

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

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ABSTRACT: Energy transitions are frequently framed as investment-led transformations, yet many countries continue to experience persistent gaps between policy ambition, financial mobilization, and realized deployment. This study argues that such gaps cannot be explained by policy design or capital availability alone, but arise from misaligned social and governance feedbacks embedded within transition systems. Drawing on expert elicitation and recent Energy Justice scholarship, the study develops a justice-sensitive causal loop diagram (CLD) that conceptualizes distributional, procedural, recognition, and intergenerational justice as endogenous mechanisms shaping transition dynamics.

Using carbon capture and storage (CCS/CCUS) and new renewable energy (NRE) pathways as illustrative cases, the analysis synthesizes expert-derived causal structures with theory-enriched justice constructs to identify reinforcing and balancing feedbacks governing implementation performance, investment effectiveness, and long-term system viability. The results reveal four structural mechanisms: (i) procedural justice functions as a deployment gate by conditioning governance legitimacy and implementation momentum; (ii) distributional injustice generates endogenous investment inefficiency through energy poverty and vulnerability feedbacks that suppress returns on investment; (iii) intergenerational justice operates as a dynamic risk regulator embedding future sustainability concerns into present policy responses; and (iv) recognition justice stabilizes transition viability by shaping human-centered design and performance evaluation.

Together, these mechanisms demonstrate that transition outcomes depend less on isolated policy instruments than on the alignment of justice-mediated feedback regimes. Transitions characterized by strong financial commitment but weak participation or unresolved vulnerability are structurally prone to stagnation. By formalizing Energy Justice as a dynamic governance architecture rather than a normative checklist, the study provides a systems-based explanation for persistent implementation failure and offers policy-relevant insight into designing transition strategies that align social inclusion with sustained deployment.

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KEYWORDS: Energy Justice; Transition Governance; Causal Loop Modeling; Socio-Technical Systems; CCS/CCUS and Renewable Energy; Feedback Dynamics.

I. INTRODUCTION

Energy transitions are increasingly understood as large-scale socio-technical transformations that require coordinated change across technological, institutional, financial, and social domains. Although policy discourse often prioritizes renewable deployment targets and investment mobilization, accumulating evidence suggests that transition outcomes are shaped less by isolated instruments than by endogenous interactions among governance credibility, social inclusion, and system-level learning dynamics (Geels et al., 2020; Markard et al., 2020).

Recent scholarship highlights persistent discrepancies between financial commitments and realized deployment, particularly in emerging economies, where regulatory fragility, institutional incoherence, and social vulnerability interact to constrain implementation capacity (Sovacool et al., 2021; Cherp et al., 2021). These constraints become especially pronounced in transition pathways that combine capital-intensive mitigation strategies—such as carbon capture and storage (CCS/CCUS)—with rapid scale-up of new renewable energy (NRE). While CCS is increasingly promoted as a bridging option for hard-to-abate sectors, concerns persist regarding its distributive implications, governance complexity, and potential lock-in effects when deployed without parallel social safeguards (Markusson et al., 2020; Carton et al., 2020).

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

In response to these challenges, Energy Justice has emerged as a central analytical framework for evaluating transition pathways beyond technical efficiency. Contemporary Energy Justice literature commonly distinguishes four interrelated dimensions: distributional justice (allocation of costs and benefits), procedural justice (participation and decision legitimacy), recognition justice (attention to vulnerable or marginalized groups), and intergenerational justice (long-term societal accountability) (Sovacool et al., 2021; Jenkins et al., 2021). Despite their widespread use as normative assessment criteria, these dimensions are rarely operationalized as endogenous system mechanisms shaping transition dynamics.

This limitation reflects a broader gap in transition governance research. Justice considerations are typically treated as external constraints or ex post evaluation metrics, rather than as feedback-generating variables that actively influence investment behavior, policy effectiveness, and implementation trajectories (Newell et al., 2021; Pickering et al., 2022). Consequently, dominant analytical approaches struggle to explain why ambitious climate targets frequently coexist with stalled deployment, persistent energy poverty, and declining public trust.

Systems-oriented scholarship increasingly argues that such outcomes arise from misaligned feedback structures rather than policy insufficiency per se (Sterman et al., 2021; Köhler et al., 2020). From this perspective, energy transitions constitute complex adaptive systems characterized by reinforcing and balancing loops linking social legitimacy, governance performance, economic returns, and sustainability expectations. Without explicit representation of these feedback architectures, transition analysis risks reproducing linear narratives that obscure structural constraints.

Causal Loop Diagrams (CLDs) offer a qualitative system dynamics approach for formalizing such feedback structures, enabling the integration of institutional, economic, and social variables within a unified causal framework (Kim & Andersen, 2012; Yearworth & White, 2013). Recent studies demonstrate the value of CLDs in revealing policy resistance, path dependence, and unintended consequences in sustainability transitions (Köhler et al., 2020; Sterman et al., 2021). However, Energy Justice constructs remain largely absent from CLD-based transition models, limiting their capacity to address equity, legitimacy, and intergenerational accountability as structural drivers.

This study addresses this gap by advancing a justice-sensitive causal systems framework for energy transition governance. Rather than treating justice as an external normative lens, we conceptualize distributional, procedural, recognition, and intergenerational justice as endogenous feedback mechanisms embedded within transition dynamics.

Specifically, the study develops a justice-sensitive Causal Loop Diagram that integrates expert-derived causal structures with focused Energy Justice scholarship. CCS/CCUS and NRE are employed as illustrative transition pathways, while Indonesia serves as an empirical anchor for expert elicitation rather than as a case-bound analytical endpoint. The objective is conceptual: to formalize how justice-mediated feedback structures condition investment effectiveness, governance credibility, and long-term system viability.

The contribution of this research is threefold. First, it advances Energy Justice from an evaluative framework to a dynamic governance architecture by embedding justice dimensions directly within causal feedback loops. Second, it introduces a reproducible qualitative–systems methodology combining expert elicitation, adjacency screening, and theory-enriched CLD synthesis. Third, it derives structural propositions explaining how procedural legitimacy, distributional inclusion, intergenerational accountability, and social recognition jointly shape transition trajectories.

By reframing energy transition as a justice-mediated feedback system rather than a linear policy problem, this study provides a conceptual foundation for designing governance interventions that align social inclusion with technological and financial transformation.

II. METHODOLOGY

A. Research Design and Epistemological Positioning

This study adopts a qualitative–systems multimethodology to construct a justice-sensitive causal representation of national energy transition dynamics. The research follows a sequential abductive design integrating expert-based qualitative inquiry, systematic literature review (SLR), and causal loop diagram (CLD) synthesis.

Rather than imposing predefined theoretical constructs, causal structure is initially elicited inductively from expert interviews and subsequently extended through focused literature integration. This approach reflects an empirically anchored, theory-extended modeling strategy in which primary qualitative evidence establishes endogenous system architecture, while contemporary theory is introduced ex post to enhance interpretive depth.

Such abductive integration—progressing from empirical discovery toward theory-informed explanation—is widely regarded as appropriate for complex socio-technical systems, where neither purely inductive nor purely deductive approaches adequately capture feedback-driven dynamics (Dubois & Gadde, 2002; Bryman, 2016).

B. Expert Interviews and Qualitative Coding

Primary empirical material was obtained through two semi-structured expert interviews (45–60 minutes each), involving an Emeritus Professor from a leading academic institution and a former Director General of Oil and Gas. Participants were purposively

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

selected to provide system-level insight across governance arrangements, institutional coordination, investment processes, and social implications of energy transition.

Interviews were transcribed verbatim and analyzed using manual qualitative coding procedures comprising open, axial, and selective stages (Strauss & Corbin, 1998). Open coding identified initial concepts, axial coding organized these into relational categories, and selective coding consolidated core constructs representing endogenous system elements.

Following the multimethodology framework proposed by Yearworth and White (2013), causal relationships were explicitly developed during axial coding, allowing feedback structures to emerge directly from qualitative material rather than being imposed post hoc. In this design, qualitative data function not merely as thematic evidence but as structural input for causal modeling.

Unlike classical grounded theory, which emphasizes theory generation through saturation, this study employs expert judgment to elicit causal architecture suitable for systems analysis. Semi-structured interviews are therefore used to identify mechanisms and interdependencies rather than to support population-level generalization.

C. Adjacency Matrix Construction and Semi-Quantitative Screening

Causal relationships identified during axial coding were translated into a directed adjacency matrix, where each cell records the frequency with which a causal link appeared across coded segments. This frequency-weighted representation enables semi-quantitative screening of qualitative relationships.

To suppress incidental associations while retaining structurally salient links, a threshold value greater than two (>2) was applied. Only relationships exceeding this threshold were retained for further modeling. This procedure operationalizes qualitative salience while preserving directional causality, consistent with established causal mapping practices in system dynamics-informed qualitative research (Yearworth & White, 2013; Kim & Andersen, 2012).

The resulting adjacency matrix constitutes the empirical backbone of the CLD, ensuring that modeled feedback structures originate from expert-derived causal understanding rather than literature abstraction.

D. Social Thematic Filtering Based on the Triple Bottom Line

To focus analysis on social sustainability, variables were thematically filtered using the social dimension of the Triple Bottom Line framework (Elkington, 1997). Only variables directly belonging to, or exerting explicit influence on, social outcomes—such as participation, vulnerability, access, legitimacy, and affordability—were retained.

Economic or technical constructs were preserved only when they demonstrated direct social coupling (e.g., energy affordability or investment optimization affecting access or vulnerability). This process yielded a socially centered causal subsystem while maintaining endogenous interdependence across governance, economic, and environmental domains.

E. Systematic Literature Review under Energy Justice

A focused SLR was conducted to extend and theoretically contextualize the empirically derived causal structure. The review targeted Q1 journal articles published within the past five years, indexed primarily in Scopus and supplemented by publisher-level screening across Elsevier, Wiley, Springer, and Taylor & Francis.

The review followed PRISMA 2020 guidelines (Page et al., 2021), documenting identification, screening, eligibility assessment, and inclusion. Search strings combined terms related to energy justice, social sustainability, governance, participation, equity, and energy transition. Only peer-reviewed research articles were included.

Importantly, the SLR does not replace interview-derived structure. Instead, it serves a theory-enrichment function, identifying justice-related mechanisms that extend, refine, and validate existing causal pathways. This sequencing distinguishes the present study from SLR-first conceptual modeling: empirical causality precedes literature integration.

F. Energy Justice as Analytical Lenses

Energy Justice dimensions—distributional, procedural, recognition, and intergenerational—are introduced after empirical structure formation and applied as analytical lenses rather than coding frames.

Distributional justice informs interpretation of allocational outcomes such as energy access and affordability; procedural justice contextualizes governance quality and participation; recognition justice captures vulnerability and marginalization; and intergenerational justice frames long-term societal consequences.

Crucially, these dimensions were not imposed during qualitative coding. Instead, they were applied ex post to organize and reinterpret empirically identified variables. This abductive integration avoids deductive bias while enabling theoretically informed reinterpretation of grounded causal structures, consistent with methodological guidance on combining qualitative systems modeling with normative frameworks (Fraser, 2009; Sovacool et al., 2017).

G. Causal Loop Diagram Synthesis

Filtered adjacency relationships and justice-enriched variables were synthesized into a CLD using Graphviz. Polarity was represented structurally through positive and negative subgraphs rather than textual edge labels, ensuring formal consistency with system dynamics conventions.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

The CLD integrates reinforcing and balancing feedback loops spanning social vulnerability, energy access, stakeholder participation, governance effectiveness, sustainability outcomes, and justice dimensions. Bidirectionality and interdependence are explicitly preserved, preventing linearization of socio-technical dynamics.

This synthesis yields a justice-sensitive causal architecture that reflects endogenous feedback behavior rather than exogenous policy pathways.

H. Methodological Contribution

Methodologically, this study advances an empirically anchored, theory-extended CLD construction framework integrating:

- expert-based qualitative coding
- semi-quantitative adjacency screening
- PRISMA-governed SLR
- abductive Energy Justice reinterpretation

This approach moves beyond purely conceptual diagrams by grounding causal structure in expert judgment while leveraging contemporary justice scholarship to enhance analytical depth, offering a reproducible pathway for embedding social legitimacy into system dynamics-informed transition modeling.

I. Methodological Limitations

Several limitations warrant acknowledgment. First, the causal structure is derived from a small number of purposively selected expert interviews. While this constrains statistical generalizability, the study does not aim at population-level inference. Instead, it adopts an expert judgment-based system elicitation approach to capture high-level institutional, governance, and socio-technical mechanisms, consistent with established practice in system dynamics modeling.

Second, causal relationships were identified through manual qualitative coding and subsequently screened using a frequency-based threshold. Although this introduces interpretive judgment, the procedure enhances transparency by explicitly documenting how qualitative salience is translated into causal structure. The adjacency matrix thus functions as a structural filter rather than a quantitative estimator.

Third, Energy Justice constructs were introduced after primary qualitative analysis and applied as analytical lenses rather than coding frames. This sequential design may omit justice dimensions not surfaced in expert narratives; however, it intentionally avoids deductive bias by allowing empirical structure to emerge prior to theoretical enrichment.

Fourth, the CLD represents conceptual system architecture rather than a fully parameterized simulation model. Accordingly, the analysis emphasizes structural dynamics and feedback dominance rather than numerical prediction, providing explanatory insight and a foundation for subsequent stock-flow formalization.

Finally, the SLR was confined to recent Q1 Energy Justice publications. While this ensures conceptual rigor and topical relevance, future research could broaden database coverage, expand expert panels, and operationalize the model quantitatively for scenario evaluation.

J. Reproducibility and Transparency Statement

To enhance transparency and reproducibility, each stage of the qualitative-systems modeling pipeline is explicitly documented, including interview design, coding procedures, adjacency matrix construction, literature review protocol, and CLD synthesis.

Reproducibility is ensured at the procedural level through clearly defined steps: (i) semi-structured interviews, (ii) open-axial-selective coding, (iii) frequency-based screening using an explicit threshold, (iv) Triple Bottom Line social filtering, (v) PRISMA-guided literature selection, and (vi) formal CLD construction using Graphviz.

All variables and causal linkages originate from either coded interview material or explicitly referenced literature. The adjacency matrix serves as an intermediate artifact linking qualitative evidence to system structure, enabling independent reconstruction of the causal architecture.

While exact replication of expert judgments is neither expected nor desirable in complex socio-technical systems research, the analytical workflow itself is fully reproducible. Future studies may apply the same protocol across alternative national contexts or expanded expert panels.

By prioritizing procedural transparency over numerical determinism, this study aligns with established qualitative system dynamics practice, where reproducibility is achieved through explicit methodological documentation rather than identical model outputs.

III. RESULT

A. Structural Configuration of the Justice-Sensitive Transition System

The integrated causal loop diagram (CLD) synthesizes expert-derived social variables and Energy Justice constructs into a multi-layered socio-technical architecture characterized by dense feedback interdependencies (Figure 1). Rather than forming a linear progression from policy to outcomes, the system exhibits recursive coupling between social legitimacy, governance effectiveness, investment performance, and sustainability trajectories.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

Two variables—Social Impact and Human Existence—emerge as structural attractors, concentrating multiple causal pathways and anchoring system-wide dynamics. These nodes mediate interactions between distributional outcomes (access and affordability), procedural processes (participation and agreement), recognition mechanisms (vulnerability and equity), and intergenerational considerations (future scenarios and climate justice).

Energy Justice dimensions—distributional, procedural, recognition, and intergenerational—are not appended as evaluative criteria but embedded directly within feedback loops governing system behavior. Literature-derived justice constructs identified through the focused SLR reinforce empirically grounded causal mechanisms and are mapped onto existing pathways, as summarized in Table I.

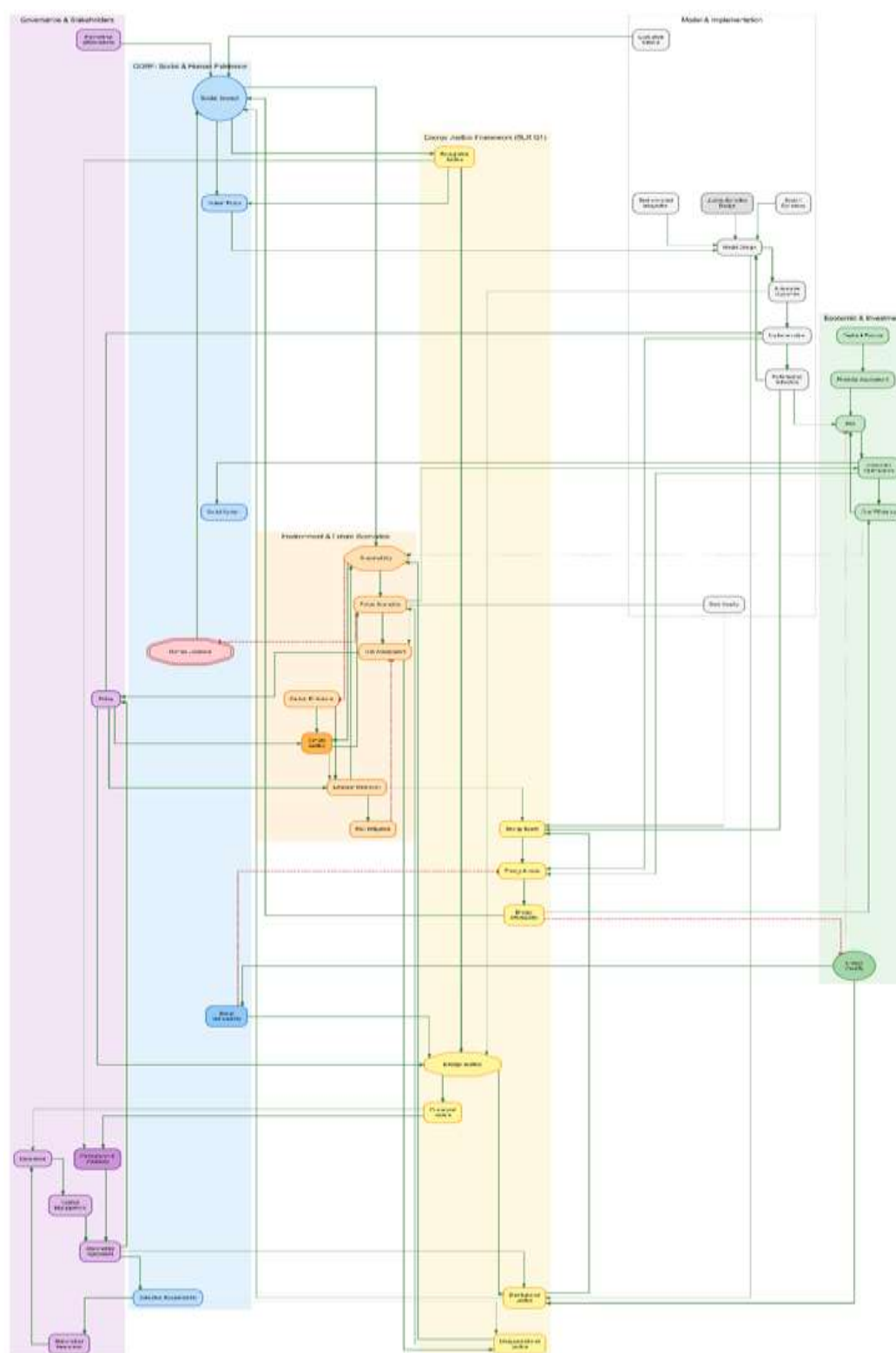


Figure 1. Integrated Justice-Sensitive Causal Loop Diagram of the National Energy Transition System

Table I. Energy Justice Constructs Identified from Q1 Literature and Their Mapping to CLD Variables

Edge (From → To)	Status	Statement/Quotation	Paper (Format APA)
Energy_Justice → Distributional_Justice	SLR	"Energy justice comprises three core tenets: distributional justice (where benefits and burdens are distributed equitably), procedural justice (who participates in decision-making), and recognition justice (who is recognized as a legitimate stakeholder)."	Heffron, R. J., & McCauley, D. (2017). The concept of energy justice across the disciplines. <i>Energy Policy</i> , 105, 658-667.
Distributional_Justice → Energy_Equity	SLR	"Distributional justice in energy systems requires attention to equity in both the spatial and social distribution of energy infrastructure, ensuring that vulnerable populations are not disproportionately burdened."	Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. <i>Energy Research & Social Science</i> , 11, 174-182.
Energy_Equity → Energy_Access	SLR	"Energy equity necessitates universal access to modern energy services as a basic human right, particularly for marginalized communities in both developed and developing nations."	Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. <i>Applied Energy</i> , 142, 435-444.
Energy_Access → Energy_Affordability	SLR	"Access to energy must be accompanied by affordability to avoid energy poverty, which affects both physical access and the ability to pay for sufficient energy services."	Bouzarovski, S., & Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty-fuel poverty binary. <i>Energy Research & Social Science</i> , 10, 31-40.
Energy_Affordability → Social_Impact	SLR	"Affordable energy directly enhances social well-being by reducing energy poverty, improving health outcomes, and enabling economic opportunities for low-income households."	Walker, G., & Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. <i>Energy Policy</i> , 49, 69-75.
Social_Impact → Recognition_Justice	SLR	"Positive social impact requires recognition justice—acknowledging diverse cultural values, knowledge systems, and the specific needs of marginalized groups in energy transitions."	McCauley, D., & Heffron, R. (2018). Just transition: Integrating climate, energy and environmental justice. <i>Energy Policy</i> , 119, 1-7.
Procedural_Justice → Participation_Inclusivity	SLR	"Procedural justice demands inclusive participation in energy decision-making, ensuring that affected communities have meaningful voice and influence in policies that affect them."	Jenkins, K. E. H. (2018). Setting energy justice apart from the crowd: Lessons from environmental and climate justice. <i>Energy Research & Social Science</i> , 39, 117-121.
Intergenerational_Justice → Sustainability	SLR	"Intergenerational justice is fundamental to sustainability, requiring that present energy decisions do not compromise the ability of future generations to meet their needs."	Gonzalez, C. G. (2020). Climate justice, human rights, and the global South. <i>University of Pennsylvania Journal of International Law</i> , 41(1), 1-50.
Energy_Poverty → Social_Vulnerability	SLR	"Energy poverty exacerbates social vulnerability, creating a vicious cycle where lack of access to modern energy services reinforces existing social and economic inequalities."	Middlemiss, L., & Gillard, R. (2015). Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor. <i>Energy Research & Social Science</i> , 6, 146-154.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

Climate_Justice → Emission_Reduction	SLR	"Climate justice demands that emission reduction strategies consider historical responsibility and differentiated capabilities, ensuring that climate action does not perpetuate existing injustices."	Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: Climate change and the discourse of environmental justice. <i>WIREs Climate Change</i> , 5(3), 359-374.
Justice_Sensitive_Design → Model_Design	SLR	"Energy system models must incorporate justice-sensitive design principles to avoid reinforcing existing inequalities and to proactively identify pathways that enhance energy justice."	Miller, C. A., Richter, J., & O'Leary, J. (2015). Socio-energy systems design: A policy framework for energy transitions. <i>Energy Research & Social Science</i> , 6, 29-40.
Policy_Energy_Justice	SLR	"Energy policies must explicitly embed justice considerations to ensure that the benefits and burdens of energy transitions are distributed fairly across society."	McCauley, D., Ramasar, V., Heffron, R. J., Sovacool, B. K., Mebratu, D., & Mundaca, L. (2019). Energy justice in the transition to low carbon energy systems: Exploring key themes in interdisciplinary research. <i>Applied Energy</i> , 233-234, 916-921.
Stakeholder_Agreement → Distributional_Justice	SLR	"Meaningful stakeholder agreements must address distributional justice concerns, ensuring that all parties benefit equitably from energy projects and policies."	Van Veelen, B., & Van der Horst, D. (2018). What is energy democracy? Connecting social science energy research and political theory. <i>Energy Research & Social Science</i> , 46, 19-28.
Energy_Access → Sustainability	SLR	"Universal energy access is a prerequisite for sustainable development, enabling the delivery of other Sustainable Development Goals while ensuring environmental protection."	Pachauri, S., van Ruijven, B. J., Nagai, Y., Riahi, K., van Vuuren, D. P., Brew-Hammond, A., & Nakicenovic, N. (2013). Pathways to achieve universal household access to modern energy by 2030. <i>Environmental Research Letters</i> , 8(2), 024015.
Social_Vulnerability → Energy_Justice	SLR	"Addressing social vulnerability is central to energy justice, requiring targeted interventions that account for differential capacities to adapt to energy transitions."	Bickerstaff, K., Walker, G., & Bulkeley, H. (2013). Energy justice in a changing climate: Social equity and low-carbon energy. Zed Books.
Recognition_Justice → Human_Focus	SLR	"Recognition justice deepens human-centered approaches by validating diverse cultural perspectives, indigenous knowledge, and local experiences in energy system design."	Whyte, K. P. (2017). The Dakota Access Pipeline, environmental injustice, and US colonialism. <i>Red Ink: An International Journal of Indigenous Literature, Arts, & Humanities</i> , 19(1), 154-169.
Future_Scenarios → Intergenerational_Justice	SLR	"Future scenario planning must incorporate intergenerational justice to evaluate the long-term impacts of current energy decisions on future generations."	Gardiner, S. M. (2011). A perfect moral storm: The ethical tragedy of climate change. Oxford University Press.
Performance_Indicators → Energy_Equity	SLR	"Performance indicators for energy systems must include equity metrics to monitor and ensure that benefits are distributed fairly across different population segments."	Groh, S., Pachauri, S., & Rao, N. D. (2016). What are we measuring? An empirical analysis of household electricity access metrics in rural Bangladesh. <i>Energy for Sustainable Development</i> , 30, 21-31.
Data_Quality → Energy_Equity	SLR	"High-quality, disaggregated data is essential for assessing energy equity, particularly to understand differential impacts on vulnerable and marginalized populations."	Delina, L. L., & Sovacool, B. K. (2018). Of temporality and plurality: An epistemic and governance agenda for accelerating just transitions for energy access and sustainable development. <i>Current Opinion in Environmental Sustainability</i> , 34, 1-6.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

Carbon_Emissions → Climate_Justice	SLR	"Disparities in carbon emissions between and within nations raise fundamental questions of climate justice, as the poorest populations contribute least but suffer most from climate impacts."	Roberts, J. T., & Parks, B. C. (2009). Ecologically unequal exchange, ecological debt, and climate justice: The history and implications of three related ideas for a new social movement. <i>International Journal of Comparative Sociology</i> , 50(3-4), 385-409.
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B. Social Core and Existential Dynamics

At the center of the system lies a reinforcing existential loop connecting Human Existence → Social Impact → Sustainability → Future Scenarios → Human Existence, with negative closure from Future Scenarios back to Human Existence (Figure 2). This structure internalizes long-term societal consequences into present system behavior: improvements in social impact strengthen sustainability outcomes, shaping favorable future scenarios that reinforce conditions for human existence, while deteriorating future scenarios exert destabilizing intergenerational effects.

Social Impact further propagates through Human Focus into Model Design, creating a feedback pathway whereby social considerations directly influence implementation architecture. This mechanism embeds recognition-oriented priorities into technical decision processes, ensuring that human-centered values are structurally encoded within model formulation rather than treated as downstream evaluation metrics.

The social core thus functions as an endogenous viability regulator: transition pathways are sustained not solely by financial or technological factors but by reinforcing interactions between social well-being and future system expectations.

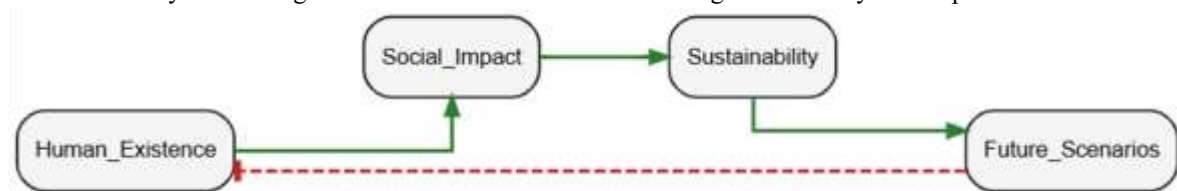


Figure 2. Existential Social Core Feedback Loop

C. Distributional Justice: Energy Access and Vulnerability Regime

Distributional justice dynamics emerge through a tightly coupled subsystem linking Energy Access, Energy Affordability, Energy Poverty, Social Vulnerability, and Social Impact (Figure 3.3). Increased affordability reduces energy poverty, which lowers social vulnerability and reinforces both energy justice and social impact. Conversely, elevated vulnerability constrains energy access, forming a balancing mechanism that suppresses transition benefits even under favorable policy or investment conditions.

Economic variables enter this regime through Cost Efficiency and Investment Optimization, which influence affordability and access. However, Energy Poverty directly reduces Return on Investment (ROI), introducing a social-cost feedback whereby distributional inequities erode financial performance. This negative coupling reveals that marginalized access conditions generate endogenous investment inefficiencies.

The resulting structure constitutes a distributional constraint regime in which social deprivation actively destabilizes economic loops, demonstrating that financial optimization alone cannot sustain transition momentum unless vulnerability and access barriers are simultaneously addressed.

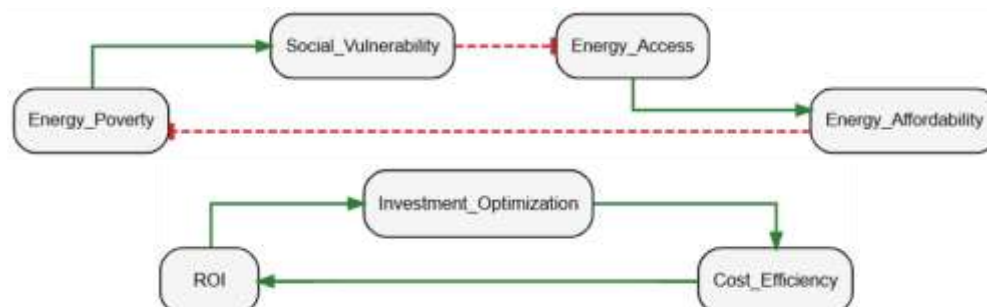


Figure 3. Distributional Justice and Energy Poverty Feedback Structure

D. Procedural Justice as a Governance Amplifier

Procedural justice is organized around a reinforcing governance loop:

Stakeholder Awareness → Discussion → Conflict Management → Stakeholder Agreement → Collective Responsibility → Stakeholder Awareness (Figure 4). This loop converts participation into agreement and collective responsibility, strengthening governance coherence.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

Participation and Inclusivity further reinforce stakeholder agreement and policy formation, which subsequently amplify energy justice outcomes. Policy feeds directly into Implementation, forming a governance–execution pathway in which participatory legitimacy conditions deployment capacity.

When participation weakens or conflicts remain unresolved, stakeholder agreement collapses, truncating policy effectiveness and suppressing downstream implementation regardless of financial availability. Procedural justice therefore operates as a structural gate: degradation in participatory processes disables reinforcing deployment dynamics even in the presence of investment capital.

This configuration highlights governance credibility as an endogenous driver rather than an exogenous institutional backdrop.

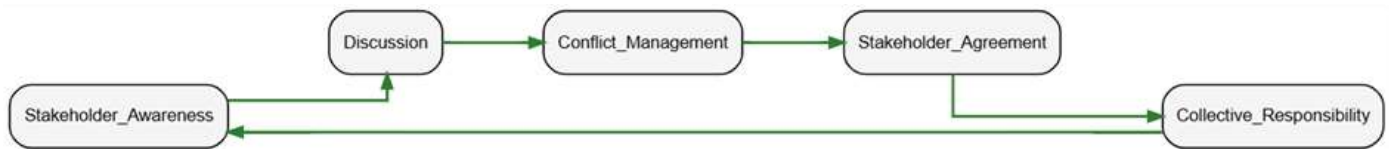


Figure 4. Procedural Justice and Stakeholder Governance Loop

E. Implementation Cycle and Model Learning Dynamics

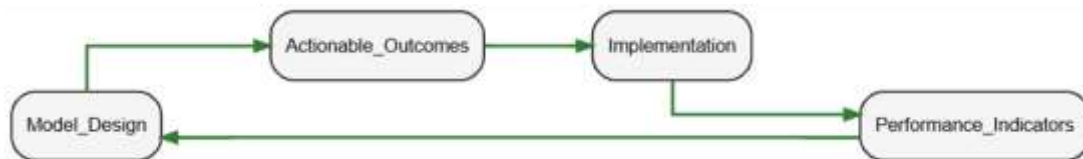


Figure 5. Implementation–Learning Reinforcing Cycle

Figure 5 represents a reinforcing implementation–learning cycle connecting Model Design, Actionable Outcomes, Implementation, and Performance Indicators. Model design generates actionable outcomes, which guide implementation. Implementation performance is subsequently measured through performance indicators, which feed back into model design.

This loop establishes implementation not as a terminal stage but as a learning process, where performance measurement actively reshapes design assumptions. The feedback from performance indicators does not directly modify social outcomes; instead, it recalibrates technical and analytical design choices, enabling iterative refinement of decision frameworks.

Structurally, this loop embeds adaptive governance into the modeling architecture. Implementation failures or underperformance do not merely reduce outcomes but propagate backward, prompting redesign and reconfiguration. As such, policy learning and technical adjustment emerge as endogenous system properties rather than external evaluation steps.

F. Emissions–Sustainability Balancing Feedback

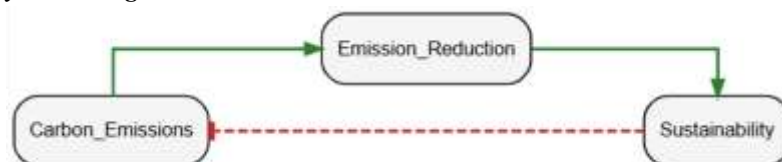


Figure 6. Emissions–Sustainability Balancing Feedback

Figure 6 captures a balancing environmental feedback linking Carbon Emissions, Emission Reduction, and Sustainability. Rising carbon emissions trigger emission reduction efforts, which enhance sustainability. Sustainability, in turn, exerts a negative effect on carbon emissions, closing the loop.

This structure formalizes environmental regulation as a self-correcting mechanism rather than a linear mitigation pathway. Emission reduction is not modeled as a one-way policy outcome but as a response activated by environmental degradation signals. Sustainability therefore functions both as an outcome and as a regulatory force that constrains future emissions.

Importantly, this loop interacts with governance and justice structures rather than operating in isolation. Emission reduction strengthens sustainability, which feeds into climate justice and future scenarios in higher-order loops, indicating that environmental stabilization contributes indirectly to social legitimacy and long-term risk governance.

G. Recognition Justice and Equity-Oriented Model Design

Recognition justice operates through feedback pathways linking Social Vulnerability, Energy Equity, Recognition Justice, Human Focus, and Model Design (Figure 7.). Vulnerability feeds into justice constructs, while recognition mechanisms redirect attention toward marginalized groups, shaping human-centered modeling priorities.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

Data Quality reinforces this loop by strengthening equity assessment and risk evaluation, underscoring the role of informational infrastructure in recognizing social disparities. This feedback embeds vulnerable populations within the system architecture rather than treating them as external beneficiaries.

Recognition justice therefore functions not only as a normative principle but as a structural mechanism influencing how models prioritize social groups and allocate attention within decision processes.

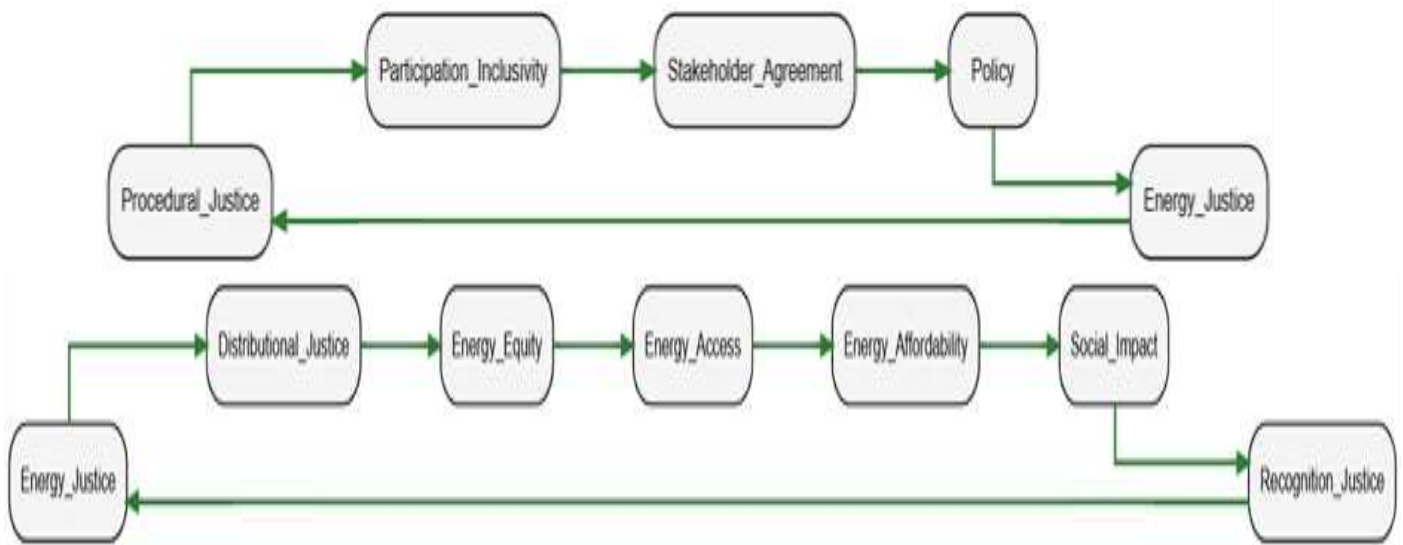


Figure 7. Recognition Justice and Equity-Oriented Design Loop

H. Intergenerational Justice and Risk–Sustainability Coupling

Intergenerational justice emerges through a reinforcing loop connecting Intergenerational Justice → Sustainability → Climate Justice → Future Scenarios → Risk Assessment → Intergenerational Justice (Figure 3.6). Sustainability improvements strengthen climate justice and future outlooks, recalibrating risk perception and reinforcing long-term societal considerations.

A complementary balancing loop links Risk Assessment → Policy → Emission Reduction → Risk Mitigation → Risk Assessment, while Sustainability simultaneously suppresses Carbon Emissions. These interacting loops integrate long-term justice concerns into short-term policy responses, structurally internalizing future accountability into present governance.

This configuration demonstrates that intergenerational considerations are embedded within operational risk management rather than confined to abstract sustainability discourse.

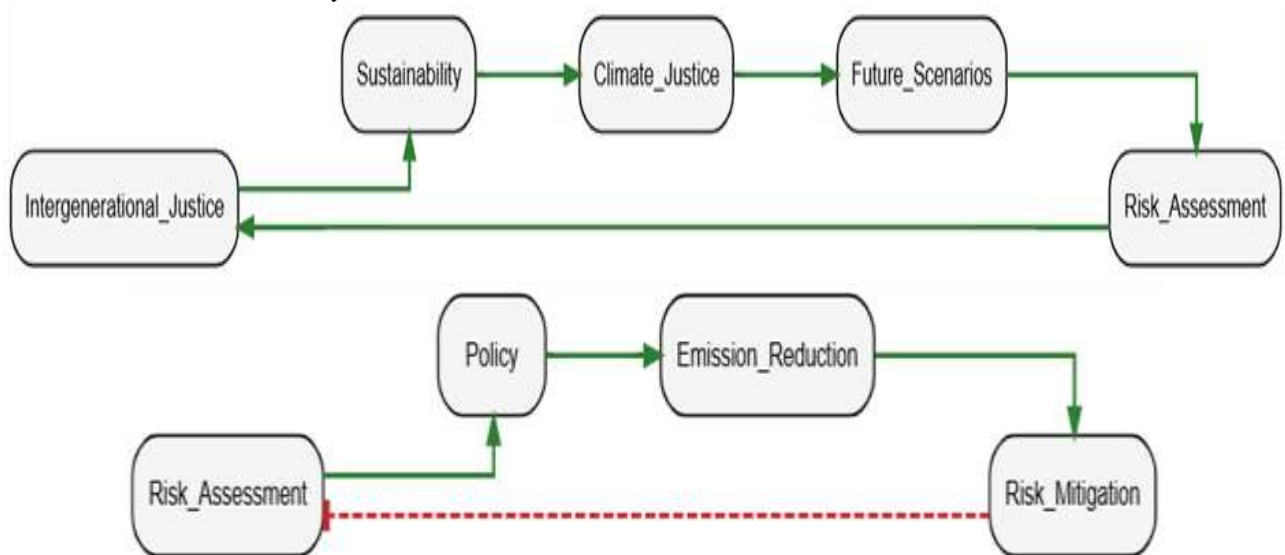


Figure 8. Intergenerational Justice and Risk–Sustainability Feedback

I. Economic–Social Coupling and Implementation Performance

Economic performance is governed by a reinforcing loop involving Financial Assessment, Payback Factors, Investment Optimization, Cost Efficiency, and ROI (Figure 9). This loop interacts directly with social variables via affordability, access, and poverty pathways.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

Performance Indicators reinforce ROI and energy equity, indirectly shaping subsequent investment optimization and justice outcomes. Actionable Outcomes and Implementation further reinforce energy justice and energy access, translating technical execution into social benefits.

However, the negative feedback from energy poverty to ROI introduces a destabilizing mechanism whereby persistent inequities erode financial returns, weakening reinvestment capacity. Social deprivation thus becomes structurally embedded within investment dynamics rather than remaining external to economic performance.

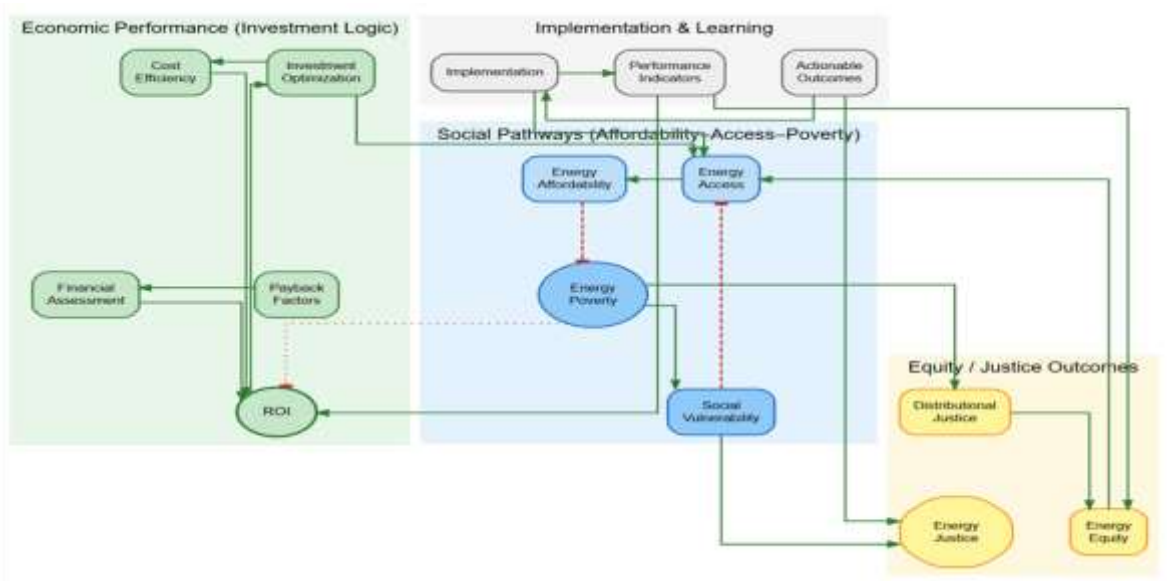


Figure 9. Economic–Social Investment Feedback Structure

J. Structural Anatomy of the Justice-Sensitive Model

To clarify the internal organization of the synthesized causal architecture, Table 3.2 summarizes the principal reinforcing and balancing feedback loops identified in the CLD, including their dominant variables and functional roles.

Rather than operating independently, these loops form nested structures that collectively govern system behavior. Reinforcing loops associated with social legitimacy (L4, L8), justice integration (L7, L9), economic performance (L2), and implementation (L5) generate momentum when alignment conditions are satisfied. In contrast, balancing loops related to risk regulation (L3), emissions control (L6), and social deprivation (L10) constrain unchecked growth and introduce stabilizing or destabilizing pressures.

The coexistence of multiple reinforcing loops with structurally embedded balancing mechanisms produces nonlinear system responses. Notably, the Energy Poverty Trap (L10) interacts directly with the Economic Engine (L2), revealing that distributional inequities act as endogenous dampers on financial performance. Similarly, the Risk Control loop (L3) and Emissions–Sustainability loop (L6) regulate environmental trajectories, while the Existential Social Core loop (L1) integrates long-term societal outcomes into present decision processes.

Together, these feedback structures constitute the model's structural anatomy, demonstrating that transition dynamics are governed by interdependent social, governance, economic, and environmental mechanisms rather than isolated sectoral drivers.

Table II. Summary of Reinforcing and Balancing Feedback Loops Identified in the CLD

Loop ID	Loop Name	Type	Dominant Variables	Primary Function
L1	Existential Social Core	Reinforcing (with negative closure)	Human_Existence, Social_Impact, Sustainability, Future_Scenarios	Couples social well-being with long-term viability
L2	Economic Engine	Reinforcing	ROI, Investment_Optimization, Cost_Efficiency	Drives financial performance
L3	Risk Control	Balancing	Risk_Assessment, Emission_Reduction, Risk_Mitigation, Policy,	Stabilizes perceived risk

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

L4	Stakeholder Consensus	Reinforcing	Stakeholder_Awareness, Agreement, Collective_Responsibility	Builds governance legitimacy
L5	Implementation Cycle	Reinforcing	Model_Design, Actionable_Outcomes, Implementation	Converts plans into outcomes
L6	Emissions–Sustainability	Balancing	Carbon_Emissions, Sustainability	Regulates environmental pressure
L7	Energy Justice Core	Reinforcing	Energy_Justice, Distributional_Justice, Energy_Access	Integrates justice into access
L8	Procedural Justice	Reinforcing	Participation_Inclusivity, Policy	Governance amplification
L9	Intergenerational Justice	Reinforcing	Sustainability, Climate_Justice, Risk_Assessment	Future-oriented accountability
L10	Energy Poverty Trap	Balancing / Destabilizing	Energy_Poverty, Social_Vulnerability, ROI	Structural deprivation constraint

Emergent Feedback Regimes and Transition Implications

Beyond individual loops, system behavior is shaped by higher-order feedback regimes emerging from loop interactions. As synthesized in Table III, three dominant regimes characterize the justice-sensitive transition system.

The Social–Governance Reinforcement Regime integrates stakeholder participation, agreement formation, policy legitimacy, and justice outcomes, enabling deployment momentum when procedural conditions are met. The Distributional Constraint Regime couples energy poverty, social vulnerability, access limitations, and reduced ROI, generating structural inefficiencies that suppress investment effectiveness under inequitable conditions. The Intergenerational Sustainability Regime links sustainability, climate justice, future scenarios, and risk perception, embedding long-term societal impacts into short-term governance responses.

These regimes do not operate sequentially but co-evolve dynamically. Strengthening one regime may be offset by degradation in another, producing asymmetric transition trajectories. For example, financial improvements can be neutralized by unresolved vulnerability, while strong governance processes may fail under persistent distributional inequities.

By elevating analysis from individual loops to regime-level dynamics, the results reveal that successful energy transition depends on coordinated alignment across social inclusion, governance credibility, and intergenerational accountability. These emergent regimes provide the analytical bridge between structural results and the theoretical and policy discussion developed in the following section.

Table III. Emergent Feedback Regimes and Their Systemic Implications

Regime	Constituent Loops	Key Variables	System Effect
Social–Governance Reinforcement	L4, L8, L7	Participation, Agreement, Policy, Energy_Justice, Social_Impact	Enables deployment through legitimacy
Distributional Constraint	L10, L2	Energy_Poverty, Social_Vulnerability, ROI	Produces capital–access decoupling
Intergenerational Sustainability	L1, L6, L9, L3	Sustainability, Climate_Justice, Risk_Assessment	Internalizes future impacts

K. Structural Propositions

Based on the emergent feedback regimes summarized in Table III, four structural propositions are derived to formalize the system-level mechanisms governing justice-sensitive energy transition dynamics.

P1. Governance–Justice Reinforcement Proposition: Energy transition momentum emerges only when procedural justice activates reinforcing feedback between stakeholder participation, agreement formation, policy legitimacy, and social impact. Formally, increases in Participation and Inclusivity strengthen Stakeholder Agreement, which enhances Policy effectiveness and reinforces Energy Justice, subsequently amplifying Social Impact. When this reinforcing loop is weakened—through low participation or unresolved conflict—policy implementation collapses regardless of financial availability. This proposition identifies procedural justice as a structural gate for deployment rather than a peripheral governance attribute.

P2. Distributional Constraint Proposition: Distributional inequities generate endogenous investment inefficiency by coupling energy poverty and social vulnerability with reduced return on investment. Higher Energy Poverty elevates Social Vulnerability, constrains Energy Access, and directly suppresses ROI, thereby weakening the Economic Engine loop. As a result, financial optimization alone cannot sustain transition progress unless vulnerability and access barriers are simultaneously addressed. This proposition reframes energy poverty from a social outcome into a core structural constraint on transition performance.

P3. Intergenerational Accountability Proposition: Long-term sustainability outcomes shape present governance behavior through reinforcing feedback between sustainability, climate justice, future scenarios, and risk perception. Improvements in Sustainability enhance Climate Justice and future outlooks, recalibrating Risk Assessment and reinforcing intergenerational considerations in policy responses. Conversely, deteriorating future scenarios destabilize current system viability. This proposition demonstrates that intergenerational justice operates as an endogenous regulatory mechanism, embedding future accountability within present decision-making.

P4. Social Viability Proposition: Social impact functions as an endogenous viability regulator of the transition system by linking human-centered outcomes to model design, sustainability trajectories, and economic performance. Elevated Social Impact strengthens Human Focus and influences Model Design, reinforcing sustainability and future system expectations. Degradation in social outcomes propagates backward through existential and economic loops, destabilizing both implementation capacity and investment returns. This proposition establishes social well-being as a structural driver of system stability rather than a downstream consequence.

Together, these propositions formalize how justice-mediated feedback structures condition energy transition trajectories, highlighting that sustainable deployment depends on the simultaneous alignment of governance legitimacy, distributional inclusion, intergenerational accountability, and social viability.

IV. DISCUSSION: JUSTICE-MEDIATED GOVERNANCE IN ENERGY TRANSITION SYSTEMS

This study advances Energy Justice from a normative evaluative framework to an endogenous structural mechanism shaping transition dynamics. Rather than treating justice dimensions as external criteria applied after policy implementation, the results demonstrate that distributional, procedural, recognition, and intergenerational justice operate as coupled feedback structures governing investment effectiveness, governance credibility, and long-term system viability.

By formalizing these dynamics through Structural Propositions P1–P4, the analysis reframes energy transition governance as a problem of feedback alignment rather than instrument selection. Transition outcomes emerge not from isolated policy interventions but from the co-evolution of social inclusion, institutional legitimacy, and future-oriented accountability.

A. Procedural Justice as a Structural Gate in Transition Governance (P1)

P1 reveals that procedural justice functions as a deployment gate rather than a peripheral governance attribute. Participation, stakeholder agreement, policy legitimacy, and social impact form a reinforcing loop that must be activated before implementation momentum can materialize.

This finding challenges dominant transition governance approaches that position participation as consultative support layered onto technocratic planning. In the modeled system, participation is not auxiliary; it is structurally constitutive. Weak stakeholder engagement disrupts agreement formation, suppresses policy effectiveness, and truncates implementation regardless of financial availability.

This mechanism reframes governance credibility as an endogenous system variable rather than an exogenous institutional condition. Transition governance therefore cannot be reduced to regulatory design or incentive alignment alone. Instead, it must be understood as a feedback-sensitive process in which legitimacy is continuously reproduced through deliberation, conflict management, and collective responsibility.

The implication is both theoretical and practical: procedural justice is not merely about fairness of process—it actively determines whether reinforcing deployment dynamics can emerge. Participation thus shifts from a democratic ideal to a structural precondition for transition viability.

Energy Justice as Governance Architecture: A Causal Loop Perspective on CCS and Renewable Energy Transitions

B. Distributional Justice and Structural Investment Inefficiency (P2)

P2 demonstrates that distributional injustice generates endogenous economic inefficiency through feedback coupling among energy poverty, social vulnerability, access constraints, and reduced return on investment.

Conventional transition frameworks implicitly assume that capital mobilization precedes social benefit: investment enables access, which improves welfare. The causal structure identified here reverses this logic. Unresolved energy poverty directly suppresses ROI, weakening reinvestment capacity and destabilizing the economic engine of transition.

This reframes distributional justice from a downstream social outcome into a core economic constraint. Inequitable access does not merely accompany weak transitions—it actively undermines financial performance from within the system.

Theoretically, this challenges linear models of green investment that treat inclusion as secondary impact. Instead, distributional justice emerges as an internal regulator of capital effectiveness. Transitions that neglect vulnerability risk entering a structural lock-in characterized by persistent financial inflows but stagnating deployment.

This mechanism offers a system-level explanation for the widely observed gap between investment commitments and realized transition outcomes, particularly in emerging economies.

C. Intergenerational Justice as an Endogenous Risk Regulator (P3)

P3 shows that intergenerational justice operates through a reinforcing loop linking sustainability, climate justice, future scenarios, and risk assessment, coupled with balancing mechanisms governing emission reduction and mitigation.

This configuration embeds future consequences directly into present governance behavior. Sustainability outcomes reshape climate justice perceptions, which influence expectations about future scenarios and recalibrate risk assessments, feeding back into policy responses.

Rather than functioning as an abstract ethical horizon, intergenerational justice becomes a dynamic risk signal modulating current decision-making. Long-term impacts are structurally internalized through feedback, not deferred to post hoc evaluation.

This challenges governance models that separate short-term policy optimization from long-term sustainability objectives. In the modeled system, future conditions actively govern present behavior. Intergenerational justice thus functions as a temporal coupling mechanism, aligning near-term actions with long-term societal viability.

D. Recognition Justice and Social Viability (P4)

P4 establishes social impact as an endogenous viability regulator linking recognition justice, human focus, model design, sustainability trajectories, and economic performance.

Recognition justice operates by redirecting attention toward marginalized groups, shaping human-centered design priorities and influencing how system performance is evaluated. Data quality reinforces this process by enabling equity-sensitive assessment and risk identification.

Crucially, degradation in social outcomes propagates backward through existential and economic loops, destabilizing both implementation capacity and ROI. Conversely, reinforcing social impact stabilizes transition pathways by strengthening sustainability expectations and governance legitimacy.

This demonstrates that social well-being is not a secondary benefit of transition but a structural stabilizer of the system itself. Recognition justice therefore functions as a design principle: when vulnerable populations are excluded, instability emerges across multiple domains.

The implication is fundamental—social inclusion is not merely ethically desirable; it is systemically necessary for maintaining transition coherence.

E. Toward a Justice-Mediated Model of Transition Governance

Taken together, P1–P4 articulate a justice-mediated governance model in which procedural justice enables deployment, distributional justice conditions investment efficiency, intergenerational justice regulates risk and sustainability, and recognition justice stabilizes social viability.

These dimensions do not operate independently. They co-evolve through interacting feedback regimes, producing nonlinear outcomes in which improvements in one domain may be offset by degradation in another.

This explains why transition strategies narrowly focused on finance, technology, or regulation often fail to deliver sustained transformation: they intervene in isolated subsystems while leaving justice-mediated feedback structures misaligned.

The core contribution of this study lies in formalizing Energy Justice as a dynamic governance architecture rather than a normative checklist. Transition success emerges from coordinated alignment across legitimacy, inclusion, accountability, and social viability—not from any single policy lever. In this framing, energy transition becomes fundamentally a problem of systemic coherence.

Table IV. Mapping State-of-the-Art Gaps to Structural Propositions

SOTA Limitation	Dominant Treatment in Literature	Structural Gap	Structural Proposition
Participation framed as consultative support	Procedural justice treated as governance quality indicator	Participation not structurally linked to deployment dynamics	P1. Governance–Justice Reinforcement Proposition
Energy poverty viewed as social outcome	Distributional justice evaluated post-deployment	Vulnerability disconnected from investment performance	P2. Distributional Constraint Proposition
Sustainability framed as future ethical concern	Intergenerational justice treated normatively	Future impacts not feeding back into present governance	P3. Intergenerational Accountability Proposition
Recognition justice treated as inclusion principle	Social recognition handled descriptively	Social well-being not embedded in system viability	P4. Social Viability Proposition

While existing scholarship treats Energy Justice as a normative lens applied to transition outcomes, this study demonstrates that procedural, distributional, recognition, and intergenerational justice operate as endogenous feedback mechanisms that structurally govern deployment, investment efficiency, risk regulation, and system viability.

V. CONCLUSION

This study reframes energy transition governance as a justice-mediated feedback system rather than a linear policy implementation problem. By integrating expert-derived causal structures with contemporary Energy Justice scholarship, it advances a conceptual framework in which distributional, procedural, recognition, and intergenerational justice operate as endogenous mechanisms shaping investment effectiveness, governance credibility, and long-term system viability.

Methodologically, the study contributes a reproducible qualitative–systems workflow combining expert elicitation, causal coding, adjacency screening, focused systematic literature review, and justice-sensitive CLD synthesis. This approach bridges qualitative insight and system dynamics structure, enabling justice constructs to be embedded directly within feedback architectures rather than treated as external evaluative criteria.

Substantively, four structural propositions formalize how justice dimensions condition transition trajectories. Procedural justice emerges as a deployment gate governing whether participation translates into implementation momentum. Distributional justice functions as an internal regulator of economic performance through energy poverty and vulnerability feedbacks. Intergenerational justice operates as a dynamic risk signal aligning present governance with future sustainability outcomes. Recognition justice stabilizes system viability by embedding social inclusion within model design and performance evaluation.

Together, these mechanisms demonstrate that transition outcomes depend less on isolated technological or financial interventions than on the alignment of justice-mediated feedback regimes. Transitions characterized by strong capital mobilization but weak procedural legitimacy or unresolved vulnerability are structurally prone to stagnation, while socially inclusive governance architectures reinforce both deployment capacity and long-term coherence.

By conceptualizing Energy Justice as a dynamic governance architecture rather than a normative checklist, this study offers a systems-based explanation for persistent gaps between ambition and implementation observed across many transition contexts. The findings suggest that effective transition design requires coordinated alignment across participation, access, accountability, and social viability, rather than optimization within any single policy domain.

Future research may formalize the conceptual CLD into stock–flow models for scenario experimentation and policy testing, expand expert panels to incorporate community-level perspectives, and apply the framework comparatively across national contexts. Integrating quantitative indicators of vulnerability, participation, and risk perception would further support hybrid modeling approaches that combine qualitative structure with empirical calibration.

Ultimately, this work underscores that energy transition is fundamentally a social transformation governed by justice-sensitive feedbacks. Designing transitions for systemic coherence—rather than isolated control—may therefore represent the central challenge of contemporary energy governance.

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REFERENCES

- 1) Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press.
- 2) Carton, W., Asiyanbi, A., Beck, S., Buck, H. J., & Lund, J. F. (2020). Negative emissions and the long history of carbon removal. *Wiley Interdisciplinary Reviews: Climate Change*, 11(6), e671. <https://doi.org/10.1002/wcc.671>
- 3) Cherp, A., Vinichenko, V., Jewell, J., Brutschin, E., & Sovacool, B. K. (2021). Integrating techno-economic, socio-technical and political perspectives on national energy transitions. *Energy Research & Social Science*, 80, 102202. <https://doi.org/10.1016/j.erss.2017.09.015>
- 4) Dubois, A., & Gadde, L. E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, 55(7), 553–560.
- 5) Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21st century business*. Capstone.
- 6) Fraser, N. (2009). *Scales of justice: Reimagining political space in a globalizing world*. Columbia University Press.
- 7) Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2020). Sociotechnical transitions for deep decarbonization. *Science*, 357(6357), 1242–1244.
- 8) Jenkins, K., Sovacool, B. K., & McCauley, D. (2018). Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change. *Energy Policy*, 117, 66–74. <https://doi.org/10.1016/j.enpol.2018.02.036>
- 9) Kim, H., & Andersen, D. F. (2012). Building confidence in causal maps generated from purposive text data. *System Dynamics Review*, 28(4), 311–328.
- 10) Köhler, J., et al. (2020). An agenda for sustainability transitions research. *Environmental Innovation and Societal Transitions*, 31, 1–32.
- 11) Markard, J., Geels, F. W., & Raven, R. (2020). Challenges in the acceleration of sustainability transitions. *Environmental Innovation and Societal Transitions*, 22, 1–14.
- 12) Markusson, N., et al. (2020). Social and political dimensions of CCS deployment. *Energy Research & Social Science*, 58, 101110.
- 13) Newell, P., Srivastava, S., & Naess, L. O. (2021). Towards transformative climate justice. *Wiley Interdisciplinary Reviews: Climate Change*, 12(6), e733.
- 14) Page, M. J., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71.
- 15) Pickering, J., Skovgaard, J., & Karnøe, P. (2022). Pathways of climate governance. *Global Environmental Change*, 73, 102115.
- 16) Sovacool, B. K., et al. (2017). Energy justice: Conceptual insights and practical applications. *Applied Energy*, 195, 108–120.
- 17) Sovacool, B. K., Hook, A., Martiskainen, M., & Baker, L. (2021). The whole systems energy injustice of carbon capture and storage. *Energy Policy*, 149, 112134.
- 18) Sterman, J. D., Fiddaman, T., Franck, T., Jones, A., McCauley, S., Rice, P., Sawin, E., & Siegel, L. (2021). *Climate Interactive: The En-ROADS climate policy simulation model*. *System Dynamics Review*, 36(2), 98–122.
- 19) Strauss, A., & Corbin, J. (1998). *Basics of qualitative research*. Sage.
- 20) Yearworth, M., & White, L. (2013). The uses of qualitative data in multimethodology: Developing causal loop diagrams during the coding process. *European Journal of Operational Research*, 231(1), 151–161.



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