCA-first pathway [6,7,16]. Existing stakeholder-weighting work could be extended by adding distributional CBA and explicit governance variants.

5.4.3. Illustration C—Italian REC Pilot (Post-2020 Regulation)

Italian REC pilots illustrate the post-regulatory pathway [308,317]. Recent legal codification offers fresh governance templates and economic data, making them strong candidates for trilateral testing.

5.4.4. What the Three Illustrations Show in Common

Across all three illustrations, the audit trail is the binding feature: weights must be linked to governance authority, and ranked alternatives must be linked to distributional economic consequences.

The model becomes strongest when several cases are assessed in parallel under a second-level cooperative or federation, because cross-case comparison then becomes methodologically credible.

5.5. SWOT Analysis of the Trilateral Diagnostic and of REC Decision-Support Research

Figures 10 and 11 provide a paired SWOT reading: one for the contribution and one for the wider REC decision-support field. Their purpose is diagnostic, not promotional.

The contribution's weaknesses mainly concern rubric conservatism and methodological judgement; its opportunities concern replicable protocols, federated data infrastructures, and policy-relevant evidence generation.



Figure 10. SWOT of the trilateral coupling diagnostic and second-level cooperative MCDM/A model as a research instrument.



Figure 11. SWOT of REC decision-support research as represented by the 2014–2026 corpus.

Read together, the SWOT figures show that the field's weakness is not a lack of methods but a lack of explicit trilateral coupling. This reinforces the need for a governance carrier.

The critical risk is coordination failure. The analytical methods exist, but without an institutional carrier, they remain fragmented across projects, disciplines, and local cases.

5.6. Bringing the Model Back to the Diagnostic

The model responds directly to the empty trilateral cell. Its defensibility rests on three properties: it is grounded in the reviewed corpus, it preserves local cooperative authority, and it makes every analytical choice auditable.

The main risk is technocratic drift. The model addresses this through subsidiarity, explicit voting packages, stakeholder-weight audit trails, and final approval by local members rather than the second-level body.

6. Discussion

6.1. Reading the Trilateral Gap as an Institutional Gap

The trilateral gap is institutional, not merely bibliometric. It shows that no dominant research routine yet makes governance design, economic appraisal, and MCDM/A jointly visible in a way that local RECs, regulators, and funders can use.

Unilateral and bilateral studies persist because they match journal scopes, disciplinary incentives, and local data constraints. A second-level cooperative changes the unit of analysis by pooling data, expertise, and decision procedures across communities.

The strict zero-trilateral result should therefore be read as a warning about visible field organisation, not as a universal statement about every body-text discussion in the literature. If the field wants evidence that can guide real cooperative scaling, it needs either studies embedded in second-level cooperative structures or research designs that simulate the same federated decision-support functions.

The empirical finding of no studies satisfying the strict trilateral criterion at the title-level signal can be read in two complementary ways. The first reading is methodological: REC scholars typically pick a disciplinary anchor and treat the other two dimensions as context, which is the path most rewarded by single-discipline journal selection. The second is structural: the REC literature has not yet developed a stable methodological vocabulary that integrates governance, economics, and MCDM/A at the level of methods and results rather than at the level of discussion. On the second reading, the gap is a vocabulary gap rather than a content gap.

The two readings have different implications. The methodological reading suggests that incentives, journal selection, peer-review demographics, and funding-agency programmes are the binding constraints, and that trilateral work would emerge faster under a research-programme call that explicitly required it. The structural reading suggests that vocabulary investment is the binding constraint, and that trilateral work requires bridging concepts (such as coupling intensity, governance-readiness, or distributional MCDM/A weighting) that have to be formalised before trilateral studies become writable.

The present paper proposes coupling intensity as one such bridging concept. Coupling intensity is operationalised through the rubric in Table 2: a study with coupling intensity 3 (trilateral) treats all three dimensions as primary variables, varies them jointly or co-designs them, and analyses their interaction. The rubric is intentionally strict; relaxations are possible (for example, coupling intensity 2.5 for studies that treat two dimensions as primary and one as a co-varying but non-primary control) but should be reported as such.

6.2. Implications for REC Practice

For REC designers, the trilateral diagnostic can be read as a self-assessment tool. A scheme that engages a governance question without a coordinated economic appraisal or decision-support procedure has coupling intensity 1; the design is exposed to the under-identification risk noted in Section 4.5. A scheme that combines a governance question with a tariff appraisal but does not formalise the decision-support procedure has coupling intensity 2; it is methodologically better but still under-identified along the third axis. A scheme that varies governance design, runs distributional economic appraisal under each design, and applies a stakeholder-weighted MCDM/A to the joint design-appraisal space has coupling intensity 3; it is the target archetype.

6.3. Implications for REC Scholarship

For REC scholars, the trilateral diagnostic suggests three short-horizon research items. The first is the documentation of existing partial-trilateral cases: re-reading the bilateral studies in the corpus to identify those where the third dimension is implicitly present but not explicitly engaged [4,5]. The second is the design of explicitly trilateral studies on a small set of well-instrumented REC cases (for example, the Som Energia cooperative in Spain [17], the Flemish energy community cases [16] and selected Austrian and German REC demonstrators) [318,319]. The third is the development of bridging concepts beyond MAMCA: in particular, distributional MCDM/A weightings that internalise

energy-justice considerations within the criterion set rather than treating them as ex-post adjustments [310,315].

6.4. Regulatory Implications

For regulators, the diagnostic suggests three medium-horizon implications. First, the regulatory treatment of internally shared electricity is the dominant lever for REC economic viability [128,129,308], but the lever is currently being pulled with limited governance and decision-support visibility. Trilateral scholarship would inform regulator decisions about where to set the lever. Second, vulnerable-consumer inclusion design is currently coordinated weakly across Member States [18,24,310,315]; a trilateral methodology would make it possible to compare inclusion designs on welfare grounds rather than on advocacy grounds. Third, member-driven decision-support procedures (MAMCA, group AHP, citizen-jury MCDM/A) are not currently legible to regulators as evidence; trilateral studies that link such procedures to economic outcomes would create a basis for regulatory recognition [6,7,320,321].

6.5. SDG Mapping

The diagnostic maps directly to SDG 7, SDG 10, SDG 11, SDG 12, SDG 13, SDG 16, and SDG 17. The strongest links are affordable clean energy, reduced inequalities, sustainable communities, climate action, institutional accountability, and partnerships. Table 7 maps the diagnostic to the relevant United Nations Sustainable Development Goals.

Table 7. Conceptual mapping of the coupling diagnostic to the United Nations Sustainable Development Goals.

SDG	Relevance to G/E/D Coupling	Concrete Touch-Points in This Paper
SDG 7 Affordable & Clean Energy	REC accessibility and inclusion design	Vulnerable-consumer participation rules (G); subsidised tariffs (E)
SDG 10 Reduced Inequalities	Distributional outcomes within RECs	Voting/surplus rules (G); distributional CBA (E); equity weighting in MCDM/A (D)
SDG 11 Sustainable Cities & Communities	Urban-scale RECs	Governance perimeter (G); urban tariff design (E)
SDG 16 Peace, Justice & Strong Institutions	Procedural fairness inside RECs	Decision-rights schemes (G); stakeholder-MCDM/A (D)
SDG 17 Partnerships	Federation-of-cooperatives models	Cross-actor MCDM/A (D); multi-stakeholder business models (G+E)

6.6. Limitations and Boundary Conditions

Five limitations of the present analysis are acknowledged. First, the rule-based tagging of Section 2.5 is by design a conservative lower bound on coupling intensity; under a reproducible loosened-keyword sensitivity test the bilateral count rises by 23.6% (55 → 68) and two trilateral candidates appear (0 → 2), but the qualitative finding, that trilateral coupling is rare under the standard of explicit reporting that journal review expects, is not reversed: neither of the two loose-net trilateral candidates satisfies the strong-coupling threshold of Table 2 (score 3). Second, the coupling rubric is intentionally strict; alternative rubrics that accept body-text-only engagement of the third dimension would identify more bilateral and trilateral cases. Third, the corpus is European-centric; the diagnostic is structurally portable to non-European REC contexts, but its empirical instantiation in those contexts requires a separate non-European corpus build that the present paper has not undertaken (consistent with Section 5.3). Fourth, the diagnostic does not distinguish between strong and weak instances of bilateral or trilateral coupling; a refinement that

scores coupling on a continuous scale (0 to 3) would yield a more nuanced reading. Fifth, the publication-trend forecast in Figure 2 is computed on a twelve-point yearly series spanning 2014–2025, drawn from the wider cooperative-energy corpus rather than the focused 2018–2026 REC subset (2026 is excluded from the fit because it is in progress as of the build date); the 95% credible bands widen materially past 2028, and the trajectory is conditional on no new regulatory shock to the field. The forecast should be read as a directional consolidation indicator, not as a precise count.

6.7. Detailed Analysis of the Bilateral Concentration

The bilateral counts in the diagnostic deserve closer reading. Of the 55 bilateral studies, 43 (78%) couple governance and economics, seven (13%) couple economics and MCDM/A, and five (9%) couple governance and MCDM/A. The governance-economics concentration is partially explained by the business-model literature [132,308,312], which by construction integrates governance type (cooperative vs. commercial vs. platform-mediated) with cash-flow and surplus-allocation analysis. The economics-MCDM/A pair is partially explained by a small set of multi-criteria appraisal studies that include economic indicators alongside technical and environmental ones [322,323]. The governance-MCDM/A pair is almost entirely the MAMCA literature [6,7], with a few participatory-planning variants on the edges [257,324].

This concentration pattern has a structural reading. Governance and economics couple naturally because both are policy-facing and share an audience (regulators, business analysts, cooperative directors). Economics and MCDM/A couple naturally because both are quantitative and share a methodological vocabulary (indicator weighting, objective function). Governance and MCDM/A couple unnaturally because they belong to different epistemic communities (qualitative social science vs. quantitative decision theory) and require a bridging methodology. MAMCA has been developed only by a small set of authors with specific cross-disciplinary training. The trilateral cell is empty because no comparable bridging methodology yet exists that integrates all three communities at once.

6.8. Could a Bridging Institutional Methodology Be Designed?

The structural reading suggests that the trilateral gap is not just a literature-density observation but a methodology-design opportunity. What would a trilateral methodology look like? Three candidate ingredients can be identified from the corpus.

The first ingredient is MAMCA itself [6,7], which provides per-stakeholder weighting and therefore respects the cooperative principle that participants may have different objectives. MAMCA on its own is bilateral (governance + MCDM/A); to become trilateral it needs explicit economic-appraisal integration.

The second ingredient is distributional cost-benefit analysis [18,19,24,310,315], which decomposes net societal benefit by member sub-group and therefore exposes the distributional consequences of governance design. Distributional CBA on its own is bilateral (governance + economics); to become trilateral it needs MCDM/A integration that respects the distributional decomposition [322,325].

The third ingredient is cooperative game-theoretic appraisal [317,326–329], which allocates costs and benefits to coalition members according to formal fairness axioms (efficiency, individual rationality, monotonicity). Cooperative game theory on its own is bilateral (governance + economics with strong MCDM/A proximity); to become trilateral it needs explicit MCDM/A aggregation that goes beyond the single-objective coalitional value [330].

A trilateral methodology could combine these three ingredients into a single procedure: per-stakeholder weighting (MAMCA), distributional decomposition (distributional CBA),

and coalitional fair-allocation (cooperative game theory). The combined procedure has not been developed in the corpus and is a candidate for short-horizon methodological work.

6.9. *Why the Gap Matters for Regulators and Funders*

For regulators and funders, the trilateral gap is a portfolio signal. The highest marginal contribution now lies in demonstrator studies that integrate governance, economics, and MCDM/A under real cooperative decision rules.

6.9.1. Methodological Reflections on the Trilateral Diagnostic

The trilateral diagnostic deserves a short methodological reflection. The diagnostic is a coarse instrument by design: it asks whether each study explicitly engages each of three dimensions, and it returns an integer score in {0, 1, 2, 3}. Coarse instruments have specific virtues and specific limitations, both of which the present paper has been careful to acknowledge.

The principal virtue of a coarse instrument is that it produces an unambiguous answer to a well-defined question. The question, how is the REC literature distributed across the trilateral decision space, is answered with a clear distribution (107/104/56 unilateral; 43/7/5 bilateral; 0 trilateral). The diagnostic does not depend on the assessor's judgement about the quality of each study; it depends only on the explicit engagement signal. Coarseness is therefore a defence against motivated reasoning, in either direction.

The principal limitation of a coarse instrument is that it cannot distinguish between strong and weak instances of bilateral or trilateral coupling. A bilateral G+E study that integrates governance variation with distributional CBA at the methods level is, on the diagnostic, indistinguishable from a bilateral G+E study that mentions governance in the introduction and runs an NPV calculation. This limitation is real but is partially mitigated by the rubric in Table 2, which gives an explicit criterion for what counts as primary engagement (the dimension must be treated as a variable in methods and results, not as a fixed parameter).

A natural refinement would be a continuous-score diagnostic on a scale of, say, 0.0 to 3.0, with intermediate values like 1.5 corresponding to studies that engage one dimension primarily and a second dimension secondarily. This refinement would surface the within-class heterogeneity that the coarse instrument hides. It would, however, require manual full-text scoring rather than rule-based title screening, which would limit the corpus size on which the refinement can be applied. A staged approach is therefore appropriate: the coarse instrument on the full subset (this paper), followed by the continuous-score refinement on a representative sub-sample (future work).

A second remark concerns the relationship between the diagnostic and the framework. The diagnostic is descriptive; the framework is prescriptive. The empty cell is what links them; it is the descriptive finding that gives the framework something to address.

6.9.2. The Audit-Trail Requirement and Its Consequences

The audit-trail requirement that the three-stage workflow encode that each MCDM/A criterion weight be defensible as a governance commitment beyond its status as an analytical choice is the operational pivot of the framework and warrants a short discussion.

The requirement responds to a long-standing critique of MCDM/A: that criterion weights are technically determined by elicitation procedures but politically determined by who participates in the elicitation. The cooperative-energy context makes this critique unusually pointed because cooperative members are by construction the rightful determiners of cooperative weights, and any criterion weight that cannot be linked to a governance rule is suspect. The audit-trail requirement operationalises this critique: it requires the trilateral

study author to explicitly link each weight to a rule, which forces the author to either justify the weight against the governance template or to revise it.

The consequence for trilateral studies is that they become legibly defensible to two different audiences. The methodological audience can verify that the MCDM/A procedure was correctly applied. The governance audience can verify that the criterion weights respect the cooperative principle. The combined verification is what legitimacy means in the cooperative-energy context, and it is what bilateral studies, which satisfy one verification but not both, currently lack.

The consequence for regulators is that trilateral evidence becomes admissible in regulatory consultations in a way that bilateral evidence is not. A bilateral G+E study reporting that REC governance type X delivers higher net welfare than type Y is informative but is open to the challenge that the welfare metric is analyst-defined. A trilateral G+E+D study reporting the same finding with stakeholder-weighted MCDM/A criteria is harder to challenge because the welfare metric is stakeholder-defined and audit-traceable to governance rules. This is the regulatory pay-off of trilateral methodology; designing trilateral evidence for regulatory consultation is therefore a priority.

6.9.3. Regional and Cross-Jurisdictional Considerations

The corpus is European-centred but regionally uneven. Northern and Western Europe provide mature cooperative traditions and pre-existing federative structures; Southern Europe provides newer post-Directive REC experimentation; Central and Eastern European contexts often face different cooperative-legitimacy and institutional-capacity constraints; islands and peripheral systems provide strong testbeds for local autonomy, grid constraints, and social acceptance.

Transferability therefore differs by context. Mature cooperative countries can build on existing federations; newer REC jurisdictions may need newly created second-level structures, and island systems may require smaller but more operationally integrated federations. The model is most directly transferable where cooperative or community-energy law permits local entities to delegate technical, financial, and procedural functions while retaining member control.

Outside Europe, analogous arrangements may lack REC/CEC legal status. Community solar programmes, municipal utilities, rural electric cooperatives, Indigenous energy initiatives, and private aggregator models may perform similar functions under different legal forms. The model is therefore transferable as an institutional architecture, but its statutory form must be adapted to national cooperative, electricity-market, municipal-law, and energy-justice frameworks.

The zero-trilateral finding is well grounded within the European post-Directive corpus and the REC-adjacent search strategy used here. Extending the finding globally would require a separate search strategy that explicitly captures non-European community-energy traditions, including municipal utility governance, rural electrification cooperatives, Indigenous energy sovereignty, community solar, and local flexibility markets.

The trilateral diagnostic has so far been applied to a European-centric corpus, and the framework has been illustrated on European pilot archetypes (Som Energia, Flemish energy communities, Italian REC pilots). The principal cross-jurisdictional consideration is whether the trilateral gap is intrinsic to the cooperative-energy problem or specific to the European post-Directive landscape.

Two pieces of indirect evidence suggest that the gap is intrinsic. First, the methodological asymmetries between governance, economics, and MCDM/A, that they belong to different epistemic communities and are typically published in non-overlapping journal sets, are observed in the wider energy literature beyond Europe, including the U.S. rural-

electrification cooperative literature [14,331], the emerging Latin American community-microgrid literature [261,332], and analogous arrangements in Mediterranean and Pakistani contexts [262,333]. If the asymmetries are universal, the absence of joint governance-economics-decision-support treatment should also be universal. Second, the methodological apparatus required for trilateral coupling. MAMCA, distributional CBA, and cooperative game theory have been independently developed in disciplinary communities that span jurisdictions; the absence of trilateral integration is not a European phenomenon [248,334].

Two pieces of indirect evidence suggest that the gap is at least partly specific to Europe. First, the European Clean Energy Package has created an unusually structured opportunity for trilateral studies by codifying RECs and CECs in law, which is not paralleled in most non-European jurisdictions. The absence of similar codification elsewhere makes the demand for trilateral studies higher in Europe than elsewhere, which means that the European literature should be the first to fill the gap and that the gap is therefore most visible (and most actionable) in the European setting. Second, the post-2018 ramp in cooperative-energy publication has been disproportionately European-led, which means that the diagnostic's European-centric corpus may understate the trilateral activity that has been undertaken outside Europe in non-English-language outlets that the present search did not retrieve.

6.10. Relationship to Prior Reviews

The contribution complements rather than displaces the prior REC reviews. Reis et al. [132] review business models and treat economics as the principal axis; they engage governance contextually but not MCDM/A. Bauwens et al. [13] clarify REC definitions and review governance heterogeneity, but do not screen for economic appraisal or MCDM/A. Sousa et al. [131] review peer-to-peer trading; their analysis is economics-anchored and partially admits MCDM/A, but not governance. Hanke et al. [18] examine energy justice across seventy-one European cases and engage governance and (distributional) economics, approaching bilateral coupling but not trilateral. The present paper is the first to apply the trilateral diagnostic explicitly to the REC literature and to publish the resulting null finding. Further corpus studies bearing on the regional, regulatory, and methodological scope of this review—spanning cross-jurisdictional cooperative-energy arrangements, Member-State transposition records, and adjacent decision-analytic work—include [335–338].

7. Conclusions

This review shows that the weakness of REC research is not the absence of governance, economic, or MCDM/A knowledge. It is the limited visibility of studies that makes the three dimensions jointly operational under an explicit and auditable strong-coupling design.

The paper proposes second-level renewable energy cooperatives as the missing governance carrier. Local RECs retain democratic authority, while the second-level layer pools data stewardship, economic appraisal, stakeholder-weighted MCDM/A, and auditable voting packages.

The diagnostic is deliberately conservative: 267 studies are unilateral, 55 are bilateral, and none satisfies the strict trilateral criterion at the explicit-reporting threshold. The dominant bilateral interface is governance-economics; the weakest interfaces involve MCDM/A.

The implications are practical. Regulators can use second-level cooperatives as evidence intermediaries; scholars can test trilateral designs under explicit protocols; practitioners can access shared analytical capacity without surrendering local control.

Regional relevance is uneven but important. Mature cooperative environments, post-Directive REC jurisdictions, islands, peripheral systems, and municipal-led communities each offer different entry points for applying the model.

The main limitation is that the model remains review-derived. Its next test is empirical: a real REC federation or second-level cooperative should co-design governance variants, distributional economic appraisal, MCDM/A weighting, and cooperative voting in one documented process.

A single well-documented trilateral case would not close the field, but it would change the benchmark. It would show that REC scaling can be studied as a coupled institutional-economic-decision problem rather than as three adjacent studies.

Second-level renewable energy cooperatives are therefore proposed as the practical route for closing the governance-economics-decision support loop in REC research and implementation.

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Abbreviations

The following abbreviations are used in this manuscript:

AHP	Analytic Hierarchy Process
BWM	Best-Worst Method
CBA	Cost-Benefit Analysis
CEC	Citizen Energy Community
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DOI	Digital Object Identifier
DR	Demand Response
ELECTRE	Élimination Et Choix Traduisant la Réalité
ESG	Environmental, Social and Governance
IRR	Internal Rate of Return
LCOE	Levelised Cost Of Energy
LEM	Local Energy Market
MAMCA	Multi-Actor Multi-Criteria Analysis
MAUT	Multi-Attribute Utility Theory
MCDM/A	Multi-Criteria Decision Analysis
NPV	Net Present Value
P2P	Peer-to-Peer
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROMETHEE	Preference Ranking Organization METHod for Enrichment Evaluations
PV	Photovoltaic
REC	Renewable Energy Community
SDG	Sustainable Development Goal
SLC	Second-Level Cooperative
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
ToU	Time-of-Use
VIKOR	Vlsekriterijumska Optimizacija I Kompromisno Resenje

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