Building Capacity to Transform Unsustainable Development Pathways into Sustainable Ones:
Lessons from scholarship and practice

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Abstract: The complex adaptive dynamics of the Anthropocene give rise to multiple development pathways (i.e., development pathways defined by high birth rates and high death rates vs. development pathways defined by low birth rates and low death rates; development pathways based on fossil fuel energy systems vs. development pathways based on renewables). These alternate development pathways are structured not only by differences in the technologies and social practices that frequently define them, but more fundamentally by the institutions (rules, norms, culture, and beliefs) that set the terms of everyday decision-making, structure incentives, shape the human use of nature, and guide long-term investments in technology, infrastructure, and innovation. Because many of today's development pathways are substantially degrading nature and undermining intra- and inter-generational equity, the way forward requires not only adaptation but rather structural transformations to new development pathways that foster human flourishing today, while simultaneously preserving the resources necessary for future generations to pursue their own well-being. Such a capacity will almost certainly require addressing four separate but interrelated challenges: i) create attainable visions of just and sustainable futures capable of guiding change; ii) overcome sociotechnical lock-in and path dependence in unsustainable development pathways; iii) counter power of incumbent interests intent on maintaining the status quo; and iv) build new institutions capable of structuring the incentives and behavior of actors toward more sustainable development pathways. This working paper provides a high-level overview of transformation scholarship in sustainability science as well as insights from the past several decades of practice in the field. The paper is designed as a jumping off point for a seminar series on Capacity for Sustainable Development (C4SD) organized by the Mossavar-Rahmani Center for Business and Government, the Sustainability Science Program, Salata Institute for Climate and Sustainability, Center for International Development, and the Belfer Center for Science and International Affairs at Harvard Kennedy School. For more information about the seminar series see this link:
https://www.hks.harvard.edu/centers/mrcbg/programs/sustainability-science-program/c4sd-seminar-series

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1. **Introduction:[1]**

What capacities are most needed for the effective pursuit of sustainability in the face of the multiple crises currently facing the Anthropocene system? Taken together these intertwined crises – climate, pandemics, extinction, inequity, and others arising from the increasingly intense interactions between nature and society – are threatening the implicit promise of sustainability which has emerged over the last decades as one of the most widely shared goals in human history: **that each generation should hand on to its successors whatever it takes to allow them to achieve a standard of living at least as good as its own, while simultaneously seeking to alleviate poverty and inequity within its own time** (Solow 1993; WCED 1987). Keeping this promise will ultimately require decisive action on multiple fronts. But in this complex world, what will it take to foster our collective ability to pursue sustainability in the face of deep uncertainty and the inevitability of unexpected change?

In the Capacity Building for Sustainable Development (C4SD) research project,[2] we argue that advocates for sustainable development should pay greater attention to building a set of strategic capacities that empower and enable actors (individuals, communities, organizations etc.) to make strategic decisions, and to take deliberate and collective action in the pursuit of sustainability. By capacity we mean both the intention and the ability to accomplish a task or achieve an outcome or, more bluntly, "the ability to get stuff done". Why? Because failure to build, exercise, and improve capacity for the pursuit of sustainability has too often resulted in a "missing middle"—an inability to connect widespread agreement on the goals of sustainable development with the scientific understanding of the dynamics of intertwined nature-society systems that set the stage on which those goals must be pursued.

Three features of today's world make the need to build such strategic capacities particularly urgent:

1) Crises challenging the goals of sustainable development are multiplying and intensifying (Folke et al. 2021), threatening the remarkable progress in many dimensions of well-being that has been achieved over the last two centuries or more (Deaton 2013; McNeill

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[1] This "Introduction" is, in large part, common to all the white papers we have written in support of the present seminar series. Readers who have already encountered it in another of those white papers can skim or skip ahead to Section 2 without loss.

[2] The Capacity Building project is an activity of the Sustainability Science Program, hosted by the Mossavar-Rahmani Center at Harvard's Kennedy School of Government.

2016). More effective action to address the multiple threats to sustainability is increasingly urgent.

2) The threats to sustainability are interconnected, as is the underlying nature-society system from which they emerge (Preiser et al. 2018). Efforts to address them one-by-one at best become a Sisyphean nightmare of whack-a-mole and often end up competing with or undermining one another. All too visible examples are provided by unsatisfactory results of siloed efforts taken in pursuit of one or another of the UN's 17 SDGs. Strategic approaches are needed to support actions likely to be effective across multiple interconnected challenges and where efforts to foster sustainable development require attention to the whole intertwined system rather than just the parts.

3) Better assessments, forecasts, and the scientific models to support them are necessary components of such strategic approaches. But they are not sufficient. The reason is that nature-society interactions constitute complex adaptive systems in which novelty (innovation, evolution), uncertainty and surprise are the norm rather than the exception (Preiser et al. 2018). This complexity virtually guarantees that even the most scientifically informed plans will eventually turn out to be at best incomplete if not altogether wrong. Effective strategies must complement "thinking through" with "acting out" approaches, i.e. with capacities to approach problems and solutions from a systems perspective, to treat interventions as experiments, to learn from those experiments, and to course correct when forecasts eventually, and inevitably, go wrong.

This working paper focuses specifically on the capacity to transform development pathways from unsustainable pathways of development to (more) sustainable ones as one of a broader set of six capacities that we argue connect the goals of sustainable development with the scientific understanding of the multiple, interacting, and complex sustainability challenges currently facing the Anthropocene. These six capacities emerged from decades of research across multiple interdisciplinary—but often disparate—research programs focused on what is needed to foster sustainability (Clark and Harley 2020). Taken together the six capacities enable collaborative action for sustainability in the face of uncertainty. As summarized in Fig. 1, they are:

1. **Capacity to measure** progress toward sustainable development
2. **Capacity to adapt** development pathways to protect human well-being in the face of shocks
3. **Capacity to transform** unsustainable development pathways into sustainable ones
4. **Capacity to advance equity** both within and among generations
5. **Capacity to govern,** i.e., to build and maintain collaborative relationships in pursuit of sustainable development
6. **Capacity to link knowledge with action** for sustainability

The remainder of this working paper is organized in three sections: the first section reviews the state of knowledge and scholarship on transformations (also often referred to as transitions[3]) and sustainable development; the second section highlights what actors are already doing at the cutting building capacity to transform development pathways towards sustainability in practice; and the third section synthesizes emerging insights from practitioners and scholars collected as part of the Capacity Building for Sustainable Development (C4SD) research project about what is needed to build and maintain and strategic capacity to transform unsustainable development pathways towards sustainable ones. We hope that the seminar series for which this background paper has been prepared will further contribute to the C4SD research project, deepening the insights found in this working paper.

2. **Transformations to Sustainability: A brief overview of the scholarship**

At the dawn of the 21st century, the sustainability science community became increasingly focused on the need for large-scale systems change, reflecting increasing concern that in the Anthropocene "merely" adapting to shocks and surprises would not be enough to avoid catastrophic tipping points to future development pathways with substantial consequences for human well-being (National Research Council 1999). In response to these concerns, the world's scientific community gathered in Tokyo, Japan for a conference titled "Transitions to

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[3] The terms transitions and transformations are often used interchangeably. We use transitions when describing the field of transitions research and its findings, and transformation when describing the social goal of sustainability transformations as well as what is known about the capacity to transform current development pathways toward more sustainable future pathways of development.

Sustainability in the 21st Century". The title of the conference was largely aspirational as little was known at the time about the dynamics of transitions or how to go about fostering largescale transformations toward sustainability (InterAcademy Partnership (IAP) 2000). In the intervening years research has begun to catch up with those early aspirations, providing a nuanced understanding of the dynamics of historic transitions (F. W. Geels 2002) and insights into the potential levers of change to support sustainability transformations in the future (F. Geels, Kern, and Clark 2023; Loorbach, Frantzeskaki, and Avelino 2017; Markard, Raven, and Truffer 2012; Mazzucato 2016; Patterson et al. 2017; Scoones et al. 2020).

This research demonstrates that development pathways are stabilized by particular assemblages of institutions (rules, norms, culture and beliefs), technologies (physical technologies, methodologies and practices) and power (compulsion, exclusion, influence), which structure how and for what actors use resources (Clark and Harley 2020; Fuenfschilling and Truffer 2014; F. Geels 2004). Sustainability transitions research focuses on how particular development pathways (called regimes in the transitions literature) might be replaced by new development pathways or ways of achieving similar social goals with new technologies and practices (Köhler et al. 2019; Markard, Raven, and Truffer 2012; Truffer, Murphy, and Raven 2015). Several generalizable findings relevant to building capacity to transform unsustainable development pathways into Sustainable Ones emerge from this literature:

1) Patterns of change are driven by the emergence of novelty and innovation at the micro-level, as well as by macro-level spatial patterns and social trends (e.g. national borders, climate zones, outbreaks of violence and disease, the geopolitics and economics of the fossil fuel industry) (Schot and Geels 2008). This means that sustainability transitions must both make use of the emergence of new technologies and emergent social change that moves pathways of development in more sustainable directions, while the same time exploiting strategic moments in the macro-environment that make transitions more feasible.

2) Dominant development pathways are often resistant to novelty, exhibiting lock-in and path dependence (Avelino et al. 2016; F. Geels 2014; Westley et al. 2011). Sustainability transformations must therefore overcome path-dependence caused by both increasing returns to scale, and powerful interests threatened by the decline of dominant development pathways (Seto et al. 2016).

3) Important tensions emerge between the speed of transitions and the degree to which those transitions address equity and justice (Newell, Geels, and Sovacool 2022). In some cases these tensions point to tradeoffs between intra- and inter-generational equity (Liao and Agrawal 2022). Building the capacity to navigate sustainability transformations therefore requires grappling with the inevitability of winners and losers that transformations will almost certainly entail.

4) While the majority of transitions scholarship focuses on individual systems (sectors and geographies), recent scholarship points to the importance of multi-system interactions (Kanger et al. 2021). Widely shared institutional principles or meta-rules (e.g. mass production; digitization; fiduciary responsibility; social welfare; cooperate social responsibility) shape the trajectory of development pathways across multiple systems (Schot and Kanger 2018). Findings suggest that interactions between systems often serve to stabilize existing development pathways and inhibit transformations. In other cases, multi-system interactions can lead to cascading transformations across multiple systems. Reorienting meta-rules toward the goals of sustainability can help foster sustainability transformations across multiple systems (Ghosh and Schot 2019). Efforts to build transformative capacity must therefore recognize that catalyzing multi-system transformations is likely to lead to deeper and more durable progress towards sustainable development.

3. Building Transformative Capacity: A brief review of practice

Practical efforts to foster sustainability transformations are already unfolding around the world. These efforts are often based in both a single geography and sector—for example energy transitions in Denmark (Lund et al. 2022). There are also efforts towards broader cross-sectoral sustainability transformations. Examples include circular economy initiatives across the EU notably in the Netherlands and Spain, as well as Costa Rica's national decarbonization plan that integrates transportation, energy, agriculture, waste management, and forestry into a comprehensive framework (Flagg 2018; Godínez-Zamora et al. 2020; Government of the Netherlands 2019; Häger et al. 2021; The Ministry for the Ecological Transition and the Demographic Challenge (MITECO) 2020; UNEP n.d.) Finally, there are substantial synergies between sectoral transformations across multiple geographies. For example, Denmark's wind

energy expertise and policy frameworks have been instrumental in supporting China's rapid expansion of offshore wind capacity, with China now leveraging this knowledge to assist Vietnam and other Southeast Asian nations in developing their renewable energy infrastructure (Lema, Fu, and Rabellotti 2020; Urban et al. 2018).

Research indicates that sectoral transformations are taking place at different speeds and depth due to different techno-economic and socio-political developments across sectors (F. Geels, Kern, and Clark 2023). Transformations in energy systems have progressed significantly with the rapid diffusion of renewables leading to rapid change across the energy production-consumption system (IRENA 2023). Global renewable capacity has grown at an unprecedented rate, with additional renewable electricity capacity reaching an estimated 507 GW in 2023, an almost 50% increase over 2022, driven largely by the booming Chinese market for solar photovoltaics (IEA 2024). There has also been progress in mobility systems away from gas automobiles and towards electric cars and other e-mobility products (Ryghaug and Skjølsvold 2023). This sector has also seen important social innovations around car-sharing, but these have not been as widespread and have faced more resistance from both socio-technical path dependence and incumbent interests (Sovacool and Axsen 2018). Finally, transformations in agri-food systems toward sustainability appear to be relatively small scale and have not substantially disrupted dominant development pathways, despite growing recognition of agriculture's significant environmental footprint (Barrett et al. 2022; Schiller et al. 2023).

Policy instruments to catalyze sustainability transformations span multiple levels of governance. At the national level, ambitious frameworks like the European Green Deal aim to make Europe the first climate-neutral continent by 2050 while ensuring a just transformation that leaves no person or region behind (European Commission 2019). Similarly, China's ecological civilization framework, enshrined in its constitution in 2018, represents a significant policy innovation that seeks to shift development away from GDP-centric growth toward more balanced ecological and social priorities (Hansen, Li, and Svarverud 2018). In the United States, the Green New Deal proposal established a vision for sustainable and just transformation that has influenced both national legislation, such as the 2022 Inflation Reduction Act, and regional initiatives including Renew New England, Gulf South for a Green New Deal, A Green New Deal for Appalachia, and California's Green New Deal (Boyle et al. 2021; Tarus, Hufford, and Taylor 2017). Place-based transformations at subnational scales also offer promising models of change.

Cities like Copenhagen, Denmark (carbon neutrality by 2025), Melbourne, Australia (biodiversity corridors and urban forests), and Medellín, Colombia (social urbanism integrating marginalized neighborhoods) demonstrate how local governments can pioneer sustainability transformations that integrate environmental, social, and economic dimensions (City of Copenhagen n.d.; Corburn et al. 2020; Melbourne Biodiversity Network 2024)

Yet despite this progress sustainability transformations face substantial barriers, including technological and infrastructural lock-in, vested interests from incumbent industries, fragmented governance arrangements, and financial constraints. Not least, political developments in the United States and elsewhere over the past months have demonstrated just how strongly incumbent interests will fight against sustainability transformations.

4. **Emerging Lessons at the Interface of Practice and Scholarship**

While the past several decades have generated enormous insights into the dynamics of historical transformations, much remains to be learned integrating insights from the research and practice of sustainability transformations. As part of the C4SD research project, we are conducting interviews with practitioners and scholars at the forefront of ongoing efforts to foster sustainability transformations to begin to distill and synthesize the lessons coming out of their work to date and point to directions forward for efforts to build and strengthen transformative capacity. What we have learned is that building a capacity to foster sustainability transformations requires attention to overcoming the sociotechnical feedbacks structuring current (unsustainable) pathways of development, while at the same time strategically fostering the visions, values, knowledge, technologies, and institutional structures that will ultimately be needed to create more sustainable pathways of development going forward. Here are five of the specific lessons that have emerged from this research so that we believe are important for building capacity to transform development pathways.

1) **Foster visions of a sustainable future:** Difficulty in imagining the radical changes required to meet sustainable development goals hampers the realization of more sustainable development pathways in practice. Recent scholarship points to the importance of 'imaginaries' or collective visions of just and sustainable futures that give legitimacy to the laws, regulations, and investments necessary for sustainability

transformations to emerge (Beck et al. 2021; Longhurst and Chilvers 2019). Experiments with multiple methods for facilitating the emergence of imaginaries of sustainable development are underway including dramatic visioning exercises aimed at influencing the types of futures political and business leaders envisage (Hajer and Pelzer 2018), efforts to catalog innovations (in both technology and practice) bubbling up around the world as a repository of the tremendous variety of possible sustainable pathways forward (Bennett et al. 2016), and participatory processes that engage local communities in imagining sustainable futures that reflect local values and goals (Johansson, Brogaard, and Brodin 2022; Pereira et al. 2018). Conversely, there is growing recognition that effectively motivating transformations to sustainable pathways of development requires grappling with undesirable futures that might emerge if such transformations fail to materialize (Kemp et al. 2022). Just as nuclear catastrophe fiction like "On the Beach" shaped public understanding of existential risks of nuclear weapons during the Cold War, climate fiction that creates more tangible imaginaries of unsustainable futures and structured exploration of "climate endgame" scenarios may serve to catalyze action by making abstract risks more tangible. The activist group Extinction Rebellion exemplifies how social movements can actively construct and embody imaginaries through their organizational practices. Extinction Rebellion's strategic deployment of disruptive non-violent direct action, including occupations of key infrastructure and public spaces in major cities, demonstrates how activism can overcome political stalemate by forcing climate emergency declarations onto policy agendas. Their deeper contribution may lie in their organizational philosophy which emphasizes the need for internal transformation alongside external resistance. Their "regenerative culture" deliberately models alternative social relations that embody the interconnected world they seek to create, demonstrating how movements can simultaneously resist unsustainable systems while cultivating new social practices supportive of sustainability transformations (Westwell and Bunting 2020). This integration of resistance with prefigurative politics represents a powerful approach to developing and spreading imaginaries of sustainable development through lived practice rather than abstract conceptualization alone.

2) **Empowerment and political mobilization:** The winners and losers created by transformative change make sustainability transformations inherently political (Avelino et al. 2016). Incumbent actors demonstrate a nuanced ability to obstruct sustainability transformations or selectively influence transformations in ways that maintain their dominate positions of wealth and power (Apajalahti, Temmes, and Lempiälä 2018). Strategies of empowerment, political mobilization and civil resistance are therefore necessary to enable activists to accelerate transformations in the face of powerful resistance (Farmer et al. 2019; Rossi, Bui, and Marsden 2019; Scoones, Leach, and Newell 2015). The youth-led Fridays for Future movement exemplifies how coordinated political protest can rapidly scale to challenge climate inaction, with Greta Thunberg's solitary school strike in 2018 expanding to millions of students across 150 countries by 2019, effectively shifting climate discourse and placing unprecedented pressure on policymakers to align climate and sustainability commitments with scientific consensus (Fisher 2019). In a second example, the Poor People's Campaign: A National Call for Moral Revival (a 21st century version of the original civil rights era movement) illustrates how intersectional approaches to transformation such as their "ecological devastation" platform, which connects concerns for ecology and environment with economic well-being and racial justice, has mobilized diverse communities across 40 U.S. states, building broader constituencies for transformative change than single-issue environmental movements (Barber 2016).

3) **Long-term community engagement:** Fostering transformations requires sustained community engagement and the resources to do so. Research on sustainability transformations shows that effective approaches are not simply imposed from above but must be co-produced through deliberative processes that integrate diverse forms of knowledge and value systems (Frantzeskaki and Rok 2018). As Köhler et al. (2019) note, transformations emerge through multi-actor processes where community participation serves not only as a means to reduce resistance but as a pathway to more robust and contextually appropriate solutions. Research emphasizes the need for "transition arenas" where communities can collectively articulate alternative visions and experiment with new practices that challenge dominant development pathways (Loorbach, Frantzeskaki,

and Avelino 2017). Furthermore, community engagement can help overcome the disconnect between technocratic policy approaches and the lived experiences of citizens, enabling transformations that address both material needs and deeper normative questions about desirable futures (Schot and Steinmueller 2018). Such engagement processes are particularly crucial in contexts where marginalized communities have historically been excluded from decision-making about development pathways that directly affect their livelihoods (Patterson et al. 2017). Ecotrust Canada's ability to foster sustained transformations across multiple sectors from energy to fisheries rests on their commitment to long-term community engagement to i) recognize the complexity of the nature-society systems in which they work; ii) co-produce visions of the future with local communities; and iii) balance the need for solutions to both short and long-term challenges. For example, Ecotrust Canada's Indigenous Home-Lands Initiative works to avoid perpetuating systemic sources of injustice by focusing on empowerment – enabling indigenous communities to identify institutional barriers to housing that have excluded them from forest resources within their territories and to realize local visions for the future of their communities. Similarly, the success of the Costa Rican government in transforming the country's energy sector to renewable energy rests on the government's commitment to long-term planning and investment as well as deep engagement with stakeholders. These include both large-scale energy producers and local communities whose well-being are heavily impacted both by the instillation of energy infrastructure as well as by the availability of rural electricity.

4) **Align incentives across levels:** Transitions literature highlights the importance of novelty and innovation as core components of sustainability transformations. It points to the need to actively create and shape protected spaces that allow for experimentation in the co-evolution of technology, user practices and regulatory structures to facilitate sustainability transformations. This scholarship emphasizes that successful transformations require synchronizing multiple levels of incentives and institutional arrangements. This multi-level alignment enables transformative change by connecting micro-level experimentation with institutional change at meso- and macro-levels, creating mutually reinforcing cycles of innovation and structural change (Schot and Geels 2008).

In line with these scholarly findings, organizations with strong track-records in supporting sustainability transformations highlight the importance of aligning incentives across levels to foster new ideas and innovations. The transformation of Ørsted from a Danish energy company heavily invested in fossil fuels to the world's leading producer of offshore wind power was driven simultaneously by macro-level government subsidies for renewable energy and an internal organizational structure conducive to experimentation and innovation. Similarly, the transformation of the Dutch water management sector demonstrates how alignment across scales can drive systemic change. Following severe flooding in the 1990s, the Netherlands launched the "Room for the River" program, which represented a fundamental shift from traditional flood control to a nature-based approach. This transformation was enabled by national policy frameworks that created space for local experimentation with new approaches to water management, while regional water authorities served as intermediaries that connected local innovations with national policy objectives (Pahl-Wostl 2019). The program's success in transforming centuries-old approaches to water management rested on this deliberate alignment between national financing and regulatory frameworks, regional coordination mechanisms, and localized experimentation spaces where engineers, ecologists, and community stakeholders could co-develop novel solutions to flood management challenges (de Boer and Bressers 2011).

5) **Be mission driven:** Nurturing and accelerating sustainability transformations requires a new approach to innovation policy. Economist Mariana Mazzucato's work argues that it is no longer sufficient for governments to de-risk innovation and solve market failures. To build the capacity to support sustainability transformations, governments must become mission-driven—that is focused on creating public value by fostering new market landscapes that serve the public interest[4] (Mazzucato 2021). Mazzucato calls for

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[4] In the case of sustainable development, the public interest can be denominated as inclusive well-being (see Harley and Clark. 2025. Building Capacity to Measure Sustainability: Lessons from scholarship and practice: https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/programs/sustsci/files/Measurement%20Capacity_SSP%20Working%20Paper.pdf . This brings up an important point about the importance of measurement in

approaches that actively shape markets through ambitious, cross-sectoral missions that create public value and foster new market landscapes (Kattel and Mazzucato 2018; Sachs et al. 2019). Several countries have begun implementing this mission-driven approach to sustainable development. The United Kingdom's Industrial Strategy Challenge Fund established specific missions including transforming construction, driving the electric revolution, and creating sustainable plastic economies (UK Research and Innovation 2020). Germany's High-Tech Strategy 2025 features six priority missions including carbon-neutral industry and circular economy (German Federal Ministry of Education and Research 2021). Perhaps most comprehensively, Japan's Moonshot Research and Development Program has established ambitious missions including the realization of a carbon-neutral society by 2050 through technologies for removing greenhouse gases and carbon recycling (Cabinet Office of Japan 2020). While this approach is based on strong historical precedent and academic scholarship, the ultimate outcomes of these experiments in mission-driven governance to reshape entire national development pathways towards remains yet unknown. But even at smaller scales, market-shaping experiments are already proving fruitful: In Bangladesh, IDCOL (https://www.idcol.org/), a government owned infrastructure and energy investment company actively uses their influence to shape new markets in Bangladesh's energy economy. For their solar irrigation initiative which aims to install fifty thousand solar irrigation pumps by 2025, IDCOL set out to align macro-level incentives for renewable energy with micro-level business models for solar irrigation pumps. Their goal is to catalyze a new market for solar irrigation pumps in Bangladesh that will eventually make IDCOL irrelevant as a market intermediary.

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building the capacity to support sustainability transformations that is worth getting into in more detail in future iterations of this working paper.

Our intention is that the seminar series for which this working paper provides a foundation will provide further opportunity to refine (or refute) these lessons as well as to add new lessons we have not yet included.
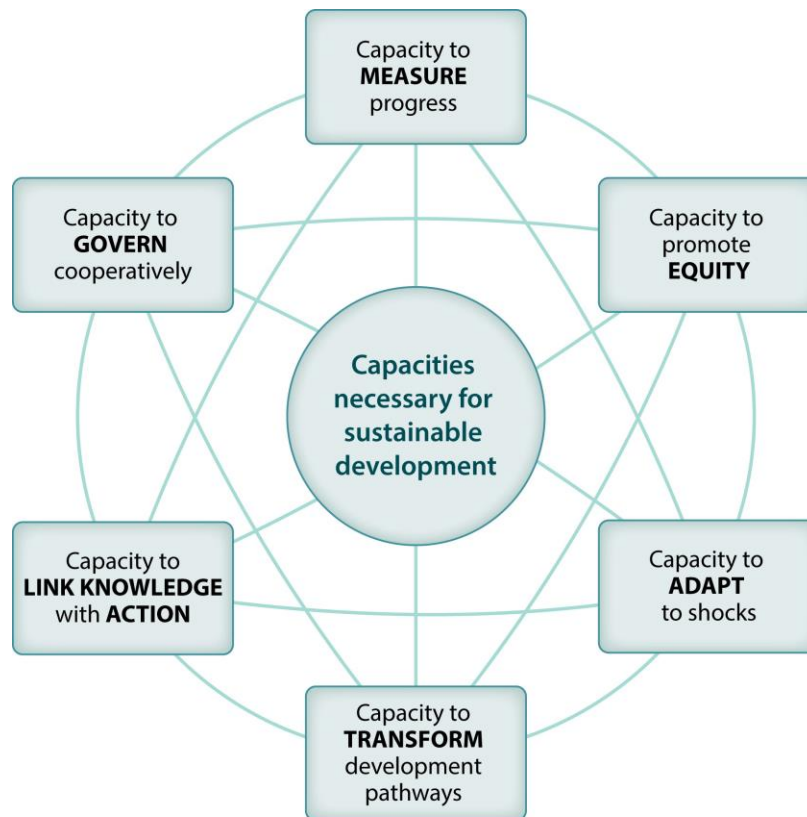
Clark WC, Harley AG. 2020.
Annu. Rev. Environ. Resour. 45:331–86

Figure 1: An integrated perspective on capacities for sustainable development. Six interdependent capacities are necessary for the successful pursuit of sustainability: (a) capacity to measure progress toward sustainable development, (b) capacity to promote equity within and between generations, (c) capacity to adapt to shocks and surprises, (d) capacity to transform the system onto more sustainable development pathways, (e) capacity to link knowledge with action for sustainability, and (f) capacity to devise governance arrangements that allow people to work together in exercising the other capacities. Source: (Clark and Harley 2020)

5. Bibliography

Apajalahti, Eeva-Lotta, Armi Temmes, and Tea Lempiälä. 2018. "Incumbent Organisations Shaping Emerging Technological Fields: Cases of Solar Photovoltaic and Electric Vehicle Charging." *Technology Analysis & Strategic Management* 30(1): 44–57. doi:10.1080/09537325.2017.1285397.

Avelino, Flor, John Grin, Bonno Pel, and Shivant Jhagroe. 2016. "The Politics of Sustainability Transitions." *Journal of Environmental Policy & Planning* 18(5, SI): 557–67. doi:10.1080/1523908X.2016.1216782.

Barber, William J. 2016. *The Third Reconstruction: How a Moral Movement Is Overcoming the Politics of Division and Fear*. Beacon Press.

Barrett, Christopher B., Tim Benton, Jessica Fanzo, Mario Herrero, Rebecca J. Nelson, Elizabeth Bageant, Edward Buckler, et al. 2022. *Socio-Technical Innovation Bundles for Agri-Food Systems Transformation*. Springer Nature. doi:10.1007/978-3-030-88802-2.

Beck, Silke, Sheila Jasanoff, Andy Stirling, and Christine Polzin. 2021. "The Governance of Sociotechnical Transformations to Sustainability." *Current Opinion in Environmental Sustainability* 49: 143–52. doi:10.1016/j.cosust.2021.04.010.

Bennett, Elena M., Martin Solan, Reinette Biggs, Timon McPhearson, Albert V. Norström, Per Olsson, Laura Pereira, et al. 2016. "Bright Spots: Seeds of a Good Anthropocene." *Frontiers in Ecology and the Environment* 14(8): 441–48.

de Boer, Cheryl, and Hans Bressers. 2011. *Complex and Dynamic Implementation Processes*.

Boyle, Alaina D., Graham Leggat, Larissa Morikawa, Yanni Pappas, and Jennie C. Stephens. 2021. "Green New Deal Proposals: Comparing Emerging Transformational Climate Policies at Multiple Scales." *Energy Research & Social Science* 81: 102259. doi:10.1016/j.erss.2021.102259.

Cabinet Office of Japan. 2020. "Moonshot Reseach and Development Program - Science, Technology and Innovation." *Cabinet Office Home Page*. https://www8.cao.go.jp/cstp/english/moonshot/top.html (March 10, 2025).

City of Copenhagen. "The City of Copenhagen 2025 Climate Plan." https://urbandevelopmentcph.kk.dk/climate (March 10, 2025).

Clark, William C., and Alicia G. Harley. 2020. "Sustainability Science: Toward a Synthesis." *Annual Review of Environment and Resources* 45: 331–86. doi:10.1146/annurev-environ-012420-043621.

Corburn, Jason, Marisa Ruiz Asari, Jorge Pérez Jamarillo, and Aníbal Gaviria. 2020. "The Transformation of Medellin into a 'City for Life:' Insights for Healthy Cities." *Cities & Health* 4(1): 13–24. doi:10.1080/23748834.2019.1592735.

European Commission. 2019. "The European Green Deal."
https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (March 10, 2025).

Farmer, J. D., C. Hepburn, M. C. Ives, T. Hale, T. Wetzer, P. Mealy, R. Rafaty, S. Srivastav, and R. Way. 2019. "Sensitive Intervention Points in the Post-Carbon Transition." *Science* 364(6436): 132–34. doi:10.1126/science.aaw7287.

Fisher, Dana R. 2019. "The Broader Importance of #FridaysForFuture." *Nature Climate Change* 9(6): 430–31. doi:10.1038/s41558-019-0484-y.

Flagg, Julia A. 2018. "Carbon Neutral by 2021: The Past and Present of Costa Rica's Unusual Political Tradition." *Sustainability* 10(2): 296-. doi:10.3390/su10020296.

Frantzeskaki, Niki, and Ania Rok. 2018. "Co-Producing Urban Sustainability Transitions Knowledge with Community, Policy and Science." *Environmental Innovation and Societal Transitions* 29: 47–51. doi:10.1016/j.eist.2018.08.001.

Fuenfschilling, Lea, and Bernhard Truffer. 2014. "The Structuration of Socio-Technical Regimes—Conceptual Foundations from Institutional Theory." *Research Policy* 43(4): 772–91. doi:10.1016/j.respol.2013.10.010.

Geels, Frank. 2004. "From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory." *Research Policy* 33(6): 897–920. doi:10.1016/j.respol.2004.01.015.

Geels, Frank. 2014. "Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective." *Theory, Culture & Society* 31(5): 21–40. doi:10.1177/0263276414531627.

Geels, Frank, Florian Kern, and William C. Clark. 2023. "System Transitions Research and Sustainable Development: Challenges, Progress, and Prospects." *Proceedings of the National Academy of Sciences* 120(47): e2206230120. doi:10.1073/pnas.2206230120.

Geels, Frank W. 2002. "Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study." *Research Policy* 31(8–9): 1257–74. doi:10.1016/S0048-7333(02)00062-8.

German Federal Ministry of Education and Research. 2021. *Federal Government Report on the High-Tech Strategy 2025*.

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: 82–95. doi:10.1016/j.erss.2018.12.001.

Godínez-Zamora, Guido, Luis Victor-Gallardo, Jam Angulo-Paniagua, Eunice Ramos, Mark Howells, Will Usher, Felipe De León, Andrea Meza, and Jairo Quirós-Tortós. 2020. "Decarbonising the Transport and Energy Sectors: Technical Feasibility and

Socioeconomic Impacts in Costa Rica." *Energy Strategy Reviews* 32: 100573. doi:10.1016/j.esr.2020.100573.

Government of the Netherlands. 2019. "Circular Dutch Economy by 2050 - Circular Economy - Government.Nl." https://www.government.nl/topics/circular-economy/circular-dutch-economy-by-2050 (March 10, 2025).

Häger, Achim, Mary Little, Elise Amel, and Gabriel Calderón. 2021. "Transformation Toward Sustainability on a Costa Rican Coffee Farm: Environmental, Socioeconomic, and Psychological Perspectives." *Case Studies in the Environment* 5(1): 1227777. doi:10.1525/cse.2021.1227777.

Hajer, Maarten A., and Peter Pelzer. 2018. "2050—An Energetic Odyssey: Understanding 'Techniques of Futuring' in the Transition towards Renewable Energy." *Energy Research & Social Science* 44: 222–31. doi:10.1016/j.erss.2018.01.013.

Hansen, Mette Halskov, Hongtao Li, and Rune Svarverud. 2018. "Ecological Civilization: Interpreting the Chinese Past, Projecting the Global Future." *Global Environmental Change* 53: 195–203. doi:10.1016/j.gloenvcha.2018.09.014.

IEA. 2024. "World Energy Outlook 2024 – Analysis." *IEA*. https://www.iea.org/reports/world-energy-outlook-2024 (March 10, 2025).

InterAcademy Partnership (IAP). 2000. "IAP Statement on Transition to Sustainability." https://www.interacademies.org/statement/iap-statement-transition-sustainability (January 6, 2022).

IRENA. 2023. *Renewable energy statistics 2023*.

Johansson, Emma Li, Sara Brogaard, and Lova Brodin. 2022. "Envisioning Sustainable Carbon Sequestration in Swedish Farmland." *Environmental Science & Policy* 135: 16–25. doi:10.1016/j.envsci.2022.04.005.

Kanger, Laur, Johan Schot, Benjamin K. Sovacool, Erik van der Vleuten, Bipashyee Ghosh, Margit Keller, Paula Kivimaa, Anna-Kati Pahker, and W. Edward Steinmueller. 2021. "Research Frontiers for Multi-System Dynamics and Deep Transitions." *Environmental Innovation and Societal Transitions*. doi:10.1016/j.eist.2021.10.025.

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. doi:10.1093/icc/dty032.

Kemp, Luke, Chi Xu, Joanna Depledge, Kristie L. Ebi, Goodwin Gibbins, Timothy A. Kohler, Johan Rockström, et al. 2022. "Climate Endgame: Exploring Catastrophic Climate Change Scenarios." *Proceedings of the National Academy of Sciences* 119(34): e2108146119. doi:10.1073/pnas.2108146119.

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: 1–32. doi:10.1016/j.eist.2019.01.004.

Lema, Rasmus, Xiaolan Fu, and Roberta Rabellotti. 2020. "Green Windows of Opportunity: Latecomer Development in the Age of Transformation toward Sustainability." *Industrial and corporate change* 29(5): 1193–1209. doi:10.1093/icc/dtaa044.

Liao, Chuan, and Arun Agrawal. 2022. "Sustainable and Just Energy Transition in the Global South." *World Development* 152: 105798. doi:10.1016/j.worlddev.2021.105798.

Longhurst, Noel, and Jason Chilvers. 2019. "Mapping Diverse Visions of Energy Transitions: Co-Producing Sociotechnical Imaginaries." *Sustainability Science* 14(4): 973–90. doi:10.1007/s11625-019-00702-y.

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. doi:10.1146/annurev-environ-102014-021340.

Lund, Henrik, Jakob Zinck Thellufsen, Peter Sorknæs, Brian Vad Mathiesen, Miguel Chang, Poul Thøis Madsen, Mikkel Strunge Kany, and Iva Ridjan Skov. 2022. "Smart Energy Denmark. A Consistent and Detailed Strategy for a Fully Decarbonized Society." *Renewable and Sustainable Energy Reviews* 168: 112777. doi:10.1016/j.rser.2022.112777.

Markard, Jochen, Rob Raven, and Bernhard Truffer. 2012. "Sustainability Transitions: An Emerging Field of Research and Its Prospects." *Research Policy* 41(6): 955–67. doi:10.1016/j.respol.2012.02.013.

Mazzucato, Mariana. 2016. "From Market Fixing to Market-Creating: A New Framework for Innovation Policy." *Industry and Innovation* 23(2): 140–56. doi:10.1080/13662716.2016.1146124.

Mazzucato, Mariana. 2021. *Mission Economy: A Moonshot Guide to Changing Capitalism*. London], UK: Allen Lane.

Melbourne Biodiversity Network. 2024. *Melbourne Biodiversity Network: Unlocking Biodiversity Networks for Community Health and Climate Resilience Strategic Plan 2024*. https://office.org.au/api/wp-content/uploads/2024/08/OFFICE_UoM_Melbourne-Biodiversity-Network.pdf (March 10, 2025).

National Research Council. 1999. *Our Common Journey: A Transition Toward Sustainability*. Policy Division. Board on Sustainable Development. doi:10.17226/9690.

Newell, Peter J., Frank W. Geels, and Benjamin K. Sovacool. 2022. "Navigating Tensions between Rapid and Just Low-Carbon Transitions." *Environmental Research Letters* 17(4): 041006. doi:10.1088/1748-9326/ac622a.

Pahl-Wostl, Claudia. 2019. "The Role of Governance Modes and Meta-Governance in the Transformation towards Sustainable Water Governance." *Environmental Science & Policy* 91: 6–16. doi:10.1016/j.envsci.2018.10.008.

Patterson, James, Karsten Schulz, Joost Vervoort, Sandra van der Hel, Oscar Widerberg, Carolina Adler, Margot Hurlbert, et al. 2017. "Exploring the Governance and Politics of Transformations towards Sustainability." *Environmental innovation and societal transitions* 24: 1–16. doi:10.1016/j.eist.2016.09.001.

Pereira, Laura, Tanja Hichert, Maike Hamann, Rika Preiser, and Reinette Biggs. 2018. "Using Futures Methods to Create Transformative Spaces: Visions of a Good Anthropocene in Southern Africa." *Ecology and Society* 23(1). doi:10.5751/ES-09907-230119.

Rossi, Adanella, Sibylle Bui, and Terry Marsden. 2019. "Redefining Power Relations in Agrifood Systems." *Journal of Rural Studies* 68: 147–58. doi:10.1016/j.jrurstud.2019.01.002.

Ryghaug, Marianne, and Tomas Moe Skjølsvold. 2023. "How Policies and Actor Strategies Affect Electric Vehicle Diffusion and Wider Sustainability Transitions." *Proceedings of the National Academy of Sciences* 120(47): e2207888119. doi:10.1073/pnas.2207888119.

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. doi:10.1038/s41893-019-0352-9.

Schiller, Katharina J. F., Laurens Klerkx, Dennis José Salazar Centeno, and P. Marijn Poortvliet. 2023. "Developing the Agroecological Niche in Nicaragua: The Roles of Knowledge Flows and Intermediaries." *Proceedings of the National Academy of Sciences* 120(47): e2206195120. doi:10.1073/pnas.2206195120.

Schot, Johan, and Frank W. Geels. 2008. "Strategic Niche Management and Sustainable Innovation Journeys: Theory, Findings, Research Agenda, and Policy." *Technology Analysis & Strategic Management* 20(5): 537–54. doi:10.1080/09537320802292651.

Schot, Johan, and Laur Kanger. 2018. "Deep Transitions: Emergence, Acceleration, Stabilization and Directionality." *Research Policy* 47(6): 1045–59. doi:10.1016/j.respol.2018.03.009.

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. doi:10.1016/j.respol.2018.08.011.

Scoones, Ian, Melissa Leach, and Peter Newell, eds. 2015. *The Politics of Green Transformations*. London; New York: Routledge.

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: 65–75. doi:10.1016/j.cosust.2019.12.004.

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. doi:10.1146/annurev-environ-110615-085934.

Sovacool, Benjamin K., and Jonn Axsen. 2018. "Functional, Symbolic and Societal Frames for Automobility: Implications for Sustainability Transitions." *Transportation research. Part A, Policy and practice* 118: 730–46. doi:10.1016/j.tra.2018.10.008.

Tarus, Lyndsay, Mary Hufford, and Betsy Taylor. 2017. "A Green New Deal for Appalachia: Economic Transition, Coal Reclamation Costs, Bottom-Up Policymaking (Part 2)." *Journal of Appalachian Studies* 23(2): 151–69. doi:10.5406/jappastud.23.2.0151.

The Ministry for the Ecological Transition and the Demographic Challenge (MITECO). 2020. *España Circular 2030: Circular Economy Spanish Stratagy*. https://climate-laws.org/document/spanish-strategy-for-circular-economy-espana-circular-2030_87c4 (March 10, 2025).

Truffer, Bernhard, James T. Murphy, and Rob Raven. 2015. "The Geography of Sustainability Transitions: Contours of an Emerging Theme." *Environmental Innovation and Societal Transitions* 17: 63–72. doi:10.1016/j.eist.2015.07.004.

UK Research and Innovation. 2020. *UKRI Annual Report and Accounts 2020 to 2021*. https://www.gov.uk/government/publications/ukri-annual-report-and-accounts-2020-to-2021 (March 10, 2025).

UNEP. "Costa Rica | NDC Action Project." https://www.unep.org/ndc/action-area/costa-rica (March 10, 2025).

Urban, Frauke, Giuseppina Siciliano, Linda Wallbott, Markus Lederer, and Anh Dang Nguyen. 2018. "Green Transformations in Vietnam's Energy Sector." *Asia & the Pacific policy studies* 5(3): 558–82. doi:10.1002/app5.251.

Westley, Frances, Per Olsson, Carl Folke, Thomas Homer-Dixon, Harrie Vredenburg, Derk Loorbach, John Thompson, et al. 2011. "Tipping Toward Sustainability: Emerging Pathways of Transformation." *AMBIO* 40(7): 762–80. doi:10.1007/s13280-011-0186-9.

Westwell, Emily, and Josh Bunting. 2020. "The Regenerative Culture of Extinction Rebellion: Self-Care, People Care, Planet Care." *Environmental Politics* 29(3): 546–51. doi:10.1080/09644016.2020.1747136.