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Perspective

Entry points for driving systemic change toward a more sustainable future

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SUMMARY

Achieving inclusive human development within planetary boundaries is an urgent and complex sustainability challenge. Despite growing interest in sustainability transitions and transformations, existing guidance on how to effectively catalyze systemic change remains fragmented, limiting progress in research and practice. A clear synthesis is needed to integrate diverse knowledge and guide transformative action. Here, we present an integrated framework of nine theoretically informed and empirically grounded analytical lenses called entry points through which systemic change can be understood, initiated, and sustained. The entry points we found are diverse and focus on momentum building, the co-development of integrated pathways to desirable futures, and the practical operationalization of change across sectors and scales. By bridging theory with practice, they offer a shared language and structure for understanding transformative processes and facilitate knowledge exchange between cases. This can eventually support more coherent policy design and enhance capacity of decision-makers to shape integrated sustainability agendas.

INTRODUCTION

Fossil fuel energy, intensive industrial agriculture, and global commons overextraction (i.e., linear patterns of taking, making, and disposing) dominate how society attains and consumes energy, food, and materials. These practices have contested sustainability outcomes and can contribute to persistent global challenges such as climate change, acute socioeconomic inequalities, and destruction of natural habitats.[1] Around the world, governments, industries, and communities are seeking widespread change in a just and orderly manner to reconfigure or eventually replace unsustainable practices.[2–4] This collective effort is calling for transitions (i.e., far-reaching and systemic change across multiple dimensions from an existing system to a more sustainable one[5]) and transformations (i.e., shifting human and environmental interactions and feedback for living within safe and just operating spaces[6]) toward a more sustainable future. For example, the Sixth Assessment Report of the United Nations (UN) Intergovernmental Panel on Climate Change dedicated a chapter to accelerating transitions,[7] the UN Food Systems Summit held science and innovation for transformation as a central focus,[8] the UN Global Sustainable Development Report 2023 called for transformative change toward sustainability,[9] and the 2024 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' assessment report's focus was on the underlying causes of biodiversity loss and options for achieving the 2050 vision for biodiversity through transformative change.[10]

Transitions and transformations are inherently complex. They involve multisectoral shifts that impact various aspects of society, often leading to trade-offs and externalities in other systems (e.g., the energy transition's trade-offs between food and biofuel production). These changes are also driven by forces at multiple scales, resulting in both top-down (government-led) and bottom-up (grassroots) shifts.[11] Navigating such interconnected sustainability transitions and transformations at the intersection of technological, social, economic, and ecological factors, and alongside critical cultural and political aspects, requires pluralistic and integrated approaches.[12,13] However, a key challenge to integrated approaches is the fragmentation of various scientific and societal bodies of knowledge, methods, and solutions across disciplines, sectors, and scales. For instance, some sustainability science and socioecological studies focus on enabling transformation through leveraging interlinkages between different synergistic aspects of sustainable development to create reinforcing interactions.[2,14] Some others, for example, in sociotechnical system studies, discuss transitions as concerted efforts to grow emerging innovations[15] and overcome

the inertia and resistance of existing systems.[16] Governance and public policy literature, however, often explores transition and transformation with emphasis on the roles of agency, institutions, power, and politics in either impeding or enabling change.[17,18] These diverse perspectives offer valuable insights, but if they remain confined within the silos of narrow theoretical paradigms, they risk imposing fixed ways of thinking onto real-world practice and policy rather than enabling exploratory, context-sensitive inquiry.

It has been broadly acknowledged that diverse, complementary analytical lenses are needed, along with cross-cutting research and policy agendas for transition and transformation that guide their integration. For example, Scoones et al.[13] proposed an overview of different conceptualisations of transformation in three categories of structural, systemic, and enabling approaches. Köhler et al.[19] provided a review of the sociotechnical transition field in relation to different areas (e.g., governance, civil society, ethical aspects). O'Brien[20] summarized the dynamics of societal change in relation to three interacting practical, political, and personal spheres of transformation. Despite valuable theoretical contributions, current integrative efforts for understanding sustainability transitions and transformations often remain constrained by a narrow empirical base. This limits our ability to identify and compare how different approaches to systemic change unfold across real-world cases and how change is initiated, navigated, and sustained. To address this gap, we need a systematic integration of analytical lenses that are both theoretically informed and grounded in diverse empirical evidence to help researchers and practitioners more effectively design, evaluate, and scale transformative efforts across varied contexts.

Here, we undertake a concept synthesis to identify diverse analytical lenses to sustainable systemic change, referred to as entry points, that are both theoretically informed and grounded in practice. The first group of entry points centers on how transitions gain momentum through evolutionary processes and sometimes radical shifts, the second group focuses on guiding transitions through systemic pathways toward more sustainable futures, and the third group of entry points is concerned with enabling and embedding change through practical actions. Together, these entry points highlight the importance of embracing multiple perspectives in understanding how change unfolds, which is an essential step for advancing transdisciplinary sustainability research and avoiding one-size-fits-all approaches.

We also explain how these entry points manifest across diverse contexts, drawing on a wide range of case studies. Using an illustrative sample of 60 case studies, we demonstrate how these entry points can be made operational by highlighting the diversity of ways in which they can inform far-reaching change in different contexts. The cases we select are geographically diverse, spanning seven continents, operating at three scales (i.e., local, national, global), and focusing on various outcomes, including sectoral (i.e., agriculture and food, energy, and climate) and societal (i.e., justice and equity and sustainable development) outcomes. They provide insights into what drives change-making efforts in different situations. A key insight from this analysis is that justice and equity are central to many transition and transformation efforts but not straightforward to achieve, requiring approaches that enable inclusive decision-making and foster the agency of individuals and communities.

TOWARD CONVERGENCE AND SYSTEMIC INTEGRATION

Bridging the fragmentation across diverse analytical lenses in research and practice requires a shift toward convergent and transdisciplinary integration—an integration capable of synthesizing scientific and societal knowledge and connecting theoretical perspectives with diverse empirical insights. This integration can play a crucial role in addressing fragmentation in transition and transformation research by helping individuals navigate multiple perspectives within a collaborative environment that fosters a more comprehensive understanding of systemic change[21,22] and better facilitates the dialectical engagement of multiple worldviews.[23] This is particularly important in sustainability transitions and transformations, where marginalized knowledge sources, such as Indigenous, grassroots, and community-based knowledge, are often excluded from mainstream policy and research frameworks.[24,25]

The idea of convergent and transdisciplinary integration is not entirely new. For example, the practices of convergence research,[26] post-normal science,[27] and systems integration[28] have long emphasized the importance of bringing diverse perspectives from across scientific disciplines as well as from empirical case studies in shaping transitions through firsthand experience. Sustainability science has also highlighted the value of diverse knowledge in supporting action and capacity building,[29] reinforcing the idea that meaningful transformation requires inclusive approaches.[12] While these conceptual foundations of convergent and transdisciplinary have been well established in academic debates, the systemic dimensions of such research for sustainability transitions and transformations remain underexplored, and as the need for integration efforts expands,[30] the complexity of synthesizing diverse knowledge systems can quickly become overwhelming. Without carefully designed and integrated approaches, efforts to unify knowledge across fields risk becoming fragmented or overly abstract.

To address the fragmentation challenge, we propose a systemic and integrated approach to classifying and connecting different analytical lenses that work with various forms of scientific and societal knowledge (e.g., local knowledge, lived experience). This integration theoretically builds on foundational work by Scoones et al.[13] on approaches to transformation, Köhler et al.[19] on review of the sociotechnical transitions field, and O'Brien[20] on interacting spheres of systemic change. It is also grounded in empirical insights drawn from our diverse set of 60 case studies examining real-world efforts in sustainability transitions and transformation. Central to this integration is the concept of entry points, or key analytical lenses to drive change, which systematically connect theoretical understandings with empirical insights from real-world implementation.

Defining entry points

The concept of entry points, originated from previous theoretical reviews of the literature, highlights diverse ways to undertand how change happens in transition and transformation processes.[13,19,20] The entry points identified here (italicized),

although it is not a systematic review, provide a selection of related important concepts and a starting point for further research. These entry points are supported by and aligned with germinal theoretical works on transition and transformation, including key reviews.[19,31]

For example, and without being exhaustive, studies have discussed how transitions emerge through different maturation stages[5] to overcome incumbency (i.e., navigating resistance to change within existing systems that constrain transitions) and mainstream emerging innovation (i.e., various ways to scale up and spread innovation more widely to drive change). Similar terms were used in other areas of literature, for example, path dependency, lock-in, and resistance to refer to overcoming incumbency,[16,32] and social tipping points, technological innovations, and system leverage points in association with mainstreaming emerging innovation.[4,14] Previous studies also discussed how transitions co-evolve from a combination of purposefully designed and emergent pathways that need to be guided and navigated to possible future states.[5] Hence, understanding transitions should also recognize leveraging positive pressures (i.e., aligning everyday actions with the momentum of long-term goals supported by exogenous policy frameworks and international commitments transitions) that can be influential in driving change.[2,33] The interplay between these three entry points (i.e., mainstreaming emerging innovation, overcoming incumbency, and leveraging positive pressures) is a classic mechanism in the sociotechnical, multilevel approach that is central in the sustainability transitions community and underpins the agenda-setting contribution by Köhler et al.[19] (Table 1). These three entry points are similar in their focus on building momentum based on understanding the emergent dynamics of transitions as an evolutionary process of change, with a combination of incremental and fundamental shifts, driven by internal and external factors.[5] These three entry points also provide a rich qualitative understanding of how change occurs that is broadly consistent with the analytical lenses that Scoones et al.[13] called structural.

In a similar way, previous studies discussed how managing transformations should be sensitive to the complexity of change and carefully leverage interactions between various dimensions of change and resulting positive or negative side effects.[58] This indicates a need for accounting for multisector dynamics (i.e., analyzing key linkages and interdependencies between different sectors and assessing risk-benefit trade-offs that transition can lead to), which builds on concepts such as trade-offs and synergies in sustainability science,[59] sectoral and systems integrations in the field of multisector (or multisystem) dynamics,[58,60] and integrated human-natural systems in integrated assessment research.[46] The theoretical literature also acknowledges that the more complex systemic changes are, the more they become exposed to uncertainty and novel risks that can disrupt change.[61] To manage these uncertainties, it was suggested that transformation efforts should envision resilient futures (i.e., exploring the effects of future uncertainties and prioritizing pathways that remain resilient in the face of potential future surprises) to better anticipate uncertainty and thus adapt and adjust regularly to resulting short-term risks and long-term vulnerabilities.[62] This aligns with more recent contributions in the field of decision-making under deep uncertainty[63] and socioecological system studies,[64] which often emphasize multiple futures and risks that can disrupt transformation, resilience, and robustness. Studies have also recognized that systemic change involves civil society, social movements, and cultural change, necessitating including people and places in approaches.[65] They argue that there is no one-size-fits-all approach in transitions and transformations, and approaches should be sensitive to context to lead to viable, fair, and inclusive outcomes in each place. This reflects contributions to the geography of transitions[66] and local sustainability,[67] which recognize the importance of the social realities of contexts in which change occurs. These three entry points (i.e., accounting for multisector dynamics, envisioning resilient futures, including people and places) are similar in their focus on navigating transitions and transformations through deliberate and systemic pathways toward potential future states (Table 1), and together correspond to analytical lenses that Scoones et al.[13] called systemic.

Finally, studies have discussed concepts such as practice (i.e., step-by-step implementation processes), power (i.e., influence, conflict, and cooperation between actors), and governance (i.e., arrangements for deciding and acting on what is needed) focused on efforts that support their wider implementation. Some of these studies emphasized the importance of transitions that are feasible in the sociocultural, ecopolitical, and technological settings of their surrounding environment and are embedded in decision processes in which they operate.[68] As such, they propose demonstrating pathway practicality (i.e., experimenting with new options and approaches in key areas to test feasibility and establish legitimacy) as an entry point to lay out plans that can articulate implementation in a step-by-step manner. Previous studies also acknowledged that the effects of transitions can inadvertently vary across context, creating "losers" and "winners."[69] They suggested that addressing disparate outcomes requires an understanding of power (e.g., conflicts, cooperation, and asymmetries in influence between actors) and politics in implementing transitions, indicating an entry point that focuses on enabling agency of change (i.e., fostering human agency and managing relationships among actors), necessary to collectively act on transition pathways to desired futures. Transitions were also discussed as inherently political processes that require building transformative governance arrangements for deciding and acting on what is needed to instigate and realize change.[17,70] These last three entry points (i.e., demonstrating pathway practicality, enabling agency of change, building transformative governance) together are focused on operationalizing change and efforts that support the wider progress of transitions across locations, sectors, and scales (Table 1). These correspond to what Scoones et al.[13] called enabling and are aligned with the literature in social experimentation,[71] governance,[70] and public policy.[69]

Beyond merely synthesizing analytical lenses from various areas of research, entry points foster critical thinking about transition and transformation. Therefore, they should be also seen as questions to explore, means of discourse, and channels through which we can learn from existing empirical evidence about why and how such efforts drive systemic change. In the following sections, we explore such further insights by examining how different contexts, whether consciously or unconsciously, emphasize certain entry points over others and why.

Table 1. Entry points to sustainability transitions and transformations, synthesized from theory and practice

Entry point[a]	Specifics	Description	Example
Entry points focused on building momentum			
Mainstream emerging innovation 	Adopt techno-economic approaches	Use technological and market-based approaches, such as green fiscal reforms and technology efficiency improvements, to drive change	The US Inflation Reduction Act has ≥20 new or modified tax incentives and $500 billion in grants and loan programs for new clean energy technology investment and deployment[34]
	Leverage behavioral incentives	Enable behavioral change via demand-side interventions or utilization of external shocks to encourage more sustainable practices	Otto et al. suggested climate education and engagement in different countries to induce positive social dynamics for low-carbon societies[14]
	Utilize governance mechanisms	Build coalitions for action via participatory frameworks and integrated approaches to policy, governance, and partnerships	Participatory governance with local community for net-zero energy transitions in Slovakia's Upper Nitra coal region was found to be critical to empowering the agency to adopt innovation[35]
Overcome incumbency 	Reset system rules and structures	Overcome structural and institutional forces that constrain change and are amplified by powerful vested interests[36]	The Asian Development Bank in Indonesia proposed changes, enacted in the Village Law, to overcome inertia in the regular planning and budget allocation system to mainstream community-driven sustainable development[37]
	Facilitate economic reform	Prepare the infrastructure and financial systems that underpin the whole economy for a shift toward increasing sustainability and equity	Italy's National Recovery and Resilience Plan identified structural reforms, digital revolution, overcoming bureaucratic difficulties (among others) in the economy in transition planning after the COVID-19 pandemic[38]
	Navigate negative reactions	Address fears of negative unintended consequences for society, important for vulnerable populations, that create public backlash	Centers for Disease Control and Prevention Investment Works in India identified loss of income and increasing poverty from coal energy phase-out, so compensation and creating alternative livelihood opportunities for workers and communities were recommended to navigate negative reactions[39]
Leverage positive pressures 	Promote low-carbon futures	Leverage efforts to limit global warming (e.g., compliance with the Paris agreement	The UK's commitments to cut significant emissions by 2030 created a window of opportunity to be leveraged in the UK Transition Plan Taskforce Implementation Guidance for accelerating net-zero transitions[40]
	Support nature-positive action	Minimize environmental degradation and encourage processes that leverage ecosystem resilience and functionality	Aligned with the 2050 Vision of the Convention on Biological Diversity, Leclere et al. suggested urgent adoption of a conservation plan that retains the remaining biodiversity and restores degraded areas[41]
	Champion sustainable development	Encourage the inclusion of development across social, economic, and environmental dimensions in sustainability transitions	The UN Development Program's "Ethiopia 2030 A Country Transformed?" built on the Sustainable Development Goals (SDGs) and the African Union's Agenda 2063 to identify options for transformations in key economic sectors, agriculture, and manufacturing[42]

(*Continued on next page*)

Table 1. ***Continued***

Entry point[a]	Specifics	Description	Example
Entry points focused on navigating pathways to future states			
Account for multisector dynamics 	Strengthen holistic approaches	Adopt a systems approach to understand and explain multidimensionality of transitions, systemic responses, and rebound effects	Boudet discussed how technology, people, and places interact in shaping public responses to new technologies in energy transitions[43]
	Harmonize human-nature systems	Interpret interactions of technology, people, and environment and identify trade-offs and synergies via integrated assessments	Bodirsky et al. analyzed connected economy, society, and environment interactions through the integration of degrowth principles with food dietary change and their climate impacts[44]
	Generate multisectoral pathways	Develop pan-sectoral options that minimize negative trade-offs and maximize positive synergies	The Food Systems Roadmap in Australia recognized that reshaping food systems requires connection and pathways across the vast and varied range of sectors within and adjacent to food systems[45]
Envision resilient Futures 	Explore future scenarios	Use what-if scenario analysis and sensitivity analysis to provide an understanding of different future trajectories	Van Vuuren et al. used the IMAGE model for the what-if scenario analysis of the need for negative emission technologies under alternative pathways to the 1.5°C goal[46]
	Create a shared vision	Develop normative directions that stakeholders identify with and can contribute to through collective social learning	The Food Systems Roadmap in Australia conducted extensive stakeholder engagements and collective social learning processes to create a vision for food system transformations[45]
	Anticipate potential vulnerabilities	Anticipate and prepare for risks, vulnerabilities, or shocks that impact society, the economy, or the environment	The National Treasury and Economic Planning in Kenya designed the Financing Locally Led Climate Action Program aimed at building resilience to climate-related risks, vulnerability, and shocks[47]
Include people and places 	Engage diverse groups of people	Ensure diverse actors are included in decision-making and/or planning of transitions to define and advance shared outcomes	Bangladesh Voluntary National Reviews adopted a whole-of-the-society approach to include diverse stakeholders in context-appropriate ways for the assessment of progress toward the SDGs[48]
	Recognize societal differences	Understand behavioral and cultural factors (e.g., expectations, lifestyle) as drivers of change that can enhance or impede transitions	Muscat et al. analyzed the drivers of circular economy, indicated that change is needed at the individual level, and recognized the role of behavioral and cultural factors as drivers of circular economy transition[49]
	Coordinate across places	Coordinate pathways between places to improve connections across geographic scales, levels of government, and jurisdictions	The Labor Congress in Nigeria for promotion of just transitions in agriculture and oil sectors articulated coordinated response from national to industry levels for social protection of workers[50]

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Table 1. ***Continued***

Entry point[a]	Specifics	Description	Example
Entry points focused on operationalizing change on the ground			
Demonstrate pathway practicality 	Experiment with options and approaches	Test technological, social, institutional, and policy innovation and evaluate their feasibility	Transition US developed and supported local grassroots groups and community design labs in the rural US to experiment with the idea of just transition from extractive to regenerative practices[51]
	Develop and test roadmaps	Develop plans to operationalize transitions via short- to long-term actions, investments, and fully costed business cases	The Sustainable Finance Action Council in Canada provided defined green and transition investment (taxonomy) through a detailed roadmap, informing Canada's Deputy Prime Minister and Minister of Finance and the Minister of Environment and Climate Change[52]
	Address unintended consequences	Anticipate and manage negative unintended consequences, side effects, and challenges arising from transition implementation	Sovacool et al. recognized vulnerabilities, injustices, and inequalities that occur in low-carbon (mining) transition in Africa, and discussed reforms needed to address them[53]
Enable agency of change 	Address inequity impacts	Foreground equity as the central focus of transitions, with inclusive processes (e.g., for gender, ethnicity, disability) in implementation	The Farm to Fork Strategy in Europe adopted an equity lens in addition to healthy and environmentally friendly approaches to food system transformations and designed tools like the Just Transition Fund to provide compensation to those affected[54]
	Empower marginalised actors	Use processes (e.g., redistribution of access to resources and community consultation) innovatively to ensure marginalized actors are included and supported to engage	The Just Rural Transition in Indonesia offered mechanisms to help smallholders secure state-subsidized loans and multi-year purchasing agreements to facilitate a steady supply of income for farmers in food system transitions as a way of empowering marginalized actors[55]
	Support bottom-up and grassroots	Support and create mechanisms for grassroots action and embedding bottom-up community stakeholder inputs in decision procedures	The Asian Development Bank in Indonesia proposed measures for building capacity in and engagement with local government agencies for mainstreaming and sustaining bottom-up, community-driven development for poverty reduction[37]
Build transformative governance 	Leverage prevailing institutions	Utilize existing institutional and political processes to leverage governance and policy support required for effective transitions	The Latrobe Valley Regional Rehabilitation Strategy in Australia provided guidance to advance mine rehabilitation planning, aligned with new regulations that came into effect requiring more transparent decision-making with greater community engagement[56]
	Adapt governance structures	Adapt governance structures to context, including transdisciplinary partnerships and centralized and decentralized governance	The Climate Change Mid-Century Strategy in Mexico, which envisioned two important bodies at the federal level to design and implement climate policy, with coordination among government levels[57]

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Table 1. *Continued*

Entry point[a]	Specifics	Description	Example
	Ensure coherence among policy domains	Coordinate implementation of policies across branches/levels of government, jurisdictions, and decision-making processes through time	Sachs et al. proposed four major governance mechanisms to design and operationalize the SDG transformations within the structures of government, such as goal-based design and technology missions and goal-based organization of government and financing[2]

The entry points were initially identified from the theoretical and conceptual literature. Subsequently, diverse ways that these entry points are implemented (i.e., specifics) were synthesised from 60 cases through content coding and clustering (see methods). Entry points can be interconnected. Thus, the distinction between them is not always clearly defined, and this is an inherent outcome of concept synthesis. For instance, multiple entry points talk about policy and governance, but each for a different purpose.

[a]Icons in this table are (in order of appearance) by syafii5758, Langtik, Royyan Wijaya, iconpro86, Attilio Baghino, IconBone, dDara, Kiran Shastry, and aristeles from Noun Project website under Creative Commons License CC BY 3.0.

Supporting entry points with empirical evidence

Through a concept synthesis of a sample of 60 cases, we demonstrate how empirical insights can support and complement the entry points identified from the theory. We draw on a sample of transition and transformation cases to identify diverse ways by which the nine entry points are applied in case studies to inform systemic change across different contexts and discuss the underlying reasons for their use. While these cases do not encompass the entire body of literature on transition and transformation, they collectively offer a sufficiently diverse sample, allowing for meaningful empirical grounding of entry points that drive change (Figure 1).

Concept synthesis that we used to identify entry points in cases is a structured process often used to identify the defining attributes of approaches and to derive generalized patterns from a variety of qualitative case studies.[72] To conduct this concept synthesis in the transition and transformation context, we collected and reviewed a sample of relevant case documents, coding and clustering key attributes in their approach for systemic change. A further detailed explanation of this process is provided in the methods section and in Data S1–S4.

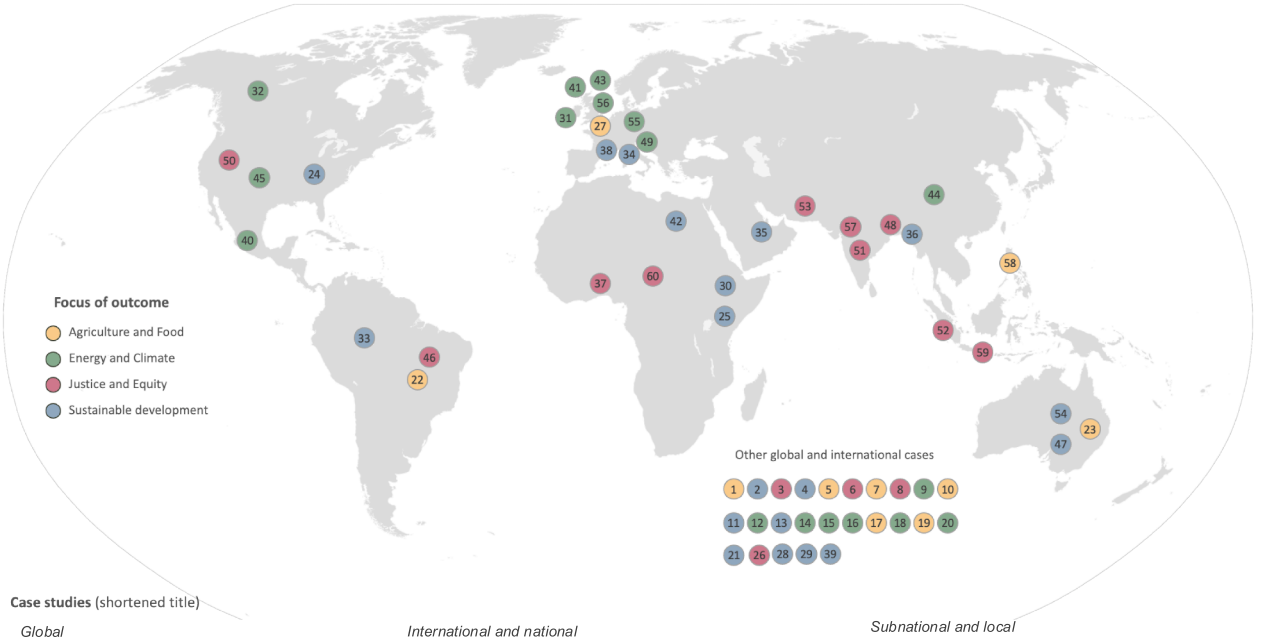
The analysis of cases revealed different specifics and examples, which demonstrate a variety of ways that entry points have been adopted in practice. They are available in Table 1 and are discussed in the following sections. Overall, we found that the entry points identified from theory align well with mechanisms identified in case studies. This is perhaps unsurprising, as our synthesis is derived from cases that are often inspired by or build upon the same communities as those that produced conceptual and agenda-setting synthesis. What our synthesis adds to these existing contributions is that for the first time it brings together the empirical evidence across multiple themes, lenses, or spheres into a coherent framework that has the potential to be meaningfully applied in the prospective design of transition governance strategies and interventions across diverse places and scales.

Building momentum

As mentioned, among the nine entry points, the first three pertain to establishing ongoing processes and conditions for systemic change (Table 1). Mainstreaming emerging innovation is a main entry point that drives transition process in many of the cases. Our cases suggest several ways by which innovation can be scaled up and spread across the system. Among them are adopting techno-economic (i.e., technological and market-based) approaches to reduce costs and create new markets[47] for innovation and leveraging behavioral incentives to stimulate demand and wider adoption of technological innovation.[14] Utilizing governance mechanisms to build agency for adopting and mainstreaming innovation is another relatively common entry point.[35] This entry point is particularly important in the justice and equity context, where transition cannot be achieved through relatively straightforward innovation like technologies or financial mechanisms alone. Instead, achieving meaningful change requires the dismantling of deeply entrenched social and economic systems themselves[73,74] and relies primarily on systemic actions at multiple social, policy, economic, and other levels, as well as novel modes of governance such as participatory models.[73] This highlights that transitions are dependent on moving beyond a narrow focus on techno-economic factors and instead be understood as relational processes that are deeply embedded in our daily lives and societal structures.[16]

Existing incumbent systems constrain transitions, which can generate inertia and resistance in various forms. The cases also meaningfully discuss how to overcome incumbency and the resistance to change, acknowledging that transitions will have to reverse unjust structures in the current systems to achieve more sustainable societies.[74] These structures are maintained and perpetuated through incumbent power and thus cannot change without the concomitant dismantling of the power of incumbent actors, structures, and systems.[16] Cases indicate important reasons underlying resistance and suggest ways to address underlying reasons, which could also inform transition in other contexts. Some cases feature sunk costs as reason for resistance (e.g., infrastructure and market structures that maintained an unsustainable status quo) and suggest facilitating broader (often economic) reform to address them.[38] Other cases highlight resistance related to powerful vested interests and suggest resetting system rules and structures constraining change in order to overcome incumbency.[36] Navigating negative reactions (e.g., public backlash) is also suggested in some cases to address the fear of potential negative impacts.[39]

Leveraging positive pressures is another common entry point across the cases. Coalescing collective and target-oriented efforts (e.g., milestones, plans) around purposeful, positive



Case studies (shortened title)

Global

1. Degrowth and emission-neutral food system
2. Political impact of the SDGS
3. Indigenous roles in conservation
4. Circular bioeconomy opportunities
5. Integrated strategy for land and biodiversity
6. Low-carbon exploitation in Africa
7. Innovation in sustainable food systems
8. Justice in clean energy transition
9. Social tipping for climate stability
10. Feeding ten billion within planetary boundaries
11. Six transformations for the SDGs
12. Public perceptions of new energy technologies
13. Urban sustainability and resilience
14. Pathways to the 1.5°C target
15. Low energy demand for 1.5°C and SDGs
16. Energy Investment for Paris Agreement and SDGs
17. Land use and climate impacts of food
18. Shared socio-economic pathways in energy
19. Meeting future food demand
20. Energy system transformations for 1.5°C

International and national

21. Global North-South cooperation for sustainability
22. Brazil's National Biodiversity Strategy and Action Plan
23. Australia's food systems transformation roadmap
24. USA's transition to clean energy economy
25. Kenya's National green fiscal incentives policy
26. Just transition in BRICS countries
27. EU's food system transformation policy mix
28. GEF's Catalysing climate change transformation
29. IPCC's chapter on accelerating transitions
30. Ethiopia's 2030: Next generation reforms
31. UK's Transition Plan Taskforce guidance
32. Canada's Taxonomy roadmap
33. Latin America's green and just transition
34. Italy's national recovery and resilience plan
35. UAE's general environmental policy
36. Bangladesh's accelerated transformative pathways to SDGs
37. Nigeria's Just transition in agriculture and petroleum
38. EU's Sustainability transitions: policy and practice
39. G7's towards mobilising green and sustainable finance
40. Mexico's climate change strategy

Subnational and local

41. Scotland's Just transition in rural post-industrial areas
42. Egypt's climate-water sustainability pathways
43. Nordic region's Just green transition in rural areas
44. China's and Germany's low-carbon rural energy transition
45. USA's Advance planning for community in transition
46. Brazil's mining royalties and development
47. Australia's Sustainable Us Initiative
48. Global South's (Bangladesh) just
49. Croatia's ecosystemic transition unit
50. USA's Regeneration Nation
51. India's Just transition finance roadmap
52. Indonesia's rejuvenating Farmer Incomes
53. Pakistan's rural economic transformation
54. Australia's Latrobe Valley rehabilitation strategy
55. Slovakia's community Participation in transformative action
56. UK's Ealing climate emergency response
57. India's Tamil Nadu rural transformation
58. Philippines' sustainable fisheries investment
59. Indonesia's community-driven development
60. Sub-Saharan Africa's transformation for rural youth labour

Figure 1. An overview of the 60 cases analyzed related to sustainability transitions and transformations to demonstrate entry points

Cases were categorized into three scales of (1) global, (2) international and national, and (3) subnational and local (each with 20 cases). Cases were also categorized based on four primary outcome foci: agriculture and food (10 cases), energy and climate (17 cases), justice and equity (14 cases), and sustainable development (19 cases). We acknowledge that some cases had more than one focus (e.g., energy and climate transitions with a justice and equity dimension), but we elected to assign only one (the most prominent) to each case for simplicity of analysis (for how we selected and analyzed these cases, see methods). Cases within each scale are arranged in reverse chronological order (most recent on the left). The colors indicate outcome foci. The name and online access to all cases are available in Data S1.

directions for the future may create windows of opportunity for catalyzing innovation and phasing out existing systems.[75] Cases seeking to promote low-carbon futures, sustainable development, and nature-positive action in particular benefit from harnessing external momentum. Among the cases, there is a relatively longer history of leveraging positive pressures through milestones and plans for emissions reduction or adoption of nature-positive solutions (e.g., in agriculture) through national and international commitments. For energy, climate, and even agri-food systems, common sustainability goals, if not unanimously agreed upon, have been at least willingly negotiated. However, leveraging change toward justice and equity is challenging as it also requires addressing historical patterns of inequity and power. Achieving justice would imply, first, deciding what "justice" means to different actors.[76] The idea of equity and fairness is to some extent subjective (e.g., fairness for whom) and highly context dependent, varying across different actors, times, and places.[77] These subjective interpretations, shaped by individuals' backgrounds and values, make it challenging to reach consensus on priorities and actions, especially when power imbalances exist, as seen in the case of the 2021 UN Food Systems Summit, which revealed the challenges of current institutional structures to meaningfully engage with equity and diversity issues.[78]

Navigating pathways

As introduced earlier, the second set of three entry points highlights various elements of navigating transitions through different pathways to potential sustainable futures (Table 1). Accounting for multisector dynamics is a common entry point for navigating transition pathways in our cases. This reflects insistent calls in

the global research agenda for the need to understand the complex nexus of factors across multiple interlinked sectors that characterize today's issues and their associated solutions.[79] The need for complexity-oriented thinking, more plural and multidisciplinary solutions, and better trade-off evaluation to support the harmonization of human-nature systems is well established and is reflected in the case studies.[44] Other ways to navigate pathways include strengthening holistic approaches to better understand the multidimensionality of transitions[43] and providing multisectoral solutions that can minimize trade-offs and maximize synergies.[41]

Envisioning resilient futures as a range of possible and normative futures evaluated among risk and uncertainty factors is another entry point that is discussed across cases. Some studies address risks and uncertainties inherent in transition processes as concerns separate from justice and equity.[80] At the same time, there are emerging areas of research that make explicit efforts to better engage with uncertainty, volatility, and resilience[81] in navigating pathways to normative futures in a just and equitable manner. For instance, there is a growing body of literature on transformative justice as a relevant approach to the unpredictability and the "messiness" of achieving sustainable long-term change.[82] Among the cases, risk and resilience are discussed in multiple ways, such as by exploring transitions in potential future states[46] and by anticipating potential vulnerabilities from transitions and preparing to respond to them.[47]

Including people and places is an entry point that helps ensure that transitions can lead to fair and inclusive outcomes. Despite a focus on including people and places, the involvement of a vast array of (until now) marginalized actors remains a largely unrealized attempt in some cases. Many efforts to foster inclusive, participatory, and diverse dialog have resulted in what is known as power grabs by dominant actors who have captured the priority agenda.[83] A lack of appropriate governance mechanisms to ensure meaningful participation may have also exacerbated the exclusion of certain actors.[84] Across our cases, we found several ways to create a shared understanding about pathways and their expected outcomes and to reduce potential sources of future contestation, such as engaging people in co-design processes.[48] Other ways involved recognizing societal differences (e.g., expectations, lifestyle) as drivers of change[49] and coordinating across places to improve pathways and connections between various locations and scales.[50]

Operationalizing change

The final set of three entry points establishes aspects of operationalizing change (Table 1). Demonstrating pathway practicality to facilitate and operationalize change, for example, through developing and testing roadmaps to specify a series of short- to long-term actions, is as an entry point that we found across our cases. Cases analyzed suggest several ways in which this can be better addressed. One way includes experimentation with options and approaches in key places through which stakeholders learn how a pathway may unfold and its suitability.[51] Developing and testing roadmaps to connect pathways to desired outcomes via necessary investment (including fully costed business cases)[39] and contingency planning to address unintended consequences that may arise during implementation are among the other ways.

Enabling agency to engage in processes, manage relationships among actors, and act collectively on pathways to desired futures is another entry point for operationalizing change. Debates around agency have historically stemmed from justice discussions, with a critical implication of justice being the ability of all people to make their own choices and determine their own goals.[85] The idea of agency is gradually gaining more traction to underscore the importance of giving all people, independent from geographical location, background, socioeconomic class, and so forth the possibility of making meaningful choices[86] (e.g., within food system debates[87]). Our cases present several ways to address this gap and foster human agency. Some cases focus on understanding who wins and who loses (i.e., equity impacts) to empower marginalized groups and address uneven power dynamics, which can create significant barriers to transitions.[88] Others include supporting and creating mechanisms for grassroots action and embedding bottom-up community stakeholder input in decision procedures.[37]

Building transformative governance to address the inherently political nature of implementing transition and transformation is an entry point that reoccurs across cases. Defining transformative governance is also receiving increasing attention in the broader body of literature on systemic change in the energy, climate, and agriculture contexts.[89,90] Across cases, we found a number of ways to address gaps in governance. One is through designing new (or adapting existing) governance structures to suit the context, whether through transdisciplinary partnerships, centrally coordinated governance, or decentralized governance across society.[57] Other ways pertain to ensuring the coherence of policy domains (i.e., breaking siloed structures of government, overcoming lack of incentives to work with other departments, and coordinating implementation of pathways across branches of government and decision-making processes[2]) and leveraging prevailing institutions (i.e., integrating pathways within the existing institutions to support implementation[56]).

NEXT STEPS FOR ADVANCING INTEGRATION

Leveraging complementarities for change

The analysis of 60 cases showed that there are multiple equally valid entry points to drive systemic change toward sustainability. There was no particular sequencing or prioritization of entry points, and timing depended on a range of factors, including the specific needs in each context. However, we observed that each case often featured more than one entry point. This indicates that entry points do not operate independently and there can be combinations of entry points that can work together and bring complementary outcomes necessary to drive change. This echoes recent discussions in the literature that different approaches are not mutually exclusive but rather are analytically and practically complementary, and they can drive real-world change when they work together and complement respective outcomes.[13]

In line with the importance of pursuing complementarities, we discuss three possible ways through which complementary entry points can work together and provide direction for creating inclusive agendas that incorporate diverse viewpoints to initiate green reform for momentum in transition, build system resilience along the way to potential negative side effects, and ensure

Box 1. Case snapshot: The US Inflation Reduction Act for clean energy economy and climate action

As an example of entry point combinations for green reform, the US Inflation Reduction Act (IRA) was signed into law by President Joe Biden in 2022 (relevant entry points and specifics in the case are italicized). The government's economic plan features ≥20 new or modified tax incentives and $500 billion in grants and loan programs for new clean energy technology investment and deployment. Viewing climate action as an economic opportunity, the act utilizes a techno-economic approach to harness economic growth and investment to advance action on climate change, pollution, and environmental injustice (i.e., leverage positive pressures). While looking for ways to save households money, the IRA also sought to accelerate the deployment of technologies across multiple sectors, including clean energy, vehicles, buildings, and manufacturing. It directly addresses financial barriers to innovation and uptake of clean technologies for households, businesses, and manufacturers; seeks to cultivate a fertile business environment; and tackles the reform of regulatory processes to facilitate more efficient and effective permitting of energy infrastructure projects.

The IRA uses governance mechanisms (e.g., legislation) underpinned by market-based mechanisms, puts technological development at the center of transition efforts, and creates a window of opportunity to promote the innovation needed to bring about country-wide change. For example, through mechanisms like grants, loans, tax provisions including rebates and incentives, and other investments, the IRA aims to overcome incumbency and resistance to change by targeting activities that enable agency "from the bottom up and the middle out," with benefits directed toward innovators and entrepreneurs, workers, manufacturers, and union jobs. Enabling agency of change and addressing equity impacts are a strong theme in the Act, with inclusion of provisions for populations most vulnerable to climate impacts, creating shared prosperity, improving resilience against health and well-being threats, directing benefits toward those historically underserved including communities living with legacy pollution, and more. The implementation of the IRA calls for close coordination among the US federal government; state, local, and Tribal governments; and relevant agencies (i.e., adapting governance structures).

equitable action for inclusive outcomes. These are just three examples among many of potential complementarities to emphasize and demonstrate how various entry points can inform one another. Further analysis with a broader body of data may reveal additional complementarities that warrant future investigation.

Green reform for momentum

Different entry points can work together to help start green reforms by setting up the right conditions for change and leveraging internal and external drivers. Among the cases reviewed in this paper, a prime example of green reform is the US Inflation Reduction Act, where economy-wide policy mixes were aimed at innovation and structural economic change together (see Box 1). Green reform in this and similar cases is primarily aligned with debates that suggest that transitions, which are often seen as facilitated by innovation and the creation of new systems, risk failure if the policies and practices that lock in old systems are not reformed in ways that make room for change.[3,91] Through the lens of green reform, transitions are perceived as long-term and continuous processes of gradual shifts through which the economy undergoes significant changes over the span of a decade or longer. These shifts are in response to a call for action, often influenced by the needs set by society and the growing urgency and commitment among policymakers to respond to these needs (i.e., leverage positive pressures). Governments often play a key role in supporting and bringing about major shifts by advocating a political agenda for stepwise reform (i.e., overcoming incumbency) of the markets, culture, policies, and technologies that underpin how society meets its needs. These shifts support transition by creating a window of opportunity for financial, technological, political, and social innovation to emerge, scale up, and eventually reconfigure or replace existing practices (i.e., mainstreaming emerging innovation).

System resilience along the way

The entry points, when working together, can be complementary in their outcomes, offering a path to transition with system resilience, as observed in several cases, including the Australian Latrobe Valley regional transition plan (see Box 2). System resilience in these cases is aligned with debates that transitions can result in complex changes with potentially significant side effects and externalities.[92] This complexity indicates the need for holistic approaches to understanding and addressing trade-offs and synergies and to delivering co-benefits against multiple priorities (i.e., account for multisector dynamics). The more complex and interconnected the systems, the more vulnerable that transitions are to risks and uncertainties. These risks necessitate flexible and adaptable pathways for transition so that adjustments can be made over time and so that locked-in, maladaptive, unsustainable pathways can be avoided,[93] while realizing shared visions (i.e., envision resilient futures). These complexities and risks are often unique to place, and the resources to address them are different across contexts. Therefore, the interplay of complexity and uncertainty requires plural pathways that consider context-specific interdependencies between sectors, places, and future states within each location and community and recognize societal differences by engaging with people and reflecting their diverse needs and aspirations in transitions (i.e., include people and places).

Equitable action for inclusive outcomes

The identified entry points are also complementary in supporting a cycle of planning, enactment, and empowerment via a path to transition that focuses on equitable action, with several examples among our cases that include the case of mainstreaming and sustaining community-driven development in Indonesia (see Box 3). Equitable action in these cases often germinates from efforts associated with evaluating feasibility (e.g., to demonstrate pathway practicality) and establishing suitable governance structures, with a mix of formal and centralized institutions with informal and decentralized networks that could be engaged in different stages of the transition process (e.g., to build transformative governance).[94] Together, these enable

Box 2. Case snapshot: Australia's Latrobe Valley energy transition plan

As an example of entry point combinations that enable system resilience through transition is the impact of the renewable energy transition on the Latrobe Valley, located southeast of Melbourne, Australia (relevant entry points and specifics in the case are italicized). Historically, the Latrobe Valley has been the center of the state of Victoria's energy industry and core to the region's economy, with three coal mines (Hazelwood, Yallourn, and Loy Yang) and five associated power stations. In 2016, owners announced a decision to close the Hazelwood power station, giving 5 months' notice. The decision impacted 1,000 workers, 500 contractors, and many businesses in the supply chain and local area. The Victorian government mobilized an immediate response, including establishing the Latrobe Valley Authority (LVA) with authority and funding to "do things differently."

The LVA prioritized an immediate response to the Hazelwood closure, then turned to recovery and capability building. In accounting for multisector dynamics and generating multisectoral pathways, early initiatives focused on worker transfer, supply chain transition, and bringing forward infrastructure builds to mitigate workforce and economic impacts. Once a measure of stability had been re-established and there was bandwidth to begin to envision resilient futures, the LVA could then turn to the challenge of strategic and sustainable growth, with goals of targeting economic diversification and resilience through major projects, business support, buying local, future industries, and worker readiness. Demonstrating the entry point including people and places at multiple levels, five core principles guided the LVA approach: coordinated effort, outcomes focus, action orientation, genuine partnership, and locally owned ideas. The LVA also sought to share and learn from other transitions across Australia and internationally, particularly referencing the European Union's Smart Specialisation strategies.

After 8 years of operation, the Victorian government announced that the LVA would be transitioned into Regional Development Victoria by the end of 2024. In total, between $1.5 and $2 billion was invested in the region in that time frame and through the support of the LVA, with a significant proportion of those funds linked to the predicted creation of 4,000 jobs through significant projects and business support. Two power stations have now closed (Energy Brix in 2014 and Hazelwood in 2016), with the likely closure of others soon. These closures gave the region an impetus to avoid a future "one-track race" and to continue investing in system resilience by building a more diverse economy in the near to intermediate term, inclusive of renewable energy.

purposeful enactment and administration of the how and when of on-the-ground action. Equitable action also recognizes the uneven spread of benefits that any change will bring across society. Independent of the pathways taken, some people gain more (or lose more) than others, creating impacts and power imbalances with enduring inequity effects that can hamper the wider implementation of transitions on the ground. Addressing power asymmetries in action requires the creation of social capacity and the empowerment of marginalized actors, for instance, by promoting more inclusive decision-making processes,[95] creating decent work opportunities,[96] or offering compensation to those negatively impacted[97] (i.e., to enable agency of change).

Importance of underlying conditions

Conditions for various combinations of entry points, such as those discussed for green reform, system resilience, and equitable action, are not equally available across the globe, and this can contribute to contestation of transition and transformation. Given the diversity of contexts in which systemic change is needed, certain foundational conditions are to be established within each context for the successful activation of various entry point combinations. This should include the existence of appropriate institutional arrangements (e.g., policy, regulations, protocols) that will also lay the groundwork for broader structural reconfigurations (e.g., alliances, partnerships). While institutional and structural conditions for entry points are diverse and warrant future research for systematic identification, we briefly discuss two initial observations based on our case studies, which should be developed further in future research. These observations highlight conditions for entry point combinations that aim for green reform, system resilience, and equitable action, as discussed above.

Our first observation is that entry points that aimed for green reform typically developed new economic entities (e.g., Canada's Sustainable Finance Action Council[52]), partnerships (e.g., the Sino-German Energy Partnership[98]), and institutional frameworks (e.g., Kenya's Green Fiscal Incentives Framework[47]). This was done to overcome financial barriers and cultivate a fertile business environment and exchange of technical and regulatory solutions. Some entry points for system resilience and equitable action primarily required building intermediary structures that help communities build resilience and adaptive capability (e.g., an international funding body to promote rural economic transition in Pakistan[99]). System resilience and equitable action were also mostly supported by governing institutions that can ensure the equitable distribution of funds and resources (e.g., a multiyear purchasing agreement with smallholder farmers to support rural agricultural transitions in Indonesia[55]). While some of these structures and institutions might exist and can be reoriented in some places, they may need to be deliberately built to support transitions in other places, given existing political and governance circumstances and the different ideas and values that transition may imply in each place.

As a second observation, we noticed a spectrum of organizations with different roles throughout the various stage of transitions. For example, entry points aiming for green reform required that governments take the position of catalysts, making commitments for economic reform to tackle sustainability challenges and, in some cases, creating markets while science and industry actors led the development of innovative solutions to these challenges. Subsequently, governments made decisions, choosing among and supporting suitable options. However, for system resilience and equitable action, the primary actors were local governments, intermediaries, and interest

Box 3. Case snapshot: Toward mainstreaming and sustaining community-driven development in Indonesia

An example of entry point combinations that aim for equitable action is the case of community-driven development in Indonesia (relevant entry points and specific in the case are italicized). With a focus on local (village-level) implementation of national policy, this case sets out lessons learned in the process of mainstreaming and institutionalizing community-driven development from a general program (i.e., PNPM-Mandiri) into a specific policy (i.e., Village Law). From its inception in 1997, the approach to community-driven development in Indonesia was formulated to achieve inclusive outcomes, like poverty reduction via equitable action. An example of engaging all people, community self-management through cooperation, participation, transparency, accountability, and capacity building were core to the approach, as was a focus on affirmative action that emphasized the participation of and benefit to women.

This case from Indonesia is an example of building transformative governance to champion sustainable development in at least two different ways. First, through the PNPM-Mandiri program, a platform was provided for locally led (village-based) decision-making, dispersal of funds, and self-management, as part of Indonesia's national strategy for poverty reduction. The program approach focused on the engagement of local government, stakeholders, and beneficiaries, directly resulting in the expansion of responsibility and capacity at the local level, creating a sense of ownership, and positively reinforcing adoption and institutionalization of community-driven development by local government agencies. This speaks to enabling agency of change by empowering marginalized actors.

The transition of community-driven development from a programmatic basis (PNPM-Mandiri) to a legal basis (e.g., enshrined within the 2014 Village Law) is an example of adapting governance structures for the purpose of sustaining both the approach and the intended benefits. The case noted several challenges in adapting governance structures, for instance, a relative absence of central government leadership during the transition to the Village Law. The case also flagged an expectation that the first few years of implementing Village Law would be challenging and would carry risks, including warning that the intended reduction of poverty and improvement of development outcomes is "neither automatic, nor is it assured," in particular because implementation is subject to the institutional capacity of local governments, accountability, and responsible application of increased power among village heads, all of which vary widely across the country (i.e., addressing unintended consequences). Seeking to address these unintended consequences of transition, the case called for risk mitigation measures to accompany the process of implementing Village Law.

groups advocating for community resilience or equitable outcomes, while national governments were often in the background providing support to mobilize resources and institutions. This pattern underscores the need for transition actors to explicitly co-define agency for change and collaboratively delineate their respective roles.

Locating entry points in emerging debates

Some aspects that are perhaps more emergent or less mainstream in the current literature should be further explored in future work as part of the application of our entry points. Here, we highlight four. First, with a rapidly evolving and deteriorating geopolitical context, our entry points perhaps are informed overwhelmingly by cases from less-turbulent times. This adds another layer to the question and complexity of how to govern sustainability transitions that only a few have started to explore in much depth (e.g., see Sivonen and Kivimaa[100] for the interplay between security and energy transitions). Second, and related to the first point, our entry points based on existing case studies are perhaps somewhat the victim of an overemphasis on and belief in the power of social learning and actors working together collectively toward common goals, while not paying full attention to processes of contestations, conflicts, and crisis in the shaping of sustainability transitions (e.g., see Yuana[101] for a recent contribution). Third, there is a need for a much deeper engagement with the challenges and legacies of colonial relationships and finding inspiration from non-Western frames and theories, as well as a need to move beyond colonial modernity in sustainability transitions.[102] While our cases cover both the Global North and South, our resulting entry points limitedly engage with Indigenous theories, frames, and philosophies. Fourth, there is a need to further interrogate our entry points for their ability (or lack of it) to achieve its intended purpose within moderately reformed economic structures, which in many parts of the world continue to be based on growth-oriented models. There is arguably a need to consider much broader and perhaps more radical imaginations of new economic models and structures beyond green reform and how these enable or impede the rapid delivery of sustainable development outcomes.[103]

Implications for policy and practice

What we learned through this paper has two main implications for policymakers and people engaged in change-making efforts and how they can understand, evaluate, and advance transitions. First, the applications of entry points across contexts indicate unique insights that each scale of analysis or sectoral focus has to offer. Even though the specificity of each place and scale needs to be acknowledged, insights can be drawn to address complex challenges prevalent in other transitions. As an example, a challenge in some food and agriculture transitions regarding how to empower diverse food actors (e.g., farmers, workers, consumers, marginalized communities, Indigenous people) equitably in the change-making process can be addressed by learning from other cases that were successful in enabling change agency.[104] This can include learning from multiple equity lenses in the broader sustainable development domain to better consider complexities that may arise from historical (e.g., colonial) legacies as well as difficulties around ongoing equitable transition processes and their outcomes.[105] This and other similar examples, aided by connecting and

coordinating insights across different areas, indicate the need for an evidence-based learning and knowledge system. This can comprise scientists, policy and government, industry, and communities, with a role to compare and share experiences of what works for systemic change in different contexts, from multiple lenses rooted in different worldviews, perspectives, and knowledge sources.[106] The accumulation, aggregation, and mobilization of transition insights and lessons through an evidence-based learning and knowledge system can also help spread effective practices and policies more widely and build the collective capacity of stakeholders to navigate transitions.

Second, the entry points and our resulting observations as presented in this paper outline a set of practical directions for transition research and practice, echoing the important message of "taking diverse knowledges seriously."[13] They can offer guidance for enhancing flexibility and deliberative reflection on diverse perspectives in planning processes and supporting strategic decision-making in projects and applications. They can be useful for researchers, practitioners, and policymakers to understand the growing diversity of approaches but also to offer guidance on what collaborative, multistakeholder efforts should concentrate on for making context-appropriate selections. The entry points should not be taken as definitive, however, but as a means to foster respectful dialog among people from diverse disciplines and perspectives. They should be used to enable different views to deliberate about the nature and form of sustainability outcomes they want to achieve, how they transition, and the choices that are most suitable for their context.

Limitations of the study

While the sample of selected cases was sufficient to ground the entry points in different contexts, we recognize that the case selection process had inherent limitations and potential biases and cannot be treated as representative of the full diversity of research and practice on sustainability transitions (i.e., not a valid statistical sample). First, although we aimed to capture diversity in terms of geographic locations, scales, and outcome foci, the selection was not exhaustive. Other cases and perspectives might be missing, which means our explanation of the entry points might reflect biases based on the cases we chose. In reality, there are numerous other examples of local, national, and global transitions and transformations documented in the scientific and gray literature that are not included in this study. As such, we recognize that the selected cases may not provide a fully neutral or comprehensive view of all transition and transformation efforts. A much larger and more representative sample would be required to make statistical inferences.

Second, the selected cases might also be biased toward verification—that is, a tendency toward and hidden preferences in choosing cases that confirm researchers' preconceived notions, given that our qualitative approach allows for more room for researchers' subjective judgment. While subjectivity and the risk of bias toward confirmation are common to most qualitative methods,[107] we took steps to address this issue (see more details in methods). Specifically, the case selection and analysis process involved three independent authors, each reviewing the cases according to a transparent and documented process. Additionally, we documented each step of the case selection process (see Data S1–S4), which allowed for reflection and ensured that the selection adhered to the defined strategies and objectives.

CONCLUSIONS

Sustainability transitions require society to shift toward a more sustainable future that champions innovation, productivity, and prosperity in a just and equitable manner for all. Actions are under way to transition current systems, industries, and places to a more sustainable future. However, these actions are often fragmented, meaning lessons in and knowledge about what is working are rarely shared. Entry points can provide an effective way to facilitate learning and knowledge sharing about transitions and transformations, helping to coordinate and collaborate on common challenges and opportunities related to systemic change.

By using entry points as a framework in this study, we gained two broad insights. First, the analysis of 60 cases uncovered multiple valid attributes in approaches to system change. This was supported by multidisciplinary thinking from different fields that reflects unique (yet sometimes overlapping) understandings that compete in the process of driving far-reaching change. The entry points highlighted the importance of embracing diverse perspectives in our understanding of transition and acknowledging the plurality of views and standpoints that are essential for transdisciplinary research.

Second, we analyzed how different entry points manifested and were articulated in various contexts. Justice and equity were found to be crucial in driving transition processes across several entry points, as transitions require more than technological or financial innovations. They also involve the dismantling of entrenched social and economic systems and should be built on participatory and inclusive governance across multiple levels. While equity is central to several entry points, we found that achieving it is complex. It involves not only addressing historical inequalities but also fostering agency, ensuring that all individuals, regardless of background, have the opportunity to make meaningful choices.

None of the entry points in isolation will be enough. More likely and in accordance with other studies,[13] a mix of many if not eventually all, depending on the context, underlying condition of transition efforts, and length of time, would be required to effect a successful transition. The question we face is not about which group of cases or which entry point is better than others. We conclude that integrating the constructive features of multiple entry points is important to navigate change in the context of global challenges with complex and uncertain dimensions. Advancing this way of thinking is important for mobilizing new sources of evidence and experiences to inform practice and policy for driving transitions toward more sustainable futures.

METHODS

Overview

The entry points are grounded in empirical evidence through a qualitative concept synthesis, which is an inductive thematic analysis of the contents of selected documents describing case studies, to identify key attributes in their approaches to

transition and transformation. This is a well-established method in socioecological system studies.[108] We began by selecting a balanced mix of cases with insights relevant to transition; identifying important concepts from transition and transformation literature inductively; coding the selected case studies using these concepts; identifying themes (entry points) inductively from this coding; and then reanalyzing the case studies by recursively coding them using the entry points. We explain this process and the theoretical grounding of our understanding of transitions in greater detail below.

Terminology

To guide our case selection, we first defined the terms "transition" and "transformation" (and other associated terms such as systemic change). Transition was originally defined in sociotechnical system research as "long-term, multi-dimensional, and fundamental transformation processes through which established sociotechnical systems shift to more sustainable modes of production and consumption."[31] There were other terms associated with transition that were used frequently (and in most cases interchangeably) in scientific and policy literature. An example is transformation, which was defined as "fundamental changes in structural, functional, relational, and cognitive aspects of sociotechnical-ecological systems that lead to new patterns of interactions and outcomes"[13] (among many other definitions[109]). Transformation is contrasted with transition in some contexts as the outcome of the fundamental shift and the resulting reconfiguration of systems,[7] but in other contexts, it is discussed as a duality that provides complementarities in terms of how to describe, interpret, and support desirable radical and non-linear societal change.[109] Systemic (systems) change was another term used in relation to transition in broader sustainability science to describe complementary shifts that cut across multiple systems and should be coherently pursued to form a transition away from currently established to emerging (and more sustainable) systems.[4] Pathway, another term associated with transition, was often used in sociotechnical systems research to describe alternative patterns through which a transition may emerge[110] or as the elaboration of social-economic-political and environmental trajectories to achieve desired futures in socioecological systems research.[111] The term pathway has also been used slightly differently in adaptive planning[112] and development studies[113] as alternative possible trajectories for knowledge, intervention, and change, which prioritize different goals, values, and functions.

While these terms have overlaps and are not entirely independent of one another, they represent how transition is conceived in different fields of research supported by various underlying theories.[109] Therefore, we considered them complementary and adopted a flexible and broader definition of transition in this paper, which is inclusive of other similar terms across different areas. We defined transition as pervasive change for persistent problems.[114] Persistent problems are the negative side effects (e.g., food insecurity, soil degradation) of existing systems. Pervasive change is the confluence of developments across sectors and scales of the economy that creates a large-scale, nonlinear, and disruptive change to address these problems. This broad definition was used as a reference point to guide the selection of relevant cases.

Selecting cases

Case selection strategy

We collected a diverse set of cases from both the scientific and gray (policy and practice) literature, spanning various geographic locations and scales (i.e., global, national, local) and covering four key sectoral areas. We followed a diversity-oriented selection strategy,[107] aimed to ensure that the cases we reviewed were representative of different regions, scales, and transition outcomes. To narrow down the selection further, we also adopted an information-oriented selection strategy,[107] where we chose cases based on their potential to provide rich, relevant information about approaches to transition and transformation to inform our analysis. Previous studies have used a similar strategy for case study selection and for identifying and generalizing patterns.[106]

As noted by Flyvbjerg,[107] there is no universal way for selecting cases based on their diversity and level of information, and case selection can vary across different research contexts. This, therefore, encouraged us to use a mixed-methods search process for case selection. Mixed-methods search often seeks to address the inherent limitation of one search method with another search method[115] and has been used in previous research.[106,116] Using a mixed-methods search of the scientific and gray literature, we selected 60 cases for review and analysis at global, national, and subnational scales (Figure 1). We included gray literature (e.g., policy and industry reports) as case studies are often documented in greater depth and first-hand within within non-academic sources. These cases (from both the scientific and gray literature) represent various attempts at transition and transformation, reflecting developments toward a more sustainable future at different levels of progress. These developments progress in various stages (e.g., emergence, acceleration, stabilization[117]); therefore, selected cases may represent different levels of progress in change. Recognizing the interconnectedness between transition and transformation, we adopted a broad, flexible definition that encompasses a range of associated terms in searching for cases (see terminology in methods above). While these associated terms may stem from different areas of research, they emphasize and enrich each other's perspective on efforts to achieve inclusive human development and Earth systems stability.[109] We specifically focused on cases that aim for far-reaching and systemic change in response to persistent, large-scale problems, issues such as food insecurity and climate change that arise from unsustainable practices. By far-reaching and systemic change, we mean developments that span multiple sectors and scales of society, driving disruptive change to address the persistent challenges. Further details of this procedure are provided in the following sections and in Data S1 and S2.

For global-scale cases, we primarily relied on the peer-reviewed scientific literature, while for national and subnational cases, we focused on the gray literature (e.g., reports, government documents). This distinction was a deliberate choice, as transition cases at the national and local levels are often more richly documented in gray literature, offering more detailed, context-specific accounts of transitions, which are crucial for understanding the dynamics at these scales. It is important to note that our aim in selecting cases from both the scientific and gray literature was not to provide a comprehensive review of the

entire body of transition knowledge but rather, we sought to examine a diverse set of cases with sufficient empirical evidence that could shed light on transition and transformation processes across different scales, regions (Global North/South, East/West), and outcomes. In doing so, we also aimed to include cases that were agnostic to specific fields or theories, ensuring that our findings would reflect a broad range of approaches to systemic change.

Global cases

To identify cases related to global scientific assessments, we searched in Web of Science because the database covers a diverse range of journals related to sustainability transition and transformation topics. It is important to note that this choice does not imply that global cases are absent from the gray literature or that national or local cases cannot be found in the scientific literature. Instead, it was a deliberate choice aligned with our diversity-oriented and information-driven case selection strategy, aimed at ensuring a broad range of cases.

To search, we identified a range of preliminary key words and tested search strings to scope the diversity of related documents being captured. The following query was eventually used with appropriate adjustments to the Boolean operators: ((TI=((transition* OR transformat*) AND (net?zero OR emission* OR climate?change OR sustainabil* OR biodiversity))) OR AB=((transition* OR transformat*) AND (net?zero OR emission* OR climate?change OR sustainabil* OR biodiversity))) OR AK=((transition* OR transformat*) AND (net?zero OR emission* OR climate?change OR sustainabil* OR biodiversity)). We limited our search to recent peer-reviewed publications that appeared post-UN Sustainable Development Goals and the Paris Agreement (i.e., 2015 or later). This resulted in an initial 66,640 documents.

These broad search queries returned many publications, which was not practical for a detailed review. Therefore, we used a set of exclusion and inclusion criteria to limit the search results to those within or directly related to transition and transformation as systemic and far-reaching change. We used exclusion criteria based on field of study (e.g., chemical engineering, genetics) to avoid papers with a focus on, for example, understanding electrochemical phase transition in lithium batteries. Conversely, the inclusion criteria included the following:

(1) Influential papers: To ensure relevance and impact, we prioritized papers that were highly cited, using a Web of Science metric that identifies papers in the top 1% for citations. This metric, which compares a paper's citation count to others published in the same field in the same year, helps identify those producing significant impact and relevance in the literature.

(2) Broad sustainability focus: We included only journals and papers that addressed transition or transformation within a broader sustainability context, excluding papers that were narrowly focused on specific technical fields like engineering or medical research.

(3) Global scale cases: As our focus in this part was on global transition cases, we intentionally limited the search to papers that addressed transitions at the global scale. This was a deliberate decision, as we later used gray literature to source cases at national, international, and subnational levels.

(4) Empirical real-world cases: We prioritized papers that presented real-world cases situated in specific sectoral contexts (e.g., agriculture, energy, climate), focusing on empirical evidence, rather than on purely theoretical or methodological papers. This allowed us to select cases that reflected actual attempts at transition and transformation.

Filtering through these four criteria significantly reduced the number of papers to 113 documents (Data S2). We reevaluated these papers by reviewing their abstracts for relevance, guided by four inclusion criteria and on the basis of expectation from their information content about transition and transformation (information-oriented selection) and the diversity that they present across sectors (diversity-oriented selection). This resulted in 20 highly relevant cases to include in our analysis. Data S2 shows the documentation of this selection process, with cases that were included versus those excluded from the rest of the analysis.

National cases

The case selection was different for cases at national scales. They were searched with a focus on the gray literature. However, this does not imply that no national-level cases can be found in the scientific literature. Rather, this was only a deliberate choice given that transition cases at the national-level are often more richly documented in gray literature, and that we wanted to diversify the types of sources used to identify the entry points.

In the gray literature, the challenge was often found in the fragmentation and siloing of relevant documents across different departments or institutions, each with distinct priorities. In some cases, the word "transition" or "transformation" was often lost, and documents became simply, for example, clean energy plans, even though they included important insights relevant to transition. Moreover, different countries have different approaches to organizing and documenting transition efforts. For example, France has a Ministry of Ecological Transition, the United Kingdom has established a Transition Plan Task Force, and Italy has integrated transition goals within its National Recovery and Resilience Plan. This inconsistency in terminology and organization led us to avoid a comprehensive search of all documents, focusing instead on a more information- and diversity-oriented strategy that aimed to capture documents rich in content and diversity, both geographically (i.e., Global South/North, East/West) and across sectors.

To identify cases related to international and national strategies, we used Google as the search engine, supplemented by targeted key words such as "sustainability transition," "sustainability transformation," and "government" to help locate official documents. Occasionally, we conducted snowball searches, following links from websites identified in the initial search results. We focused on documents in English, French, Italian, Spanish, and Portuguese, based on the linguistic capabilities of our co-authors. Initially, we prioritized high-income countries, recognizing that these nations are often the largest contributors to sustainability challenges and tend to have more resources for transition efforts. In the second round, we expanded our search to include low- and middle-income countries, ensuring the cases

represented a broad geographic diversity. From each country, we selected three to five reports for further review. Two documents were chosen from each country for in-depth analysis, with one co-author ultimately selecting the final document for inclusion. We also incorporated several highly relevant reports suggested by co-authors from international organizations, resulting in a total of 20 cases at the international/national scale. The choice of the number 20 cases was made to ensure balance with the number of global-scale cases previously identified and to keep the selection manageable for detailed analysis.

Local cases

For subnational and local cases, we also focused on the gray literature. Our search was limited more by the nature of the available documents, which were often hosted on websites. To address this, we performed broad searches using terms like "local transition" or "local transformation," followed by snowball searches based on the initial results. This process revealed that many local initiatives were part of a larger, networked effort. As a result, multiple local initiatives were often included as part of a broader network of transition actions. In some cases, local-scale transition initiatives were presented as general sustainable development plans, encompassing a wide range of areas, from energy and food systems to waste management while still including approaches to systemic change. As with the national cases, we applied a diversity- and information-oriented selection, ensuring a balance in terms of geographic locations (Global South/North, East/West) and sectoral focus, as well as cases that offer relevant contents about transition and transformation. Initially, one co-author selected 31 local initiatives. Data S2 documents this selection process. After further evaluation by a second co-author to ensure relevance, the list was narrowed down to 20 initiatives that were deemed most relevant and diverse in terms of their contribution to subnational and local transitions. This resulted in 20 cases at the subnational/local scale, again a number deliberately chosen to maintain balance with the global and national cases and to ensure that the selection was manageable for detailed review.

Reviewing selected cases

We reviewed the contents of the selected cases and analyzed the insights that each case, directly or indirectly, offered about transition and transformation. First, from each of the cases, we identified metadata such as source title (for journal publications), year of publication, authors, the terminology used (e.g., transition, transformation, pathway, transformative change/pathway, green growth, net-zero), the location of the case, and the sector of transition (e.g., energy, agriculture, governance, finance).

Second, we analyzed each case discussion and coded their contents against nine entry points. Within the 60 cases selected and based on entry points identified from theory, we used a coding procedure that (1) assigned three subjective levels to indicate the extent to which the case discussed the entry point or strength of association (i.e., 0, 1, and 2 referred to no, implicit, and explicit discussion, respectively) and (2) provided an insight or example (by referring to the exact text in case documents) to explain in what way the case talked about the entry point directly or indirectly. To implement this coding procedure, three primary co-authors initially reviewed all cases and specified their assessment of strength of association and insights/examples in relation to each entry point (Data S3). To mitigate the risk of biases in this subjective coding procedure, a secondary co-author reviewed all the cases independently and flagged those that could be coded differently for further deliberation and modification by the original coders.

We also categorized cases into four areas based on their primary outcome foci, either sectoral outcomes like agriculture and food and energy and climate, or societal impacts concerning justice and equity and broader sustainable development. Categorizing cases based on their focus faced two primary challenges, which we addressed differently:

(1) Initially, the dilemma was whether to consolidate various sectoral and societal outcomes into singular context category or to keep them separated; for instance, merging energy and climate in one or two categories. Starting with many potential categories (e.g., decarbonization, energy transition, and circular economy, biodiversity conservation, urban transition), we realized that a larger number of sectoral/societal outcomes resulted in fewer cases in each and a highly uneven number of cases across these foci on outcomes (e.g., circular economy had only one relevant case, whereas energy transition had nine cases). This impeded robust and comparable conclusions about transition in each and across contexts. Consequently, we decided to merge sectoral/societal outcomes into four broad categories with a similarity of what they focus on to enhance the meaningfulness of our conclusions and ensure a balanced distribution of cases across them.

(2) The second challenge involved the assignment of cases to a single or multiple context categories, a task complicated by the multifaceted nature of the cases, often spanning multiple outcomes (e.g., an energy transition case that also focuses on justice and equity). While we acknowledged the multiple aspects that each case has, we decided to assign the case to only one primary focus on outcome that was central to the case to improve the clarity of analytical process.

Clustering case insights

The analysis of cases in relation to the entry points introduced above resulted in a significant diversity of insights. The 60 cases coded under 9 entry points resulted in 540 data points (Data S3). Despite differences between cases, there were similarities and recurring insights in the coded materials that indicated an opportunity for clustering. We performed a qualitative clustering to identify these recurring insights, which we then labeled as entry points and their specifics. Clustering can be performed computationally or manually, but we chose to do it manually and qualitatively in this research to ensure that we captured the nuances of insights discussed in each case.

To cluster, three primary co-authors simplified all the coded materials (Data S3) and created shortened insights that were more specific and intuitive for qualitative clustering (Data S3). A secondary co-author then grouped all the shortened insights based on their similarity in two hierarchical steps of entry points (as higher-level insights) and their specifics (as more detailed

insights). This was a fully iterative process where the shortened insights were grouped and regrouped several times to minimize the variance within each entry point while maximizing the meaningful difference between different entry points (a standard balance often sought in other clustering examples[106,116]). Eventually, the clustering of coded materials from cases resulted in a set of nine entry points, each with three specific means of implementation (Data S4). Despite efforts to maintain this balance, we acknowledge that the distinction between entry points is not always clear-cut (which is an inherent feature of clustering). For instance, multiple entry points talked about policy and governance, but each came at them from a different perspective and for a different purpose.

DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

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