Designing for Climate Innovation: Configurational Pathways of Transformation Across National Systems

Parsa Namaki[1]*, Marloes Korendijk[2], Nader Naderpajouh[3]

1. PhD Candidate, The University of Sydney, Greater Sydney Area, NSW 2037, Australia. Email: parsa.namaki@sydney.edu.au; *Corresponding Author*
2. Postdoctoral Researcher, The University of Sydney, Greater Sydney Area, NSW 2037, Australia. Email: marloes.korendijk@sydney.edu.au;
3. Associate Professor, Head of School of Project Management, The University of Sydney, Greater Sydney Area, NSW 2037, Australia. Email: nader.naderpajouh@sydney.edu.au;

1. Research Problem and Motivation

Climate change poses a profound challenge to contemporary socio-technical systems, demanding transformations that go far beyond incremental improvements or isolated technological fixes (Garud et al., 2014; Sengers et al., 2019). Although innovation is widely recognized as essential for climate change mitigation and adaptation (Köhler et al., 2019), much of the existing literature continues to explain climate innovation through linear models that isolate individual drivers, such as policy incentives, firm capabilities, or environmental pressure, without adequately accounting for how these conditions combine into broader configurations shaping innovation outcomes (Adams et al., 2016; Unger & Nippa, 2024). Such approaches struggle to explain why some countries generate sustained climate innovation without acute external pressure, why others fail despite high exposure to climate risks, and why collaboration sometimes substitutes for missing system supports.

These limitations are particularly problematic when climate change is understood as a non-business-as-usual condition characterized by uncertainty, disruption, and the need for coordinated responses across multiple actors and organizational levels (Porter et al., 2020). Such responses are increasingly realized through projects, programs, and project-based organizing arrangements that mediate how systemic conditions are translated into action (Geels & Locatelli, 2024). In these contexts, innovation outcomes are not simply the result of strong individual components, but of how systems are designed, aligned, or fragmented across institutional, market, business, and knowledge domains. From a project organization perspective, this raises a fundamental question: how are national systems configured in ways that enable, suppress, or redirect pathways of climate innovation and transformation?

To answer this question, in this study we shift the focus from identifying single "drivers" of climate innovation to examining configurational pathways through which climate innovation emerges, or fails to emerge, across countries. We conceptualize national systems as designed configurations whose coherence or fragmentation shapes the space for innovation, adaptation, and collaboration. By doing so, we contribute to ongoing debates in engineering project organization and transformation research about how organizing, coordination, and governance shape responses to grand societal challenges such as climate change.

2. Conceptual Lens: Designing for Transformation Through the Multi-Level Perspective

To analyze climate innovation as a system-level design challenge, we draw on the Multi-Level Perspective (MLP) on socio-technical transitions (Geels, 2002; Köhler et al., 2019). MLP conceptualizes socio-technical systems' transitions as the outcome of interactions across three analytical levels: landscape pressures (macro), socio-technical regimes or systems (meso), and niche innovations (micro) (Geels & Turnheim, 2022). Rather than viewing innovation as a linear response to external shocks, MLP emphasizes alignment, misalignment, and timing across levels as critical to transformative change (Geels, 2020).

In this study, we mobilize MLP as a design-oriented lens for understanding national systems. We conceptualize countries as organized configurations of institutional arrangements, market structures, business capabilities, and knowledge capital that collectively shape the conditions under which climate innovations can emerge, scale, or stagnate. Landscape-level environmental pressure, such as climate-related shocks or chronic stressors, may destabilize existing arrangements, but whether this destabilization translates into innovation depends on the design readiness of the system (Figure 1).

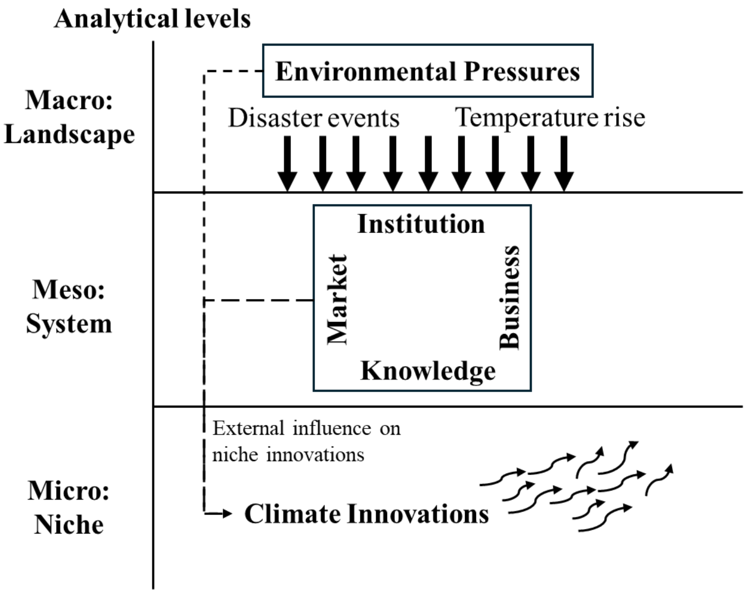

Figure 1 Schematic overview of MLP contextualization for identifying pathways for climate change innovations

MLP foregrounds two key ideas central to *"Design for Transformations"*. First, transformation is inherently emergent and non-linear: similar outcomes can arise through different pathways, and strong conditions in one domain may not compensate for misalignment elsewhere. Second, actors may actively redesign organizing arrangements, for instance, through collaboration and co-innovation, when existing systems fail to provide sufficient support. MLP, therefore, allows us to examine not only successful innovation pathways but also suppression, lock-in, and compensatory responses that are highly relevant to project-based organizing under uncertainty.

3. Methodological Approach

We adopt a configurational approach using fuzzy-set Qualitative Comparative Analysis (fsQCA) (Fiss, 2007; Ragin, 2009) to examine how combinations of system- and landscape-level conditions shape national climate innovation outcomes. fsQCA is particularly well suited to studying transformation processes characterized by causal complexity, equifinality, and asymmetry, features that align closely with both MLP and design-oriented perspectives on organizing.

Our empirical analysis covers 88 countries over the period 2010–2022. Climate innovation is conceptualized as a niche-level outcome and measured using climate change-related patent activity, normalized on a per-capita basis. In addition, we conduct a post-hoc analysis of climate co-innovation, capturing the share of climate-related patents developed through collaborative invention. Guided by MLP, we examine five conditions: system level conditions, including business enabling conditions, institutional enabling conditions, market enabling conditions, knowledge capital, and environmental pressure at the landscape level. Rather than estimating net effects, fsQCA allows us to identify configurations of conditions that are sufficient for high or low innovation outcomes, revealing multiple pathways through which climate innovation and collaboration emerge across national systems. To support interpretation of the identified configurations, we complemented the fsQCA with targeted analysis of secondary documents, including policy reports, international organization publications, and country-level archival sources, which were used to contextualize and illustrate the underlying organizing dynamics within selected cases.

4. Key Findings: Configurational Pathways as Design Logics

Our analysis identifies five distinct pathways, which we interpret as alternative design logics shaping climate innovation outcomes across countries (Table 1).

First, *system-driven proactivity* describes a pathway in which strong alignment across institutional, market, business, and knowledge domains enables high levels of climate innovation even in the absence of strong environmental pressure. Here, transformation is proactively designed into the system: innovation emerges from internal coherence rather than crisis response. In this configuration, system-level alignment reduces uncertainty, lowers coordination costs, and enables firms and public actors to invest proactively rather than reactively.

Second, *landscape-induced reactivity* captures cases where high environmental pressure activates climate innovation, but only when minimum levels of system readiness, particularly in business capabilities, markets, and knowledge capital, are present. In this pathway, external pressure opens windows of opportunity, yet innovation remains conditional on partial system alignment. Here, environmental pressure acts as a catalyst rather than a driver, triggering innovation only when organizational and market infrastructures are sufficiently developed to absorb and translate that pressure.

Third, *system deficiency lock-in* reflects configurations where the joint absence of core system elements, especially business capabilities, market support, and knowledge capital, suppresses climate innovation regardless of environmental pressure. These systems exhibit durable lock-in, illustrating how poor system design constrains transformation even under severe climate stress. In these cases, environmental pressure exacerbates vulnerability rather than stimulating innovation, as the absence of core system supports prevents actors from mobilizing resources or coordinating responses.

Fourth, *fragmented system suppression* highlights contexts in which some system components, notably firm-level capabilities, are present, but misalignment across institutional and market domains prevents innovation from scaling. This pathway shows that isolated strengths cannot substitute for systemic coherence. It illustrates how partial capacities become ineffective when institutional and market arrangements fail to align incentives, resulting in stalled or localized innovation efforts.

Finally, based on the post-hoc analysis, *niche compensatory co-innovation* reveals a distinctive pattern in which high levels of climate collaboration emerge precisely where system-level enabling conditions are weak or absent. In these contexts, actors engage in co-innovation as a compensatory organizing strategy, pooling resources, sharing risks, and accessing external capabilities to overcome domestic system deficiencies. Here, co-innovation functions as an alternative organizing mechanism, allowing actors to bypass domestic system constraints by redistributing risk, knowledge, and coordination across organizational and national boundaries.

Together, these pathways demonstrate that climate innovation is not driven by single factors, but by how national systems are designed and configured, and, in some cases, redesigned through collaborative action.

Table 1 Overview of the results for fsQCA on the main outcome and post hoc outcome.

	Main analysis				**Post hoc analysis**			
	High climate change innovation output		**Low climate change innovation output**		**High share of climate change co-innovations**	**Low share of climate change co-innovations**		
	Conf 1	**Conf 2**	**Conf 3**	**Conf 4**	**Conf 5**	**Conf 6**	**Conf 7**	**Conf 8**
Business	●	●	⊗	•	⊗	•	•	⊗
Institution	•			⊗	⨂		⊗	●
Market	•	•	⨂	⨂	⨂	●		●
Knowledge	●	●	⊗		⊗	●	●	⊗
Environment		•		⊗			⊗	•
Consistency	0.951	0.934	0.979	0.942	0.837	0.817	0.862	0.850
Raw coverage	0.776	0.610	0.688	0.160	0.577	0.630	0.153	0.131
Unique coverage	0.213	0.047	0.568	0.041	0.577	0.452	0.040	0.024
Solution Coverage	**0.823**		**0.728**		**0.577**	**0.690**		
Solution Consistency	**0.930**		**0.970**		**0.837**	**0.814**		

5. Implications

These findings offer implications for research and practice in engineering project organization. First, they underscore the importance of designing systems rather than optimizing isolated components. Policies or programs that target individual enablers without considering systemic alignment may inadvertently reinforce fragmentation and suppression. Beyond their practical relevance, this insight also contributes theoretically by shifting attention from project- or policy-level interventions to the configurational properties of the systems in which projects are embedded, highlighting how alignment and misalignment shape innovation outcomes.

Second, the results highlight co-innovation as an emergent design response under conditions of system failure. From a project organizing perspective, collaboration should not be viewed only as a strategic choice in resource-rich environments, but also as an adaptive mechanism through which actors redesign organizing arrangements in constrained contexts. Theoretically, this finding extends existing accounts of collaboration by showing how project-based co-innovation can function as a compensatory organizing mechanism when formal institutional, market, or knowledge supports are weak or absent.

Third, the study contributes to debates on transformation under uncertainty by showing that environmental pressure alone does not guarantee innovation. Transformation depends on how systems are organized to absorb, translate, or resist such pressure, an insight that has direct relevance for the governance of large-scale, climate-related project portfolios. At the same time, this contributes to transition theory by illustrating how landscape pressures are filtered through system-level configurations, shaping whether niche-level innovations emerge, stagnate, or take collaborative forms.

References

Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., & Overy, P. (2016). Sustainability-oriented innovation: A systematic review. *International Journal of Management Reviews*, *18*(2), 180-205.

Fiss, P. C. (2007). A set-theoretic approach to organizational configurations. *Academy of Management review*, *32*(4), 1180-1198.

Garud, R., Gehman, J., & Giuliani, A. P. (2014). Contextualizing entrepreneurial innovation: A narrative perspective. *Research policy*, *43*(7), 1177-1188.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274.

Geels, F. W. (2020). Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. *Technological forecasting and social change*, *152*, 119894.

Geels, F. W., & Locatelli, G. (2024). Broadening project studies to address sustainability transitions: Conceptual suggestions and crossovers with socio-technical transitions research. *International Journal of Project Management*, *42*(7), 102646.
Geels, F. W., & Turnheim, B. (2022). *The Great Reconfiguration*. Cambridge University Press.
Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., & Boons, F. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental innovation and societal transitions*, *31*, 1-32.
Porter, A. J., Tuertscher, P., & Huysman, M. (2020). Saving our oceans: Scaling the impact of robust action through crowdsourcing. *Journal of Management Studies*, *57*(2), 246-286.
Ragin, C. C. (2009). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press.
Sengers, F., Wieczorek, A. J., & Raven, R. (2019). Experimenting for sustainability transitions: A systematic literature review. *Technological forecasting and social change*, *145*, 153-164.
Unger, B., & Nippa, M. (2024). Determinants of firms' initiative and inertia in pursuing climate neutrality strategies—Theoretical explanations and empirical evidence. *Business Strategy and the Environment*, *33*(5), 4086-4107.