Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Environmental Sustainability

Is the 1.5°C target possible? Exploring the three spheres of transformation

Karen O'Brien

Carbon roadmaps and pathways are important for describing, planning and tracking the technical, managerial and behavioral changes that are consistent with the Paris Agreement. Nevertheless, roadmaps and pathways for decarbonization often gloss over a fundamental question: '*How do deliberate social transformations happen*?' Often the social complexity of transformation processes is downplayed or ignored in favor of technical solutions and behavioral approaches. In this article, I explain why they are incomplete and unlikely to 'bend the curves' to reduce emissions in accordance with the Paris Agreement. I first discuss the distinction between technical and adaptive challenges and why this is relevant. I then review and describe the dynamics of social change in relation to three related and interacting 'spheres' of transformation: the practical, political, and personal spheres. Finally, I explore how these three spheres can be used to identify leverage points for transformations that support the 1.5°C target.

Address
Department of Sociology and Human Geography, University of Oslo, P. O. Box 1096 Blindern, 0317 Oslo, Norway

Corresponding author: O'Brien, Karen (karen.obrien@sosgeo.uio.no)

Current Opinion in Environmental Sustainability 2018, **31**:153–160

This review comes from a themed issue on **Sustainability governance and transformation**

Edited by **Bronwyn Hayward** and **Linda Sygna**

For a complete overview see the Issue and the Editorial

Available online 30th April 2018

Received: 28 July 2017; Accepted: 16 April 2018

https://doi.org/10.1016/j.cosust.2018.04.010

Introduction

Is hitting the 1.5°C target — or even limiting global warming to 2°C — likely or even possible? This question has dominated science and policy debates in the aftermath of the Paris Agreement on climate change [1,2]. Scientists have been tracking current progress while analyzing Nationally Determined Contributions (NDCs) and their potential for achieving levels of emissions reductions consistent with the Paris goals [1]. This approach recognizes that 'a break in current emission trends is urgently needed in the short term' [3]. More specifically, Rockström *et al.* [4] emphasize that '[m]eeting the Paris Agreement goals will require bending the global curve of CO_2 emissions by 2020 and reaching net-zero emissions by 2050' (p. 1270). The Deep Decarbonization Pathways Project [5] contends that drastic emissions reductions are technically feasible, emphasizing that '[a]ll pathways incorporate, at scale, efficiency and conservation, decarbonization of fuels and electricity, and the switch to low-carbon energy' (p. 8) [6]. Project Drawdown explores a broad range of solutions that, if implemented at scale, could potentially reverse global warming [6]. In short, numerous roadmaps and pathways for rapid decarbonization have been developed, acknowledging the need for transformations in all sectors, including energy, agriculture, construction, transport, manufacturing, and finance [4].

Carbon roadmaps and pathways are important for describing, planning and tracking the technological, managerial, institutional and behavioral changes consistent with the Paris goals. As discussed by Rosenbloom and Meadowcroft [7], the concept of pathways is increasingly used to communicate plausible stories about large-scale transformations. Along with technical, economic, and biophysical adjustments, these pathways also involve changes in social arrangements [7]. Nevertheless, roadmaps and pathways for decarbonization often gloss over a fundamental question: '*How do deliberate social transformations happen*?' Calls for rapid transformations tend to overlook a long history of social science research that includes both established and emerging theories of social change, as well as a growing body of research on transitions and transformations. Theories ranging from rational choice to constructivism to coevolutionary approaches have been reviewed by Geels [8], who highlights differences in foundational assumptions about causal relationships. A variety of social theories on transformation can be used to both critique existing approaches to climate change mitigation, and offer alternatives [9•,10,11••,12,13••,14•,15,16].

In this article, I present a heuristic tool for understanding the breadth and depth of transformations needed to meet the goals of the Paris Agreement. I first make a distinction between technical problems and adaptive challenges, and discuss the dangers of prioritizing technical solutions and behavioral approaches to emissions reductions without attention to the political and personal dimensions. I then consider processes of social transformations in relation to three embedded and interacting 'spheres' of transformation: the practical, political, and personal spheres. Finally, I explore how the three spheres of transformation can be

used to identify leverage points for transformations that support the 1.5°C target. A main point of the article is that if the 1.5°C goal is taken seriously, the practical, political *and* personal dimensions of social transformations must *all* be recognized.

Technical problems and adaptive challenges

Most scientists and policy makers already recognize that climate change is a complex social challenge and a call for urgent action. Rogelj *et al.* [17], for example, describe efforts to limit warming to no more than 2°C relative to pre-industrial levels as a *societal* challenge, and they point out that 'preparing for a global transformation of development pathways is critical' (p. 637). Yet societal challenges and global transformations of development pathways can take many forms and directions. Proposed pathways can represent fundamentally different visions and theoretical approaches to change. Within the transformations literature, reference is often made to incremental versus transformative change, or to reformist versus radical change [18,19]. Heifetz *et al.* [20] introduce a different distinction in relation to the challenge of change: technical versus adaptive. This distinction is important; rather than describing the quality or rate of change, it relates to the type of problem that is being addressed.

Technical problems are those than can be successfully addressed by applying greater expertise, more innovation, and better management. The current approach to realizing the 1.5°C target has been predominantly technical, largely informed by Integrated Assessment Models, which are closely linked to techno-economic approaches, ecological modernization and rational choice models of decision-making [21]. Yet the pursuit of mitigation through technological innovations and 'green growth' often ignores equity and distributional issues, underplays the importance of power and politics in transformation processes, and underestimates the potential of people to generate systemic change [12,22,23]. As Brand [12] notes, there is a tendency to ignore the conflicts, tensions, and contradictions that arise in transformation processes — and these are often linked to other environmental and social issues that represent the root causes of risk and vulnerability.

Approaching the 1.5°C target as an adaptive challenge is quite different. Adaptive challenges are referred to as 'adaptive' because they require a new way of viewing both problems and solutions. They usually have technical aspects, but they also recognize the importance of mindsets, especially the beliefs, values, and worldviews that influence how problems and solutions are perceived, approached and addressed. Beliefs in particular are critical to shaping ideas about what is possible, including the 1.5°C target. Indeed, as Nilsson [24, p. 15] notes, '[o]ur beliefs play important roles in perceiving a current situation, in identifying appropriate actions, and in predicting the effects of these actions.' Values, which can be thought of as those things considered desirable, help define what is important and significant. Together, beliefs and values contribute to individual and shared worldviews or models of reality [25,26]. Yet the adaptive elements of climate change are not just personal — they are also political, in that they are used to validate social norms, to legitimate certain forms of governance, and to define what is desirable and achievable. When viewed as an adaptive challenge, the personal and political dimensions of climate change become essential to the success of practical strategies to reduce emissions [27].

The rapidly growing literature on transitions and transformations draws attention to the many factors and processes related to mitigation, adaptation, disaster risk reduction and sustainable development [10,19,28,29,30•,31,32]. However, there are also numerous frameworks, approaches and analyses of social change that do not directly or strategically reference climate change, which can nonetheless provide valuable insights on deliberate transformations to sustainability [33–35]. As one example, Eric Olin Wright's theory of emancipatory social transformation considers both the obstacles and possibilities for transformative social change [35]. Relevant to the adaptive challenge of climate change, Wright [35, p. 6] emphasizes that social arrangements inherited from the past are transformable human creations rather than immutable facts of nature, and that 'what is pragmatically possible is not fixed independently of our imaginations, but is itself shaped by our visions. Self-fulfilling prophecies are powerful forces in history . . . ' Here, mindsets play an important role, particularly related to the paradigms or patterns of thought that guide policies [36•]. In her study of mobility systems in Malmö, Sweden, Essebo [37] describes path-dependency and lock-in as a myth, or a depoliticized and naturalized story that justifies and guides practices based on unconscious or unquestioned beliefs.

Significant here are the dangers of dismissing a particular vision or goal as 'unrealistic,' for it can have powerful consequences. For example, a study by Raftery *et al.* [38] indicates that there is only a 5% or 1% chance of reaching the Paris Agreement targets by 2100. The research, based on technical modeling studies, may inadvertently support a self-fulfilling belief that the only viable responses involve adapting to the impacts of significant climate change or pursuing geoengineering solutions to avoid them [39]. Yet the forecasting model used in the study 'does not explicitly incorporate future legislation that could change future emissions' nor does it account for 'the possibility that decreasing prices for alternative energy could cause a sudden massive shift to alternative energy' [35, p. 4]. Assumptions based on extrapolations of past experiences can indeed contribute to the myth of path dependency [37].

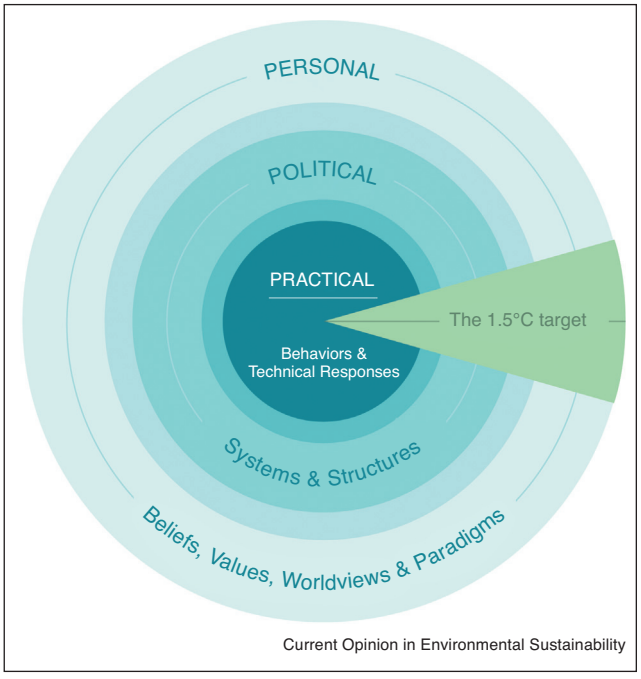
In exploring the potential to create desirable, viable and achievable changes that promote social and political justice, Wright [35] stresses the importance of a combination of ruptural, interstitial, and symbiotic transformations — in other words disruptive, incremental, *and* collaborative/cooperative approaches to change. Wright [35] also points out that 'both deliberate and unintended processes of social change are crucial for emancipatory transformation' (p. 298). This suggests that transformations are better conceived as continuous and messy processes of change that cannot be controlled and managed within existing paradigms [40]. Recognizing that the political and personal dimensions of adaptive challenges can create 'bumpy and convoluted pathways,' it becomes clear that the 1.5°C target is not limited to decarbonization strategies. The real challenge involves broader and deeper social transformations to sustainability [41].

Three spheres of transformation

The 'three spheres of transformation' (Figure 1) do not represent a theory of change *per se*, but rather a heuristic that can 'hold' and integrate different theories of deliberate transformations [42–44]. The so-called practical, political and personal spheres of transformation are abstractions that capture both the breadth and the depth of the changes needed to realize a particular goal or outcome, in this case the 1.5°C target. Although most existing and emerging theories of social change recognize interactions among multiple spheres, there is a tendency to emphasize only one or two dimensions. The heuristic emphasizes that transformation processes involve all three spheres of transformation. It is an adaptation of Monica Sharma's conscious full-spectrum approach to radical transformational leadership [45], which was developed through empirical work in the field of development. The three spheres also integrates aspects of process ontologies [46] and Integral Theory [47,48]. Integral Theory recognizes that behaviors, systems, culture, and experiences are interdependent, and that mindsets and paradigms influence how systems are viewed, which theories, relationships and goals are deemed legitimate and desirable, and which behaviors are prioritized [46–48].

The notion of 'spheres' is used figuratively here to reflect areas or domains that are an intrinsic part of a larger whole. The labels applied to the spheres do not correspond directly to disciplinary academic interpretations, nor to traditional spheres of sustainability, such as economic, social and environmental [49], or economy, society and biosphere [50]. The three spheres represent both the objective and subjective dimensions of transformation processes, both of which have been widely described in the literature on climate change responses, yet seldom integrated [36•,51]. Objective refers here to technical or seemingly 'unbiased' aspects of knowledge, an approach that might be effectively applied to automobiles or energy systems and perhaps sometimes to behaviors.

Figure 1



The three spheres depict the dynamic relationships between the practical, political and personal dimensions of transformation. They draw attention to the importance of the political and personal spheres in generating the conditions for practical transformations that contribute to the 1.5°C target.

Subjective dimensions refer to individual and shared perspectives that are interpreted through beliefs and assumptions, values, worldviews, interests, and emotions.

The *practical sphere* is at the core of the figure, and it represents specific actions, interventions, strategies and behaviors that directly contribute to a desired outcome, such as the 1.5°C target. For example, these might include more solar installations, reduced meat consumption, upgrading infrastructure, developing new educational tools, promoting bicycle riding, building sea walls, and so on. The practical sphere has been the primary focus of most climate change mitigation and adaptation research, policies and actions. This is not surprising, as technical and behavioral interventions produce results that can be measured, monitored and evaluated. Progress in the practical sphere is easily tracked by indicators, such as the energy intensity of GDP or the share of non-fossil energy in total energy use, which can be used in integrated assessment models [1]. Often transformations in the practical sphere (e.g. technologies for sharing information and products) can support or trigger transformations in the political and personal spheres. Yet transformations in the practical sphere are often easier to identify and develop than to implement at scale, as they face a range of barriers associated with the political and personal spheres.

The *political sphere* represents the systems and structures that facilitate or constrain practical responses to climate change. Systems can be described as relationships between parts that form a larger whole, and structures describe the norms, rules, regulations, institutions, regimes and incentives that influence how systems are designed, organized and governed. Systems and structures are interpreted here as 'the political sphere' because they are often created, codified and managed through political processes, which include collective actions and struggles that shape the spaces for responses in the practical sphere. For example, both energy and economic systems consist of relationships that have been formalized and institutionalized through rules and regulations, infrastructures, and cultural norms that contribute to habits and practices. Wilhite [52••] draws on social practice theory to explore the ways that actions involved in everyday habits within wealthy economies (in the practical sphere) are linked to capitalist imperatives of growth, commodification and individualization (in the political sphere). Wilhite argues that these structures are inconsistent with low carbon strategies [52••], and Brand [53, p. 505] emphasizes that it is these 'deeply inscribed socioeconomic, political, cultural, and subjective social relations as well as societal nature relations that need to be transformed.'

The political sphere includes what Gillard *et al.* [13••] describe as social fields, a space where shared interests and understandings exist, but also where disagreement and dissent are expressed, which can produce tensions and conflicts. It is in the political sphere where norms are challenged, social movements are formed to address structural injustices, and where interest groups lobby to defend or transform the status quo. It is also where cooperation, collaboration and compromise can lead to new alliances and social innovations such as circular and sharing economies. As an example, the Paris Agreement has successfully mobilized both state and non-state actors toward a shared goal, which may create new structures that encourage sustainability innovations in the practical sphere.

The *personal sphere* of transformation represents the subjective beliefs, values, worldviews and paradigms that influence how people perceive, define or constitute systems and structures, as well as their behaviors and practices. This sphere represents both individual and shared understandings and assumptions about the world, which influence perceptions, interpretations and constructions of reality. It also defines what is individually and collectively imaginable, desirable, viable and achievable based on different understandings of causality, levels of social consciousness and future consciousness, perceptions of agency, and assumptions about leadership [25,43,54,55]. These subjectivities influence and inform whether, where and how boundaries are drawn between 'us' and 'other,' who or what is included or excluded (or allowed or prohibited) and who or what is considered to have power in any given relationship. The personal shows up in the political and practical spheres in material and non-material ways, influencing how people and resources are treated, both in the present and future.

Although individual and shared beliefs and worldviews are often considered the most difficult to transform, the personal sphere is not static and fixed. Beliefs, values and worldviews can change within individual lifetimes and over generations, and also through pivotal events [56]. Under some conditions, worldview transformations may lead to 'more constricted, fear-based, threat-oriented, intolerant, or narrow views of the world and a person's place in it' [25]. However, it is more often the case that challenging assumptions, questioning beliefs, and exploring alternatives leads to more expansive and inclusive worldviews that can potentially transform dominant paradigms and models of reality. Enhanced personal and political agency is often the result of being able to 'look at' rather than 'look through' one's beliefs and to question what is socially or culturally given, rather than to consciously or unconsciously accept them as filters through which the world is viewed [56]. Manuel-Navarrete and Pelling [55] consider how the dynamics of subjectivity influence political spaces that enable reflection, contestation, and purposive action in the political sphere. In arguing for a theory of conscious agency, Wright [35] recognizes the powerful role that beliefs play in transformation processes — especially beliefs about what is possible.

Individual and shared beliefs, values, worldviews and paradigms can be used to justify ideologies, policies and actions, which in turn may reinforce existing beliefs and worldviews. Although it is tempting to equate 'culture' with the personal sphere, it is in fact represented within all three spheres, whether as shared beliefs, values and worldviews; as norms and institutions, or as specific behaviors and material artifacts. Culture is a powerful subjective construction that influences human-environment relationships. As Benhabib [57, p. 8] writes, 'human cultures are constant creations, recreations, and negotiations of imaginary boundaries between "we" and the "other(s)".' Understanding the role of culture in social transformations is vital, as it can be a powerful catalyst for achieving the 1.5°C target.

As a heuristic device, the three spheres of transformation draw attention to the relationships and interactions among the practical, political and personal dimensions of change processes. For example, hierarchical or individualistic worldviews may prioritize values and goals that support (and are reinforced by) norms, rules, incentives, and systems that benefit some and exclude others. These can contribute to inequitable outcomes and 'winners and

losers.' Relevant to decarbonization strategies, Healy and Barry [58] discuss energy justice and injustice, criticizing the 'depoliticized, techno-optimistic hopes that "green innovation" will suffice to achieve a transition to clean energy' (p. 456). Focusing on the political space for mobilizing civil society around energy justice and fossil fuel divestment campaigns, they argue that radical and system-disruptive interventions are essential to energy justice. Although path dependency and lock-in are often used as explanations or excuses for continuing with the status quo, path-dependency can also be considered a mindset [36•,37].

The spheres are depicted as concentric and embedded for several reasons: the practical sphere is figuratively centered at the core of transformation processes, as technical and behavioral changes tend to produce outcomes and impacts that can be readily measured and monitored in relation to a specific goal, such as the 1.5°C target; the personal sphere is represented as the outermost because, while it is not deterministic, it does have a pervasive, often subconscious impact on the political and practical spheres, which in turn shape the context in which worldviews are reproduced or transformed; the political sphere is located between the practical and personal spheres because it plays a central role in moderating and maintaining the structures and systems of society; as a collective action problem, climate change has to be addressed systemically as well as individually; finally, the relative size of the spheres corresponds to the potential leverage of an intervention. As discussed below, transformations in the personal sphere can, especially in relation to paradigms, have significant consequences for systems.

Leveraging change

The three spheres provide a simple and accessible way to think about social transformations that is generally consistent or compatible with many other theories and approaches, including the literature on the multi-level perspective, social-ecological transformations, social innovation, and social practice theory [15,32,52••,59]. The three spheres correspond quite well with the 12 leverage points for systems change identified by Donella Meadows [60] (Figure 2), which have been considered a useful framework for conceptualizing transformation [61]. According to Meadows, constants, parameters and numbers (e.g. taxes, interest rates, etc.), along with the size of buffers (e.g. forests, soils, atmosphere, Green Climate Fund, etc.), are considered the two least powerful leverage points. Nonetheless, these tend to receive significant attention in climate policy. Although they are certainly important, greater leverage is found in the political sphere, through policies that strengthen or weaken feedbacks, information flows, and most importantly, through the rules of the system and those who have power to change the rules. The power to influence rules is critical, thus political agency can be a key driver of social transformations [62].

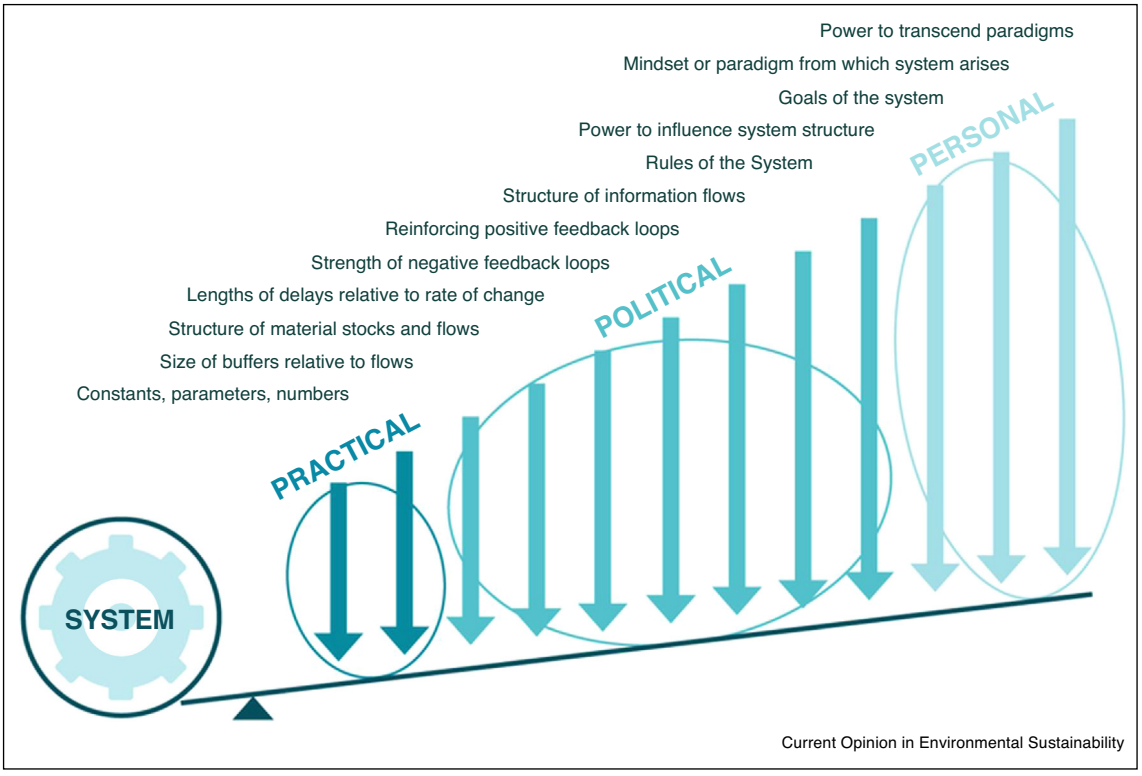
However, Meadows argues that the most powerful leverage points are the goals of the system and 'the mindset or paradigm out of which the system — its goals, structure, rules, delays, parameters — arises' [60]. This falls into the realm of the personal sphere, that is, the individual and collective ideas about what is just, desirable and sustainable, which are in turn inherited, formed, transformed, negotiated or fought for in the political sphere and realized in the practical sphere. Importantly, Meadows [60] considers the very highest leverage point to be the power to transcend paradigms, or 'to keep oneself unattached in the arena of paradigms, to stay flexible, to realize that NO paradigm is "true".' Such an approach calls for 'openness, humility and courage.' This can be challenging when the stakes are high and prospects seem daunting, as is the case with the 1.5°C target. However, this also suggests that there are opportunities to explore alternative ideas and approaches for realizing the target, including alternative and speculative paradigms [63].

Understanding the human and social dimensions of transformation is critical to reaching the 1.5°C target, which itself can serve as a powerful metaphor for radical change. Yet how do we turn insights and understandings of social transformation into strategies that can 'bend the curves' in an equitable, ethical and sustainable way? There is a risk here that transformations within the personal sphere will only be implemented in the practical sphere, turning (inter)subjective change into an object to be changed by imposing certain values and worldviews on others in a culturally invasive way [27]. A more effective starting point would be to engage individuals and groups with all three spheres of transformation, such that they shift from being seen as 'objects to be changed' and reduced to their carbon footprints, to viewing themselves as subjects or agents of change who are capable of contributing to systemic transformations. This implies less attention to altering or manipulating people's behavior, and more on creating the conditions that promote the development and expression of social consciousness and futures consciousness in all three spheres [25,54]. Political empowerment can be facilitated, for example, through transformative learning processes and transdisciplinary research that contribute to new narratives and stories about change [11••,34,64,65].

Conclusion

To catalyze rapid and large-scale systems change will no doubt involve multiple approaches, some radical and conflictive and others incremental and collaborative, and there will be both intended and unintended consequences [35]. Although roadmaps and pathways for low-carbon development are important, the paradigms, perspectives and power of the mapmakers and pathbreakers

Figure 2



Leverage points for systems change based on Meadows [60] and their relationship to the practical, political and personal spheres of transformation.

are seldom neutral — with the best of intentions they often perpetuate old paradigms and ideas, pave overly deterministic pathways that risk becoming self-fulfilling prophecies, and exclude other ways of framing and approaching problems and solutions.

Generating rapid social change involves broader and deeper approaches to transformations, which include activating leverage points in the political and personal spheres. Drawing on Wright's [35] idea of strategic indeterminacy, which recognizes that there is no single way to realize egalitarian ideals of social and political justice, one could extend his thoughts to say: '[The 1.5°C target] will not happen simply as a by-product of unintended social change; if this is to be our future, it will be brought about by the conscious actions of people acting collectively to bring it about' (p. 370). Directly recognizing and engaging people as agents of change can drastically speed up low-carbon transformation processes because everyone is part of a system, and everyone has a sphere of influence. Activating conscious human agency that is critically reflective of individual and shared assumptions, beliefs and paradigms is a powerful way to shift norms and institutions in ways that support the roadmaps and pathways consistent with the Paris Agreement. This means treating climate change not as merely a technical problem, but as an adaptive challenge. Without such a shift in focus, all of the detailed roadmaps and pathways for decarbonization may just lead to a dead end.

Conflict of interest

None declared.

Acknowledgements

This paper has been supported through funding from the Research Council of Norway and the University of Oslo through the AdaptationCONNECTS project (Project 250434). I would like to thank the project research group, particularly Morgan Scoville-Simonds and Gail Hochachka, for their comments and suggestions on the manuscript, as well as two anonymous reviewers for valuable feedback.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Peters GP, Andrew RM, Canadell JG, Fuss S, Jackson RB, Korsbakken JI, Le Quéré C, Nakicenovic N: **Key indicators to track current progress and future ambition of the Paris Agreement**. *Nat Clim Change* 2017, **7**:118-122.

2. Anderson K, Peters G: **The trouble with negative emissions**. *Science* 2016, **354**:182-183.

3. Friedlingstein P, Andrew RM, Rogelj J, Peters GP, Canadell JG, Knutti R, Luderer G, Raupach MR, Schaeffer M, van Vuuren DP

et al.: **Persistent growth of CO_2 emissions and implications for reaching climate targets**. *Nat Geosci* 2014, **7**:709-715.

4. Rockström J, Gaffney O, Rogelj J, Meinshausen M, Nakicenovic N, Schellnhuber HJ: **A roadmap for rapid decarbonization**. *Science* 2017, **355**:1269-1271.

5. Deep Decarbonization Pathways Project: *Pathways to Deep Decarbonization 2015 Report*. 2015.

6. Hawken P: *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming*. Penguin Books; 2017.

7. Rosenbloom D, Meadowcroft J: **The journey towards decarbonization: exploring socio-technical transitions in the electricity sector in the province of Ontario (1885–2013) and potential low-carbon pathways**. *Energy Policy* 2014, **65**:670-679.

8. Geels FW: **Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective**. *Res Policy* 2010, **39**:495-510.

9. • Fazey I, Moug P, Allen S, Beckmann K, Blackwood D, Bonaventura M, Burnett K, Danson M, Falconer R, Gagnon AS *et al.*: **Transformation in a changing climate: a research agenda**. *Clim Dev* 2017 http://dx.doi.org/10.1080/17565529.2017.1301864.
This paper presents a forward-looking agenda for research on transformations within the context of climate change. The agenda pays attention to theories of change and questions that cut across the practical, political and personal spheres of transformation, including the role of human consciousness and futures consciousness.

10. Shaw A, Burch S, Kristensen F, Robinson J, Dale A: **Accelerating the sustainability transition: exploring synergies between adaptation and mitigation in British Columbian communities**. *Glob Environ Change* 2014, **25**:41-51.

11. •• Ziervogel G, Cowen A, Ziniades J: **Moving from adaptive to transformative capacity: building foundations for inclusive, thriving, and regenerative urban settlements**. *Sustainability* 2016, **8**:955.
This paper explores the concept of transformative capacity and how it relates to adaptive capacity. The authors identify reconnection to life-support systems, agency, and social cohesion as three foundational aspects that need to be strengthened to develop transformative capacity. They emphasize that lasting social change calls for collective actions that shift cultural habits and values, and describe the benefits of transdisciplinary research.

12. Brand U: **"Transformation" as a new critical orthodoxy: the strategic use of the term "transformation" does not prevent multiple crises**. *GAIA — Ecol Perspect Sci Soc* 2016, **25**:23-27.

13. •• Gillard R, Gouldson A, Paavola J, Van Alstine J: **Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation**. *Wiley Interdiscip Rev Clim Change* 2016, **7**:251-265.
This article presents a critical assessment of a systems perspective on transformations. Drawing on insights from social theory, the authors discuss the broad set of interrelated processes that influence transformational social change, including how power, politics and social relations influence social fields and responses to climate change.

14. • Feola G: **Societal transformation in response to global environmental change: a review of emerging concepts**. *Ambio* 2015, **44**:376-390.
This article reviews the concept of transformation and how it has been interpreted and used in the environmental change literature. Feola points to the conceptual diversity of research approaches, and notes how the concept of transformation can be used to promote distinct political programs, including those that maintain the status quo. He warns of the dangers of attributing a transformative character to any instance of social change.

15. Olsson P, Moore M-L, Westley F, McCarthy D: **The concept of the Anthropocene as a game-changer: a new context for social innovation and transformations to sustainability**. *Ecol Soc* 2017, **22**.

16. Pelling M, O'Brien K, Matyas D: **Adaptation and transformation**. *Clim Change* 2015, **133**:113-127.

17. Rogelj J, den Elzen M, Höhne N, Fransen T, Fekete H, Winkler H, Schaeffer R, Sha F, Riahi K, Meinshausen M: **Paris Agreement climate proposals need a boost to keep warming well below 2°C**. *Nature* 2016, **534**:631-639.

18. Pelling M: *Adaptation to Climate Change: From Resilience to Transformation*. Routledge; 2011.

19. Nalau J, Handmer J: **When is transformation a viable policy alternative?** *Environ Sci Policy* 2015, **54**:349-356.

20. Heifetz RA, Grashow A, Linsky M: *The Practice of Adaptive Leadership: Tools and Tactics for Changing Your Organization and the World*. Harvard Business Press; 2009.

21. Geels FW, Berkhout F, van Vuuren DP: **Bridging analytical approaches for low-carbon transitions**. *Nat Clim Change* 2016, **6**:576-583.

22. Stirling A: **Emancipating transformations: from controlling "the transition" to culturing plural radical progress**. *The Politics of Green Transformations*. Earthscan; 2015:54-67.

23. Marino E, Ribot J: **Adding insult to injury: climate change and the inequities of climate intervention**. *Glob Environ Change* 2012, **22**:323-328.

24. Nilsson NJ: *Understanding Beliefs*. The MIT Press; 2014.

25. Schlitz MM, Vieten C, Miller EM: **Worldview transformation and the development of social consciousness**. *J Conscious Stud* 2010, **17**:18-36.

26. Hedlund-de Witt A: **Worldviews and their significance for the global sustainable development debate**. *Environ Ethics* 2013, **35**:133-162.

27. O'Brien KL, Selboe E: **Climate change as an adaptive challenge**. *The Adaptive Challenge of Climate Change*. Cambridge University Press; 2015:1-23.

28. Mapfumo P, Onyango M, Honkponou SK, Mzouri EHE, Githeko A, Rabeharisoa L, Obando J, Omolo N, Majule A, Denton F *et al.*: **Pathways to transformational change in the face of climate impacts: an analytical framework**. *Clim Dev* 2015:1-13.

29. Berman R, Quinn C, Paavola J: **The role of institutions in the transformation of coping capacity to sustainable adaptive capacity**. *Environ Dev* 2012, **2**:86-100.

30. • Patterson J, Schulz K, Vervoort J, van der Hel S, Widerberg O, Adler C, Hurlbert M, Anderton K, Sethi M, Barau A: **Exploring the governance and politics of transformations towards sustainability**. *Environ Innov Soc Transit* 2016 http://dx.doi.org/10.1016/j.eist.2016.09.001.
This article draws attention to the importance of governance and politics intransformations to sustainability. Through its focus on the political sphere, the paper addresses how structures, processes, rules and traditions related to how people make decisions and share power can contribute to shaping or steering transformations.

31. Kagan S: **Cultures of sustainability and the aesthetics of the pattern that connects**. *Futures* 2010, **42**:1094-1101.

32. Shove E, Walker G: **CAUTION! Transitions ahead: politics, practice, and sustainable transition management**. *Environ Plan A* 2007, **39**:763-770.

33. Polanyi K: *The Great Transformation: The Political and Economic Origins of Our Time*. Beacon Press; 2001.

34. Mälkki K: **Building on Mezirow's theory of transformative learning: theorizing the challenges to reflection**. *J Transform Educ* 2010, **8**:42-62.

35. Wright EO: *Envisioning Real Utopias*. Verso; 2010.

36. • Göpel M: *The Great Mindshift: How a New Economic Paradigm and Sustainability Transformations Go Hand in Hand*. Springer; 2016.
This book explores the role of economic paradigms in sustainability transformations, including how mindsets influence political, cultural and economic circumstances: Göpel emphasizes the importance of political economy in transformations, and explains how it can potentially serve as a powerful leverage point for change.

37. Essebo M: *Lock-in as Make-Believe Exploring the Role of Myth in the Lock-in of High Mobility Systems*. University of Gothenburg; 2013.

38. Raftery AE, Zimmer A, Frierson DMW, Startz R, Liu P: **Less than 2°C warming by 2100 unlikely**. *Nat Clim Change* 2017, **7**:637-641 (advance online publication).

39. Dalby S: **Geoengineering: the next era of geopolitics?** *Geogr Compass* 2015, **9**:190-201.

40. Termeer CJAM, Dewulf A, Biesbroek GR: **Transformational change: governance interventions for climate change adaptation from a continuous change perspective**. *J Environ Plan Manag* 2017, **60**:558-576.

41. O'Brien K, Selboe E: **Social transformation: the real adaptive challenge**. In *The Adaptive Challenge of Climate Change.* Edited by O'Brien K, Selboe E. Cambridge University Press; 2015:311-324.

42. O'Brien K, Sygna L: **Responding to climate change: the three spheres of transformation**. In *Proceedings of Transformation in a Changing Climate*. University of Oslo; 2013:16-23.

43. Sharma M: **Personal to planetary transformation**. *Kosm J* 2007.

44. O'Brien K, Eriksen S, Inderberg TH, Sygna L: In *Climate Change and Development: Adaptation Through Transformation.* Edited by Inderberg TH, Eriksen S, O'Brien K, Sygna L. 2015:273-289.

45. Sharma M: *Radical Transformational Leadership: Strategic Action for Change Agents*. North Atlantic Books; 2017.

46. Roberts T: **From things to events: Whitehead and the materiality of process**. *Environ Plan Soc Space* 2014, **32**:968-983.

47. Riddell D: **Bring on the R/Evolution: integral theory and the challenges of social transformation and sustainability**. *J Integral Theory Pract* 2013, **8**:126-145.

48. Wilber K: *A Brief History of Everything*. Shambhala Publications; 2000.

49. O'Connor M: **The "Four Spheres" framework for sustainability**. *Ecol Complex* 2006, **3**:285-292.

50. Folke C, Biggs R, Norström AV, Reyers B, Rockström J: **Social-ecological resilience and biosphere-based sustainability science**. *Ecol Soc* 2016, **21**.

51. Esbjorn-Hargens S: **An integral overview of climate change: why truth is not enough**. *MetaIntegral Found Store* 2010, **5**.

52. •• Wilhite H: *The Political Economy of Low Carbon Transformation: Breaking the Habits of Capitalism*. Routledge, Taylor & Francis Group; 2016.
This book looks at habits of consumption and how they are related to the capitalist economic system. Building on social practice theory, Wilhite relates everyday practices and habits to the structures and ideas that the capitalist system has promoted. This book is important in that it demonstrates the limits to carbon emissions reductions within capitalist economies, and the importance of challenging systems through experimentation.

53. Brand U: **How to get out of the multiple crisis? Contours of a critical theory of social–ecological transformation**. *Environ Values* 2016, **25**:503-525.

54. Sharpe B, Hodgson A, Leicester G, Lyon A, Fazey I: **Three horizons: a pathways practice for transformation**. *Ecol Soc* 2016, **21**.

55. Manuel-Navarrete D, Pelling M: **Subjectivity and the politics of transformation in response to development and environmental change**. *Glob Environ Change* 2015, **35**:558-569.

56. Kegan R, Lahey LL: *Immunity to Change: How to Overcome It and Unlock the Potential in Yourself and Your Organization*. 2009.

57. Benhabib S: *The claims of culture: equality and diversity in the global era*. Princeton University Press; 2002.

58. Healy N, Barry J: **Politicizing energy justice and energy system transitions: fossil fuel divestment and a "just transition"**. *Energy Policy* 2017, **108**:451-459.

59. Geels FW: **The multi-level perspective on sustainability transitions: responses to seven criticisms**. *Environ Innov Soc Transit* 2011, **1**:24-40.

60. Meadows DH: *Leverage Points: Places to Intervene in a System*. 1999.

61. Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, von Wehrden H, Abernethy P, Ives CD, Jager NW *et al.*: **Leverage points for sustainability transformation**. *Ambio* 2017, **46**:30-39.

62. O'Brien K: **Political agency: the key to tackling climate change**. *Science* 2015, **350**:1170-1171.

63. O'Brien KL: **Climate change and social transformations: is it time for a quantum leap?** *Wiley Interdiscip Rev Clim Change* 2016, **7**:618-626.

64. Ingram M, Ingram H, Lejano R: **Environmental action in the Anthropocene: the power of narrative networks**. *J Environ Policy Plan* 2015 http://dx.doi.org/10.1080/1523908X.2015.1113513.

65. Veland S, Scoville-Simonds M, Gram-Hanssen I, Schorre A, El Khoury A, Nordbø M, Lynch A, Hochachka G, Bjørkan M: **Narrative matters for sustainability: the transformative role of storytelling in realizing 1.5°C futures**. *Curr Opin Environ Sustain* 2018, **31**:41-47.