Energy Research & Social Science 127 (2025) 104293

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

Pathways towards just transitions in the Global South

Johanna Gather [a], Martin Prowse [b,c,*], Daniel Seussler [d]

[a] University of Mannheim & Centre for Evaluation and Development, Mannheim, Germany
[b] Independent Evaluation Unit, Green Climate Fund, South Korea
[c] School of Global Development, University of East Anglia, United Kingdom
[d] Centre for Evaluation and Development, Mannheim, Germany

ARTICLE INFO

Keywords:
Just transitions
Realist review
Qualitative comparative analysis

ABSTRACT

As global decarbonization efforts accelerate, ensuring a just transition has become a critical objective, especially in low- and middle-income countries where climate action intersects with entrenched development challenges. This study uses a realist review and fuzzy-set qualitative comparative analysis of 80 interventions across 76 studies to identify the configurations of financial, institutional, and governance conditions that contribute towards just transitions in developing countries. We find seven distinct causal pathways, with robust funding and strategic planning emerging as universally necessary conditions. Surprisingly, factors often considered essential—such as stakeholder engagement and policy alignment—are not consistently present. Complementary fractional logistic regression reinforces the centrality of funding and planning, while underscoring the limited predictive power of single variables. Our findings highlight the configurational and context-dependent nature of just transition outcomes. By illuminating diverse pathways to inclusive decarbonization, this article contributes to bridging the empirical gap in understanding transition policy in developing countries.

1. Introduction

As the necessity to decarbonize global energy systems intensifies, questions of equity and social inclusion have become central to energy policy and research. The concept of a "just transition", initially developed by labour unions in North America to address the potential job losses resulting from environmental regulation, has since evolved into a broader policy objective. Today, it is used to capture the need for climate and energy transitions that are environmentally sustainable, socially fair, economically inclusive, and politically legitimate [1,2]. The Paris Agreement explicitly recognizes the importance of a just transition, committing signatory nations to "take into account the imperatives of a just transition of the workforce and the creation of decent work" as they pursue climate goals [3]. While just transition debates have gained traction in policy and academic circles, they remain dominated by perspectives and empirical cases from high-income countries. This leaves a blind spot in understanding how the concept translates to developing country contexts, where transitions intersect with long-standing development challenges such as poverty, informality, energy access, and institutional fragility. In many parts of the Global South, fossil fuel industries remain central to economic development and employment; at the same time, many people still lack access to electricity [4]. The transition to low-carbon systems in such settings raises acute distributional and procedural questions: Who bears the cost of transition? Who participates in decision-making? And what institutional conditions are needed to ensure that climate action supports rather than disrupts development objectives?

The broad appeal of the just transition concept lies in its ethical framing and flexibility. Yet this very flexibility also creates analytical challenges. What constitutes a "just" transition can vary widely across regions, sectors, and social groups. Achieving both climate and social outcomes requires more than good intentions; it requires understanding the enabling conditions (policy, institutional, financial, and social) that shape whether and how just transitions materialize in practice. Despite

* Corresponding author at: Independent Evaluation Unit, Green Climate Fund / School of Global Development, University of East Anglia, United Kingdom. ORCID ID 0000-0002-1271-468X.
E-mail address: M.Prowse@uea.ac.uk (M. Prowse).

https://doi.org/10.1016/j.erss.2025.104293
Received 3 February 2025; Received in revised form 6 August 2025; Accepted 14 August 2025

the increasing normative emphasis on justice, there is still limited empirical knowledge of what these conditions look like in low- and middle-income countries (LMICs), and what kinds of interventions have succeeded or failed in navigating the trade-offs between decarbonization, equity, and development.[1] While the term 'just transition' carries diverse and sometimes contested meanings, our use in this paper refers to interventions that produce tangible social and environmental outcomes aligned with justice objectives, particularly distributional fairness and the protection of vulnerable groups. Deeper questions of recognition and procedural justice, though conceptually important, are only partially captured by our indicators and methods.

This article contributes to addressing that gap by investigating the conditions under which externally supported interventions in developing countries are contributing to just transitions. We respond to the call for energy research which is novel, rigorous and, at least in our view, has a semblance of style by combining a realist synthesis, which summarised theories of change for 99 interventions across energy, infrastructure, agriculture/food, and ecosystems [5], to examine how different combinations of contextual factors, mechanisms, and institutional features have influenced the achievement of both social and climate outcomes.[2] The study focuses on non-Annex I countries, in line with the evolving priorities of multilateral climate finance institutions, and builds upon a growing recognition that transition policies must be tailored to local realities. The objective of this study is to understand the causal configurations that provide the basis for the effectiveness of interventions. To this end, we employ Qualitative Comparative Analysis (QCA), a set-theoretic method that allows us to identify combinations of conditions associated with just transition outcomes. We complement this with fractional logistic regression analysis to compare insights from configurational and probabilistic logics, offering a multidimensional understanding of the pathways through which just transitions can be achieved. By combining a realist synthesis with qualitative comparative analysis, this study contributes to both theory and practice. Conceptually, it advances the understanding of just transition as a context-dependent and multi-dimensional process rather than a singular policy model. Empirically, it offers new insights from underrepresented geographies in the energy justice literature. Methodologically, it responds to calls for more rigorous and transparent approaches to studying complexity, causality, and institutional diversity in energy transitions [6]. Our research focuses on what combinations of conditions enable externally supported interventions in developing countries to contribute towards a just transition, and how these vary across sectors and contexts. In answering this question, we aim to contribute to future policy and programmatic efforts by identifying the specific configurations of financial, institutional, and participatory mechanisms that have supported socially inclusive decarbonization.

The remainder of the paper is structured as follows: Section 2 explains the conceptual framework within which the study is taking place. Section 3 provides details on the data set and methods used. Section 4 describes the findings from the QCA and fractional logistic regression. The results are discussed in Section 5. Section 6 concludes.

[1] We use the terms low- and middle-income countries, Global South and developing countries interchangeably in this article. When doing so we refer to non-Annex I countries as defined by the Kyoto Protocol of the United Nations Framework Convention on Climate Change. All cases come from non-Annex I countries, as categorized by the UNFCCC, that demonstrated documented evidence of interventions aiming at outcomes consistent with a just transition. Interventions in Annex I and II Parties were excluded from the realist review and thus the QCA.

[2] See Sovacool et al. (2018) on a call for robust, multi-method, comparative, interdisciplinary and impactful research to accelerate the contribution that energy social science can make to both theory and practice.

2. Conceptual framework

The concept of a just transition has evolved from its origins in labour movement activism into a cornerstone of contemporary climate governance and energy policy. At its core, a just transition seeks to ensure that the benefits and burdens of climate action are equitably distributed, that vulnerable populations are protected, and that those affected by structural changes, such as the decline of fossil fuel industries, are included in decisions that shape their futures. Early formulations focused narrowly on protecting workers in high-carbon sectors from job losses associated with environmental regulation [7]. Over time, however, the scope of the concept has expanded to include procedural justice, recognition of historically marginalized groups, and long-term developmental equity, particularly in LMICs [8,9].

Academic scholarship has increasingly situated just transition within broader frameworks of climate and energy justice, with key authors conceptualizing this through three dimensions: distributional justice (how benefits and burdens are shared), procedural justice (who participates and how decisions are made), and recognitional justice (which identities, values, and knowledge systems are acknowledged) [10]. These dimensions are especially salient in the context of energy transitions, which often involve not only technological shifts but deep structural changes in employment, livelihoods, infrastructure, and land use. In this sense, a just transition becomes a vehicle through which energy systems are reimagined in more inclusive, participatory, and context-sensitive ways. However, the translation of just transition principles into practice is far from straightforward, particularly in developing countries. These contexts often feature high levels of labour informality, fossil fuel dependency, weak regulatory institutions, and limited fiscal space for social protection. For example, many countries in sub-Saharan Africa and Southeast Asia rely on coal or oil for employment and government revenue, while simultaneously grappling with severe energy access deficits and poverty [4,11]. Transitions in these settings involve trade-offs between decarbonization, development, and social protection, creating tensions that are not easily resolved through conventional policy templates. Transitions that fail to engage informal workers or respect local political economies risk exacerbating inequalities rather than reducing them [12]. At the same time, developing countries also face opportunities to leapfrog carbon-intensive development pathways through investments in distributed renewable energy, local value chains, and green jobs. Realizing these opportunities, however, depends on factors such as political will, institutional coordination, access to finance, and participatory governance. As several studies have shown, even well-intentioned interventions can falter without local ownership, capacity alignment, or trust among stakeholders [7,13]. This underlines the importance of context: a just transition in one setting may not be replicable in another without adaptation to local conditions.

Concepts such as institutional lock-in [14] and path dependency explain why energy systems tend to resist change, even in the face of urgent climate imperatives. Conversely, transitions are often enabled by policy windows or shifts in governance coalitions that realign political and economic incentives [15]. In the Global South, where governance structures are often fragmented and decision-making is influenced by multilateral finance, just transition policies depends on aligning international ambitions with national and local capabilities, a process fraught with power asymmetries and coordination challenges. Thus, understanding causality becomes particularly complex. Rather than being driven by a single factor, such as funding or stakeholder participation, just transitions typically result from specific combinations of enabling conditions that interact in non-linear and context-dependent ways. These include hard enablers like financing and infrastructure, and soft enablers like trust, policy alignment, or participatory processes. Our analytic approach described below is based on this causal complexity.

While justice-based frameworks provide essential normative grounding, they must be situated within the broader political economy of climate transitions, particularly in developing countries where global

governance structures, market dynamics, and financial relationships shape what is possible on the ground. The just transition agenda is increasingly mediated by multilateral negotiations and international financial flows, such as the Just Energy Transition Partnerships (JETPs) announced at COP26, which aim to mobilize billions in concessional finance to support fossil fuel phaseouts in countries like South Africa, Indonesia, and Vietnam. Yet, these arrangements are far from neutral. Countries vary widely in their bargaining power, fiscal autonomy, and ability to shape the terms of such agreements. For instance, China, classified as a developing country under the UNFCCC, but a geopolitical and economic heavyweight, negotiates climate finance and technology partnerships from a position of strength, often setting its own terms. In contrast, smaller nations like South Africa, while politically significant within the African continent, face tighter fiscal constraints, conditionalities tied to donor priorities, and contestation over whether promised renewable energy investments will materialize into decent work, industrial diversification, or local ownership [16].

This divergence in capacity and leverage underscores the need to treat just transitions not only as technocratic or governance challenges, but also as contested political processes shaped by power, interest, and institutional legacies. The assumption that financing alone guarantees justice ignores the deep structural inequalities that shape how benefits are distributed, who participates in design and delivery, and which visions of transition are prioritized. Indeed, several recent critiques highlight how externally driven transition initiatives risk reproducing existing inequalities or undermining local energy sovereignty when not properly contextualized [17,18].

3. Data and methods

This study employs a mixed-methods design integrating a realist synthesis and QCA, supported by fractional logistic regression. The realist synthesis was a collaboration between the Green Climate Fund, the world's largest multilateral climate fund, and the International Labour Organization. Led by the corresponding author for this article, the realist synthesis identified and coded 99 interventions from 76 studies across four sectors: energy, infrastructure, agriculture/food systems, and ecosystem services. These interventions were selected for their relevance to just transition goals, presence of a theory of change (explicit or implicit), and sufficient evidence of outcomes at either the output or outcome level.

3.1. Realist review and case selection

Realist reviews are an important evaluative tool to understand the impact of complex interventions, which are at an early stage of implementation and likely to have diverse outcomes. They summarise a wide range of literature on a specific set of interventions through analysing programme theories (that is, theories of change) which outline how an intervention is expected to lead to specific changes in specific contexts, connecting activities, outputs, outcomes, and impacts [19,20]. This involves extracting details of each programme theory, including context, mechanism and outcome variables. By reconciling, juxtaposing, adjudicating and ultimately summarising the cases under review, a realist review offers an opportunity to understand underlying mechanisms, the role of context, including contingent conditions and replicable settings. Our realist synthesis followed a six-stage process involving identification of programme theories, literature search and screening using PICOs criteria, quality appraisal, data extraction, model refinement, and synthesis [21]. A total of 8726 documents were initially screened, with 76 retained and 99 interventions extracted. These 99 interventions represented diverse geographies, with interventions contributing towards just transition outcomes in a wide range of national, regional, and local settings across 45 developing countries. The most frequent countries represented in the dataset of 99 interventions were India, South Africa, Indonesia, China and Ethiopia. In contrast, the review found a very limited number of studies from Small Island Developing States.[3] These geographical findings may be linked to the sole focus on studies published in English [5]. Each case was assessed for the presence of climate outcomes (e.g., adoption of low-emission technologies, resilience improvements) and social equity outcomes (e.g., job creation, protection for vulnerable groups, human rights). For the purposes of the QCA, interventions with no evidence of either outcome were excluded ($n = 19$), resulting in a final QCA sample of 80 cases.

3.2. Qualitative Comparative Analysis

To investigate the contextual and combinatorial nature of just transition outcomes, we apply Qualitative Comparative Analysis (QCA), a configurational method that bridges qualitative and quantitative paradigms by using set theory to identify combinations of causal conditions (configurations) associated with outcomes. Unlike variable-based approaches that assume additive and symmetric effects, QCA is attuned to equifinality (the principle that different combinations of conditions can produce the same outcome), causal asymmetry (what causes positive outcomes may not prevent failure), and the importance of necessary and sufficient conditions. It is especially suited to medium-N studies involving complex, conjunctural causality. These characteristics make QCA especially appropriate for analysing interventions across heterogeneous settings, such as the 99 cases included in this study.

For this study, 28 explanatory conditions were identified across 99 interventions and calibrated using fuzzy-set logic. Each case was assigned a membership score ranging from 0 (fully out of the set) to 1 (fully in), with intermediate values reflecting partial membership (e.g., 0.25, 0.5, 0.75). Calibration thresholds were derived from a combination of theoretical criteria (e.g., what constitutes “strong” funding or “high” alignment) and empirical patterns observed during data review. Each condition was scored based on carefully documented rules (detailed in Appendix 1), and scores were validated through cross-case comparison and quality checks. Membership scores of 0.5, which can cause ambiguity in QCA, were incrementally adjusted (i.e., as 0.51) to preserve analytical clarity. To reduce complexity and enhance interpretability, conditions were grouped into 11 thematic categories:

A. **Robust Funding** (e.g., financing mechanisms, infrastructure investment)
B. **Alignment** (e.g., policy coherence, political ownership)
C. **Stakeholder Engagement** (e.g., trust-building, participatory planning)
D. **Technical Knowledge** (e.g., programmatic experience, innovation use)
E. **Clustering and Synergies** (e.g., alignment across project components)
F. **Uncertainty** (e.g., legal, financial, or political risk)
G. **Structural Challenges** (e.g., system inertia, difficulty scaling)
H. **Implementation Constraints** (e.g., coordination delays, bottlenecks)
I. **Resource Barriers** (e.g., cost, skills shortages)
J. **Social Policy Planning** (e.g., inclusive resilience measures, social protection)
K. **Community Participation** (e.g., local engagement, social dialogue)

The outcome variables were also calibrated as fuzzy sets. These included climate outputs (e.g., adoption of climate-smart technologies, emissions reductions), social equity outputs (e.g., worker protection, job creation, rights recognition), and a composite just transition outcome, weighted to prioritize social equity (5/8) over climate outputs (3/8),

[3] Yeung et al. (2024) offer a range of qualitative case studies which offer details of specific interventions included in the realist review

reflecting the diversity and complexity of social outcomes.

Missing data posed a methodological challenge, particularly for interventions that were still in early implementation stages and lacked output documentation. Our primary approach was to assign zero membership scores to missing outcome values—a conservative strategy ensuring analytical consistency and maximizing sample size. However, to evaluate the potential for bias, we tested alternate imputation methods, including leaving missing values uncalibrated (which resulted in significant case loss) and applying mean or median substitution. These alternative methods produced configurations that were substantively consistent with the main analysis, indicating the robustness of results. Based on this, we retained the zero-imputation strategy to balance inclusivity with validity while transparently acknowledging this as a methodological limitation.

Following calibration, a truth table was constructed to list all observed combinations of conditions and their corresponding outcomes. We applied a consistency threshold of 0.80 to identify sufficient conditions and a minimum frequency threshold of 1, reflecting best practices for medium-sized samples. For identifying necessary conditions, we used a higher consistency threshold of 0.90, in line with standard QCA guidelines [22]. All threshold choices were informed by theory and tested for sensitivity. Slight adjustments to the thresholds did not alter the core solution terms, confirming their robustness. Final solutions were assessed using two criteria:

- Consistency, which measures the degree to which a configuration reliably leads to an outcome, and
- Coverage, which assesses how much of the outcome is explained by the configuration.

These values help evaluate both the empirical validity and practical relevance of the solutions.

3.3. Fractional Logistic Regression

To complement the QCA and provide a point of triangulation, we applied fractional logistic regression to the same dataset. This model assessed the marginal effects of individual variables on just transition outcomes, providing a probabilistic interpretation of influence that contrasts with QCA's set-theoretic, configurational approach.

4. Findings

4.1. QCA findings on just transitions

Employing the QCA, we identified seven distinct configurations of conditions that consistently led to positive just transition outcomes. These are derived from the complex solution, which incorporates only empirically observed cases and avoids assumptions about unobserved or logically possible configurations. While this approach prioritizes empirical precision, it may limit generalizability. Nonetheless, the complex solution explains approximately 47.4 % of cases with positive outcomes in the dataset (solution coverage = 0.474) and demonstrates a high level of internal consistency (solution consistency = 0.898), indicating that the identified pathways are reliable and robust. Table 1 provides a detailed overview of these configurations. Each row represents a distinct combination of conditions that, when jointly present, lead to a positive just transition outcomes. The table also shows the coverage and consistency of each configuration and indicates the sectors in which these combinations are most relevant. The energy sector appears in nearly every configuration, often alongside agriculture or ecosystem services, illustrating the multisectoral nature of transition processes.

Across all configurations, two conditions emerge as foundational: robust funding (Group A) and strategic planning (Group J). Both are present in every configuration that contributes towards a just transition, and necessity analysis confirms their importance. Funding in particular stands out as both a necessary and sufficient condition: it is consistently present alongside positive just transition outcomes and appears across diverse contexts and sectors. Similarly, strategic planning is essential for structuring complex interventions and ensuring alignment between goals, resources, and timelines.

By contrast, other conditions play more contingent or context-specific roles. For example, the absence of uncertainty (Group F) appears in most configurations, suggesting that stable institutional environments—characterized by predictable legal, financial, or political conditions—facilitate transitions. Similarly, the absence of resource barriers (Group I) and implementation bottlenecks (Group H) indicates that overcoming practical constraints is associated with improved outcomes.

However, not all conventionally desirable governance attributes are found to be universally necessary. Stakeholder engagement (Group C), while normatively valued, is absent in all but one configuration. This finding suggests that inclusive governance is not always a prerequisite

Table 1
Complex solution of the minimization process for the just transition indicator.

	Configuration	Raw coverage	Unique coverage	Consistency	>0.5 membership
A	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,159	0,001	0,999	Energy, agriculture/ food, ecosystem services
B	A_funding* ~ B_alignment* ~ C_engagement* ~ D_knowledge* ~ E_clustering*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,158	0,005	0,999	Energy, agriculture/ food
C	A_funding* ~ B_alignment* ~ C_engagement* ~ D_knowledge* ~ E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,230	0,067	0,964	Energy
D	A_funding*B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,242	0,055	0,942	Energy, agriculture/ food, ecosystem services,
E	A_funding*B_alignment*C_engagement*D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,084	0,026	0,935	Agriculture/food, ecosystem services
F	A_funding*B_alignment* ~ C_engagement*D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints*I_resource_barriers*J_planning*K_community_participation	0,115	0,022	0,904	Energy
G	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,159	0,001	0,999	Energy, agriculture/ food, ecosystem services

Note: Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.903725, solution coverage: 0.473896; solution consistency: 0.898029.

for contributing to a just transition, particularly in contexts where strong central coordination can substitute for participatory planning. Policy alignment (Group B) is also absent in more than half the configurations, implying that some transitions occur more effectively outside rigid policy frameworks. This may reflect the value of flexibility and experimentation, especially where existing institutions are slow to adapt. Other conditions, such as technical knowledge (Group D), clustering of interventions (Group E), and structural challenges (Group G), are variably present, pointing to the diversity of transition pathways.

Table 2 synthesizes the empirical role of each condition in contributing towards just transition outcomes, drawing from the necessity and sufficiency analyses. Robust funding and strategic planning emerge as both necessary as well as sufficient in configurations, emphasising their importance across all interventions contributing towards a just transition. In contrast, other conditions (such as policy alignment, stakeholder engagement, or technical knowledge) feature as part of sufficient configurations but are not universally required. Their influence appears contingent on specific institutional or sectoral contexts. Several conditions, including structural challenges, uncertainty, and resource barriers, show ambiguous or context-dependent roles, appearing in some pathways towards just transitions but not others. Implementation constraints are notably absent from configurations that contribute towards a just transition, suggesting that while operational delays may exist, they do not systematically hinder positive outcomes. This pattern reinforces the configurational logic of QCA: multiple pathways can contribute towards a just transition, but some foundational supports (particularly funding and planning) are consistently critical. Further detail on the empirical thresholds and condition metrics is provided in Appendix 2.

To help translate these empirical findings into actionable insights, Table 3 outlines the principal configurations alongside their sectoral relevance and associated policy implications. This shows the diversity of pathways that can contribute towards a just transition, while also pointing to context-specific governance and implementation strategies. For example, some configurations suggest strong financial and organizational support can compensate for limited stakeholder participation or policy alignment. Others reflect more conventional models of good governance, where engagement, technical knowledge, and coordinated implementation coalesce.

Table 2
Necessary and sufficient conditions for positive Just Transition outcomes.

Condition	Empirical role	Interpretation
Robust funding (A)	Necessary and part of sufficient paths	Present in all configurations and consistently associated with positive just transition outcomes
Policy alignment (B)	Sufficient in some cases	Contributes towards positive just transition outcomes but is not always present or required
Stakeholder engagement (C)	Sufficient in some cases	Normatively valued, but empirically absent in most pathways towards a just transition
Technical knowledge (D)	Sufficient in some cases	Useful in certain configurations; not universally influential
Clustering (E)	Sufficient in some cases	Facilitates synergy; not required across all transition types
Uncertainty (F)	Ambiguous role	Absence often accompanies positive just transition outcomes, but not uniquely decisive
Structural challenges (G)	Ambiguous or dual role	Present in both enabling and non-enabling environments
Implementation constraints (H)	Largely irrelevant	Rarely appears alongside positive just transition outcomes; low explanatory value
Resource barriers (I)	Ambiguous role	Presence does not consistently inhibit or enable positive just transition outcomes
Strategic planning (J)	Necessary and part of sufficient paths	Recurrent across solutions; essential for coordination and implementation
Community participation (K)	Sufficient in some cases	Enhances outcomes when present, but not essential in all contexts

Detailed metrics and thresholds are reported in Appendix 2.

Table 3
Principal configurations and their policy implications across sectors.

Configuration ID	Key conditions	Sectors represented	Policy implications
A	Funding, planning, absence of stakeholder engagement, and alignment	Energy, Agriculture/ Food, Ecosystem Services	Strong, well-funded design may substitute for broad stakeholder processes in some institutional contexts
B	Funding, planning, structural challenge, absence of engagement, and knowledge	Energy, Agriculture/ Food	Structural reform and policy flexibility may compensate for limited engagement and capacity
C	Funding, planning, absence of knowledge, engagement, and structural challenges	Energy	Technocratic interventions can be effective if basic enablers are strong, even with limited systemic change
D	Funding, planning, engagement, clustering, technical knowledge, alignment	All sectors	Classic good governance configuration: participatory, well-coordinated, and technically robust
E	Funding, planning, stakeholder engagement, technical knowledge, and the absence of uncertainty	Agriculture/ Food, Ecosystem Services	Planning under certainty and trust enhances outcomes, especially in decentralized settings
F	Funding, planning, technical knowledge, and resource constraints present	Energy	High capacity can mitigate constraints; useful in contexts with strong institutions but limited resources
G	Funding, planning, policy misalignment, and structural challenges	All sectors	Transition pathways can emerge outside formal alignment when financial and organizational support is stable

4.2. Results from a fractional logistic analysis

To complement the QCA analysis, fractional logistic regression models were estimated for each outcome using the set of aggregated conditions. Table 4 presents the results for the reduced set of 11 conditions. Across all three models, the statistical significance of robust funding highlights its central role in increasing the likelihood of outcomes, consistent with the findings from the QCA analysis. However, the lack of statistical significance for most other conditions suggests the need for multiple, interacting conditions to explain the presence of the outcomes under consideration. For instance, conditions such as stakeholder engagement, and technical knowledge show non-significant coefficients. This pattern partly reflects methodological limitations, particularly the low sample size ($n = 79$), and indicates that no single dimension strongly predicts the outcomes on its own. Instead, and as shown by the QCA analysis, an interplay of conditions is likely to be necessary for a comprehensive understanding of the pathways to just transition outcomes. The three conditions that show significance are:

- **Robust funding** (significant at the 1 % level for just transition and climate models, and at the 5 % level for the social equity model)
- **Strategic planning** (significant at the 10 % level only for the social equity model)

Table 4
Fractional regression results for the reduced set of 11 conditions.

	Climate	Social equity	Just transition
(Intercept)	−0.86*	−1.75***	−1.37***
	(0.34)	(0.29)	(0.20)
Robust funding (A)	1.40**	1.02*	1.15***
	(0.53)	(0.44)	(0.30)
Policy alignment (B)	−1.14*	0.47	−0.21
	(0.47)	(0.40)	(0.27)
Stakeholder engagement (C)	−0.24	−0.19	−0.22
	(0.51)	(0.43)	(0.30)
Technical knowledge (D)	0.03	−0.55	−0.26
	(0.52)	(0.46)	(0.31)
Clustering (E)	0.21	0.30	0.26
	(0.53)	(0.43)	(0.30)
Uncertainty (F)	0.19	−0.70	−0.29
	(0.49)	(0.45)	(0.30)
Structural challenges (G)	0.19	0.48	0.37
	(0.60)	(0.48)	(0.34)
Implementation constraints (H)	−0.27	−0.58	−0.45
	(0.46)	(0.41)	(0.28)
Resource barriers (I)	0.44	−0.09	0.12
	(0.54)	(0.45)	(0.31)
Strategic planning (J)	0.05	0.67+	0.40
	(0.45)	(0.37)	(0.26)
Community participation (K)	0.11	0.35	0.24
	(0.42)	(0.34)	(0.24)
Num.Obs.	79	79	79
R2 Adj.	0.01	0.15	0.22
RMSE	0.21	0.15	0.11
Deviance	20.37	10.22	5.12
DF Resid	67	67	67

+ $p < 0.1$, * p < 0.05, ** $p < 0.01$, *** $p < 0.001$.
Note: The coefficients from the fractional logistic regression model represent changes in the log-odds of the outcome for a one-unit increase in each predictor, holding other variables constant. Positive coefficients indicate higher odds of the outcome occurring, while negative coefficients indicate lower odds. The standard error of the coefficient is shown in parentheses.

- **Alignment with existing policies** (significant at the 10 % level for the climate model with a negative coefficient, reflecting the absence of this condition within the QCA analysis)

Moreover, some conditions demonstrate differing effects across the outcomes, as indicated by coefficients with different signs. For instance, alignment with existing policies shows a negative and statistically significant effect for the climate outcome (−1.14, $p < 0.05$), but a positive (albeit non-significant) effect for social equity (0.47). These findings reinforce the complexity of the just transition framework and underscore the need for integrated approaches that capture multi-dimensional influences such as the QCA presented in this article.

5. Discussion

Adequate financing is widely recognized as a critical enabler of just transitions in developing countries. Many LMICs lack the domestic fiscal capacity to finance green industrial policies or inclusive labour protections, necessitating support from international climate finance and technology transfers [4,23]. Institutions such as the UN and World Bank have emphasized that, without robust and predictable funding, implementation of social protection measures and infrastructure investments will stall. Indeed, the Paris Agreement itself (Article 4.15) calls explicitly for international cooperation to support a just transition in developing economies.

We find that robust funding consistently features in all configurations with positive just transition outcomes, aligning with the broader literature: financial resourcing is widely understood to be the foundational condition for delivering both environmental and social outcomes [4,24]. Countries like South Africa have demonstrated that when major climate finance packages, such as the Just Energy Transition Partnership, are available, governments can offer retraining, social cushioning, and renewable energy development in tandem [25]. Yet, forms and sources of finance matter both in terms of ensuring a transition doesn't reduce fiscal space as well as, where appropriate, signifying a restorative dimension to financial flows.

Stakeholder engagement is often viewed as a cornerstone of just transition frameworks, reflecting the principle of procedural justice. International frameworks like the ILO's Just Transition Guidelines [24] stress that affected workers and communities must be involved in planning and implementation. This aligns with energy justice literature, which emphasizes the role of inclusive governance in building legitimacy and ensuring that transitions are accepted by those most affected [26]. However, our QCA findings indicate that stakeholder engagement was absent in most configurations leading to positive outcomes. This challenges conventional assumptions and raises questions about the diversity of governance models across contexts. Some authors argue that in certain settings, particularly those with centralized or top-down governance structures, strong state capacity and clear direction can substitute for consultative processes in the short term [23]. These approaches have been observed in China and Vietnam, where authoritarian environmentalism has enabled rapid transitions without the type of broad consultation found in wider countries [2]. While this may reflect temporary or strategic omissions, it does not diminish the normative value of procedural justice. Rather, it suggests that in some contexts, transitions can be accelerated under centralized leadership, although this may affect long-term trust and sustainability.

Another finding from the QCA indicates the absence of policy alignment with broader development strategies does not always prevent a contribution towards just transition outcomes. This is unexpected, given that the literature emphasizes the need for vertical and horizontal alignment across climate, energy, labour, and development policies [7,25]. A possible interpretation is that certain interventions may benefit from operating outside rigid institutional frameworks, particularly when existing policies reinforce fossil fuel dependence or institutional inertia. International development literature acknowledges that "policy misalignment" can sometimes allow experimentation and create a degree of "institutional freedom" to innovate, especially when interventions are externally financed or locally piloted [8]. Still, these arrangements may lack durability without eventual institutional integration. From a political economy perspective, alignment failures can reflect deeper institutional fragmentation, regulatory capture, or weak capacity at subnational levels [9]. In that light, the finding is less about the normative value of alignment and more about the constraints and path dependencies in many developing country settings.

The findings align in part, but also complicate, core theories of just transition, which emphasize distributive, procedural, and recognition justice [9,26]. Distributive justice — fairness in the allocation of benefits and burdens — is strongly supported through the finding on the importance of funding and strategic planning. These enable job creation, access to clean energy, and safety nets for affected populations. Recognition justice is partly reflected in the calibration of outcome variables (e.g., respect for human rights and gender equity), though limited stakeholder engagement challenges its full realization.

Procedural justice, on the other hand, is called into question by our findings. While the literature strongly advocates for inclusive, participatory planning [24], this study suggests that procedural inclusion may not be a necessary condition in all cases. This highlights a need to differentiate between normative ideals and empirical observations, and to consider context-dependent governance strategies. Importantly, the literature suggests that where transitions lack procedural justice, long-term legitimacy and social stability may be at risk [7,26].

From a methodological standpoint, our results point to the value of combining QCA with other approaches such as process tracing or longitudinal research to better understand causality and dynamic feedback loops [27,28]. The absence of conditions like policy alignment or engagement may indicate transitional phases or compensatory

mechanisms rather than long-term substitutes. QCA helps uncover these patterns of equifinality, where multiple pathways lead to the same outcome, and causal asymmetry, where the absence of a factor does not simply mirror its presence [29–33]. This is particularly useful in development contexts where heterogeneity is the norm. However, the possibility of endogeneity, particularly with funding, must be acknowledged. It is plausible that interventions receiving climate finance were already more likely to achieve positive outcomes, or that positive outcomes made them more attractive to donors. While QCA is not designed to test causality directionally, future research could explore these relationships through temporal or network-based methods. We therefore interpret our results as indicative of associative patterns, while encouraging future studies to explore dynamic feedback loops and causal mechanisms through longitudinal or process-tracing approaches.

The term *just transition* also carries considerable normative expectations, particularly in relation to procedural and recognition justice. Our analytical approach emphasizes social equity and climate outcomes, operationalised through calibrated indicators such as job creation, protection of vulnerable groups, and rights recognition. While these provide an empirically grounded proxy for assessing progress towards just transitions, they do not fully capture other justice dimensions, including voice, agency, and historical aspects (such as colonialism). In this sense, our study identifies configurations of conditions that contribute towards *elements* of a just transition rather than whether transitions are fully or normatively just. We see this as both a methodological and conceptual boundary: the QCA method, while powerful in identifying combinations, is limited in its ability to adjudicate deeper contestations over justice. Further research employing participatory or place-based methods is thus necessary to address potential blind spots and to better understand how diverse communities articulate and pursue justice within transitions.

6. Conclusion

The concept of just transition is not uniformly applicable across counties and sectors, which makes international public policy interventions for developing nations so challenging. The energy sector is at the centre of just transition debates with immense potential for transformation, primarily due to the emergence of more affordable low emission energy technologies. Within developing countries there is a tricky balance between producing sufficient energy for a growing population, developing low-carbon energy infrastructure, and providing alternatives to workers dependent on fossil fuel extraction and power generation. Transitioning to sustainable energy systems may involve reallocating a significant portion of budgets to clean energy, clean electricity incentives and social investments. There are many risks and challenges associated with this transition, and it is critical that a just transition identifies and mitigates risks and enhances positive employment and social impacts. A turn away from high-emitting infrastructure, involving decarbonizing energy systems (especially in urban areas), improving the energy efficiency of buildings, resilient urban planning design and circular economy practices, will also lead to challenges which are institutional, technical, financial and social through ensuring access to housing and decent jobs.

Broadly similar trade-offs are also apparent in the agricultural sector: the world's population is increasing, leading to greater demand on food systems, and changing weather patterns and extreme climate events place additional strain on food systems. As agriculture and food systems adjust to changing conditions and as governments, organizations, and corporations implement interventions that will lead to more resilient systems and lower GHG emissions, social and economic impacts on workers, suppliers and consumers will need to be approached with great care and awareness of potential harms, while leveraging opportunities and benefits. Ecosystem services straddle the three systems outlined above, intersecting with numerous just transition challenges and opportunities, including through implementation of nature-based solutions, improving forest management (reforestation and restoration), protecting and restoring grasslands and peatlands, managing watersheds sustainably, restoring wetlands, and instituting sustainable fishing practices.

This article contributes to closing the evidence gap on just transitions in LMICs, combining a data set from a realist synthesis with QCA. Across all four of the sectors outlined above, we find seven distinct causal pathways for contributing towards just transitions, with robust funding and strategic planning emerging as universally necessary conditions. Surprisingly, factors often considered essential, such as stakeholder engagement and policy alignment, are not consistently present in effective interventions. Complementary fractional logistic regression reinforces the centrality of funding and planning, while underscoring the limited predictive power of single variables. Our findings highlight the configurational and context-dependent nature of just transition outcomes, and by illuminating diverse pathways to inclusive decarbonization, we hope this article contributes to bridging the empirical gap in transition policy for the Global South, while also contributing to a grounded discussion of what partial or context-specific forms of 'justice' look like in practice.

CRediT authorship contribution statement

Johanna Gather: Supervision, Project administration, Writing – review & editing, Writing – original draft. **Martin Prowse:** Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization, Writing – review & editing, Writing – original draft. **Daniel Seussler:** Formal analysis, Data curation, Writing – review & editing, Writing – original draft.

Declaration of competing interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Acknowledgements

The authors would like to thank all the authors of the GCF-IEU and International Labour Organization (ILO) "Realist review: Just transitions towards low emission, climate resilient and more inclusive societies in developing countries," which created the dataset this manuscript analyses using qualitative comparative analysis. In particular, the authors wish to thank Camilla Roman from the ILO who co-funded the realist review and offered comments on this paper. The authors would also like to particularly thank Catherine Cameron and Gemma Norrington-Davies from Aghulas Applied Knowledge alongside Lekha Tlhotlhalemaje.

Appendix 1. Guide for calibrating variables for a just transition analysis using fuzzy-set QCA

This document provides a systematic and cohesive approach to calibrating the dataset for a fuzzy-set qualitative comparative analysis (fsQCA). It includes detailed instructions for evaluating the explanatory (condition) and dependent (outcome) variables to determine necessary and sufficient conditions for contributing towards a just transition.

A just transition refers to a shift to a low-carbon and sustainable economy in a way that ensures fairness and inclusivity. It aims to:

- Protect vulnerable workers and communities during economic and environmental changes
- Promote social equity, gender equality, and human rights
- Achieve environmental sustainability and climate resilience

A just transition ensures that no one is left behind as the world moves towards sustainability.

QCA is a method used to explore the relationships between conditions (independent variables) and outcomes (dependent variables) across cases. FsQCA allows for nuanced analysis by assigning fuzzy membership values (0 to 1) to reflect the degree to which a variable is present.

Fuzzy-set membership scoring

Membership scores for all variables range from 0 (fully out) to 1 (fully in), with intermediate values representing partial membership:

- 0 (fully out): The condition or outcome is absent
- 0.25 (mostly out): Weak evidence or minimal presence of the condition/outcome
- 0.5 (crossover/neutral): Mixed evidence or partial presence
- 0.75 (mostly in): Strong evidence, with minor limitations
- 1 (fully in): Clear and full presence of the condition/outcome

We start by selecting the dependent variables we seek to investigate.

Calibration of dependent variables (outputs)

Dependent variables represent the outputs we aim to explain, categorized into climate outputs and social equity outputs.

Outputs are intermediary achievements on the way to just transition outcomes. The scale of these outputs varies across interventions, depending on the available input and the selected activities.

Across interventions, outputs can be categorized as climate or social equity and social gains outputs.

A. Climate outputs

We have three climate outputs:

- Increased adoption of low emission/resilient/sustainable production practices and technologies
- Increased supply of affordable, low emission technologies, such as renewable energy, drip irrigation and water harvesting
- Changes in consumption towards low-emissions patterns

Examples and scoring for climate outputs.

- Changes in consumption towards low-emissions patterns:
  - 1: Significant, measurable reductions in emissions
  - 0.75: Substantial reductions with some limitations
  - 0.5: Mixed evidence of partial reductions
  - 0.25: Minimal reductions or marginal relevance
  - 0: No emissions reductions or increased emissions
- Increased adoption of low emission/resilient/sustainable production practices and technologies:
  - 1: Clear adoption of resilience measures (e.g. drought-resistant crops)
  - 0.75: Significant progress but with gaps in coverage
  - 0.5: Mixed results or partial resilience improvements
  - 0.25: Minimal progress with marginal impact
  - 0: No resilience improvements

B. Social equity outputs

Social equity outcomes evaluate fairness and inclusivity, such as job creation or protections for vulnerable groups.

We have five social equity and social gains outputs:

- Enhanced benefits for the local economy, prosperity and job creation, such as diversified livelihoods, increased incomes, and health and nutrition co-benefits
- A workforce with skills relevant to job and livelihood opportunities
- Vulnerable workers and communities protected from negative impacts
- Respect for human rights and gender equity
- Broad stakeholder consensus

Examples and scoring for social equity output:

- Enhanced benefits for the local economy, prosperity and job creation, such as diversified livelihoods, increased incomes, and health and nutrition co-benefits
  - **1:** Clear evidence of substantial job creation
  - **0.75:** Significant jobs created, but with some gaps
  - **0.5:** Mixed evidence or partial job creation
  - **0.25:** Minimal jobs created with marginal relevance

- **0:** No job creation or evidence of job losses
- Vulnerable workers and communities protected from negative impacts
  - **1:** Comprehensive social protections (e.g. retraining, financial support)
  - **0.75:** Substantial protections with gaps in implementation
  - **0.5:** Partial protections for some groups
  - **0.25:** Minimal protections with limited impact
  - **0:** No social protections

We now select plausible explanatory conditions.

Calibration of explanatory variables (conditions)

Enablers and mechanisms

The overall theory of change explains our findings on how interventions are intended to contribute towards a just transition. It is based on accounts of those plans or intentions (explicit or implicit) and the contextual factors likely to enable or obstruct progress identified in the interventions studied.

We will have seven variables:

1. Robust funding and financing models (e.g. international, government, private sector) provide sufficient finance over an adequate period
2. Strong alignment with national and/or sub-national development policies and priorities
3. High-level political ownership and robust government coordination and buy-in at national/provincial/local levels
4. Strong stakeholder engagement and buy-in to build trust, awareness and knowledge of potential benefits
5. Technical expertise, knowledge and data
6. Building on existing knowledge, data and programme learning – innovation, including use of contextually appropriate information
7. Strategically clustering and designing multi-purpose interventions to maximize benefits

To evaluate the enabling factors for each study case, we use a score based on the guide's examples:

- 1 (fully in): Clear, actionable mechanisms driving change
- 0.75 (mostly in): Strong enablers but with challenges
- 0.5 (neutral): Mixed or inconsistent enablers
- 0.25 (mostly out): Weak evidence
- 0 (fully out): No significant enablers

Barriers and risks

These are obstacles that hinder just transition efforts, such as socio-economic inequities, infrastructure limitations, or resistance.

The dataset contains 10 possible barriers and risks:

1. Lack of certainty around political and financial commitments
2. Misalignment of programme objectives with stakeholder needs (e.g., national, regional and/or community levels)
3. Bureaucratic and legal barriers, including gaps between policy reform and implementation
4. Continued competition from dominant systems, enhanced by the macro environment, skewing incentives
5. Small-scale and context-specific interventions preventing scale-up
6. Project management and coordination constraints delay implementation
7. Limited stakeholder engagement and participation, including the exclusion of certain groups (e.g. women, and indigenous communities), hinders the uptake of new approaches and technologies
8. Lack of clarity around benefits and unequal distribution of benefits reduces trust and buy-in
9. High costs associated with new systems and technologies act as a barrier to participation and uptake
10. Inadequate technical skills, materials and labour supply undermine momentum towards a transition

Each of these barriers form one fuzzy variable (10 in total) according to:

- 1: Severe and widespread barrier
- 0.75: Significant barrier, partially mitigated
- 0.5: Moderate or mixed barrier
- 0.25: Minimal impact barrier
- 0: No significant barrier

Contexts

Contexts describe socio-economic, political, social, and environmental settings that influence interventions (four variables).

- 1: Highly challenging context
- 0.75: Significant challenges but with mitigating factors
- 0.5: Mixed enabling and hindering factors
- 0.25: Favourable with minor challenges
- 0: Completely supportive contexts

Activities

There are seven fuzzy variables here:

1. Mechanisms in place for coherence across climate, economic, and social programmes and investments
2. Ex ante assessments of livelihood and social impacts of planned interventions
3. Social dialogue, community participation, and stakeholder engagement
4. Creation of an enabling environment
5. Incentives and standards (e.g. subsidies, manufacturing incentives)
6. Investments in infrastructure and technology
7. Development and implementation of inclusive social policies, programmes and investments (e.g. social protection, livelihoods programmes, skills development and training)

These are the specific interventions carried out to achieve just transition outcomes.

- 1: Comprehensive and impactful activities
- 0.75: Strong activities with some gaps
- 0.5: Partially implemented with moderate results
- 0.25: Poorly designed or minimal activities
- 0: No relevant activities

Overall, we have seven enabler and mechanism variables, ten risks and barriers, four context variables, and seven activity variables. So, we have 28 explanatory (condition) variables. This is within scope as QCA allows around 3–4 cases for each condition being examined.

Calibration process

1. Review evidence: Analyze qualitative and quantitative data for each case and variable.
2. Assign membership scores: Use the criteria outlined above to assign scores (0, 0.25, 0.5, 0.75, 1)
3. Document justifications: Provide a brief explanation for each score, citing data sources
4. Validate scores: Compare scores across cases to ensure consistency and resolve discrepancies
5. Input data: Enter calibrated scores into the fsQCA software for analysis

Pitfalls to avoid

- Assumptions over evidence: Scores must be based on documented evidence, not assumptions
- Inconsistent scoring: Ensure criteria are consistently applied across cases
- Lack of documentation: Justifications must be clearly documented for all scores

Final notes

- Thorough review: Ensure all scoring is supported by data and evidence
- Collaborate: Engage with peers to resolve uncertainties or ambiguous cases
- Iterative process: Adjust scores as necessary based on emerging patterns or new insights

Appendix 2. Sufficiency and necessity analysis

Table 5
Necessity analysis for the just transition indicator.

Condition	inclN	RoN	covN
b_alignment	0.80	0.65	0.45
a_funding	0.79	0.79	0.56
k_community_participation	0.75	0.68	0.45
j_planning	0.71	0.76	0.50
d_knowledge	0.68	0.74	0.47
e_clustering	0.55	0.85	0.54
c_engagement	0.35	0.88	0.47
i_resource_barriers	0.32	0.91	0.50
f_uncertain	0.30	0.90	0.46
g_structural_challenges	0.30	0.96	0.67
h_constraints	0.10	0.91	0.25

Note: inclN = Consistency of Necessity; RoN = Relevance of Necessity; covN=Coverage of Necessity.

Table 6
Sufficiency analysis for the just transition indicator.

Condition	inclS	PRI	covS	covU
a_funding	0.62	0.08	0.80	0.02
b_alignment	0.47	0.03	0.77	0.00
k_community_participation	0.49	0.04	0.75	0.00
j_planning	0.55	0.03	0.72	0.04
d_knowledge	0.50	0.05	0.67	0.00
e_clustering	0.61	0.06	0.56	0.00
c_engagement	0.53	0.00	0.36	0.00
i_resource_barriers	0.59	0.02	0.34	0.00
f_uncertain	0.55	0.04	0.32	0.00
g_structural_challenges	0.77	0.12	0.31	0.00
h_constraints	0.30	0.00	0.11	0.00

Note: inclS=Consistency of Sufficiency; PRI=Proportional Reduction in Inconsistency; covS=Coverage of Sufficiency; covU=Unique Coverage.

Table 7
Necessity analysis for the climate outcome.

Condition	inclN	RoN	covN
a_funding	0.71	0.81	0.63
k_community_participation	0.70	0.71	0.52
b_alignment	0.67	0.66	0.46
j_planning	0.63	0.78	0.55
d_knowledge	0.59	0.75	0.50
e_clustering	0.49	0.87	0.60
c_engagement	0.33	0.90	0.55
i_resource_barriers	0.31	0.93	0.61
f_uncertain	0.29	0.92	0.57
g_structural_challenges	0.25	0.96	0.72
h_constraints	0.12	0.93	0.38

Note: inclN=Consistency of Necessity; RoN = Relevance of Necessity; covN=Coverage of Necessity.

Table 8
Sufficiency analysis for the climate outcome.

Condition	inclS	PRI	covS	covU
a_funding	0.63	0.28	0.71	0.04
k_community_participation	0.52	0.19	0.70	0.02
b_alignment	0.46	0.12	0.67	0.00
j_planning	0.55	0.16	0.63	0.05
d_knowledge	0.50	0.17	0.59	0.00
e_clustering	0.60	0.20	0.49	0.00
c_engagement	0.55	0.14	0.33	0.00
i_resource_barriers	0.61	0.19	0.31	0.00
f_uncertain	0.57	0.17	0.29	0.00
g_structural_challenges	0.72	0.32	0.25	0.00
h_constraints	0.38	0.00	0.12	0.00

Note: inclS=Consistency of Sufficiency; PRI=Proportional Reduction in Inconsistency; covS=Coverage of Sufficiency; covU=Unique Coverage.

Table 9
Necessity analysis for the social equity outcome.

Condition	inclN	RoN	covN
b_alignment	0.80	0.65	0.45
a_funding	0.79	0.79	0.56
k_community_participation	0.75	0.68	0.45
j_planning	0.71	0.76	0.50
d_knowledge	0.68	0.74	0.47
e_clustering	0.55	0.85	0.54
c_engagement	0.35	0.88	0.47
i_resource_barriers	0.32	0.91	0.50
f_uncertain	0.30	0.90	0.46
g_structural_challenges	0.30	0.96	0.67
h_constraints	0.10	0.91	0.25

Note: inclN=Consistency of Necessity; RoN = Relevance of Necessity; covN=Coverage of Necessity.

Table 10
Sufficiency analysis for the social equity outcome.

Condition	inclS	PRI	covS	covU
b_alignment	0.45	0.07	0.80	0.00
a_funding	0.56	0.15	0.79	0.03
k_community_participation	0.45	0.06	0.75	0.00
j_planning	0.50	0.08	0.71	0.03
d_knowledge	0.47	0.09	0.68	0.00
e_clustering	0.54	0.08	0.55	0.00
c_engagement	0.47	0.03	0.35	0.00
i_resource_barriers	0.50	0.00	0.32	0.00
f_uncertain	0.46	0.03	0.30	0.00
g_structural_challenges	0.67	0.14	0.30	0.00
h_constraints	0.25	0.00	0.10	0.00

Note: inclS=Consistency of Sufficiency; PRI=Proportional Reduction in Inconsistency; covS=Coverage of Sufficiency; covU=Unique Coverage.

Appendix 3. Just transition – QCA results

Table 11
Parsimonious solutions of the minimization process for a just transition.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	A_funding*C_engagement*J_planning	0,206	0,000	0,926	Agriculture/food and ecosystem services
B	A_funding* ~ B_alignment* ~ H_constraints*J_planning	0,367	0,000	0,914	Energy, agriculture/food, agriculture/food and ecosystem services
C	A_funding* ~ H_constraints*J_planning*K_community_participation	0,421	0,055	0,895	Energy, agriculture/food, agriculture/food and ecosystem services
D	A_funding* ~ B_alignment* ~ F_uncertain*J_planning	0,377	0,005	0,895	Energy, agriculture/food
E	A_funding* ~ D_knowledge* ~ H_constraints*J_planning	0,412	0,000	0,877	Energy, agriculture/food
F	A_funding* ~ D_knowledge* ~ F_uncertain*J_planning	0,414	0,000	0,859	Energy
G	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ H_constraints	0,551	0,000	0,853	Energy, agriculture/food, agriculture/food and ecosystem services
H	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ F_uncertain	0,556	0,005	0,848	Energy, agriculture/food and ecosystem services
I	G_structural_challenges* ~ I_resource_barriers	0,296	0,033	0,821	Energy, agriculture/food, agriculture/food and ecosystem services
J	A_funding*C_engagement*E_clustering	0,178	0,002	0,813	Agriculture/food and ecosystem services
K	A_funding* ~ C_engagement* ~ D_knowledge* ~ E_clustering* ~ H_constraints	0,592	0,000	0,799	Energy, agriculture/food
L	A_funding* ~ C_engagement* ~ D_knowledge* ~ E_clustering* ~ F_uncertain	0,599	0,011	0,798	Energy

Note: Parsimonious solutions for the just transitions model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.903725, solution coverage: 0.787665, solution consistency: 0.752948.

Table 12
Intermediate solutions of the minimization process for a just transition.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,15,937	0,000846	0,999,337	Energy, agriculture/food and ecosystem services
B	A_funding*B_alignment* ~ C_engagement*D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints*I_resource_barriers*J_planning*K_community_participation	0,11,483	0,0215736	0,99,862	Energy
C	A_funding* ~ B_alignment* ~ C_engagement* ~ D_knowledge* ~ E_clustering*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,158,471	0,00523478	0,964,286	Energy, agriculture/food
D	A_funding* ~ B_alignment* ~ C_engagement* ~ D_knowledge* ~ E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,230,312	0,0669239	0,946,884	Energy
E	A_funding*B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,0880217	0,0210448	0,942,264	Energy
F	A_funding*B_alignment*C_engagement*D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,0844437	0,0263853	0,935,012	Agriculture/food and ecosystem services
G	A_funding*B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,242,051	0,0554321	0,903,725	Agriculture/food and ecosystem services, agriculture/food, energy

Note: Intermediate solutions for the just transitions model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.903725, solution coverage: 0.473896; solution consistency: 0.898029.

Appendix 4. Climate outcomes – QCA results

Table 13
Complex solutions of the minimization process for climate outcomes.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	~A_funding* ~ B_alignment*C_engagement* ~ D_knowledge* ~ E_clustering*F_uncertain*G_structural_challenges* ~ H_constraints*I_resource_barriers*J_planning*K_community_participation	0,047	0,014	1	Energy and infrastructure
B	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,134	0,092	0,955	Energy, agriculture/ food and ecosystem services
C	A_funding* ~ B_alignment*C_engagement* ~ D_knowledge* ~ E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ J_planning* ~ K_community_participation	0,159	0,111	0,931	Energy, energy and infrastructure
D	~A_funding* ~ B_alignment* ~ C_engagement* ~ D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints*I_resource_barriers*J_planning* ~ K_community_participation	0,060	0,022	0,900	Agriculture/food

Note: Complex solutions for the climate outcome model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.9, solution coverage: 0.301428, solution consistency: 0.924072.

Table 14
Parsimonious solutions of the minimization process for climate outcomes.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	E_clustering*I_resource_barriers* ~ K_community_participation	0,135	0,005	0,849	Agriculture/food
B	~B_alignment* ~ F_uncertain*G_structural_challenges	0,204	0,000	0,843	Energy, agriculture/food and ecosystem services
C	A_funding* ~ B_alignment* ~ E_clustering* ~ J_planning	0,465	0,000	0,840	Energy, energy, and infrastructure
D	A_funding* ~ B_alignment* ~ F_uncertain*K_community_participation	0,352	0,015	0,838	Energy, agriculture/food and ecosystem services
E	~F_uncertain*G_structural_challenges*K_community_participation	0,199	0,008	0,819	Energy, agriculture/food and ecosystem services
F	A_funding* ~ D_knowledge* ~ E_clustering* ~ J_planning	0,499	0,034	0,812	Energy, energy and infrastructure
G	~B_alignment*C_engagement* ~ F_uncertain* ~ K_community_participation	0,262	0,000	0,810	Energy, energy and infrastructure
H	A_funding* ~ B_alignment*C_engagement	0,203	0,000	0,805	Energy, energy and infrastructure
I	~B_alignment*E_clustering*I_resource_barriers	0,118	0,000	0,788	Agriculture/food
J	C_engagement* ~ H_constraints*I_resource_barriers	0,182	0,006	0,778	Energy and infrastructure
K	~A_funding*E_clustering*I_resource_barriers	0,150	0,005	0,760	Agriculture/food
L	C_engagement* ~ D_knowledge* ~ F_uncertain* ~ K_community_participation	0,282	0,000	0,759	Energy, energy and infrastructure
M	A_funding*C_engagement* ~ D_knowledge	0,223	0,000	0,759	Energy, energy and infrastructure
N	~D_knowledge*E_clustering*I_resource_barriers	0,119	0,000	0,752	Agriculture/food
O	C_engagement* ~ D_knowledge* ~ J_planning	0,293	0,000	0,741	Energy, energy and infrastructure
P	~B_alignment*C_engagement* ~ J_planning	0,273	0,000	0,736	Energy, energy and infrastructure
Q	C_engagement* ~ D_knowledge* ~ F_uncertain* ~ H_constraints	0,296	0,000	0,705	Energy, energy and infrastructure

Note: Parsimonious solutions for the climate outcome model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.9, solution coverage: 0.69789, solution consistency: 0.720244.

Table 15
Intermediate solutions of the minimization process for climate outcomes.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	~A_funding* ~ B_alignment*C_engagement* ~ D_knowledge* ~ E_clustering*F_uncertain*G_structural_challenges* ~ H_constraints*I_resource_barriers*J_planning*K_community_participation	0,047	0,014	1000	Energy and infrastructure
B	A_funding* ~ B_alignment* ~ C_engagement* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,134	0,092	0,955	Energy, agriculture/ food and ecosystem services
C	A_funding* ~ B_alignment*C_engagement* ~ D_knowledge* ~ E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ J_planning* ~ K_community_participation	0,159	0,111	0,931	Energy, energy and infrastructure
D	~A_funding* ~ B_alignment* ~ C_engagement* ~ D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints*I_resource_barriers*J_planning* ~ K_community_participation	0,060	0,022	0,900	Agriculture/food

Note: Intermediate solutions for the climate outcome model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.9, solution coverage: 0.301428, solution consistency: 0.924072.

Appendix 5. Intermediate solutions of the minimization process for social equity outcomes

Table 16
Complex solutions of the minimization process for social equity outcomes.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	A_funding*B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,101	0,035	0,989	Energy
B	A_funding*B_alignment*C_engagement*D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,092	0,088	0,930	Agriculture/food and ecosystem services
C	A_funding* ~ B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,094	0,032	0,900	Agriculture/food and ecosystem services

Note: Complex solutions for the social equity model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.9, solution coverage: 0.221093, solution consistency: 0.922879.

Table 17
Parsimonious solutions of the minimization process for social equity outcomes.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	A_funding*C_engagement*J_planning	0,214	0,061	0,883	Agriculture/food and ecosystem services
B	A_funding*C_engagement*E_clustering	0,192	0,039	0,806	Agriculture/food and ecosystem services
C	D_knowledge*G_structural_challenges* ~ I_resource_barriers	0,186	0,160	0,805	Energy, agriculture/food and ecosystem services

Note: Parsimonious solutions for the social equity model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.9, solution coverage: 0.413087, solution consistency: 0.827959.

Table 18
Intermediate solutions of the minimization process for social equity outcomes.

	Configuration	Raw coverage	Unique coverage	Consistency	Cases with >0.5 membership
A	A_funding*B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,101	0,035	0,989	Energy
B	A_funding*B_alignment*C_engagement*D_knowledge*E_clustering* ~ F_uncertain* ~ G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning* ~ K_community_participation	0,092	0,088	0,930	Agriculture/food and ecosystem services
C	A_funding* ~ B_alignment* ~ C_engagement*D_knowledge* ~ E_clustering* ~ F_uncertain*G_structural_challenges* ~ H_constraints* ~ I_resource_barriers*J_planning*K_community_participation	0,094	0,032	0,900	Agriculture/food and ecosystem services

Note: Intermediate solutions for the social equity model. Quine-McCluskey algorithm; frequency cutoff: 1; consistency cutoff: 0.9, solution coverage: 0.221093, solution consistency: 0.922879.

Data availability

Data will be made available on request.

References

[1] R.J. Heffron, D. McCauley, What is the 'just transition'? Geoforum 88 (2018) 74–77.
[2] P. Newell, D. Mulvaney, The political economy of the just transition, Geogr. J. 179 (2) (2013) 132–140.
[3] United Framework Convention on Climate Change, Paris Agreement, 2015 (12 December).
[4] R.J. Heffron, Achieving a Just Transition to a Low-Carbon Economy, Springer, 2021.
[5] T. Yeung, et al., Realist review on just transition towards low emission, climate resilient and more inclusive societies in developing countries, in: IEU learning paper (May). Songdo, Independent Evaluation Unit, Green Climate Fund, South Korea, 2024.
[6] B.K. Sovacool, J. Axsen, S. Sorrell, Promoting novelty, rigor, and style in energy social science: towards codes of practice for appropriate methods and research design, Energy Res. Soc. Sci. 45 (2018) 12–42.
[7] B. Galgóczi, Just transition on the ground: challenges and opportunities for social dialogue, Eur. J. Ind. Relat. 26 (4) (2020) 367–382.
[8] P. Newell, D. Mulvaney, The political economy of the just transition, Geogr. J. 179 (2) (2013) 132–140.
[9] D. McCauley, R.J. Heffron, Just transition: integrating climate, energy, and environmental justice, Energy Policy 119 (2018) 1–7.
[10] Teresa Anderson, Principles for a Just Transition in Agriculture, ActionAid, Johannesburg, South Africa, 2019.
[11] A.M. Eisenberg, Just transitions: legal frameworks for fair decarbonization, South. Calif. Law Rev. 92 (2) (2019) 273–329.
[12] K. Hart, Informal income opportunities and urban employment in Ghana, J. Mod. Afr. Stud. 11 (1) (1973) 61–89.
[13] A. Mayer, A just transition for coal miners? Community identity and support from local policy actors, Environ. Innov. Soc. Trans. 28 (2018) 1–13.
[14] Unruh, Understanding carbon lock-in, Energy Policy 28 (12) (2000) 817–830.
[15] F.W. Geels, The multi-level perspective on sustainability transitions: responses to seven criticisms, Environ. Innov. Soc. Trans. 1 (1) (2011) 24–40.
[16] M. Burke, J.C. Stephens, Political power and renewable energy futures: a critical review, Energy Res. Soc. Sci. 35 (2018) 78–93.
[17] P. Newell, J. Phillips, Necropolitics and climate justice: sovereignty, sacrifice and the sacred on the frontlines of global heating, Geopolitics 27 (1) (2020) 131–153.
[18] D. Ohlhorst, Just energy transitions or green colonialism? Contesting external finance mechanisms in the global south, Glob. Transit. 4 (2022) 32–42.
[19] R. Pawson, et al., Realist review - a new method of systematic review designed for complex policy interventions, J. Health Serv. Res. Policy 10 (1) (2005) 21–34.
[20] Ray Pawson, Evidence-Based Policy, SAGE, London, 2006.
[21] C. Cameron, et al., Realist review on just transition – approach paper, IEU approach paper (May 2023), Independent Evaluation Unit, Green Climate Fund, Songdo, South Korea, 2023.
[22] C.Q. Schneider, C. Wagemann, Set-Theoretic Methods for the Social Sciences, Cambridge University Press, 2012.

[23] X. Wang, K. Lo, Just transition: a conceptual review, Energy Res. Soc. Sci. 82 (2021).
[24] ILO, "Guidelines for a just transition towards environmentally sustainable economies and societies for all." 2 February. Geneva, Switzerland, 2016.
[25] Climate Investment Funds & CSIS, Just Transitions in Coal-Dependent Communities, 2021.
[26] K. Jenkins, et al., Energy justice: a conceptual review, Energy Res. Soc. Sci. 11 (2016) 174–182.
[27] C.C. Ragin, The Comparative Method: Moving beyond Qualitative and Quantitative Strategies, University of California Press, 1987.
[28] C.C. Ragin, Redesigning Social Inquiry: Fuzzy Sets and beyond, University of Chicago Press, 2008.
[29] De Weger E. others 2020 What's in a realist configuration? Deciding which causal configurations to use, how, and why Int J Qual Methods 19.
[30] R. El Sherif, P. Pluye, Q.N. Hong, B. Rihoux, Using qualitative comparative analysis as a mixed methods synthesis in systematic mixed studies reviews: guidance and a worked example, Res. Synth. Methods 15 (1) (2024) 450–465.
[31] C. Rubinson, M. Jayawardena, R. Watkins, J. Butscher, N. Berrah, Qualitative Comparative Analysis: Exploring Causal Links for Scaling up Investments in Renewable Energy, World Bank Publications, 2022.
[32] K.C. Longest, S. Vaisey, Fuzzy: a program for performing qualitative comparative analyses (QCA) in Stata, Stata J. 8 (1) (2008) 79–104.
[33] C.Q. Schneider, C. Wagemann, Standards of good practice in qualitative comparative analysis (QCA) and fuzzy-sets, Comp. Sociol. 9 (3) (2010) 397–418.