

Transformative Innovation Policy: An Analytical Review of Key Methods and Challenges

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Keywords

[AU: Please provide up to 6 keywords for search and indexing purposes.**]**

Transformative innovation policy; policy experimentation; transformative outcomes;

directionality; sustainability; justice

Abstract

Systems such as energy, food, and mobility are currently organized in unsustainable modes of production and consumption, with negative consequences on social justice and planetary health. Disruptive and systemic innovations are required, beyond solely improving technologies or financial instruments, to address wicked and complex societal and environmental challenges. Transformative innovation policy (TIP) is a new generation of innovation policy that promises to enable just transitions in these socio-technical systems. The promise is to be able to tackle wicked problems and polycrisis of inequities, social injustices, environmental degradations, and accelerated impacts of climate change through new policymaking approaches that support, nurture, and scale transformative socio-technical innovations.. **[**AU: Edit OK?**Yes, thanks. I have further shortened it]** We review emerging TIP literature to discuss key elements in TIP design and implementation, such as experiment, monitoring, and learning through formative evaluation; codesigning a systemic theory of change; enhancing policy capabilities; building knowledge infrastructure; and empowering communities of practice. Two cases in Spain and Indonesia illustrate key aspects of the TIP method. Our major contribution lies **[**AU: delete?** YES, fine]** in articulating what an alternative innovation policy could look like to mitigate transformational failures observed in current system change efforts and explore how directionalities such as being democratic, elevating decolonial sensibilities, enhancing well-being, and navigating futures can make innovation policies more transformative. Policymakers must adopt new ways of thinking and acting on persistent challenges, beyond the traditional way of setting social and climate targets at the beginning of policy process and a summative policy evaluation at the very end. TIPs of the future should incorporate multiple directionalities negotiated among diverse actors and knowledge systems and by learning from failure in context-sensitive ways.**[**AU: Edit OK?** YES, thanks]**

[AU: PLEASE ADD CALLOUTS TO FIGURES 1 AND 2 AND TABLE 1 IN TEXT WHERE APPROPRIATE (E.G., “(FIGURE 1)”** DONE]**

1. INTRODUCTION

Transformative innovation policy (TIP) represents a new generation of **innovation** policy that

promises to tackle persistent unsustainability in modern societies, manifested through economic inequities, social injustices, environmental degradations, and accelerated impacts of climate change (1). Historical approaches to policy and governance of innovation have focused primarily on investments in research and development (R&D) and setting up national systems of innovation (NSI) focused on building state and entrepreneurial innovation capabilities. The emerging field of TIP provides a more purposive and inclusive approach to innovation that could harness innovation's potential in tackling the "polycrisis" (2), the intertwined and causally entangled challenges of inequalities, loss of biodiversity, marginalization of communities, and major disturbances in peace and harmony of societies across the globe[**AU: Edit OK? **Yes, thanks] (3, 4). The new approach to innovation policy foregrounds the need and process of changing entire systems of food, energy, mobility, education, and healthcare, as transformations toward sustainability require "fundamental changes in structural, functional, relational, and cognitive aspects of socio-technical-ecological systems" (5[**AU: Please provide page number for quote **Page 2]). The mechanism of such change involves supporting acceleration of sustainable socio-technical innovations and shifting away from incumbent unsustainable systems such as fossil fuel-dependent energy and car-centric mobility (6). The key premise is that to transform unsustainable systems, innovation policy must embrace transformative approaches to policymaking, including systems thinking, **experimental policy engagements (EPE)**, and **formative evaluation (FE)**, as well as enhancing policy capabilities, building **knowledge infrastructures (KIs)** and empowering CoPs (each elaborated in Section 3 of this article) (7–9).

Innovation: an alternative configuration of new technologies, new actors, and new rules that is emerging through protection from markets and through policy and must be mainstreamed to replace or reconfigure existing and unsustainable socio-technical systems

Experimental policy engagements (EPE): organized and transdisciplinary learning experience, bounded in time and directed to enhancing policy impact potential for transformative system change through an engaged policy process.

Formative evaluation (FE): real-time, inclusive, flexible, and reflexive monitoring aimed at improving the definition, design, and implementation of an innovation policy intervention through generating both first- and second-order learning

Knowledge infrastructure (KI): sensemaking platforms that contain specific assets (e.g., reading materials, tools, physical and virtual meeting, exchange and collaboration spaces), aimed toward individual and collective capacity building for specific purposes (e.g., justice, sustainability, regional development) and translated into actions, synthesizing diverse knowledge domains

Despite its strong foundation in science, technology and innovation (STI) studies and sustainability transitions theory, policymakers and practitioners face severe challenges in designing and implementing TIP in the real-world contexts. **[**AU: Edit OK?** I have made it simpler]** Several policy paradoxes underpin this challenge, such as conflicting interests in policy and politics, science- -driven, evidence-informed actions with potential unintended consequences, and transition tensions between low-carbon transition pathways and social justice (10, 11). Although TIP's key focus is supporting innovation with directionality, the emerging literature holds gaps in elucidating which directionalities are nonnegotiable and which conceptual and methodological tools might help TIP to embrace these directionalities. "Being democratic" is a key directionality of TIP, but more research is needed on how experimental policy engagements (EPEs), which are so central to the TIP method, could democratize innovations. **Decoloniality**, well-being, and desired futures are other directionalities implicit in TIP literature that require unpacking in and through TIP implementation methods; for example, could **second-order learning** (a key aspect of FE) elevate decolonial sensibilities, to avoid perpetuating colonial trends of extractive and exclusionary pathways to economic growth and industrial modernity (12)? Furthermore, how can processes such as experimentation, learning, and capability development, which are central to TIP, deliver holistic well-being and navigate plurality and contestation over desired futures? **[**AU: Edit OK?** Yes thanks]** These four directionalities, namely, being democratic, elevating decolonial sensibilities, enhancing holistic well-being, and navigating desired futures, are pertinent to guide transformative change through innovation policy. **[**AU: Edit OK?** Yes thanks]** Our key contribution is to highlight three major areas of conceptual and methodological gaps, namely, societal engagement, context sensitivity, and epistemic justice (see Section 4). By considering the directionalities upfront and deeply engaging with them, future research on TIP can address these gaps through paying more attention to the intentions, purposes and impact of various processes, outcomes, and in creating long-term enabling conditions for system change.

Decoloniality: a transformative approach that centers on valuing diverse, marginalized ways of knowing and dismantling colonial legacies through relationality, humility, and ethical action

Second-order learning: a process that challenges and alters underlying collective assumptions, beliefs, and values and ultimately leads to changes in shared routines and practices, reframing both knowing what and knowing how, and enhancing cognitive and behavioral flexibility

Section 2 explains the rationale of TIP in the context of innovation policy's different

framings and roles throughout history, especially how TIP sits in the wider family of missions, challenge-driven innovation policy, and Responsible Research and Innovation (RRI). The eight subsections in Section 3 describe the core of TIP theory and analytical framework, comprising key methods, processes, and enablers of TIP. Section 4 introduces four key directionalities of TIP discussing what a democratic, decolonial, well-being, and contested desirable futures-oriented TIP could look like. Section 5 highlights key challenges and methodological gaps and explains how these challenges encountered in TIP design and implementation can be sufficiently addressed through paying sincere attention to the directionalities. We draw conclusions and suggest summary points and future issues in Sections 6, 7, and 8, respectively.

2. TIP: STATE OF THE ART

The literature on TIP has evolved rapidly in the past seven years (since 2018), advancing the theory through applications in diverse empirical contexts on one hand (see [13–15](#)) and through critiques on the other (see [16, 17](#)). Reviewing the history of STI policy since World War II, Schot & Steinmueller ([3](#)****AU: Please add page number for quote**Page 1554**), in their seminal paper, argued that “it is time to articulate more forcefully and to experiment in practice with a framing for science, technology and innovation policy that emphasizes socio-technical system change.” This framing is proposed to mitigate the challenges observed in frame 1 (innovation for growth) and frame 2 (NSI), such as linear understanding of universal welfare driven by growth or the role of the nation-state in human capability development.****AU: Edit OK?** I would keep the full form “national systems of innovation”here. Rest is OK** In framing 1, innovation policies incentivize curiosity-led scientific research and technology development through R&D investments and offer regulatory instruments for fixing market failures in the process of commercialization of technologies. This framing pays little attention to “innovation from below” and other “varieties of innovation” ([18](#)) and could exacerbates inequalities between socioeconomic groups and between countries with varying R&D capacities and infrastructures. Since the 1980s, NSIs have dominated the innovation policy debate—which is considered as the second frame—emphasizing the nation-states’ important role in investing in organizational capabilities and entrepreneurship for global competitive advantage and supporting wider societal diffusion of innovation for inclusive development (18a) ****AU: This reference is**

not in the Lit. Cited. Please add there or remove from here.Added as 18a, here as comment as well as in reference list]).** Despite a stronger normative focus on improving economic and social welfare, frame 2 falls short **[**AU: fails?**no, we meant ‘falls short’]**in directly associating innovations to the polycrisis , which would require flexible, purposive and opportunity-driven approaches, beyond growth narratives, institutional change and top-down governance efforts dominated by the elite voices of scientific communities, businesses, and bureaucrats (18b, [19](#)).

Both R&D and NSI framings are still relevant because they propose essential processes and mechanisms of innovation but are insufficient in redirecting innovation toward the polycrisis facing the world today **[**AU: Edit OK?** Yes thanks](2, 4)**. The emerging third frame do not discourage stimulate R&D toward innovations with directionalities and building NSIs for green and inclusive growth, net-zero, and just transition missions. Innovation policy for transformative change is therefore more anticipatory and outward-looking, foregrounding the questions of innovation for what and whom; and negotiating corresponding choices on which innovations need nurturing. At the same time, the third framing is also processual: It proposes building new transition arenas **[**AU: Is this a direct quote? If not, okay to remove quotations?** removed]**for collaborative, inclusive, and reflexive processes of innovation ([20](#)). Given the complex problems in society and the environment, the key proposition is that innovations must do more than fix market failures and rely on nation-states to develop entrepreneurship capabilities ([21](#)). Greater emphasis must be placed on which innovations are desirable, accounting for unintended consequences and the dark side of innovation, as well as the nature of challenges in transforming societal systems through innovation (e.g., resistance by powerful actors in changing current systems of provision). Innovation policies for decarbonization and net-zero, which overlook entrenched relations of power and inequities embedded in the current energy system, are under-equipped to deliver long-term transformation. Here spatial inequalities are also important to consider: Socioeconomically vulnerable communities bear many of the costs of industrial development and digitization, through displacements due to land acquisitions, mineral extractions, destroyed local ecologies, and waste accumulation that is detrimental to their health and well-being **[**AU: Edit OK?**Yes, looks great thanks](22)**. TIP highlights the importance of inclusivity in processes of innovation and across space and time.

In terms of its core method, TIP embraces a systemic ToC (6) to show pathways for localized

transformations by achieving transformative outcomes (TOs) (15). These outcomes are conceptualized as leverage points for innovation policies to be transformative, building on research on sustainability transitions (6, 23–25). As an emerging policy paradigm, TIP embraces a societal policy agenda and a broad understanding of innovation as a multi-actor, multi-activity, and multimodal political process addressing uncertainties and contestations (26, 27). It is part of a family of emerging and complementary innovation policy paradigms, such as challenge-driven innovation policy (28), mission-oriented innovation policy (MoIP) (29, 30), and RRI policies (31, 32)—all advancing theories and practices of socially relevant, evidence-based, and ethical science technology and innovation policy. MoIP advocates for a government-led process that addresses social and environmental challenges by defining bold targets or missions (29, 30). RRI advocates for open, transparent, and responsive governance of science and technology development by deliberately addressing equitable access, involving multiple stakeholders in the innovation process, and nurturing a willingness to respond and adapt to changing knowledge and circumstances (31, 32). What distinguishes TIP is the emphasis on socio-technical system change through influencing niche–regime interaction dynamics and uncovering multiple transition pathways. TIPs can be mission oriented (see 33 for transformative mission-oriented policies) but emphasize experimentation, learning, and community empowerment and measure transformative potential in systems through TOs. **[**AU: Edit OK?**] Yes fine thanks** TIP can also incorporate aspects of RRI through facilitating responsible knowledge coproduction in transdisciplinary spaces (34).

TIP practitioners promote being intentional about selecting specific directions of transformative change (35). Diercks et al. (7**[**AU: Please provide page number for quote** Page 884]**; see also 36) recognize the normative turn in the innovation policy paradigm, suggesting that innovations need “strategic directionality and guid(ing) processes of transformative change towards desired societal objectives.” The literature does not sufficiently unpack what is desired, by whom, and the unintended consequences of such strategies. Powerful policy and supply-side actors might give direction, which may not be desired by marginalised society and for the protection of the environment. Different actors across different policy processes in multiple stages of policy implementation influence the directions of TIP (36, 37). Penna et al. (27**[**AU: Please provide page number for quote** Page 424]**) explained that “a diversity of end-states and directionalities [may be present] to address a societal challenge,” and

there might be political conflicts in “defining directions, ... [to answer] the question of “end-state for whom?” Multiple directionalities and pathways are needed to address wicked problems under conditions of uncertainty. Others emphasize the need to include actors from the demand side of innovation processes such as users, communities and civil **society actors in TIP**, recognising directionalities will be contested among actors within and across each category **[**AU: Please clarify end of quotation and add page number** I have removed quotes](36)**. Such inclusion of actors, knowledge, and contestations is central to democratic and decolonial processes, yet what it means to be truly democratic and decolonial is not discussed explicitly in the literature. Furthermore, scholars have emphasized the importance of focusing on enhancing human and environmental well-being consistent with achieving Sustainable Development Goals (SDGs) (38, 39), particularly in the Global South (40, 41). Sustainable and **desirable futures** is also contested and plural. TIP directionality is not about achieving the SDGs by any means but shaping and steering STI to create the conditions for achieving multiple SDGs in democratic and decolonial ways (42). The literature lacks detailed engagement with these directionalities. Haddad & Bergek (43) **[**AU: Please provide page number for quote** Page 5)** suggest that TIP evaluation frameworks so far have not adequately handled directionality”, i.e. “which development paths the focal policy has supported and whether these are desirable/acceptable or not.” Diercks et al. **[**AU: Reference 7? Please provide page number for quote** Yes it is reference 7, Page 892]**) conclude, “What is now needed is a better understanding of the actual practices, struggles and implementation of the transformative innovation policy paradigm.” This is the core ambition of this article, through illustrating the cornerstones, macro-processes, key enablers and guiding directionalities of TIP (See Figure 1). **Desirable futures: collectively envisioned futures in socio-technical configurations that reflect societal values and aspirations, guiding strategic action toward just, resilient outcomes while considering diverse perspectives and navigating uncertainties**

3. KEY CONSTITUENTS OF THE TIP METHOD

In preparation for this review, a Web of Science search was conducted for “transformative innovation policy” in all fields. The result showed 70 publications (as of July 30, 2024 **[**AU: Correct? Yes]**), which were used as the starting points for this review. Furthermore, references and citations of key papers in the TIP literature (e.g., 3, 7, 8, 15, 43, 44) are used to

snowball the literature to build the arguments of this pragmatic review of the key constituents of the TIP method.[**AU: Edit OK?** Yes thanks]

3.1. Experimentation in Policy

Experimentation is a core method for designing and implementing TIP. EPEs, also known as engaged policy experimentation or, simply, policy experiments, are innovative arrangements through which policies can be designed, implemented, and evaluated to enable transformative change in society ([27](#), [45](#), [46](#)). The innovation lies in deep intent for “interventions in larger multi-actor transformation processes” beyond policy support for isolated projects, foregrounding collective learning as the way to resolve uncertainties[**AU: Please specify source/provide page number for quote** Its Page 2 in reference 15] ([15](#), [47](#)). EPE allows exploration of diverse solutions and alignments through negotiation and consensus building around collective and shared visions ([48](#)). Through EPE, TIP entrepreneurs apply design thinking and critically examine the evidence combining technical expertise with democratic participation, and creative imagination ([49](#), [50](#)). Building and maintaining mutual trust among all involved and openness to a variety of techniques and ideas and unfamiliarity are key to experimentation ([14](#)).[**AU: Edit OK?** I like the original better – please see new formulation of the sentence in my comment]

Experimentation for TIP follows the ethos of tentative governance as “provisional, flexible, revisable, dynamic and open approaches” of policy design, implementation, and evaluation[**AU: Please clarify quotation marks and provide page number if necessary** reference 51, Page 1091] ([51](#): pg 1091). The nonlinear and messy process discourages premature specification of policy solutions, which might later prove to be suboptimal in meeting climate and social objectives ([52](#)). This implies a modular approach in “safe enough spaces” (52a), where policy developments are not locked in prematurely but can be adjusted in light of new evidence of injustices, repercussions to previous actions, and external shocks. Such modularity is implicitly decolonial because it moves away from a technocratic imposition of universal practices and recognise that the many (the wider society) decides for the many ([53](#)).

TIP EPE may begin with system mapping (see Section 3.3), envisioning desirable futures, and cocreating pathways to the future systems, translated into a localized transformative ToC (TToC). Policy experimentation can also be about creating portfolios or clusters of policies that

are individually piecemeal and ineffective yet, as a portfolio for shared and strategic agendas such as SDGs or smart specialization, can provide more transformative solutions (see [54](#) for **AU: the or a?** the. Added to the text] the policy portfolio in Sweden and [55](#) for shared agendas in Catalunya). Another type of experimentation could be about creating “transformative bundles” in which public and private finance are combined to create transformative investment ([56](#)). EPEs help review pre-existing assumptions such as what policies are for, who leads, and how policies are implemented and evaluated, thereby inviting scenarios in which practices can and should be modified to stretch transformative potential of policy interventions.. For TIP to be a widely accepted framing of innovation policy, experimental mindset within policy space must be institutionally embedded and anchored in conventional governance (see the sidebar Example 1: The RIS3CAT 2030) ([57](#), 57a).

EXAMPLE 1: THE RIS3CAT 2030

The RIS3CAT 2030 is part of the EU Cohesion Framework, promoting democratic, collaborative approaches to regional transformation. It prioritizes seven systemic changes, including sustainable food, energy, mobility, socio-health, industrial, educational, and cultural systems. Experimentation in RIS3CAT 2030 include engaging a wide range of stakeholders to create a shared future vision for addresses complex regional challenges 55). The RIS3CAT supports transformative innovation initiatives involving ecosystems of actors in the design and monitoring of solutions, grounded in a commitment to a greener, fairer future. At the heart of this approach are the Shared Agendas—portfolios of initiatives that respond to strategic challenges. They emphasize inclusive governance, continuous learning, and the cocreation of solutions, ensuring alignment with broader strategies like the EU’s innovation missions. The Shared Agendas are outstanding illustration of a democratic and transformative policy process, building trust and cooperation to achieve well-being and sustainable development across the Catalunya region.

3.2. Formative evaluation in Policy with TOs

Increasing complexity in addressing the polycrisis calls for new approaches to policy evaluation (57b). Both ex-ante and ex-post policy evaluation require new approaches that go beyond prescriptive and rigid planning, “anchored in a traditional, quantitative, and rationalistic model of evaluation” ([54](#) **AU: Please provide page number for quote** Page 343]), toward more reflective, analytical approaches to support the STI policy ([58](#)). The FE methodology of TIP supports this new approach and offer tools for real-time evaluation throughout the policy cycle, encouraging continuous and constructive monitoring and “purposive learning” to gain insights

from the past and anticipated successes and failures (44). The necessity of reflexive learning is undeniable for effective policymaking, as it allows revision and adaptation of strategies throughout the process rather than ex post policy evaluation. **[**AU: Edit OK? lets keep ‘of strategies’, rest is okay]** This shift from the traditional summative evaluation paradigm “sits uncomfortably with mainstream thinking” on policy evaluation (7, page 891). The central role is played by “reflective practitioners” (54, page 341), who are evaluators with attitudes for innovation regarding what is possible and how to achieve what was viewed previously as unrealistic, idealistic, or infeasible (14).

An experimental mindset in policy allows a “safe and respectful space” (14, page 586) for FE through openness to deliberation and continuous adjustments. FE is a major element in EPEs, where policy initiatives are assessed collectively for their potential to stretch in transformative directions. In geographically and time-bounded EPEs, FE includes (a) developing a TToC that includes detailed visualizations of inputs, assumptions, activities, outcomes, and outputs desired from TIP and (b) a constructive monitoring plan through detailed documentation of verbal and nonverbal cues of change in perspectives and mindsets, in a “participatory pluralistic process” of negotiation and interactions (44, 54, page 338). Building on this, Haddad & Bergek (43) called for a more comprehensive and integrated TIP evaluation that incorporates elements like defining a transition focus, developing a ToC, analyzing socio-technical change processes, identifying and revising causal mechanisms, and assessing the trajectory of change in relation to intended directions. Through participatory processes, localized TToCs specific to system and place are derived from generic transition theory.

A set of TOs is proposed as a new analytical framework for evaluating TIP with ambitions to stretch the policy outcomes to be more transformative for the long term rather than measuring immediate impacts (15). Kivimaa et al. (13 **[**AU: Please provide page number for quote** page 681]**) used TOs to show “how specific horizontal and cross-sectoral policy programmes may connect to TIP efforts with their strategic intent towards sustainability transitions and how such an intent can be assessed.” TOs act as references for evaluating “how one can tell whether the experiment has been successful” (58a, page 1) and “can be stretched for transformation purposes” thereby connecting policy intervention activities and the desired impact **[**AU: Please provide page number for quote** Done, I have added a new reference 58a for the first quote, see comment and addition to reference list]** (15, page 3). TOs has been applied in

EPEs on the Living Catchments Project in South Africa (59), the Swedish food mission (14), sustainable and inclusive water resource management in small-scale agriculture in Chile, the inclusion and empowering of lemon producers in Mexico (60) and circular economy in schools in Indonesia (60a) (illustrated in sidebar Example 2: The Mundane Circular Economy Policy Project). In these experiments, TOs act as boundary objects between theory and practice, because they help flexibly negotiate the meaning of transformation in various EPE contexts (61).

EXAMPLE 2: THE MUNDANE CIRCULAR ECONOMY POLICY PROJECT

The Mundane Circular Economy Policy (MCEP) project in Indonesia focuses on integrating Circular Economy (CE) principles into schools. Principals act as change agents, translating CE principles like Rethink, Reduce, Reuse, Repair, and Recycle into everyday school practices. This experimental approach allows schools to test various circular practices and adjust them based on context, resources, and collective learning outcomes. MCEP's modular framework fosters a flexible and adaptive environment where policies evolve with new evidence and stakeholder feedback. MCEP coproduced the Onion Ring Model of Transformative Pathways for Mundane Circular School Transition (60a). Tools like Multi-Criteria Mapping (MCM) and Transformative Outcomes (TOs) are employed to assess the impact and prioritize decisions. The project emphasizes continuous learning and real-time adjustments ensuring that policy outcomes are aligned with long-term sustainability goals. By embedding these TIP methods, MCEP promotes a practical and scalable approach to fostering a circular economy within educational institutions.

3.3. Socio-Technical System Change

An important ambition of TIP is to deliver socio-technical system change. Most real-world policies attempt to solve economic or structural issues and as a result are designed to optimise the current systems. Policies barely map the systemic nature of the societal and environmental problems and instead are often mission driven to support techno-fixes. EPEs allow system transformation, beyond optimization, into system redesign and (fundamental) system change mobilizing a generic ToC (14).

As a first step in the transformation process, system mapping helps take stock of the state of the art of the existing system, through identifying actors and power relations, analysing problems and recognizing sources of resilience as well as vulnerabilities in each dimension of the socio-technical system.. A socio-technical system map is a clear view of technologies, infrastructures, and materials,; actor networks; and expectations, values, and routines (known as, rules) that drive actor choices and decisions. Therefore, system mapping involves identifying not only the prominent stakeholders, or just the variety of technologies and policies, but also connections and

alignments between rules across at least five system dimensions such as i. science and engineering, ii. Policy and governance, iii. industry, iv. Users and market, and v. nature and culture ([62](#), [23](#)).

A ToC shows the dynamic interaction between the dominant configuration of a system (regime) and its innovation alternatives (niches) in relation to external shocks and pressures (landscape). It considers rules that are resilient in existing regimes and hence difficult to change; recognizes promising alternative rules aligning with contextually relevant future visions; illustrates rules for preparedness for shocks, and pinpoint vulnerabilities existing in the system that can be leveraged for change.. **[**AU: Please recast sentence for clarity. Particularly, to which list does d) refer?** Please see revisions]** The process involves reflecting on whether innovations are locally relevant beyond “technology transfer from the global north to the global south”**[**AU: Edit OK?**]** ([40](#), page 576), by inviting perspectives of local actors and co-creating visions of desirable futures ([63](#), 63a). In the case of e-waste policies in Ghana, actors include e-waste artisans and collectors, government agencies, international development partners and private actors, and nongovernmental organizations (NGOs) ([37](#)). Therefore, system mapping is, by design, a bottom-up participatory process that ensures that new systems include marginalized voices, and are changed in the right directions.

The theory of system change shows that transformative innovations are not just technologies developed by scientists and engineers but also new, “deliberate,intentional social practices” ([64](#): page 80, [27](#)) that support, accelerate, and stabilize new behaviors, lifestyles, and norms. EPEs can also provide ways to coordinate between multiple existing regimes and influence the landscape trends, identifying policy intervention points (65) in the TToC. The process of changing systems is fruitful only if current systems are transformed into ones that are resilient to shocks, such as pandemics and heatwaves, as well as just for all.

3.4. Nurturing and Mainstreaming Niche Innovations

Niche innovations can provide alternative technologies and rules with the potential to change systems, when and as required. A niche is typically a sociopolitical environment or ecosystem of actors and rules that is tolerant to new ideas and works as a protective space for nurturing innovations. R&D labs can provide this space for technological innovations, and NSIs can offer incentives to entrepreneurs to nurture their business efforts against competition from the

incumbents. Yet, building and mainstreaming alternative, transformative innovations for system change require more. Developing and nurturing a niche requires a *broad and deep network* of actors supporting the innovations; *second-order learning* among the actors, *navigating diverse expectations* of visionary actors; and *active as well as passive shielding* of the innovations from regime pressures. **[**AU: Edit OK?**]** EPEs can support these processes of strategic niche management (see [66](#)). An EPE can be designed to establish trust and cooperation among niche actor networks who are engaged in technology design, new market creation, and end-user acceptance of technologies ([67](#)). The depth and breadth of such networks are important indicators of niche quality ([68](#)). High quality networks in EPE and FE process allow deep learning on what works and what doesn't (i.e first order learning) as well as why things work in the way they do and what assumptions are underlying actions (i.e second order learning). **[**AU: Please recast for clarity** I have now rewritten this sentence, Does this look better?]** EPEs can further provide the space to navigate diverse expectations about new innovations and outcome possibilities, thereby fostering stronger and better alternatives and a common understanding of directionalities of transformation that “goes beyond the nation state” ([69](#)**[**AU: Page number for quote?**page 4]**). Actor networks, and governance processes can be rearranged through EPEs to shield a niche, e.g., political, financial, or institutional support for “local and community social initiatives” ([64](#)**[**AU: Page number for quote?** page 82]**).

TIP scholars propose several processes for accelerating and mainstreaming niche innovations. **[**AU: Is this a quotation? If so, please provide closing quotation mark and attribution**I have shortened the sentence and kept just the part that is needed]** ([15](#), [45](#), [66](#), [69](#)). TOs for mainstreaming innovations involves upscaling, replicating, circulating, anchoring, and institutionalizing them ([15](#), 58a). In EPEs, actor networks may devise strategies to increase adoption of the emergent system by new users (*upscaling*); recontextualize innovation from elsewhere through coordination between actors in multiple levels (*replicating*); scale out ideas from one context ([64](#)), transfer and rescale ([70](#)) ideas and learnings in another (*circulating*); create durable, firm niche–regime connections to increase acceptance of the innovations by regime actors and embed them in local institutional and innovation systems contexts (*anchoring*); and help normalize the new niche beliefs, values, and practices among a wider set of actors (*institutionalizing*) ([23](#), [40](#), 58a, [69](#)). **[**AU: Edit OK?**Yes thanks, I added 58a which is a new paper as reference for this part]** In TIP, FE involves monitoring

interventions to enable these niche-level processes through EPE.

3.5. Unlocking Regimes

Nurturing and mainstreaming of niche innovations are unable to deliver transformative system change if the incumbent regime continues to remain stable and resistant to change. Societies currently are locked into unsustainable modes of production and consumption, such as fossil fuel-based energy, car-based mobility, or unaffordable health care, with negative consequences for social justice and planetary health (71). To tackle transformation failure, discontinuation, dismantling, phasing-out or reconfiguration of unsustainable regimes is necessary yet these processes are extremely difficult due to lock-in effects, making transformation a complex, negotiated process full of political struggle (71a). Reducing regime resistance is key to prevent transformation failure (21, 72). Phaseout and taxation policies provide destabilizing momentum; however, more durable transformations are achieved through incumbent actors *unlearning*, shifting away from existing practices and illustrating the openness to relearn new ways of acting and decisionmaking. TToCs can include actions to help *dissolve* existing coalitions and *delegitimize* dominant frames and narratives supporting unsustainable systems (58a). The process of unlocking regimes could also involve strengthened interaction between regime and niche actors, often orchestrated by regime-based intermediary organizations, encouraging niche empowerment for regime diversity and renewal [**AU: Edit OK? **Yes thanks] (48). Another outcome of unlocking regimes is to perceive landscape trends such as atmospheric warming as issues that can be tilted in positive directions (65) through policy and technological interventions. TIP scholars propose that the methods of EPE and FE can be designed and mobilized to achieve these TOs. (For a full list of TOs, see **Table 2.**)

<COMP: PLEASE INSERT TABLE 2 HERE>

3.6. Enhancing Capabilities

Transformative change in society is incomplete without enhanced human capabilities, agencies and conversation factors to act on system change (72a). EPEs are important vehicles for nurturing unique and dynamic capabilities among governance and societal actors (8) [**AU: Please specify reference number ** It is reference 8]. Scholars argued that “governing transformative change requires new types of capacities and capabilities of the public sector such as organisational structures, competencies, and administrative rules and processes (...) which

differ from traditional innovation and economic growth programmes,” owing to the complex challenges at hand **[**AU: Please specify source/page number for quote** its reference 54, page 337](** [54](#): page 337). Capabilities can be individual, cognitive, or collective ([73](#)) and based on access to resources or skills and competences ([74](#)).

Considering TIP as an innovation governance framework, Termeer et al., (2015**[**AU: Please add to lit. cited**Done]**) ([74a](#)) suggested targeting four governance capabilities: (a) reflexivity, or the capability to deal with multiple frames; (b) resilience, or the capability to adjust actions to uncertain changes; (c) responsiveness, or the capability to respond to changing agendas and expectations; and (d) revitalization, or the capability to unblock stagnations. University-based boundary organizations can play an important role in enhancing policy capacities, such as analytical, operational, coordination, and learning and reflection skills ([64](#), [75](#)).

EPEs considerably enhance capabilities for transformative change. Through system mapping, actors develop system awareness, or the ability to embrace uncertainty, and agility for change. TIPs that “aim at stretching ongoing transformation initiatives” cannot operate in silos ([27](#)**[**AU: Page number for quote?**page 424]**). Capabilities of actors to identify unintended consequences of their actions as well as unrecognised sources of resilience in some regimes, allow them to make EPEs for TIP contextually relevant. **[**AU: Incomplete sentence; please recast for clarity**I have now adjusted the sentence. Thank you!]**Acknowledging that transformation does not happen “one system at a time” ([76: page 55](#))**[**AU: Page number for quote?**reference 76, page 55]**, capabilities among policy actors to align policy objectives, instruments, and activities across multiple policy domains (horizontal coordination) and for multilevel governance (vertical coordination) ([69](#)) are essential for multisystem transformation. Such a multisystem view in turn helps address single-system blind spots and repercussions, such as injustices caused through energy transitions, industrial modernization and unsustainable development **[**AU: Edit OK?**Yes, I have refined it]**([22](#), 58a, [76](#)). EPEs incorporating collective imagination of desirable futures build anticipatory capabilities and recognition of the role of future narratives and metaphors in present-day action strategies (63a, [77](#)). These are all part of “strategic intelligence” capabilities that the Organisation for Economic Cooperation and Development (OECD) ([78](#)) suggests governments invest in “to monitor and evaluate socio technical transitions, and to formulate, design and implement effective STI policy agendas and

measures.” Revitalization is a capability that supports unlocking regimes, through skills of reimagining and negotiating that are essential to shaping TIP directionalities (22, 72a).

The participatory processes embodied in EPEs follow the principles of human capabilities approach (79), which highlights people’s ability to explore and exercise their choices and freedoms to convert their personalities, skills, knowledge, assets, and information into functionings (i.e., utilization to achieve common goals)(72a) . **[**AU: Edit OK?**]**Following this principle, the freedom to transcend institutional, political, sociocultural, and economic constraints is what TIP could truly strive to achieve.

3.7. Transdisciplinary KIs

Epistemic injustices (including epistemicide, or silencing of alternative knowledge systems) occur when knowledge systems are entrenched by power asymmetries and exclude plural and diverse knowledge sources **[**AU: Moved definition of epistemicide to first use, okay?** OK. But where is the first use definition?](80)**. Transdisciplinary knowledge infrastructure (KI)s are fluid cognitive spaces, shared by actors from different system dimensions, allowing translation and meaningful constellations between new forms of transdisciplinary knowledges (61, 81). Such infrastructures are essential for “generative dialogues” to broaden and deepen knowledges for evidence and action for societal transformation **[**AU: Source/page number for quote?** Page 5 of reference 9]** (9: page 5, 80). Given the complexity of system change and processes such as niche development, mainstreaming and unlocking of entrenched regimes, building appropriate KIs is essential to nurturing and institutionalizing transformative innovation.

Existing KIs associated with TIP include (a) the TIP Consortium, where public science funders (i.e., ministries) invest in science-policy practice (82); (b) nontraditional conferences where knowledge from policy and civil society is exchanged with academic knowledge (9); and (c) tool kits and databases of blogs, policy briefs, and podcasts that codify and aggregate knowledge from diverse actors and contexts (see eg. TIP Resource Lab). **[**AU: Edit OK?**]** The literature highlights universities’ role in providing spaces for transdisciplinary knowledge generation and circulation (75). EPEs for TIP design must create and maintain such infrastructures where diverse knowledge and evidence is synthesized into shaping collective intelligence for societal needs (83).

3.8. Empowered CoPs

Deliberate networks and CoPs are at the heart of a transformative innovation ecosystem (9, 84). Beyond epistemic communities of knowledge experts (85), networks of practitioners are now widely recognized as key enablers of “system-wide impacts” (86, 64). Within the TIP Consortium, the establishment of a global network of coaches who can apply TIP in their contexts, critique, and redirect system optimization efforts toward system change exemplified efforts to empower a TIP CoP (9).**[**AU: Edit OK?**Yes]**

Experimentation in TIP should enable collaboration with communities who practice transformation in their day-to-day work and living (87). It should empower communities as well as policy actors for innovation governance that includes new constellations of actors at local and regional scales **[**AU: please clarify source of quotation and page number** I have revised and removed quotes](51, 70)**. An empowered CoP substantially enhances the quality of deliberation as they exercise their agency to evaluate systemic challenges, test solutions, and mobilize their competencies to achieve more TOs. They further allow TIP scholars to learn from context-relevant practices. This could lead to effective management of policy initiatives (i.e., community assemblies, participatory budgets). Empowered CoPs are therefore key enablers of higher transformative impact.

4. DIRECTIONALITIES FOR TIP

4.1. Being Democratic

Democratic structures and practices are fundamental to social justice, freedom, and equity (79) **[**AU: Please add reference to literature cited** its reference 79]**. The principles of deepening democracy include inclusion **[**AU: consideration, to prevent repetition?**]**of diverse voices, giving all communities the power, freedom, and agency to choose and act against socioeconomic and political disempowerment and marginalization (19). Literature on democracy encourages exploring multiple alternatives to address place-based challenges, emphasizing diversity and pluralism through the broad participation of social actors in developing new narratives and practices (88). Being democratic means to “open up the political space” for collectively shaping directions of innovation and transformation (19**[**AU: Please provide page number for quote**page 5]**). This is achieved through deepening democracy—one that

supports initiatives and capacities for addressing power imbalances. Democracy can also be deepened outside the state by promoting autonomy and self-management through assembly spaces that pressure and shape policy processes. It is also deepened by building a stronger civil society, through co-governance mechanisms aimed at constructing self-organized spaces, and through improving the quality of deliberation by stimulating collective debate, sensemaking, and narrative construction with different epistemic voices (14). The TIP directionality of being democratic promises innovation that is ethical and just, promoted through confronting disagreements, resisting the “tyranny of the majority” (89), avoiding “co-optation” (90), and addressing “paradoxes of social choice” (91).

4.2. Elevating Decolonial Sensibilities

Decolonial thinking links the past, present, and future of and for our world by tracing the problematic origins of modernity and the resulting Eurocentric worldviews, while seeking to break out from the unjust impulses these have wrought on the planet, peoples, nature, and other species (92). Birthed by modernity, the racial capitalist system and colonialism function through the logic of unbridled economic growth based on extracting resources, labor, and land from the oppressed in the periphery (94). Across centuries, coloniality has manifested through epistemicide, dispossession, violence, gender discrimination, othering, and overengineering of nature (95–97).

Coloniality, associated with modern economies, is powered by innovation and continues to manifest through inequalities, unfair concentration of privilege for the winners -those with more resources for more extraction and ‘power-over’losers -those living in harmony with nature with less income and social privileges in and between the Global North and South **[**AU: Edit OK?** I would keep ‘power-over’ in single quotes, as it is known concept](98)**. The current green growth paradigm and climate action represents a new frontier for capital accumulation through continued tech-centered and neoliberal approaches to development (99, 100) and risks reproducing these injustices and harms to nature and all species (101, 102). It is now documented that decarbonization has a potentially darker side; e.g., battery manufacturing depends on cobalt mined, sometimes by children, in the Democratic Republic of Congo, where the threat of dispossession looms over local communities (99). The idea of transformation itself, if uninterrogated by justice and decoloniality frames, may represent yet another iteration in the

dark march of colonial injustices and racial capitalism ([97](#), [104](#), [105](#)).

A TIP directionality of elevating decolonial sensibilities will attend to the *manner of transformation*, i.e., the core values and insights that guide action for and in transformation, and the *means of transformation*, i.e., different operational solutions, methods, and practices [****AU: Edit OK? yes thanks**]([106](#)). Being decolonial in TIP entails relationality, humility for diverse ways of knowing, and openness to attend to the resistance and desires of the historically marginalised.

4.3. Enhancing Well-Being

The Intergovernmental Panel on Climate Change (1) defines well-being as a state of existence that fulfils various human needs, including material living conditions, meaningful social and community relationships and quality of life, as well as the ability to pursue one's goals, to thrive, and feel satisfied with one's life.

Well-being, from this perspective, goes beyond consumption and economic wealth ([79](#), [107](#)) and into a holistic view on sustainable welfare where social progress is 'nature-inclusive' ([108–111](#)). An emphasis on well-being allows a broader understanding of sustainability and complex entanglements and trade-offs between social life, ecological balance, and economic prosperity ([112–115](#)). Scholars across climate science and well-being studies highlight public policy's central role in enacting intergenerational and ecological well-being as a focal point to tackle climate change ([116–118](#)). The emergence of alternative indices to gross domestic product, e.g., Gross National Happiness ([119](#)), Human Development Index ([120](#)), Better Life Index ([121](#)), and Happy Planet Index ([122](#)), highlights the multidimensional nature of human, intergenerational, interspatial, and ecological well-being, which is integral to sustainable development and staying within planetary boundaries ([124](#), [125](#)). A TIP directionality of enhancing well-being strengthens the quality and outcomes of innovation, EPEs, , and capacity building, in line with the SDGs and inclusivity principles ([126](#), [127](#)).

4.4. Navigating Contestations on Desirable Futures

Future imaginaries are an important area of studying societal values and aspirations as well as fears, worries, and anxieties about the future [****AU: Edit OK? yes, I have also revised**]([128](#)). Future thinking involves various techniques of anticipation and creative imagination of multiple potential future scenarios to navigate uncertainties. Normative social

imaginaries of the future consider desirable goals and explore paths to achieve these goals, often through envisioning futures beyond current limitations. They represent collectively held visions that motivate human action (129, 130).

Different actors hold diverse visions or expectations about the future, stemming from divergent values, interests, and power dynamics (130), leading to contestations and struggles that shape technological trajectories and social outcomes (104, 131). Our visions are locked in the past and present colonial ways of knowing and thinking, which blur our views of true just and resilient futures from non-eurocentric perspectives (92, 132). Backcasting is used frequently to assess the feasibility of visions and create strategic plans (133, 134). Yet, without normative considerations of which visions are desirable and for whom, injustices might prevail. Normative visions of desirable futures help identify opportunities and justifications for policy support for linking grassroots initiatives to broader movements (134–137).

A TIP directionality of mobilizing future visions, which are contested yet collectively desired and attainable, necessitates flexibility and reflexivity in policy design and anticipatory capabilities that enable individuals and organizations to prepare for both opportunities and challenges, enhancing resilience and strategic decision-making (138–142).

Figure 1 Transformative innovation policy (TIP) constituents and directionalities. The butterfly is used as a metaphor for transformation, capturing the multidimensional and evolutionary nature of systemic change. The head represents the *TIP cornerstones*: experimenting with and evaluating policy with transformative outcomes. The body signifies the *macro-processes of transformation*: socio-technical system change, nurturing and mainstreaming niches, unlocking regimes, and enhancing capabilities. The support structure at the base illustrates the *enablers that sustain TIP practices*: building knowledge infrastructures and empowering communities of practice. The wings represent four *guiding directionalities*: being democratic, decolonial, well-being oriented, and futures oriented. **[**AU: Okay to put simply “Democratic,” “Decolonial,” “Well-being oriented, and “Futures oriented” into butterfly wings? **Yes ok]** Together, these elements (see sections 3 and 4) reflect the integrative and values-driven approach of TIP to fostering just, inclusive, and long-term societal transformations.

5. NAVIGATING GAPS AND CHALLENGES OF TIP

In this section, we discuss the major challenges faced in TIP design and implementation under three broad issues, namely societal engagement, context sensitivity, and epistemic justice, as analyzed from the review of TIP literature. We highlight the challenges and gaps that future

research can aim to fulfill. We argue that an explicit and deeper engagement with the four directionalities might be a productive way to be socially inclusive, context sensitive and just in future research (See Figure 2).

5.1. Societal Engagement

The first major challenge faced in TIP is how to engage with multiple societal actors meaningfully and inclusively. In rapidly evolving societal contexts and for accelerated action for climate mitigation, democratic processes of engagement is often rushed, even in experimental governance settings (57). Disagreements on visions and strategies between policy and societal actors, priority misalignments, and clashes in expectations generate tensions in policy processes (11). Imaginaries are often bounded (77) by current structures and norms and a lack of collective and shared vision hinders system change (48). How can actors with diverse motivations and interests be persuaded to collaborate and agree on shared strategies? **[**AU: Edit OK?**]** The issue is common in messy consultative policy processes, where wider participation may be invited but limited perspectives are cherry-picked, creating dissatisfactions, exclusions, and disempowerment of many actors (143). Second, local actors are perceived as lacking the capacity to offer easily implementable solutions. The lack of trust can be a major issue in network formation and circulation of knowledge. Third, although cross-departmental and multilevel policy coordination is often associated with positive change, it does not fix transformation failure due to exclusion of non-dominant voices. Fourth, incumbent actors might be against wider participation of actors who would contest the current unjust practices. Even when policies are evaluated ex ante to set aims and expected outcomes as part of developing a TToC, powerful voices may dictate which policy aims are to be fulfilled and who is expected to benefit from the policy (144). Such resistance from the powerful regime actors perpetuates inequities, and cooperation among these actors creates barriers to innovation, experimentation, and capacity development.

5.1.1. Misalignment of perspectives.

Focussing on the directionalities helps address some of these issues. Democratic, participatory processes that extend beyond representation ensure policies align with diverse public interests, fostering mutual accountability. Well-designed EPEs can include participatory workshops to address conflict, and integrate diverse experiences, fostering shared visions of the future (14)

(Felt, 2015[**AU: Please add to literature cited**I have cited reference 14, no need to add new references]). Systems thinking allows citizens and end users to become part of the solutions and active stakeholders in change ([72](#)). Participatory dialogues seek out and attend to resistance, desire, and frustrations of people, especially those marginalised by coloniality. Experimentation provides the space for justice when marginalized stakeholders refuse to take part in unjust processes. Centering the identities, cultural values, and experiences of historically marginalised actors helps facilitate transformative futures by allowing the most vulnerable to (re)imagine and (re)create just worlds as a form of resistance to the dehumanizing impulses of colonialism, beyond the limited visions of the future that neocolonialism often presents ([96](#), [132](#), [146](#)).

5.1.2. Including nonexperts.

Inclusive and transformative policies include voices of not only scientific experts and technocrats but also people with wider interests and innovation capacities, such as indigenous communities and citizens who innovate in everyday life, through behavioural and social adjustments in response to everyday struggles ([145](#), [147](#), [148](#), 156). Formative policy evaluation with communities could attend to greater awareness of trans-species well-being and nurture relational understanding between actors to share responsibilities of enhancing well-being ([111](#), [149](#)). Including demand-side actors such as end users in the TIP implementation processes is congruent with demand-side climate mitigation strategies, such as promotion of active mobility and energy and water saving by end users ([36](#), [38](#), [40](#), [150](#)). Plural future storylines enable continuous interactions among scientific and policy experts, and citizens for legitimacy and credibility of future actions and build shared ownership of decisions, which in turn increases public acceptance of evidence-based policy ([1](#), [77](#)).

5.1.3. Transformative partnerships.

Deepening democracy entails deliberate strategies to enhance interaction and partnerships between policy actors, academics, private investors, and NGOs ([151](#), [152](#)). A common goal, such as managing the COVID-19 response, is a powerful mechanism to organize actors with different roles in the innovation ecosystem to form transformative partnerships ([13](#), [84](#)). Intermediaries are key to orchestrating connections between various actors in multiple levels, facilitate strategic coordination and trust building between actors with different interests in different policy departments and levels of governance ([27](#), [59](#)). Where partnerships are truly transformative,

capabilities to exercise choice and freedom among historically marginalized actors and those perceived as nonexperts can develop and sustain, through reflexivity, resilience, responsiveness, and revitalization (72a, 74a).

5.1.4. Resistance from the powerful.

While powerful actors might resist wider participation in decision making, an explicit attention to human and environmental well-being as a common goal in TIP will necessitate citizen engagement for localised solutions to wicked problems (59). Democratic and decolonial arrangements in EPEs can foster actors' confidence to resolve conflicts over natural resource and land use, confront neocolonial development, and operationalise locally adapted scenarios linked to global futures scenarios through international deliberation in science-policy diplomacy[**AU: Edit OK? yes, I have also revised a bit] ([154](#), [155](#)).

5.2. Context Sensitivity

Societal transformation is contextual. In contexts of poverty and vulnerability to climate change, experimentation and learning seem to be slow and counterintuitive to urgent and accelerated actions. How can transformation be fast and just? Furthermore, identifying system boundaries and assessing the vulnerability of system configuration are challenging in many sociopolitical and economic contexts. Local political and institutional contexts determine how powerful actors encourage or resist transformations., Colonial histories shape political, and cultural, differences between the Global South and Global North ([63](#), [156](#), [157](#)). Despite independence and postcolonial narratives, legacy effects remain in the previously colonised regions' structures and capacities. How can TIP ensure locally just and post-colonial transformations? Countries in the South tend to “catch up” and follow development trajectories of the North, which poses challenges of lock-in and overlooking locally empowering innovations (157a). How can the Global South shape its own trajectories of development?

5.2.1. Urgency versus learning from failure.

The directionalities can help address the dichotomy between accelerated and just transitions. Deepening democracy principles suggest that policy processes must prioritize giving voice, enhancing agency, and empowering actors instead of achieving missions by any means. Future visioning allows learn from the past, “consensus-building at the local and national level” ([158](#):

page 11) on the means and outcomes of accelerated transitions. Shared visions therefore helps about broader repercussions, and further marginalization of non-dominant voices, from decisions made by a few. **[**AU: Please recast sentence for clarity**I have now revised and broken the sentence into two]** Urgency is often popularized by technocrats with vested interests in short-term technological solutions ([159](#)). A collaborative approach to imagining desirable futures centered on reciprocal relationships between nature and people can be seen not as a hindrance to speed but as essential for justice **[**AU: Edit OK?**Yes thanks](**[160](#), [161](#)**).** For TIP the real urgency is in the need to go beyond static, linear, and deterministic pathways of transformation and learning about “diverse subjectivities, priorities and values that influence [...] decision-making” for the longer term (**[**AU: Please specify source of quote and provide page number** added]**[47](#): page 1, [92](#)).

5.2.2. A relational understanding of system boundaries.

In most contexts, multiple regimes coexist with different degrees of maturity and with complex entanglement, making system change an ambiguous target. Democratic deliberation in EPEs can reveal entanglements between economic, social, and cultural factors and leverage points for acting toward enhancing well-being. How innovations achieve system-wide effects is contextual, with different trajectories and impact potentials ([64](#)). Decolonial thinking allows us to approach systems in a relational way ([111](#), [149](#)). Ubuntu philosophy shows that, system awareness means recognising humanity as part of a collective. Without a relational view between humans, we have little agency to make and break systems ([162](#)). A relational approach helps address the additional challenge [“whether observed systemic changes can be attributed to (a particular) policy”] (**[**AU: Please provide page number for quote**]**[43](#): page 4) by foregrounding the importance of coordination and collaboration across individuals and policies. Empowering CoPs and building KIs to sustain beyond a single policy intervention advance this relational understanding of people and policies. A decolonial TIP opens up the space for connections between peoples with diverse ways of knowing and being, in various spaces and times ([94](#), [149](#)). Powerful technocrats’ efforts to scale up innovations and draw clear boundaries around socio-technical systems could dehumanise transformations, which decolonial sensibilities would resist ([52a](#), [103](#)).

5.2.3. Legacy effects.

Institutional contexts determine the political and cognitive embedding of TIP. Institutional structures limit an organization's capacity to embrace and advance alternative governance approaches such as EPEs. In historically colonized countries, political and legal institutions carry colonial legacies and act as “sticking points” (7) for sectoral silos and inadequacy of resources for cross-sectoral initiatives, bottlenecks, and lack of institutional support for innovations that transcend sectoral boundaries (150). Emphasizing the holistic well-being of people and the planet and a common directionality (69) might challenge such siloed perceptions and build momentum for “new connections and capacities” and “shifting power relations between the ministries” as strategies for TIP **[**AU: Please provide page number for quote** page 686 for both quotes]** (13: page 686).

5.2.4. Contextualizing innovations.

When technological innovations from the North are transferred to the ‘technology-poor’ Global South countries, , the process erases local ingenuities, philosophies, and ways of knowing, doing, and being (163). Innovations away from the western mindset can be technological or social (40). Informality is a key feature in transitions in the Global South leveraging unique local knowledge to meet local needs (164, 52a). For sustainable mobility, innovations in southern megacities include fuel efficient vehicles as well as new models for equitable access to improved public transport options. The latter discourages the demand shift from shared to private mobility and ensures mobility justice (62, 166). Embedding locally situated desired futures, decolonial and well-being oriented TIP can “support place-based leaders to address key challenges to SDG localization” (152, 59, 139); **(I have deleted this part)** to embrace “flexibility, adaptability and creativity” in informal transformative spaces (52a: pg. 1) and incrementally transform fragmented, splintered, and coexisting regimes for reconfiguration and change (62, 70, 77, 166, 167). **[**AU: Edit OK?** yes thanks, please also accept my revisions]**

5.2.5. Navigating power relations.

Implementing TIP in a power-sensitive manner means reflecting on *where* experimentation takes place, initiated *by whom*, *how* governments at different levels (local, regional, national) coordinate, and *what* political dynamics within and across governments can facilitate pursuing normative agendas **[**AU: AU: Please recast list for clarity** I have revised, please check]** (61, 168, 169). Democratic processes of developing a TToC could help navigate power relations

in leveling the field for negotiations of diverging worldviews about how to enact change. The FE method could focus on reflecting on the sources of power, bringing to the forefront power differentials created by coloniality between humans and other species (manifested through deforestation and environmental damages), and in humans' relations to nature (170). EPEs can provide a new approach toward shifting perceptions from limitless growth toward intergenerational well-being and space for reflexive learning for confronting fears and frustrations around polycrisis (170a, 170b). Critical futures methods elucidate who wins from certain future scenarios (171) and who remain as 'losers'; thereby empowers new actors to reimagine their positions in shifting the power dynamics (70).**[**AU: Edit OK?***Yes, I have also revised]**

5.3. Epistemic Justice

The challenges of societal engagement (section 5.1) and context sensitivity (section 5.2) culminate in a deeper challenge: lack of recognition of diverse knowledge systems. Although societal engagements promise a broad range of perspectives, many perspectives remain overlooked and "lost in translation" (172). Even when deliberate efforts are made to invite conflicting perspectives, the transdisciplinary policy process of TIP faces challenges in integrating these knowledges for transformative change. Imposition of codified, scientific evidence, disregarding localized, practice-based tacit and experiential knowledges might unhelpfully widen the gap between science and practice. **[**AU: Edit OK?***I have revised the sentence]**Finally, efforts to empower and build capacities from the outside might rob **disempower** **[**AU: rob?***yes]**CoPs of their agency inherent capabilities to steer change in context sensitive ways (40). Engaging with the four TIP directionalities helps resolve these issues.

5.3.1. Diverse knowledge recognition.

Transformations require engaged and evidence-based policies instead of "heroic interference" (159: page 773). Democratic spaces will allow non-elite, non-western-scientific communities to generate evidence through collaborative sensemaking among diverse stakeholders (173, 174). Transdisciplinary knowledge co-creation often leads to conflicts and tensions that deliberative discourses can resolve (34, 81, 112). Scientists and policymakers can gain valuable insights from indigenous knowledge as a source of collective intelligence, e.g., from the Bishnoi community in

India or Australian aborigines on sustainable land management to conserve biodiversity and ensuring eco-friendly social life ([147](#)–[149](#), [174](#)–[175](#), [177](#)). Traditional farming in Taiwan and Nepal and livestock management in the Massai community (Kenya) further show the importance of local knowledge in maintaining food security and community well-being ([178](#)–[180](#)).

Intentional inclusion of actors with conflicting perspectives in TIP fosters epistemic diversity by valuing alternative expertise of the local, marginalized, and indigenous ([174](#), [181](#)). Such epistemic pluralism is promoted in Nature Futures framework ([136](#)) and deemed necessary for intergovernmental efforts ([181a](#)).

5.3.2. Diverse knowledge integration and translation.

TIP practice informed by deliberative democracy can harness the full potential of fluid spaces—spaces where TOs act as boundary objects ([61](#)). Universities can play a significant role by acting as ““Campus living labs” ([181b](#): page 1) for knowledge exchange and translation at science–society interfaces. Universities providing a “collaborative construction space” ([75](#): page 10) **[**AU: Page number for quote? done]** can help address knowledge coloniality (i.e., some forms of knowledge being considered superior to others). Colonial injustices historically shaped knowledge hierarchies ([80](#), [175](#)). . A decolonial TIP could build on the ideas of “Ubulungisa” and “right relations” ([182](#), [183](#)), concepts that signify the continuous seeking and doing of reparative justice within lived and across diverse incarnations of beings. Widening the involvement of “epistemic communities” ([154](#): page 32), a democratic, decolonial and future oriented TIP can further strengthen relational understandings of people and their epistemic capacities ([156](#), [181](#)).

5.3.3. Harnessing capabilities of CoP.

One source of epistemic injustice is when knowledge produced and held in western universities and Global North NGOs suppresses and marginalizes knowledge held in Global South communities and local sociocultural spaces ([150](#)). **[**AU: Edit OK? I have deleted this sentence, it is repetitive]** TIP efforts should steer toward learning from CoPs. TIP scholars and practitioners should harness capacities to nurture and stretch existing ideas and solutions, rather than building new ones ([52a](#)). **[**AU: Edit OK?]** Frameworks such as TOs should be used flexibly and responsibly, adapting to contextual needs. Lazarevic et al.’s ([69](#)) efforts to add new TOs to Ghosh et al.’s ([15](#)) framework to analyze Finland’s new circular economy policies is a

step in this direction (see [Table 2](#)). Oral histories, narrative and collaborative storytelling could unpack knowledges from the past, across generations and temporalities **[**AU:**

temporalities? Yes thanks]**; i.e., short-, medium-, and long-term experiences of change could help discover hidden capabilities of local people and shift knowledge hierarchies (52a, 177, 179).

Decolonial TIP embraces epistemic pluralism as the future of transformative science-policy and invites reflects on what is considered legitimate knowledge or data for decision-making. . It opens possibilities for escaping the model land, and incorporating plural storylines in climate and social governance (183a, 183b). **[**AU: As meant? If not, please recast for clarity**I have changed this sentence]** A democratic and decolonial KI and CoP of and for TIP incorporates knowledges co-produced in diverse and innovative ways, such as “humanistic, arts-based and performative approaches” (183b: page 737) that can help expand and deepen understanding of transformationsThis in turn help avoid transformation failure through incorporating lessons from diverse ways of knowing, deciding, governing and being in the world ([53](#), [92](#), [146](#), 183b).**[**AU: Edit OK?** I have now edited this]**

[AU: Please call out Figure 2 where appropriate** Done at the end of first paragraph of section 5, hence the figure can be moved there]**

Figure 2 Major challenges in transformative innovation policy (TIP) design and implementation, under three broad category of issues, namely, societal engagement, context sensitivity, and epistemic justice, as analyzed from the review of TIP literature. Attending to the TIP directionalities such as democratic decision-making, decolonial sensibilities, well-being and futures orientation is seen as crucial to addressing each of the challenges and thereby avoiding transformational failures.

6. DISCUSSION AND CONCLUSION

TIP embodies what an alternative innovation policy could look like to mitigate “transformational failures” ([58](#)). TIP theory and practice constitute the approaches and tools to address entangled complexities of socio-environmental challenges. Building on the previous framings of innovation policy, TIP emphasizes purpose-driven innovations and transdisciplinary approaches to innovation policy to address the SDGs. TIP invites policymakers to adopt agility and a new way of thinking and acting about policy and innovation that transcends the traditional way, which typically included setting social and climate targets and missions at the beginning of policy

process and a summative policy evaluation at the end. Instead, TIP oriented toward transformative governance (43) must be about opening up the problem and solutions space, inviting wider engagement in pluriversal processes (88) and continually evaluated in a formative way. In this article, we discuss the characteristics and components of designing and implementing TIP and ways in which TIP practices could be more democratic, decolonial, well-being and desirable futures oriented.

This review underlines the actionable knowledge underpinning TIP—knowledge that could guide and steer human actions for mitigating social and environmental challenges. The analysis shows how TIP can be implemented in democratic and decolonial ways by considering human well-being in harmony with nature as well as plural, contested, and desired future imaginaries. As systemic transformations unfold, it might become necessary to measure the outcomes and effectiveness of existing innovation policies through “transition indicators” **[**AU: Edit OK? yes thanks](41)**. Embracing decolonial praxis, such indicators should remain subjective, context sensitive and inclusive of diverse epistemologies. Unfolding transformations are neither predictable nor certain. Measurement efforts must therefore be reflexive and collaborative instead of top-down and summative. Qualitative, and codesigned guidelines need to accompany quantitative models for monitoring impacts and to explore the readiness of policy practices in stretching = in more transformative directions.

SUMMARY POINTS

1. Transformative innovation policy (TIP) is an emerging approach that fosters innovation aimed at transforming systems of service provision, such as energy, food, and mobility, with a normative focus on addressing the complex social and environmental challenges of the current polycrises.
2. TIP can be enhanced by developing four key directionalities, namely, being democratic, elevating decolonial sensibilities, enhancing well-being, and navigating contestations on desirable futures.
3. Experimentation in policy is a core TIP methodology that includes codesigning a localized theory of change with a diverse range of people and organizations (actors) and continuous monitoring, evaluation, and learning, using transformative outcomes

- as leverage points.
4. Enhancing policy capabilities, building knowledge infrastructures, and empowering communities of practice are key mechanisms for institutionalizing transformative innovation.
 5. TIP requires building long-term partnerships among academic and nonacademic actors and navigating misalignment of perspective and resistance from powerful incumbent actors.
 6. Context sensitivity is a key consideration for TIP in terms of spatial and socioeconomic environments and in the context of innovations, systems, institutional stickiness, power asymmetries, and urgency.
 7. TIP invites innovation scholars and practitioners to **take justice into consideration** **[**AU: Please clarify** revised]** in all policy decisions by designing for collaboration, inclusion, learning, and contextualization as part of experimental policy process.

FUTURE ISSUES

1. More research is needed on measuring transformation using quantitative and qualitative tools by developing indicators, metrics, and pathways suitable in diverse contexts, as well as extending the transformative outcomes for evaluating the true impact of democratic and decolonial actions on transformative system change.
2. Conceptual alignment and misalignment should be resolved between the three frames of innovation and how they could coexist in productive ways, ultimately feeding into a shared sustainability transformation agenda.
3. Empirical and methodological research is needed into complementarities of transformative and mission-oriented innovation policies, highlighting the promises of a collaborative rather than a contentious research agenda.
4. More applied research is needed on methods for designing policy experiments in different contexts and scales, including mapping key actors, recognizing and including previously excluded actors, managing tensions in multi-stakeholder processes, and addressing perceived trade-offs between learning and action.

5. Methods of developing and applying ex ante measurements of policy readiness for transformative system change are needed. Such methods will help policy practitioners understand the transformative potential of their intended policy strategies in the early stages of TIP design .
6. Strategies, prototypes, and pilot projects should be developed that bridge small-scale, context-specific experiments with the broader goal of transforming socio-technical systems.
7. Scholars need to engage further with theories and examples of justice, e.g., through the human development and capabilities approach, to elicit the true meaning of a just transition, especially in Global South contexts.
8. Decolonial scholars can enrich TIP by unpacking the knowledges and capabilities of indigenous communities and identifying ways to harness these knowledges and capabilities to drive contextual transformations.
9. We need better tools for recognizing a wide range of collective emotions (including desires, climate anxiety and transition pain) associated with disruptive change and deep transitions.

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DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

AUTHORSHIP STATEMENT

The authors confirm contribution to the article as follows: B.G.: conception and design, writing and editing the manuscript. B.G., D.C.V.M., K.C., P.M., and S.L.Y.: Writing sections, reviewing

and editing.

ACKNOWLEDGEMENTS

We would like to thank colleagues in the TIP Consortium and Deep transitions Lab for their continuous support for this research. We would especially mention Johan Schot, Ed Steinmueller, Alejandro Boni and participants of International Sustainability Transitions conference in Oslo, 2024 for comments and feedback on earlier versions of this paper. We extend our gratitude to the anonymous reviewers and copyeditors for comments and edits that immensely improved the paper.

[**AU: Would you like to add an Acknowledgments section? This is the final opportunity to do so.**Added, thanks]

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LITERATURE CITED

1. Lee H, Romero J, eds. 2023. *Climate change 2023: synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Rep., Intergovernmental Panel on Climate Change
2. Lawrence M, Homer-Dixon T, Janzwood S, Rockström J, Renn O, Donges JF. 2024. Global polycrisis: the causal mechanisms of crisis entanglement. *Glob. Sustain.* 7:E6
3. Schot J, Steinmueller WE. 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. *Res. Policy* 47(9):1554–67
4. Maliphol S, Aridi A, Lee J-D, Woodson T. 2024. Innovation policy responses to address vulnerabilities of national innovation systems: long-lasting impacts of COVID-19. *Sci. Public Policy* 51(6):1191–94
5. Patterson J, Schulz K, Vervoort J, van der Hel S, Widerberg O, et al. 2017. Exploring the governance and politics of transformations towards sustainability. *Environ. Innov. Soc. Transit.* 24:1–16
6. Loorbach D, Frantzeskaki N, Avelino F. 2017. Sustainability transitions research: transforming science and practice for societal change. *Annu. Rev. Environ. Resour.* 42:599–626

7. Diercks G, Larsen H, Steward F. 2019. Transformative innovation policy: addressing variety in an emerging policy paradigm. *Res. Policy* 48(4):880–94
8. Haddad CR, Nakić V, Bergek A, Hellsmark H. 2022. Transformative innovation policy: a systematic review. *Environ. Innov. Soc. Transit.* 43:14–40
9. Velasco D, Ghosh B, Boni A, Schiller K, Winkler L. 2024. Building a knowledge infrastructure for Transformative Innovation Policy (TIP). An analytical approach based on the experimental TIP conference 2022. *Environ. Sci. Policy* 160:103832
10. Ansell C, Sørensen E, Torfing J. 2023. Public administration and politics meet turbulence: the search for robust governance responses. *Public Adm.* 101(1):3–22
11. Ciplet D, Harrison JL. 2020. Transition tensions: mapping conflicts in movements for a just and sustainable transition. *Environ. Polit.* 29(3):435–56
12. Kanger L, Tinitis P, Pahker A-K, Orru K, Tiwari AK, et al. 2022. Deep transitions: towards a comprehensive framework for mapping major continuities and ruptures in industrial modernity. *Glob. Environ. Change* 72:102447
13. Kivimaa P, Lukkarinen J, Lazarevic D. 2023. Analysis of COVID-19 recovery and resilience policy in Finland: a transformative policy mix approach. *Sci. Public Policy* 50(4):681–94
14. Boni A, Velasco D, Molas-Gallart J, Schot J. 2023. Evaluating transformative innovation policy in a formative way: insights from Vinnova’s food mission experiment. *Res. Eval.* 32(3):577–90
15. Ghosh B, Kivimaa P, Ramirez M, Schot J, Torrens J. 2021. Transformative outcomes: assessing and reorienting experimentation with transformative innovation policy. *Sci. Public Policy* 48(5):739–56
16. Fagerberg J. 2018. Mobilizing innovation for sustainability transitions: a comment on Transformative Innovation Policy. *Res. Policy* 47(9):1568–76
17. Lundvall B-Å. 2024. Transformative innovation policy—lessons from the innovation system literature. *Innov. Dev.* 14(2):297–314
18. Edwards-Schachter M. 2018. The nature and variety of innovation. *Int. J. Innov. Stud.* 2(2):65–79
- 18a. Chaminade, C., Lundvall, B.Å. and Haneef, S., 2018. Advanced introduction to national innovation systems. Edward Elgar Publishing.
- 18b. Aerni, P., 2025. Innovation in times of crisis: a pragmatic and inclusive approach to cope

- with urgent global sustainability challenges. *Frontiers in Environmental Economics*, 4, p.1498138.
19. Stirling A. 2024. Responsibility and the hidden politics of directionality: opening up “innovation democracies” for sustainability transformations. *J. Responsib. Innov.* 11(1):2370082
 20. Steward F. 2012. Transformative innovation policy to meet the challenge of climate change: sociotechnical networks aligned with consumption and end-use as new transition arenas for a low-carbon society or green economy. *Technol. Anal. Strateg. Manag.* 24(4):331–43
 21. Weber KM, Rohrer H. 2012. Legitimizing research, technology and innovation policies for transformative change: combining insights from innovation systems and multi-level perspective in a comprehensive “failures” framework. *Res. Policy* 41(6):1037–47
 22. Sovacool BK, Hook A, Martiskainen M, Baker L. 2019. The whole systems energy injustice of four European low-carbon transitions. *Glob. Environ. Change* 58:101958
 23. Elzen B, Geels FW, Green K, eds. 2004. *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*. Edward Elgar
 24. Geels FW. 2024. *Advanced Introduction to Sustainability Transitions*. Elgar Advanced Introductions. Edward Elgar Publishing
 25. Köhler J, Geels FW, Kern F, Markard J, Onsongo E, et al. 2019. An agenda for sustainability transitions research: state of the art and future directions. *Environ. Innov. Soc. Transit.* 31:1–32
 26. Diercks G. 2019. Lost in translation: how legacy limits the OECD in promoting new policy mixes for sustainability transitions. *Res. Policy* 48(10):103667
 27. Penna CCR, Alvial-Palavicino C, Ghosh B, Schot J. 2023. Transformative innovation policy. In *Encyclopedia of Social Innovation*, ed. J Howaldt, C Kaletka. Edward Elgar
 28. Mazzucato M, Kattel R, Ryan-Collins J. 2020. Challenge-driven innovation policy: towards a new policy toolkit. *J. Ind. Compet. Trade* 20(2):421–37
 29. Janssen MJ, Torrens J, Wesseling JH, Wanzenböck I. 2021. The promises and premises of mission-oriented innovation policy—a reflection and ways forward. *Sci. Public Policy* 48(3):348–44
 30. Mazzucato M. 2018. Mission-oriented innovation policies: challenges and opportunities. *Ind. Corp. Change* 27(5):803–15

31. Stilgoe J, Owen R, Macnaghten P. 2013. Developing a framework for responsible innovation. *Res. Policy* 42(9):1568–80
32. Robinson DKR. 2009. Co-evolutionary scenarios: an application to prospecting futures of the responsible development of nanotechnology. *Technol. Forecast. Soc. Change* 76(9):1222–39
33. Penna, C.C., Schot, J., Velasco, D. and Molas-Gallart, J., 2025. The formative evaluation of open-ended transformative missions: The Vinnova experience in the food system. In *Transformative Mission-Oriented Innovation Policies* (pp. 98-118). Edward Elgar Publishing. **[**AU: Please provide publication information** Done]**
34. Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, et al. 2013. Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Curr. Opin. Environ. Sustain.* 5(3–4):420–31
35. Chaminade C. 2020. Innovation for what? Unpacking the role of innovation for weak and strong sustainability. *J. Sustain. Res.* 2(1):e200007
36. Parks D. 2022. Directionality in transformative innovation policy: Who is giving directions? *Environ. Innov. Soc. Transit.* 43:1–13
37. Akon-Yamga G, Daniels CU, Quaye W, Ting BM, Asante AA. 2021. Transformative innovation policy approach to e-waste management in Ghana: perspectives of actors on transformative changes. *Sci. Public Policy* 48(3):387–97
38. Creutzig F, Niamir L, Bai X, Callaghan M, Cullen J, et al. 2022. Demand-side solutions to climate change mitigation consistent with high levels of well-being. *Nat. Clim. Change* 12(1):36–46
39. Bhandari MP, ed. 2024. *Social Inequality: Past, Present And Future*. Social Issues, Justice and Status. Nova Science
40. Bugge MM, Berg R, Tømte CE. 2023. Transformative innovation policies detached from existing systems of innovation in the Global South. *Innov. Dev.* 14(3):563–86
41. Engelhardt A, Francesconi W, Ghosh B, Guo S, Kim Y-G, et al. 2024. *Transition indicators to broaden perspectives beyond adaptation and mitigation*. Rep., Climate Strategies
42. Aminullah E. 2020. STI policy and R&D governance for the attainment of SDGs: envisioning the Indonesia's future. *Asian J. Technol. Innov.* 28(2):204–33
43. Haddad CR, Bergek A. 2023. Towards an integrated framework for evaluating transformative innovation policy. *Res. Policy* 52(2):104676

44. Molas-Gallart J, Boni A, Giachi S, Schot J. 2021. A formative approach to the evaluation of transformative innovation policies. *Res. Eval.* 30(4):431–42
45. Lazarevic D, Morkkila S, Kivimaa P, Lukkarinen J, Toppinen A. 2024. Municipal experimental policy engagements in the built environment. *Environ. Innov. Soc. Transit.* 52:100888
46. Ghosh B, Torrens J. 2020. Towards a transformative innovation policy (TIP) research agenda. Work. Pap., Transformative Innovation Policy Consortium
47. McClure A, Ziervogel G, Patel Z. 2024. Expansive learning of climate scientists towards transdisciplinarity. *Clim. Risk Manag.* 45:100642
48. Könnölä T, Eloranta V, Turunen T, Salo A. 2021. Transformative governance of innovation ecosystems. *Technol. Forecast. Soc. Change* 173:121106
49. Sengers F, Wieczorek AJ, Raven R. 2019. Experimenting for sustainability transitions: a systematic literature review. *Technol. Forecast. Soc. Change* 145:153–64
50. Howlett M, Mukherjee I, eds. 2020. *Routledge Handbook Of Policy Design*. Routledge Handbooks. Routledge
51. Kuhlmann S, Stegmaier P, Konrad K. 2019. The tentative governance of emerging science and technology—a conceptual introduction. *Res. Policy* 48(5):1091–97
52. Boon W, Edler J. 2018. Demand, challenges, and innovation. Making sense of new trends in innovation policy. *Sci. Public Policy* 45(4):435–47
- 52a. Mungekar, N., Janssen, A., Hölscher, K. and Loorbach, D., 2025. Nurturing transformative spaces to challenge technocratic hegemony: Leveraging informality in Indian cities. *Action Research*, p.14767503251347422.
53. Deranger ET, Sinclair R, Gray B, McGregor D, Gobby J. 2022. Decolonizing climate research and policy: making space to tell our own stories, in our own ways. *Community Dev. J.* 57(1):52–73
54. Rohrer H, Coenen L, Kordas O. 2023. Mission incomplete: layered practices of monitoring and evaluation in Swedish transformative innovation policy. *Sci. Public Policy* 50(2):336–49
55. Velasco D, Acebillo-Baqué M, Boni A, Fernández T. 2023. Imaging and realising futures in Catalonia: shared agendas for just sustainability transitions. In *Reparative Futures And Transformative Learning Spaces*, ed. M Walker, A Boni, D Velasco. Springer Nature

56. Penna CCR, Schot J, Steinmueller W. 2023. Transformative investment: new rules for investing in sustainability transitions. *Environ. Innov. Soc. Transit.* 49:100782
57. Eneqvist E, Karvonen A. 2021. Experimental governance and urban planning futures: five strategic functions for municipalities in local innovation. *Urban Plan.* 6(1):183–94
- 57a. Prabhu, J. and Jain, S., 2024. Transformative Innovation Policy in Practice: The Case of India's Digital Public Infrastructure. Available at SSRN 5018291.
- 57b. Patton, M. Q. (2024). Evaluation in the Polycrisis Epoch. In *The Political Economy of Evaluation in Greece: Interdisciplinary Perspectives for an Inclusive and Forward-Looking Evaluation* (pp. 15-37). Cham: Springer Nature Switzerland.
58. Gómez-Valenzuela V. 2023. Stated preference methods and STI policy studies: a foreground approach. *Res. Eval.* 32(2):171–87
- 58a. Kanger, L., Ghosh, B. and Entsaló, H., 2025. Integrated framework of intervention points and transformative outcomes for single-and multi-system transitions. *Technological Forecasting and Social Change*, 216, p.124146.
59. Boni A, Velasco D, Tau M. 2021. The role of transformative innovation for SDGs localisation. Insights from the South-African “Living Catchments Project.” *J. Hum. Dev. Capab.* 22(4):737–47
60. Matias R. 2023. *Abriendo Paso a Políticas y Prácticas de Innovación Transformativa en América Latina*. HUB Latin American and Caribbean Transformative Innovation. Editorial Tirant Lo Blanch. 1st ed.
- 60a. Yuana, S.L., Wiliyanto, W., Hadiyantono, T.A., Figueroa, M.J., Hapsari, M. and Pinem, M.L.B., 2024. Mundane circular economy policy: Mainstreaming CE education through the agency of schools. *Journal of Cleaner Production*, 440, p.140847.
61. Ramirez M, Boni A, Wade I, Byrne R. 2024. How does transformative innovation policy travel across physical and cognitive spaces? Exploring the role of mutable fluid space in experimental policy engagements. *Environ. Innov. Soc. Transit.* 52:100881
62. Ghosh B, Schot J. 2019. Towards a novel regime change framework: studying mobility transitions in public transport regimes in an Indian megacity. *Energy Res. Soc. Sci.* 51:82–95
63. Yuana SL, Boon W, Raven R, Hajer MA, Sengers F, Ghosh B. 2023. Pluralizing urban futures: a multicriteria mapping analysis of online taxis in Indonesia. *Futures* 154:103260
- 63a. Gianelli, I., Trimble, M., Juri, S., Beretta, N., Torena, D., Acosta, M., Acosta, R., Del Bó, M., Fuster, J., González, V., Kurta, D., Kurta, M., López, T., Marfetán, M., Montes De Oca, P., Morales, A., Pardo, V., Sandoval, J., Schuch, N., Taroco, C., Norström, A., Pereira, L., Villasante, S., 2024. Envisioning

desirable futures in small-scale fisheries: a transdisciplinary arts-based co-creation process. E&S 29, art20. <https://doi.org/10.5751/ES-14869-290120>

64. Edler J, Ostertag K, Schuler J. 2024. Social innovation, transformation, and public policy: towards a conceptualization and critical appraisal. *Sci. Public Policy* 51(1):80–88
65. Kanger L, Sovacool BK, Noorkõiv M. 2020. Six policy intervention points for sustainability transitions: a conceptual framework and a systematic literature review. *Res. Policy* 49(7):104072
66. Raven R, Bosch SVD, Weterings R. 2010. Transitions and strategic niche management: towards a competence kit for practitioners. *Int. J. Technol. Manag.* 51(1):57–74
67. Denes_Santos D, Da Cunha SK. 2020. Transformative innovation policy for solar energy: particularities of a developing country. *Clean Technol. Environ. Policy* 22(1):43–57
68. Penna CCR, Romero Goyeneche OY, Matti C. 2023. Exploring indicators for monitoring sociotechnical system transitions through portfolio networks. *Sci. Public Policy* 50(4):719–41
69. Lazarevic D, Salo H, Kautto P. 2022. Circular economy policies and their transformative outcomes: the transformative intent of Finland’s Strategic Policy Programme. *J. Clean. Prod.* 379:134892
70. Madsen SHJ. 2022. A constructivist approach to the spatial organization of transformative innovation policy. *Environ. Innov. Soc. Transit.* 42:340–51
71. Simoens MC, Leipold S, Fuenfschilling L. 2022. Locked in unsustainability: understanding lock-ins and their interactions using the case of food packaging. *Environ. Innov. Soc. Transit.* 45:14–29
- 71a. Rinscheid, A., Rosenbloom, D., Markard, J. and Turnheim, B., 2021. From terminating to transforming: The role of phase-out in sustainability transitions. *Environmental Innovation and Societal Transitions*, 41, pp.27-31.
72. Raven R, Walrave B. 2020. Overcoming transformational failures through policy mixes in the dynamics of technological innovation systems. *Technol. Forecast. Soc. Change* 153:119297
- 72a. Boni, A., Velasco, D. and Ghosh, B., 2025. A human capability approach to transformative innovation policy. Theoretical insights and practical implications for directionality. *Journal of Responsible Innovation*, 12(1), p.2440966.

73. O'Donovan C, Michalec AO, Moon JR. 2022. Capabilities for transdisciplinary research. *Res. Eval.* 31(1):145–58
74. Ainhua A, Magro E, Wilson J. 2023. Building policy capacities for tackling grand social challenges: exploring the boundary-spanning potential of university research in the social sciences. *Ekon. Rev. Vasca Econ.* 104(2):56–77
- 74a. Termeer, C.J., Dewulf, A., Breeman, G. and Stiller, S.J., 2015. Governance capabilities for dealing wisely with wicked problems. *Administration & Society*, 47(6), pp.680-710.
75. Villa-Enciso E, García-Mosquera J, Valencia-Arias A, Medina-Valderrama CJ. 2023. Exploring the role of Latin American universities in the implementation of transformative innovation policy. *Sustainability* 15(17):12854
76. Kanger L, Schot J, Sovacool BK, Van Der Vleuten E, Ghosh B, et al. 2021. Research frontiers for multi-system dynamics and deep transitions. *Environ. Innov. Soc. Transit.* 41:52–56
77. Yuana SL, Boon W, Raven R, Hajer MA, Sengers F, Ghosh B. 2023. Pluralizing urban futures: a multicriteria mapping analysis of online taxis in Indonesia. *Futures* 154:103260
78. OECD. 2023. *OECD Science, Technology and Innovation Outlook 2023: Enabling Transitions in Times of Disruption*. OECD Science, Technology And Innovation Outlook. OECD
79. Sen A. 1999. *Development as Freedom*. Alfred A. Knopf. 1st ed. 80. Fazey I, Schöpke N, Caniglia G, Hodgson A, Kendrick I, et al. 2020. Transforming knowledge systems for life on earth: visions of future systems and how to get there. *Energy Res. Soc. Sci.* 70:101724
81. Pohl C, Hadorn GH. 2008. Methodological challenges of transdisciplinary research. *Nat. Sci. Soc.* 16(2):111–21
82. Bernal-Hernández P, Minding BA. 2024. *The gap between policymakers and researchers: the TIPC transformative learning history*. Rep., Transformative Innovation Policy Consortium. <https://tipconsortium.net/publication/tipc-learning-history/>
83. Mulgan G. 2023. Collective intelligence and governance. In *The Routledge Handbook Of Collective Intelligence for Democracy and Governance*, ed. S Boucher, CA Hallin, L Paulson. Routledge. 1st ed.
84. Dedehayir O, Mäkinen SJ, Roland Ortt J. 2018. Roles during innovation ecosystem genesis: a literature review. *Technol. Forecast. Soc. Change* 136:18–29

85. Haas PM. 1992. Introduction: epistemic communities and international policy coordination. *Int. Organ.* 46(1):1–35
86. Miterev M, Engwall M. 2024. Experimental networks: A missing link in facilitating systemic transitions through projects? *Proj. Manag. J.* 56(3):343–57
87. Walker M. 2024. Repair in education spaces. *J. Hum. Dev. Capab.* 25(1):1–20
88. Stirling A. 2008. “Opening up” and “closing down”: power, participation, and pluralism in the social appraisal of technology. *Sci. Technol. Hum. Values* 33(2):262–94
89. De Tocqueville A, Bevan GE, Kramnick I, De Tocqueville A, De Tocqueville A. 2003. *Democracy in America: and Two Essays on America*. In Penguin Classics. Penguin
90. Bua A, Bussu S. 2021. Between governance-driven democratisation and democracy-driven governance: explaining changes in participatory governance in the case of Barcelona. *Eur. J. Polit. Res.* 60(3):716–37
91. Arrow KJ. 2012. *Social Choice and Individual Values*. Cowles Foundation Monograph Series. Yale University Press[**AU: Edit OK?**]
92. Terry N, Castro A, Chibwe B, Karuri-Sebina G, Savu C, Pereira L. 2024. Inviting a decolonial praxis for future imaginaries of nature: introducing the entangled time tree. *Environ. Sci. Policy* 151:103615
93. Deleted in proof
94. Machado de Oliveira V. 2021. *Hospicing Modernity: Facing Humanity’s Wrongs And The Implications For Social Activism*. North Atlantic Books
95. Ndlovu-Gatsheni SJ. 2015. Decoloniality as the future of Africa. *Hist. Compass* 13(10):485–96
96. Tuck E, Yang KW. 2012. Decolonization is not a metaphor. *Decolonization* 1(1):1–40
97. Maldonado-Torres N. 2007. On the coloniality of being: contributions to the development of a concept. *Cult. Stud.* 21(2–3):240–70
98. Malhi Y. 2017. The concept of the anthropocene. *Annu. Rev. Environ. Resour.* 42(1):77–104
99. Bruna N. 2022. Green extractivism and financialisation in Mozambique: the case of Gilé National Reserve. *Rev. Afr. Polit. Econ.* 49(171):131–60
100. De Almeida L, Van Zeben J. 2023. The EU’s circular energy system and the Green Deal. In *Law in the EU’s Circular Energy System*, ed. L De Almeida, J Van Zeben. Edward Elgar Publishing

101. Pulido L, De Lara J. 2018. Reimagining “justice” in environmental justice: radical ecologies, decolonial thought, and the Black Radical Tradition. *Environ. Plan. E* 1–2:76–98
102. Cole L, Low M. 2023. Transforming planning and policy making processes at the intersections of climate, equity, and decolonization challenges. *npj Urban Sustain.* 3(1):46
103. Sovacool BK, Turnheim B, Hook A, Brock A, Martiskainen M. 2021. Dispossessed by decarbonisation: reducing vulnerability, injustice, and inequality in the lived experience of low-carbon pathways. *World Dev.* 137:105116
104. Dunlap A. 2022. “I don’t want your progress! It tries to kill ... me!” Decolonial encounters and the anarchist critique of civilization. *Globalizations*. In press.
<https://doi.org/10.1080/14747731.2022.2073657>
105. Blythe J, Silver J, Evans L, Armitage D, Bennett NJ, et al. 2018. The dark side of transformation: latent risks in contemporary sustainability discourse. *Antipode* 50(5):1206–23
106. Bentz J, O’Brien K, Scoville-Simonds M. 2022. Beyond “blah blah blah”: exploring the “how” of transformation. *Sustain. Sci.* 17(2):497–506
107. Graham C, Nikolova M. 2015. Bentham or Aristotle in the development process? An empirical investigation of capabilities and subjective well-being. *World Dev.* 68:163–79
108. Barbier EB. 2016. Sustainability and development. *Annu. Rev. Resour. Econ.* 8(1):261–80
109. Hirvilammi T. 2020. The virtuous circle of sustainable welfare as a transformative policy idea. *Sustainability* 12(1):391
110. Brown K, Westaway E. 2011. Agency, capacity, and resilience to environmental change: lessons from human development, well-being, and disasters. *Annu. Rev. Environ. Resour.* 36(1):321–42
111. Helne T. 2021. Well-being for a better world: the contribution of a radically relational and nature-inclusive conception of well-being to the sustainability transformation. *Sustain. Sci. Pract. Policy* 17(1):220–30
112. Van Kerkhoff L, Lebel L. 2006. Linking knowledge and action for sustainable development. *Annu. Rev. Environ. Resour.* 31(1):445–77
113. Chakraborty K. 2015. Measuring socio-economic inequality: from dwellers’ perspective within Bangalore urban agglomeration. *J. Des. Built Environ.* 15(1):1–14
114. Clark WC, Harley AG. 2020. Sustainability science: toward a synthesis. *Annu. Rev.*

Environ. Resour. 45:331–86

115. Heffron RJ. 2021. *Achieving a Just Transition to a Low-Carbon Economy*. Springer International
116. Adler MD, Fleurbaey M, eds. 2016. *The Oxford Handbook of Well-Being and Public Policy*. Oxford University Press
117. Sachs JD, Bernard L, Semmler W. 2015. Climate change and intergenerational well-being. In *The Oxford Handbook of the Macroeconomics of Global Warming*, ed. W Semmler, Bernard L. Oxford University Press
118. Dasgupta P. 2024. *The Economics of Biodiversity: The Dasgupta Review*. Cambridge University Press
119. Chetri S. 2023. Gross national happiness: the interdependent domains of happiness. In *Handbook Of Happiness*, ed. S Chetri, T Dutta, MK Mandal, P Patnaik. Springer Nature Singapore
120. UNDP (United Nations Development Programme), ed. 2022. *Uncertain times, unsettled lives: shaping our future in a transforming world*. Hum. Dev. Rep. 2021/2022, UNDP
121. Greco S, Ishizaka A, Resce G, Torrissi G. 2020. Measuring well-being by a multidimensional spatial model in OECD Better Life Index Framework. *Socio-Econ. Plan. Sci.* 70:100684
122. Abdallah, S. 2022. The Happy Planet Index. In: Unger, C., Ferns, N., Loveridge, J. and Borowy, I. ed. *Perspectives on the History of Global Development*. Berlin, Boston: De Gruyter Oldenbourg, pp. 251-258.
124. Parris TM, Kates RW. 2003. Characterizing and measuring sustainable development. *Annu. Rev. Environ. Resour.* 28:559–86
125. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, et al. 2015. Planetary boundaries: guiding human development on a changing planet. *Science* 347(6223):1259855
126. Henderson K, Loreau M. 2023. A model of sustainable development goals: challenges and opportunities in promoting human well-being and environmental sustainability. *Ecol. Model.* 475:110164
127. Chaigneau T, Coulthard S, Daw TM, Szaboova L, Camfield L, et al. 2021. Reconciling well-being and resilience for sustainable development. *Nat. Sustain.* 5(4):287–93
128. Levidow L, Papaioannou T. 2013. State imaginaries of the public good: shaping UK

- innovation priorities for bioenergy. *Environ. Sci. Policy* 30:36–49
129. Taylor C. 2004. *Modern Social Imaginaries*. Public Planet Books. Duke University Press
 130. Jasanoff S, Kim S-H. 2009. Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea. *Minerva* 47(2):119–46
 131. Andersson J, Keizer A-G. 2014. Governing the future: science, policy and public participation in the construction of the long term in The Netherlands And Sweden. *Hist. Technol.* 30(1–2):104–22
 132. Müller-Mahn D. 2020. Envisioning African futures: development corridors as dreamscapes of modernity. *Geoforum* 115:156–59
 133. Van Der Voorn T, Pahl-Wostl C, Quist J. 2012. Combining backcasting and adaptive management for climate adaptation in coastal regions: a methodology and a South African case study. *Futures* 44(4):346–64
 134. Wiek A, Iwaniec D. 2014. Quality criteria for visions and visioning in sustainability science. *Sustain. Sci.* 9(4):497–512
 135. Sellberg MM, Norström AV, Peterson GD, Gordon LJ. 2020. Using local initiatives to envision sustainable and resilient food systems in the Stockholm city-region. *Glob. Food Secur.* 24:100334
 136. Pereira LM, Davies KK, Den Belder E, Ferrier S, Karlsson-Vinkhuyzen S, et al. 2020. Developing multiscale and integrative nature-people scenarios using the Nature Futures framework. *People Nat.* 2(4):1172–95
 137. Bennett EM, Solan M, Biggs R, McPhearson T, Norström AV, et al. 2016. Bright spots: seeds of a good Anthropocene. *Front. Ecol. Environ.* 14(8):441–48
 138. Bakker S, Van Lente H, Engels R. 2012. Competition in a technological niche: the cars of the future. *Technol. Anal. Strateg. Manag.* 24(5):421–34
 139. Devine-Wright P, Ryder S. 2024. Place-based reflexivity for just energy social science. *Nat. Energy* 9:1–5
 140. Lehmann R, Tittor A. 2023. Contested renewable energy projects in Latin America: bridging frameworks of justice to understand “triple inequalities of decarbonisation policies.” *J. Environ. Policy Plan.* 25(2):182–93
 141. Adam B, Groves C. 2007. *Future Matters: Action, Knowledge, Ethics*. Supplements to the Study of Time, Vol. 3. Brill

142. Vervoort J, Gupta A. 2018. Anticipating climate futures in a 1.5°C era: the link between foresight and governance. *Curr. Opin. Environ. Sustain.* 31(2017):104–11
143. Ghosh B, Arora S. 2021. Smart as (un)democratic? The making of a smart city imaginary in Kolkata, India. *Environ. Plan. C* 40(1):318–39
144. Raven R, Ghosh B, Wieczorek A, Stirling A, Ghosh D, et al. 2017. Unpacking sustainabilities in diverse transition contexts: solar photovoltaic and urban mobility experiments in India and Thailand. *Sustain. Sci.* 12(4):579–96
145. Trischler J, Svensson PO, Williams H, Wikström F. 2023. Citizens as an innovation source in sustainability transitions - linking the directionality of innovations with the locus of the problem in transformative innovation policy. *Public Manag. Rev.* 25(11):2093–115
146. Smith LT. 2021. *Decolonizing Methodologies: Research and Indigenous Peoples*. Zed. 3rd ed.
147. Houde M, Krümmel EM, Mustonen T, Brammer J, Brown TM, et al. 2022. Contributions and perspectives of Indigenous Peoples to the study of mercury in the Arctic. *Sci. Total Environ.* 841:156566
148. Parsons M, Fisher K, Nalau J. 2016. Alternative approaches to co-design: insights from indigenous/academic research collaborations. *Curr. Opin. Environ. Sustain.* 20:99–105
149. Tynan L. 2021. What is relationality? Indigenous knowledges, practices and responsibilities with kin. *Cult. Geogr.* 28(4):597–610
150. Giachi S, Alvarez-Tinoco R. 2022. Innovation policy development for sustainable fisheries in the Global South: from R&D to system transformation. *Innov. Dev.* 12(1):113–34
151. Lambin EF, Thorlakson T. 2018. Sustainability standards: interactions between private actors, civil society, and governments. *Annu. Rev. Environ. Resour.* 43:369–93
152. Boorman C, Jackson B, Burkett I. 2023. SDG localization: mobilizing the potential of place leadership through collective impact and mission-oriented innovation methodologies. *J. Change Manag.* 23(1):53–71
154. Özkarağöz Doğan E, Uygun Z, Akçomak IS. 2021. Can science diplomacy address the global climate change challenge? *Environ. Policy Gov.* 31(1):31–45
155. Casula M. 2022. Implementing the transformative innovation policy in the European Union: How does transformative change occur in member states? *Eur. Plan. Stud.* 30(11):2178–204
156. Ghosh B, Ramos-Mejía M, Machado RC, Yuana SL, Schiller K. 2021. Decolonising

- transitions in the Global South: towards more epistemic diversity in transitions research. *Environ. Innov. Soc. Transit.* 41:106–9
157. Arora S, Stirling A. 2023. Colonial modernity and sustainability transitions: a conceptualisation in six dimensions. *Environ. Innov. Soc. Transit.* 48:100733
- 157a. Berkhout, F., Angel, D. and Wieczorek, A.J., 2009. Asian development pathways and sustainable socio-technical regimes. *Technological Forecasting and Social Change*, 76(2), pp.218-228.
158. Otlhogile M, Shirley R. 2023. The evolving just transition: definitions, context, and practical insights for Africa. *Environ. Res. Infrastruct. Sustain.* 3:013001
159. Streit RP, Morrison TH, Bellwood DR. 2024. Coral reefs deserve evidence-based management not heroic interference. *Nat. Clim. Change* 14(8):773–75
160. Pereira LM, Hichert T, Hamann M, Preizer R, Biggs R. 2018. Using futures methods to create transformative spaces: visions of a good Anthropocene in Southern Africa. *Ecol. Soc.* 23(1):19
161. Kok MTJ, Kok K, Peterson GD, Hill R, Agard J, Carpenter SR. 2017. Biodiversity and ecosystem services require IPBES to take novel approach to scenarios. *Sustain. Sci.* 12(1):177–81
162. Mawere M, Marongwe N, Van Stam G, Duri FPT, Mubaya TR, eds. 2016. *Violence, Politics and Conflict Management in Africa: Envisioning Transformation, Peace and Unity in the Twenty-First Century*. Langaa
163. Mavhunga CC. 2017. *What Do Science, Technology, and Innovation Mean from Africa ?* MIT Press
164. Harrington E. 2024. Filling gaps in local knowledge and technology assurance: informal intermediation in the diffusion of off-grid solar technologies in rural Kenya. *Res. Policy* 53(8):105052
166. Khatoon T, Kivimaa P, Brisbois MC, Saadi SA. 2024. A Global South perspective on the interplay between innovation policy mix and technological innovation systems dynamics: the case of Dhaka City’s road passenger transport system. *J. Transp. Geogr.* 118:103932
167. van Welie MJ, Cherunya PC, Truffer B, Murphy JT. 2018. Analysing transition pathways in developing cities: the case of Nairobi’s splintered sanitation regime. *Technol. Forecast. Soc. Change* 137:259–71
168. Williams S, Robinson J. 2020. Measuring sustainability: an evaluation framework for

- sustainability transition experiments. *Environ. Sci. Policy* 103:58–66
169. Scoones I. 2016. The politics of sustainability and development. *Annu. Rev. Environ. Resour.* 41(1):293–319
170. Ndlovu-Gatsheni SJ, Moyo I. 2022. *The Paradox of Planetary Human Entanglements: Challenges of Living Together*. Routledge. 1st ed.
- 170a. Zaki, B. L., V. Pattyn, and E. Wayenberg. 2024. “Policy Learning from Evidence during Polycrises: A Case of EU Environmental Policy.” *Policy Design and Practice* 1–19.
- 170b. Kuhlmann, S., J. Franzke, N. Peters, and B. P. Dumas. 2024. “Institutional Designs and Dynamics of Crisis Governance at the Local Level: European Governments Facing the Polycrisis.” *Policy Design and Practice* 1–21.
171. Inayatullah S. 1990. Deconstructing and reconstructing the future. *Futures* 22(2):115–41
172. Ulmanen J, Bergek A, Hellsmark H. 2022. Lost in translation: challenges in creating new transformative innovation policy practices. *PLOS Sustain. Transform.* 1(10):e0000031
173. Preuß S, Galvin R, Ghosh B, Dütschke E. 2021. Diversity in transition: Is transitions research diverse (enough)? *Environ. Innov. Soc. Transit.* 41:116–18
174. Beckett RC, O’Loughlin A. 2024. The utility of indigenous knowledge in the pursuit of a UN Sustainable Development Goal. *Collect. Intell.* 3(2).
<https://doi.org/10.1177/26339137241241295>
175. Sultana R, Muhammad N, Akm Z. 2018. Role of indigenous knowledge in sustainable development. *Int. J. Dev.* 8(2), pp.18902-18906. [****AU: Please add volume and page number** Done!**]
176. Hayward B, Roy J. 2019. Sustainable living: bridging the North–South divide in lifestyles and consumption debates. *Annu. Rev. Environ. Resour.* 44:157–75
177. Mukhopadhyay D. 2009. indigenous knowledge and sustainable natural resource management in the Indian Desert. In *The Future of Drylands*, ed. C Lee, T Schaaf. Springer Netherlands
178. Ghimire M, Khanal A, Bhatt D, Dahal D, Giri S. 2024. Agroforestry systems in Nepal: enhancing food security and rural livelihoods - a comprehensive review. *Food Energy Secur.* 13(1):E524
179. Kereto J, Oywaya Nkurumwa A, Obara J, Mango N. 2022. Livestock management and protection using indigenous technical knowledge among the Maasai of Narok County,

Kenya. *Cogent Soc. Sci.* 8(1):2040793

180. Ba Q-X, Lu D-J, Kuo W, Lai P-H. 2018. Traditional farming and sustainable development of an indigenous community in the mountain area—a case study of Wutai Village in Taiwan. *Sustainability* 10(10):3370
181. Zwart H, Barbosa Mendes A, Blok V. 2024. Epistemic inclusion: a key challenge for global RRI. *J. Responsible Innov.* 11(1):2326721
- 181a. Wiegleb, V. and Bruns, A., 2025. Whose knowledge counts? Unpacking the uneven geographies and politics of knowledge co-production in IPBES. *Human Ecology*, 53(1), pp.73-86.
182. Gram-Hanssen I, Schafenacker N, Bentz J. 2022. Decolonizing transformations through “right relations.” *Sustain. Sci.* 17(2):673–85
183. Zanotti L, Apok C, Ambrozek C, Carothers C, Coleman J, Huang S. 2020. Political ecology and decolonial research: co-production with the Iñupiat in Utqiagvik. *J. Polit. Ecol.* 27(1):43–66
- 183a. Thompson, E., 2022. Escape from model land: How mathematical models can lead us astray and what we can do about it. Basic Books.
- 183b. Rusca, M., Sverdlik, A., Acharya, A., Basel, B., Boyd, E., Comelli, T., Dodman, D., Fraser, A., Harris, D.M., Lindersson, S. and Mazzoleni, M., 2024. Plural climate storylines to foster just urban futures. *Nature Cities*, 1(11), pp.732-740.

TERMS AND DEFINITIONS

[AU: Terms have been inserted upon first use in text. “Transdisciplinarity” does not appear in text; okay to tag to “transdisciplinary”?** Yes, call it transdisciplinary research]**

Transdisciplinarity: a research approach that requires collaborative efforts from multiple knowledge domains, integrating knowledge from both scientists and practitioners, aimed at addressing complex problems characterized by high uncertainty and ambiguity in their definition, implications, and solutions

Table 1 Comparison of IP1, IP2, and IP3 (adapted from References 3, 54)

Ways to distinguish	Different IP framings	
	IP1 and IP2	IP3
Role of innovation	IP1: R&D-led economic growth IP2: Growth through national systems and capability development predominantly	Just transition; achieving SDGs, addressing grand challenges and polycrisis, inclusive development
Role of actors	IP1: Scientists advance science, public sector funds scientific research, and private sector commercializes innovations IP2: Public sector invests in capacities and entrepreneurship and in advancement of science by scientists[**AU: Edit OK?**Yes]	Scientists, policymakers and public and private sectors work together with civil society to cocreate strategies, and solutions and navigate contestations in transdisciplinary settings. They develop deep networks and invest resources in learning.
Policy process/practices	IP1: Regulations, procurement; summative ex post policy evaluation IP2: Incentives for startups and training Learning what works (first-order learning)	Policy codesign with experimental policy engagements (EPE) Emphasis on formative policy evaluation through reflexive and continuous monitoring Learning why certain things work, what assumptions are at play (second-order learning)
Expected outcomes	IP1: Welfare through economic growth; technologies in higher readiness levels IP2: Structural change in institutions; readiness in organisations and institutions for change	Transformational change in socio-technical systems, nurturing and acceleration of niches; opening up and unlocking regimes, enhanced capacities of actors; higher policy and system readiness for avoiding transformational failures

Epistemology/knowledge	IP1 and IP2: Positivist and constructivist technoscientific knowledge; dominated by disciplinary domains of economics, political science, and engineering	Interdisciplinary and transdisciplinary knowledge, integrated through collaboration between natural scientists, social scientists and engineers Interpretative flexibility and complex system thinking with civil society; inclusion of indigenous knowledges
Rationale for policy intervention	IP1: Fixing market failure IP2: Rectifying structural/system failure (innovation infrastructures, institutions, capabilities)	Avoiding transformational failures owing to lack of directionality, as well as insufficient demand articulation, policy integration, and limited reflexivity and learning
Associated and alternative framings	IP1: Appropriate technologies in developing countries IP2: Training and capacity development	Mission-oriented innovation policies, challenge-led innovation policies, Responsible research and innovation.

Abbreviations: IP, innovation policy; R&D, research and development; SDG, Sustainable Development Goal; EPE, Experimental policy engagement

Table 2 A comparative view of the evolving framework of TOs [adapted from Ghosh et al., 2021[**AU: Reference 15 or 156 meant? ** its reference 15], Lazarevic et al. (69), and Kanger et al., 2025 (58a) [**AU: Please add to lit. cited or provide all authors, e.g., “L. Kanger & J. Smith, manuscript forthcoming” ** its 15, 58a and 69(numbers might shift due to new references added)]]

Macro-processes of TIP	Original framework (Ghosh et al., 2021[**AU: 15 or 156? ** 15])	Lazarevic et al. (69)	Integrated framework (Kanger et al., 2025 (58a))
Nurturing niches (see Section 3.4)	TO1. Shielding TO2. Learning TO3. Networking TO4. Navigating expectations	Unchanged from Ghosh et al. 2021	Unchanged from Ghosh et al. 2021
Mainstreaming niches (see Section 3.4)	TO5. Upscaling TO6. Replicating TO7. Circulating TO8. Institutionalizing	Unchanged from Ghosh et al. 2021	Unchanged from Ghosh et al. 2021, except TO7. Anchoring
Unlocking regimes (see Section 3.5)	TO9. Dealigning and destabilizing regimes TO10. Unlearning and deep learning in regimes TO11. Strengthening regime–niche interactions TO12. Changing perceptions of landscape pressure	Unchanged from Ghosh et al. 2021	TO9. Unlearning TO10. Dissolving coalitions TO11. Deinstitutionalizing TO12. Delegitimizing visions
Addressing broader repercussions of regime destabilization	Repercussions not considered in the original framework	TO13. Reducing socioeconomic impact TO14. Societal deliberation	TO13. Anticipating and mitigating injustices TO14. Anticipating and mitigating rebound effects

Provide coordination to multiple regime interaction	Multisystem interaction was not considered in the original framework	TO15. Strengthening regime–regime interactions (horizontal coordination) TO16. Strengthening multilevel governance interactions (vertical)	Incorporated as part of the other TOs
Tilting the landscape	Perceived to be captured through changing perceptions of the landscape pressure	TO17. Enabling a common directionality of change	TO15. Setting acceptable boundaries TO16. Building resilience

Abbreviations: TIP, transformative innovation policy; TO, transformative outcome.