Sustainability Science • Sustainability Science: A guide for researchers

Capacity to Promote Transformations

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"Transformations" are shifts from one regime and its associated development pathways to another.

Sustainability transformations¹ are shifts from regimes associated with unsustainable pathways of development to alternative regimes in which development pathways are (provisionally thought to be) sustainable, e.g., from fossil to renewable energy regimes ([Geels et al. 2017](#)) or from declining to prospering fisheries ([Lubchenco et al. 2016](#)). The need to hasten transformations of current development pathways toward sustainability is increasingly central to social and political discourse around the world ([Wibeck et al. 2019](#)).

1 Findings: Innovation, assessment, and incumbency

The sustainability science community has been interested in the concepts of system transformation or transition since its founding ([National Research Council 1999](#)). The terms transformation and transition are used interchangeably and without consistent distinctions in much of the literature ([Hölscher, Wittmayer, and Loorbach 2018](#)). We use transformation as a term for both in this Research Guide. Multiple programs of relevant research have been active over the past decade, most with a focus on specific resources. Examples include transformations in forest use ([Rudel et al. 2019](#)), demography ([Barnett and Adger 2018](#)), environmental justice ([Evans and Phelan 2016](#)), industry ([Schaffartzik et al. 2014](#); [Haberl et al. 2019](#)) and, more broadly, socio-technical systems ([Köhler et al. 2019](#)). We cannot cover in detail the rich findings of this research. We refer readers interested in a deeper dive into sustainability transformations to four papers that review the growth of this field and synthesize results ([Scoones 2016](#); [Loorbach, Frantzeskaki, and Avelino 2017](#); [Markard, Raven, and Truffer 2012](#); [Geels 2019](#)). We draw heavily on these reviews for the high-level summary provided below.

Transformative capacity is a necessary complement of adaptive capacity: Transformations involve shifts across regime thresholds resulting in future development pathways that are qualitatively different than they would have been if the shift had not occurred. When current regimes are unsustainable, tendencies toward path-dependence and lock-in can make incremental adaptation an insufficient and even counter-productive strategy for the successful pursuit of sustainability over the long run ([Seto et al. 2016](#); [Díaz et al. 2019](#)). A capacity for promoting qualitative transformations of regimes and their associated development pathways is thus a necessary (but not sufficient) condition for sustainable development.

Transformative capacity must embrace the intertwined dynamics of the Anthropocene: Recent research on transformations is struggling to move beyond its earlier focus on single resources to

embrace interactions among the full range of natural and anthropogenic resources described in the [Chapter on a Framework for Research](#). Its focus is thus increasingly on transforming the intertwined, coevolutionary interactions of nature and society ([Ahlborg et al. 2019](#)). Transformations, like adaptations, are also coming to be seen not as discrete events but rather as dynamical cascades entailing multi-dimensional regime shifts and associated qualitative changes in development pathways ([Rocha et al. 2018](#)). The implications of this dynamic character of transformation pathways for efforts to build capacity for guiding, much less managing, them are only beginning to be explored ([Scoones et al. 2020](#)). Especially underexplored are the dynamics of transformations in developing countries where issues of informality and inequality are among the defining challenges ([Hansen et al. 2018](#)).

The heart of transformative capacity is innovation: The pursuit of sustainability is ultimately about finding novel ways to mobilize resources of the Anthropocene System to create inclusive well-being ([Binz and Truffer 2017](#); [Kattel and Mazzucato 2018](#)). Not surprisingly, concerns for stimulating and managing appropriate innovation have therefore been at the center of many of the formative documents of the field. These have highlighted the importance of innovations not only in science and technology ([Anadon et al. 2016](#)) but also in institutions and in social goals for sustainability ([Westley, McGowan, and Tjörnbo 2017](#)). The difficulties of stimulating innovations to promote sustainability have been explored at length, particularly those due to the public good character of many of those that are most needed ([Silvestre and Tîrcă 2019](#)). Long missing from sustainability science, however, was either empirical case studies or conceptual models to help understand and promote the full innovation process: incentives for invention, uptake of the results, their spread and displacement of existing ways of doing things, and ultimately the transformation of practices at system scale.

This unsatisfactory state of affairs has itself been transformed through the gradual adoption into the mainstream of sustainability science of an initially independent program theorizing the history of large-scale socio-technical transformations ([Loorbach, Frantzeskaki, and Avelino 2017](#)). This exciting work has demonstrated the importance of connectivity and cross-level interactions for understanding the role of novelty in general and innovation in particular in both regime stability and change. A particularly useful approach to conceptualizing the relationships between connectivity and innovation in transformation studies has been the **multi-level perspective (MLP)**² from which the Sustainability Science Framework we presented in [Figure 1](#) draws inspiration ([Geels 2019](#); [2020](#)). The MLP takes as its point of departure the observation that in any given action situation, prevailing development pathways are structured by regimes (see [Chapter on Capacity for Equity](#)). The positive feedbacks of the regime create path dependencies that make transformations to new development pathways difficult. Exogenous changes at higher levels of organization such as global economic orthodoxies, wars, and climate change put pressure on regimes that can sometimes create openings for change. But disruptions to dominant regimes are unlikely without sources of novelty. These usually are rooted in

micro-levels of organization. Novelty can take many forms including new or re-combined traits of organisms, technologies or practices; institutional structures; actors' goals, values or behaviors; and knowledge about the Anthropocene System.

The MLP and the related literature on strategic niche management emphasize the importance of fostering diverse forms of novelty and innovations at the micro-level. The likelihood that innovations will prosper and spread is often improved by the creation of niches or protected spaces that allow for experimentation, adaptation, and the coevolution of novelty, user practices, and regulatory structures shielded from the forces of dominant regime structures ([Sengers, Wieczorek and Raven 2019](#)).

Managing connectivity between the micro- and meso-level is important for transforming development pathways, just as it is for adaptation. The flows of novelty from the micro- to the meso-level are influenced not only by the appropriateness of an innovation itself but also by selection rules of the relevant regime ([Hausknost and Haas 2019](#); [Ghosh and Schot 2019](#)). Actors seeking to transform development pathways must therefore attempt to change the selection relationships created by the relevant regime ([Schot and Steinmueller 2018](#)); [Fagerberg 2018](#)).

Transformation must overcome path dependence: The path dependency that hinders transformation of regimes has two causes, one passive and one active. The passive cause, often cited in the literature on technological innovation, is increasing returns to scale. This is a general property of complex adaptive systems, caused by learning effects, economies of scale, adaptive expectations, and network economies ([Foxon 2011](#)). The active cause is action by powerful actors to block novelty that threatens the established position of winners in dominant regimes. Those actors mobilize multiple dimensions of power (see [Chapter on Capacity for Equity](#)) to reinforce regimes that favor them, thus protecting their continued advantage. Indeed, powerful incumbents demonstrate a nuanced ability not only to create barriers to expansion of novelty that threatens their interests but also to selectively influence the emergence of novelty in ways that maintain the stability of dominant regimes ([Bakker 2014](#); [Apajalahti, Temmes, and Lempiälä 2017](#)). An ability to destabilize existing regimes and overcome incumbency is therefore a fundamental component of the capacity for transformation. It should thus be at the cutting edge of transformation research for sustainability.

2 Building Capacity: Anticipation, imagination, and integration

The capacities for adaptation and transformation are not unrelated. But two challenges for building transformation capacity merit special attention: promoting collective visions of what sustainability transformations of the Anthropocene System might look like; and combining sectoral transformations into integrated regional transformations for sustainability.

Transformations to what? Integrating anticipation and imagination:

Transformations to what? This is a question that needs to be answered, given that the novelty and regime changes discussed earlier in this chapter simply send development pathways somewhere else. If that somewhere is to be toward sustainability, then transformation research needs to be self-conscious about what it is aiming for. Two approaches, recently characterized as “anticipation” and “imagination” ([Burch et al. 2019, 11](#)), have offered partial answers. Both have strengths and weaknesses. The challenge now for sustainability science is to integrate them and thus provide better answers for its “to what” question.

Anticipatory approaches have generally started with present trends in development, sought to illuminate potentially dangerous outcomes of continuation of those trends, and explored the likely efficacy of alternative interventions designed to avoid or mitigate the dangers. Transformation research guided by such anticipatory studies is largely about shifting away from development pathways that risk being unsustainable toward a “safe operating space” for humanity ([Anderies, Mathias, and Janssen 2018](#)). Common methods employed in anticipatory research include modeling, assessments, foresight exercises, and some forms of scenario building ([Mach and Field 2017](#); [Cashore et al. 2019](#); [Spangenberg 2019](#)). Imagination-driven approaches, in contrast, have been less about what people want to avoid and more about their shared visions of what they want to achieve. Common methods do make use of science but tend to do so in a qualitative and discursive manner that can tap the arts and humanities as well. An early example is the work of the Global Scenarios Group and its successor, the Great Transition Initiative ([Raskin 2016](#)). More recent work is reflected in the creative use of imagination-driven scenarios in the Millennium Ecosystem Assessment and its successor, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) ([Sitas et al. 2019](#)).

Neither anticipation-driven nor imagination-driven approaches are pure types, and in recent years scholars have increasingly combined the two in their efforts to envision targets for sustainability transformations and plans for achieving them (e.g., [Pereira et al. 2019](#); [Hajer and Versteeg 2018](#)). What is becoming clear in all of these approaches is the implicit conservatism of most efforts to address the “Transformation to what?” question. In particular, most efforts leave unchanged existing assumptions about relevant actors, institutions, and power structures—exactly the features that lie at the core of many worrisome development pathways ([Stirling 2019](#)).

The narrow framing of most efforts to envision sustainability transformations is now being questioned by scholarship emphasizing the importance of crafting more radical shared **imaginaries**³ ([Schot and Steinmueller 2018](#)). Imaginaries are collectively held visions of good or attainable futures—with an emphasis on their institutions and power relations—that serve to envision the possible and motivate action toward new development pathways ([Jasanoff and Kim 2015](#)). These in turn can stimulate new

laws, regulations, and investments in research and development of new technologies that fit the aspirations of the imagined social order ([Beckert and Bronk 2018](#)).

What are the prospects for creating collectively held sustainability imaginaries—ones that create visions of good and attainable futures and justify investments in research and development and scale-up of more sustainable technologies and socio-technical systems? Practitioners and activists are now leading the way on this question. For example, recent talk of a Green New Deal in many ways offers its own kind of sustainable imaginary—one that tightly couples solutions to climate change with social justice and job creation ([White 2019](#); [Ocasio-Cortez 2019](#)). The challenge for sustainability science is, once again, to catch up with practice in their explorations of the question “Transformations to what?” The essence of this challenge is to build a capacity for generating answers that simultaneously make the best use of available knowledge; encourages pluralistic answers to the question for specific action situations; and create shared visions that can help to guide the collective action needed to achieve results at scale (see [Chapter on Capacity for Governance](#)).

Integrating sectoral transformations:

Combining sectoral transformations into integrated regional sustainability transformations poses an additional challenge for capacity building. When is it useful explicitly to combine work on transformations in particular sectors like energy or food into broader visions of sustainability transformations? Understanding of nexus interactions among sectors may not be sufficiently advanced to justify pushing transformation research to integrate across them. However, there is every reason to suppose that efforts to advance individual sectors in isolation will result in competition and conflict (e.g., [Nepal et al. 2019](#); [Shah, Giordano, and Mukherji 2012](#)). Many worry that such counterproductive interactions are inevitable if the UN’s multiple SDGs are pursued independently ([Schot et al. 2018](#); [Sachs et al. 2019](#)). A way forward may be available through combining frontier work on transformations with advances in the integrated measurement of sustainable development that we reviewed in the [Chapter on Capacity to Measure](#). Indeed, one possible answer to the “Transformation to what?” question would be to define a sustainability transformation as a shift from a regime in which development pathways are characterized by declining inclusive wealth to a regime in which development pathways are characterized by stable or increasing inclusive wealth. To our knowledge, this has not yet been seriously explored by sustainability science. It almost certainly should be, although with a heavy dose of humility in how far scholarship can take us in such an ultimately imaginative endeavor ([Jasanoff 2018](#)).

Building a capacity for transformation necessarily involves the creation of sustainability imaginaries and the integration of siloed sectoral approaches. Perhaps even more challenging however, a capacity for sustainability transformation will require the ability to destabilize existing regimes that seek to preserve the unsustainable status quo ([Kanger and Schot 2019](#)). We defer discussion of what research

can tell us about building the capacity for the collective mobilization required to destabilize dominant regimes to [Section 2 in the Chapter on Capacity for Governance](#).

Footnotes

1. **Transformations:** shifts from one regime and its associated development pathways to another; also called transitions (contrast with adaptation) [↵](#)
2. **Multi-level perspective (MLP):** a hierarchical framework for analyzing innovation in sociotechnical systems [↵](#)
3. **Imaginaries:** collectively held visions of good or attainable futures that serve to envision the possible and motivate action toward new development pathways [↵](#)

Citations

1. Geels, Frank W., Benjamin K. Sovacool, Tim Schwanen, and Steve Sorrell. 2017. “Sociotechnical Transitions for Deep Decarbonization.” *Science* 357 (6357): 1242–44. <https://doi.org/10.1126/science.aao3760>. [↵](#)
2. Lubchenco, Jane, Elizabeth B. Cerny-Chipman, Jessica N. Reimer, and Simon A. Levin. 2016. “The Right Incentives Enable Ocean Sustainability Successes and Provide Hope for the Future.” *Proceedings of the National Academy of Sciences* 113 (51): 14507–14. <https://doi.org/10.1073/pnas.1604982113>. [↵](#)
3. Wibeck, Victoria, Björn-Ola Linnér, Melisa Alves, Therese Asplund, Anna Bohman, Maxwell T. Boykoff, Pamela M. Feetham, et al. 2019. “Stories of Transformation: A Cross-Country Focus Group Study on Sustainable Development and Societal Change.” *Sustainability* 11 (8): 2427. <https://doi.org/10.3390/su11082427>. [↵](#)
4. National Research Council. 1999. *Our Common Journey: A Transition toward Sustainability*. National Academy Press. http://www.nap.edu/catalog.php?record_id=9690. [↵](#)
5. Hölscher, Katharina, Julia M. Wittmayer, and Derk Loorbach. 2018. “Transition versus Transformation: What’s the Difference?” *Environmental Innovation and Societal Transitions* 27 (June): 1–3. <https://doi.org/10.1016/j.eist.2017.10.007>. [↵](#)
6. Rudel, Thomas K., Patrick Meyfroidt, Robin Chazdon, Frans Bongers, Sean Sloan, H. Ricardo Grau, Tracy Van Holt, and Laura Schneider. 2019. “Whither the Forest Transition? Climate Change,

- Policy Responses, and Redistributed Forests in the Twenty-First Century.” *Ambio* 49 (1): 74–84. <https://doi.org/10.1007/s13280-018-01143-0>. [↵](#)
7. Barnett, Jon, and W. Neil Adger. 2018. “Mobile Worlds: Choice at the Intersection of Demographic and Environmental Change.” *Annual Review of Environment and Resources* 43 (1): 245–65. <https://doi.org/10.1146/annurev-environ-102016-060952>. [↵](#)
8. Evans, Geoff, and Liam Phelan. 2016. “Transition to a Post-Carbon Society: Linking Environmental Justice and Just Transition Discourses.” *Energy Policy* 99 (December): 329–39. <https://doi.org/10.1016/j.enpol.2016.05.003>. [↵](#)
9. Schaffartzik, Anke, Andreas Mayer, Simone Gingrich, Nina Eisenmenger, Christian Loy, and Fridolin Krausmann. 2014. “The Global Metabolic Transition: Regional Patterns and Trends of Global Material Flows, 1950–2010.” *Global Environmental Change* 26 (May): 87–97. <https://doi.org/10.1016/j.gloenvcha.2014.03.013>. [↵](#)
10. Haberl, Helmut, Dominik Wiedenhofer, Stefan Pauliuk, Fridolin Krausmann, Daniel B. Müller, and Marina Fischer-Kowalski. 2019. “Contributions of Sociometabolic Research to Sustainability Science.” *Nature Sustainability* 2 (3): 173–84. <https://doi.org/10.1038/s41893-019-0225-2>. [↵](#)
11. Köhler, Jonathan, Frank W. Geels, Florian Kern, Jochen Markard, Elsie Onsongo, Anna Wieczorek, Floortje Alkemade, et al. 2019. “An Agenda for Sustainability Transitions Research: State of the Art and Future Directions.” *Environmental Innovation and Societal Transitions* 31 (June): 1–32. <https://doi.org/10.1016/j.eist.2019.01.004>. [↵](#)
12. Scoones, Ian. 2016. “The Politics of Sustainability and Development.” *Annual Review of Environment and Resources* 41 (1): 293–319. <https://doi.org/10.1146/annurev-environ-110615-090039>. [↵](#)
13. Loorbach, Derk, Niki Frantzeskaki, and Flor Avelino. 2017. “Sustainability Transitions Research: Transforming Science and Practice for Societal Change.” *Annual Review of Environment and Resources* 42 (1): 599–626. <https://doi.org/10.1146/annurev-environ-102014-021340>. [↵](#)
14. Markard, Jochen, Rob Raven, and Bernhard Truffer. 2012. “Sustainability Transitions: An Emerging Field of Research and Its Prospects.” *Research Policy* 41 (6): 955–67. <https://doi.org/10.1016/j.respol.2012.02.013>. [↵](#)
15. Geels, Frank W. 2019. “Socio-Technical Transitions to Sustainability: A Review of Criticisms and Elaborations of the Multi-Level Perspective.” *Current Opinion in Environmental Sustainability* 39 (August): 187–201. <https://doi.org/10.1016/j.cosust.2019.06.009>. [↵](#)

16. Seto, Karen C., Steven J. Davis, Ronald B. Mitchell, Eleanor C. Stokes, Gregory Unruh, and Diana Ürge-Vorsatz. 2016. “Carbon Lock-In: Types, Causes, and Policy Implications.” *Annual Review of Environment and Resources* 41 (1): 425–52. <https://doi.org/10.1146/annurev-environ-110615-085934>. [↵](#)
17. Díaz, Sandra, Josef Settele, Eduardo S. Brondízio, Hien T. Ngo, John Agard, Almut Arneth, Patricia Balvanera, et al. 2019. “Pervasive Human-Driven Decline of Life on Earth Points to the Need for Transformative Change.” *Science* 366 (6471). <https://doi.org/10.1126/science.aax3100>. [↵](#)
18. Ahlborg, Helene, Ilse Ruiz-Mercado, Sverker Molander, and Omar Masera. 2019. “Bringing Technology into Social-Ecological Systems Research—Motivations for a Socio-Technical-Ecological Systems Approach.” *Sustainability* 11 (7): 2009. <https://doi.org/10.3390/su11072009>. [↵](#)
19. Rocha, Juan C., Garry Peterson, Örjan Bodin, and Simon Levin. 2018. “Cascading Regime Shifts within and across Scales.” *Science* 362 (6421): 1379–83. <https://doi.org/10.1126/science.aat7850>. [↵](#)
20. Scoones, Ian, Andrew Stirling, Dinesh Abrol, Joanes Atela, Lakshmi Charli-Joseph, Hallie Eakin, Adrian Ely, et al. 2020. “Transformations to Sustainability: Combining Structural, Systemic and Enabling Approaches.” *Current Opinion in Environmental Sustainability* 42 (February): 65–75. <https://doi.org/10.1016/j.cosust.2019.12.004>. [↵](#)
21. Hansen, Ulrich Elmer, Ivan Nygaard, Henny Romijn, Anna Wieczorek, Linda M. Kamp, and Laurens Klerkx. 2018. “Sustainability Transitions in Developing Countries: Stocktaking, New Contributions and a Research Agenda.” *Environmental Science & Policy* 84 (June): 198–203. <https://doi.org/10.1016/j.envsci.2017.11.009>. [↵](#)
22. Binz, Christian, and Bernhard Truffer. 2017. “Global Innovation Systems—A Conceptual Framework for Innovation Dynamics in Transnational Contexts.” *Research Policy* 46 (7): 1284–98. <https://doi.org/10.1016/j.respol.2017.05.012>. [↵](#)
23. Kattel, Rainer, and Mariana Mazzucato. 2018. “Mission-Oriented Innovation Policy and Dynamic Capabilities in the Public Sector.” *Industrial and Corporate Change* 27 (5): 787–801. <https://doi.org/10.1093/icc/dty032>. [↵](#)
24. Anadon, Laura Diaz, Gabriel Chan, Alicia G. Harley, Kira Matus, Suerie Moon, Sharmila L. Murthy, and William C. Clark. 2016. “Making Technological Innovation Work for Sustainable Development.” *Proceedings of the National Academy of Sciences* 113 (35): 9682–90. <https://doi.org/10.1073/pnas.1525004113>. [↵](#)
25. Westley, Frances, Katharine McGowan, and Ola Tjörnbo. 2017. *The Evolution of Social Innovation: Building Resilience Through Transitions*. Cheltenham, UK: Edward Elgar Publishing. [↵](#)

26. Silvestre, Bruno S., and Diana Mihaela Țîrcă. 2019. “Innovations for Sustainable Development: Moving toward a Sustainable Future.” *Journal of Cleaner Production* 208 (January): 325–32. <https://doi.org/10.1016/j.jclepro.2018.09.244>. [↵](#)
27. Geels, Frank W. 2020. “Micro-Foundations of the Multi-Level Perspective on Socio-Technical Transitions: Developing a Multi-Dimensional Model of Agency through Crossovers between Social Constructivism, Evolutionary Economics and Neo-Institutional Theory.” *Technological Forecasting and Social Change* 152 (March): 119894. <https://doi.org/10.1016/j.techfore.2019.119894>. [↵](#)
28. Sengers, Frans, Anna J. Wieczorek, and Rob Raven. 2019. “Experimenting for Sustainability Transitions: A Systematic Literature Review.” *Technological Forecasting and Social Change* 145 (August): 153–64. <https://doi.org/10.1016/j.techfore.2016.08.031>. [↵](#)
29. Hausknost, Daniel, and Willi Haas. 2019. “The Politics of Selection: Towards a Transformative Model of Environmental Innovation.” *Sustainability* 11 (2): 506. <https://doi.org/10.3390/su11020506>. [↵](#)
30. Ghosh, Bipashyee, and Johan Schot. 2019. “Towards a Novel Regime Change Framework: Studying Mobility Transitions in Public Transport Regimes in an Indian Megacity.” *Energy Research & Social Science* 51 (May): 82–95. <https://doi.org/10.1016/j.erss.2018.12.001>. [↵](#)
31. Schot, Johan, and W. Edward Steinmueller. 2018. “Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change.” *Research Policy* 47 (9): 1554–67. <https://doi.org/10.1016/j.respol.2018.08.011>. [↵](#)
32. Fagerberg, Jan. 2018. “Mobilizing Innovation for Sustainability Transitions: A Comment on Transformative Innovation Policy.” *Research Policy* 47 (9): 1568–76. <https://doi.org/10.1016/j.respol.2018.08.012>. [↵](#)
33. Foxon, Timothy J. 2011. “A Coevolutionary Framework for Analysing a Transition to a Sustainable Low Carbon Economy.” *Ecological Economics* 70 (12): 2258–67. <https://doi.org/10.1016/j.ecolecon.2011.07.014>. [↵](#)
34. Bakker, Sjoerd. 2014. “Actor Rationales in Sustainability Transitions – Interests and Expectations Regarding Electric Vehicle Recharging.” *Environmental Innovation and Societal Transitions* 13 (December): 60–74. <https://doi.org/10.1016/j.eist.2014.08.002>. [↵](#)
35. Apajalahti, Eeva-Lotta, Armi Temmes, and Tea Lempiälä. 2017. “Incumbent Organisations Shaping Emerging Technological Fields: Cases of Solar Photovoltaic and Electric Vehicle Charging.” *Technology Analysis & Strategic Management* 30 (1): 44–57. <https://doi.org/10.1080/09537325.2017.1285397>. [↵](#)

36. Burch, Sarah, Aarti Gupta, Cristina Y.A. Inoue, Agni Kalfagianni, Åsa Persson, Andrea K. Gerlak, Atsushi Ishii, et al. 2019. “New Directions in Earth System Governance Research.” *Earth System Governance* 1 (January): 100006. <https://doi.org/10.1016/j.esg.2019.100006>. [↵](#)
37. Anderies, John M., Jean-Denis Mathias, and Marco A. Janssen. 2018. “Knowledge Infrastructure and Safe Operating Spaces in Social–Ecological Systems.” *Proceedings of the National Academy of Sciences* 116 (12): 5277–84. <https://doi.org/10.1073/pnas.1802885115>. [↵](#)
38. Mach, Katharine J., and Christopher B. Field. 2017. “Toward the Next Generation of Assessment.” *Annual Review of Environment and Resources* 42 (1): 569–97. <https://doi.org/10.1146/annurev-environ-102016-061007>. [↵](#)
39. Cashore, Benjamin, Steven Bernstein, David Humphreys, Ingrid Visseren-Hamakers, and Katharine Rietig. 2019. “Designing Stakeholder Learning Dialogues for Effective Global Governance.” *Policy and Society* 38 (1): 118–47. <https://doi.org/10.1080/14494035.2019.1579505>. [↵](#)
40. Spangenberg, Joachim. 2019. “Scenarios and Indicators for Sustainable Development: Towards a Critical Assessment of Achievements and Challenges.” *Sustainability* 11 (4): 942. <https://doi.org/10.3390/sul1040942>. [↵](#)
41. Raskin, Paul. 2016. *Journey to Earthland: The Great Transition to Planetary Civilization*. 1. Aufl. Boston, MA: Tellus Institute. <https://greattransition.org/publication/journey-to-earthland> [↵](#)
42. Sitas, Nadia, Zuzana V. Harmáčková, Jonathan A. Anticamara, Almut Arneth, Ruchi Badola, Reinette Biggs, Ryan Blanchard, et al. 2019. “Exploring the Usefulness of Scenario Archetypes in Science-Policy Processes: Experience across IPBES Assessments.” *Ecology and Society* 24 (3). <https://doi.org/10.5751/es-11039-240335>. [↵](#)
43. Pereira, Laura, Nadia Sitas, Federica Ravera, Amanda Jimenez-Aceituno, and Andrew Merrie. 2019. “Building Capacities for Transformative Change towards Sustainability: Imagination in Intergovernmental Science-Policy Scenario Processes.” Edited by Anne R. Kapuscinski, Kim A. Locke, and Michele-Lee Moore. *Elementa: Science of the Anthropocene* 7 (January). <https://doi.org/10.1525/elementa.374>. [↵](#)
44. Hajer, Maarten, and Wytse Versteeg. 2018. “Imagining the Post-Fossil City: Why Is It so Difficult to Think of New Possible Worlds?” *Territory, Politics, Governance* 7 (2): 122–34. <https://doi.org/10.1080/21622671.2018.1510339>. [↵](#)
45. Stirling, Andy. 2019. “How Deep Is Incumbency? A ‘Configuring Fields’ Approach to Redistributing and Reorienting Power in Socio-Material Change.” *Energy Research & Social Science* 58 (December): 101239. <https://doi.org/10.1016/j.erss.2019.101239>. [↵](#)

46. Jasanoff, Sheila, and Sang-Hyun Kim. 2015. *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago; London: The University of Chicago Press.
http://nrs.harvard.edu/urn-3:hul.ebookbatch.GEN_batch:EDZ000128427620160622. [↵](#)
47. Beckert, Jens, and Richard Bronk. 2018. *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*. First edition. Oxford: Oxford University Press. [↵](#)
48. White, Damian. 2019. “Just Transitions/Design for Transitions: Preliminary Notes on a Design Politics for a Green New Deal.” *Capitalism Nature Socialism* 31 (2): 20–39.
<https://doi.org/10.1080/10455752.2019.1583762>. [↵](#)
49. Ocasio-Cortez, Alexandria. 2019. *Recognizing the Duty of the Federal Government to Create a Green New Deal*. H. Res. 109. 116th Congress (2019–2020), 1st session. [↵](#)
50. Nepal, Santosh, Nilhari Neupane, Devesh Belbase, Vishnu Prasad Pandey, and Aditi Mukherji. 2019. “Achieving Water Security in Nepal through Unravelling the Water-Energy-Agriculture Nexus.” *International Journal of Water Resources Development* 37 (1): 67–93.
<https://doi.org/10.1080/07900627.2019.1694867>. [↵](#)
51. Shah, Tushaar, Mark Giordano, and Aditi Mukherji. 2012. “Political Economy of the Energy-Groundwater Nexus in India: Exploring Issues and Assessing Policy Options.” *Hydrogeology Journal* 20 (5): 995–1006. <http://dx.doi.org.ezp-prod1.hul.harvard.edu/10.1007/s10040-011-0816-0>. [↵](#)
52. Schot, Johan, Alejandra Boni, Matias Ramirez, and Fred Steward. 2018. “TIPC Research Brief: Addressing the Sustainable Development Goals Through Transformative Innovation Policy.” 2018–01. Brighton, UK: Transformative Innovation Policy Consortium. [↵](#)
53. Sachs, Jeffrey D., Guido Schmidt-Traub, Mariana Mazzucato, Dirk Messner, Nebojsa Nakicenovic, and Johan Rockström. 2019. “Six Transformations to Achieve the Sustainable Development Goals.” *Nature Sustainability* 2 (9): 805–14. <https://doi.org/10.1038/s41893-019-0352-9>. [↵](#)
54. Jasanoff, Sheila. 2018. “Just Transitions: A Humble Approach to Global Energy Futures.” *Energy Research & Social Science* 35 (January): 11–14. <https://doi.org/10.1016/j.erss.2017.11.025>. [↵](#)
55. Kanger, Laur, and Johan Schot. 2019. “Deep Transitions: Theorizing the Long-Term Patterns of Socio-Technical Change.” *Environmental Innovation and Societal Transitions* 32 (September): 7–21.
<https://doi.org/10.1016/j.eist.2018.07.006>. [↵](#)