The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions

ARTICLE *in* ECOLOGY AND SOCIETY · MARCH 2014

Impact Factor: 2.77 · Source: OAI

2 AUTHORS:

Adrian Smith
University of Sussex
98 PUBLICATIONS **3,235** CITATIONS
SEE PROFILE

Andy Stirling
University of Sussex
230 PUBLICATIONS **4,337** CITATIONS
SEE PROFILE

Smith, A., and A. Stirling. 2010. The politics of social-ecological resilience and sustainable socio-technical transitions. *Ecology and Society* **15**(1): 11. [online] URL: http://www.ecologyandsociety.org/vol15/iss1/art11/

Synthesis, part of a Special Feature on Transitions, Resilience and Governance: Linking Technological, Ecological and Political Systems

The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions

Adrian Smith [1] *and Andy Stirling* [1]

ABSTRACT. Technology-focused literature on socio-technical transitions shares some of the complex systems sensibilities of social-ecological systems research. We contend that the sharing of lessons between these areas of study must attend particularly to the common governance challenges that confront both approaches. Here, we focus on critical experience arising from reactions to a transition management approach to governing sustainable socio-technical transformations. Questions over who governs, whose system framings count, and whose sustainability gets prioritized are all pertinent to social-ecological systems research. We conclude that future research in both areas should deal more centrally and explicitly with these inherently political dimensions of sustainability.

Key Words: *governance; social-ecological resilience; socio-technical transitions*

INTRODUCTION

Research into social-ecological systems recognizes technology as an important influence on resilience (e.g., Anderies et al. 2004, Langridge et al. 2006, Young et al. 2006). This influence may alternatively be positive or negative, depending on the context (Berkes et al. 2003; A. Stirling, *unpublished manuscript*). There are technologies that undermine particular notions of resilience and those that have the potential to enhance it. Understandably, the social-ecological systems literature rarely considers the dynamics of technological change in any detail. A parallel literature that focuses on transition management toward more sustainable socio-technical systems does consider technology dynamics in depth (Rip and Kemp 1998, Rotmans et al. 2001, Smith et al. 2005).

Researchers claim that these two areas of study conceptualize their objects of study in similar ways (van der Brugge and Van Raak 2007, Foxon et al. 2008). Social-ecological systems and socio-technical systems are understood to display complex, dynamic, multiscale, and adaptive properties; recommendations for their sustainable governance emphasize learning, experimentation, and iteration. Such similarities facilitate dialogue (J.-P. Voss, A. Smith, V. Galaz, and P. Olsson, *unpublished manuscript*). At present, dialogue is limited to a fairly uncritical comparison of the favored governance strategies: adaptive governance for improving the resilience of social-ecological systems, and transition management for promoting sustainable socio-technical systems (van der Brugge and Van Raak 2007, Foxon et al. 2008). Discussions of adaptive governance have generally focused on the experimental ways that flexible collective capabilities can be built up in actor networks that maintain or enhance the resilience of social-ecological systems (Olsson et al. 2006). A recent thread has added, however, that social-ecological systems in an undesirable basin will require governance for transformability (Walker et al. 2004), where undesirable is a social-ecological state deemed no longer to be delivering key services for groups dependent upon the system. An aspiration to create entirely new system states brings the transformability side of social-ecological research even closer to the aims in transition management.

Constructive criticism must also be part of the lesson-sharing process. Herein, we have three purposes. First, we begin by elaborating the roles

[1]SPRU - Science & Technology Policy Research, University of Sussex

played by technology in social-ecological resilience. Second, we argue that it is important to bear in mind the differences between the two areas of study, in terms of problem framings and intellectual histories, as well as the similarities. Only then can lessons from each area of study be interpreted carefully and fruitfully by the other. This is important for our third purpose, which is to identify in transition management some critical governance challenges that are valid for social-ecological research. Given our technology focus here, it is sensible to move in that direction. Of course, potential lessons can also move the other way, but that is a task for another study.

We first introduce a way of thinking about technology as a socio-technical system. We then compare and contrast sustainability objectives for socio-technical systems with those for social-ecological systems. Next, we introduce transition management and discuss the critical challenges confronting the transition management approach. Finally, we discuss the relevance of this work for social-ecological systems governance is addressed in the concluding section. We suggest that, rather than developing ever more idealized notions of governance, critical insights from transition management might be used in a more engaged way with the politics of sustainable development that already exists.

TECHNOLOGY AS A SOCIO-TECHNICAL SYSTEM

All technologies rely on the natural world to furnish raw materials, provide energy, and assimilate wastes. Technologies help us monitor and understand our effects on the natural world, with consequences for how we understand social-ecological resilience. Technologies stimulate economic growth and the development of social structures, with further consequences for social-ecological resilience. Cleaner technologies improve the efficiency of material exploitation, and remediation technologies can help improve degraded environments (Berkhout and Gouldson 2003). In all these ways, technologies help constitute social-ecological systems. As used here, the term 'social-ecological system' extends beyond ecosystem services to include technological use of natural resources such as minerals.

For example, institutions coordinate investment in infrastructure and production technology. Technology choices affect the production function, which affects relations between users and the ecosystem. In turn, governance strategies for promoting greater social-ecological resilience must consider technology choice, use, and control.

Understandably, given an already complex social-ecological system, technology is conceptualized as an exogenous factor. Technological processes operate outside the social-ecological system. Nevertheless, the dynamics of technology development carry important implications for resilience.

Researchers interested in sustainable technologies find a multilevel socio-technical systems perspective attractive for two reasons. First, the creation and diffusion of cleaner technologies is predicated on facilitating changes in broader social, economic, and political systems. Second, some environmental goals such as dramatic reduction in carbon emissions cannot be achieved through individual cleaner technologies alone, e.g., renewable energy, but require structural changes to encompassing socio-technical systems, e.g., energy infrastructure.

Social processes shape the development and use of technology, but technologies in turn open up possibilities for new social practices (Russell and Williams 2002). New technologies never appear fully formed and in obvious working order (Bijker 1997). They arise through active development, linkages, and the alignment of heterogeneous, social, and technical elements into working configurations. For example, the development of electricity systems based on fossil fuels has been shaped by the institutions developed to facilitate their operation and expansion and has led to a reinforcing development of electricity-using goods and services. For instance, institutions are required to train engineers and provide facilities for developing particular styles of technology. These must in turn be linked to institutionally structured market incentives, marketing possibilities, and the needs of prospective consumers. Beyond this, broader social, demographic, and ideological processes are at work. These include the cultural milieu in which the technology operates, whereby social movements, lifestyle expectations, environmental stresses, behavioral patterns, and resource endowments exercise important influences on patterns of technology development and use. These processes, operating beyond, but interconnected with, specific socio-technical systems, form an

overarching socio-technical landscape addressed at a macro level of analysis (Rip and Kemp 1998).

Hence, the focal concern becomes not just artifacts, but the structures, agents, and processes that reproduce a socio-technical system (Rip and Kemp 1998). Some socio-technical systems are entrenched more deeply than others, in the sense that they enjoy greater institutional support, larger economic significance, more supportive infrastructures, better integration with other social practices, and broader political legitimacy. These strongly embedded, self-reinforcing systems are referred to as socio-technical regimes, and form a meso level of analysis (Rip and Kemp 1998, Geels 2002). Electricity systems based on centralized generation from fossil fuels and distributed to users through grids is an example of a regime in wealthy societies, which contrasts with systems using local renewables, for example, for which institutional support is less entrenched.

Socio-technical systems condition the way functions like lighting a room or powering a machine are conceived. They constrain possible or desirable ends as well as the choice of means. A socio-technical systems perspective allows us to appreciate the recursive relationship between the social and the technological.

Many sustainable socio-technical systems are at a distinct structural disadvantage compared to those constituting incumbent regimes. The aim of transition research is to understand how sustainable regimes might become established over time. This involves studying how incumbent regimes become unsettled and replaced by alternatives. These alternatives develop in niches, which are the micro level in analysis for sustainability transitions.

Contexts and pathways for change will vary from case to case for complex socio-technical regimes (Smith et al. 2005, Geels and Schot 2007). In the context of sustainability, it is the possibility of accelerating transitions away from unsustainable regimes and along more sustainable pathways that preoccupies analysts and policy makers. Here, we debate a particular mode of purposive transition or transition management (Kemp et al. 1998, Rotmans et al. 2001, Smith et al. 2005, Loorbach 2007). We subsequently discuss critical issues in transition management with the purpose of generating cautionary lessons of relevance to social-ecological systems research. Before doing so, however, we contrast socio-technical systems research with social-ecological research, so that these lessons can be interpreted carefully.

SOCIO-TECHNICAL TRANSFORMATION AND SOCIAL-ECOLOGICAL RESILIENCE

The focus of socio-technical transitions research is different from social-ecological systems research in a number of respects: objects, objectives, structure or function, and resilience and transformation.

Objects

The unit of analysis in social-ecological research is a social-ecological system. This moves over time through a trajectory of states conditioned by various endogenous and exogenous processes, including technologies (Walker et al. 2006). Although comprising multiple interacting scales and levels, a social-ecological system is typically rooted in a particular spatial context such as a watershed, a rangeland, a forest, or a region. Here, resilience is the ability to maintain system structure and function in the light of both shocks and stresses in this wider environment (Berkes et al. 2003). The focus is on a particular setting in which material resources, ecological configurations, and environmental services may be implicated in, and affected by, the development and operation of a number of technological regimes.

For their part, socio-technical regimes are also complex, dynamic systems. Multilevel interactions such as niche, regime, and landscape constantly recondition configurations along path-dependent trajectories. Processes variously characterized as momentum (Hughes 1983), autonomy (Winner 1978), or lock-in (Arthur 1989) also involve the maintenance of given configurations in the face of shock or stress. In this respect, these properties are formally comparable to social-ecological resilience (Stirling, *in press*). However, socio-technical regimes are not as place-bound as social-ecological systems. Regimes operate simultaneously across multiple loci. As such, there exists no necessary mapping between the two objects of attention.

Consider, for example, the global automotive regime constituted by vehicles, road infrastructures, fuel supply networks, private transportation institutions, and car culture. Different sustainability

concerns are prompting various actors to explore switches from fossil fuels to biofuels, hydrogen, electricity, or synfuels. Each change implicates different patchworks of social-ecological systems through resource extraction, service consumption, and waste assimilation (Fig. 1).

Objectives

In social-ecological systems research, the objective is usually to support resilience in existing desired systems or, less frequently, transform such systems into more desirable states (Walker et al. 2006). Perspectives may differ, often implicitly, on the detail, but the desirability of states is typically judged in terms of the normative qualities highlighted in sustainability debates. These comprise various dimensions of human well-being, social equity, and ecological integrity. These qualities are addressed primarily in terms of a localized social-ecological setting.

In much research on socio-technical regimes, normative aims also reflect broad 'Brundtland qualities' (WCED 1987). But here, regime performance is typically framed in terms of more distributed technological and social practices that satisfy and help constitute human needs. Under the even more disparate perspectives that this entails, there is correspondingly greater scope for divergences of interpretation, evaluation, and prioritization. Attention is also more often directed at radical regime change than at maintaining the dynamic resilience in existing regimes. Indeed, where existing regimes are judged to be unsustainable, for instance, in energy, food, transport, water, or housing sectors, the point is that socio-technical resilience is an undesirable property (Walker et al. 2006). The aim of socio-technical research is thus usually focused on explaining and overcoming this negative resilience (Hoogma et al. 2002, Raven 2004, Smith 2007).

Structure or function?

Social-ecological research views resilience as the ability to maintain system structure and function in the face of both shocks and stresses (Berkes et al. 2003). If structures are synonymous with functions, as might conceivably be the case when ecological systems are viewed as subject to natural processes of dynamic stability, then this need not pose problems. However, as attention expands to include social and technological systems and to contemplate transformations in social-ecological systems as they stand, the point is often precisely that resilient structure can undermine the functions being sought. Thus, critical questions arise as to whether the object of resilience is structure or function (Stirling, *in press*; A. Stirling, *unpublished manuscript*). Definitions of resilience that explicitly conflate the two can become seriously problematic.

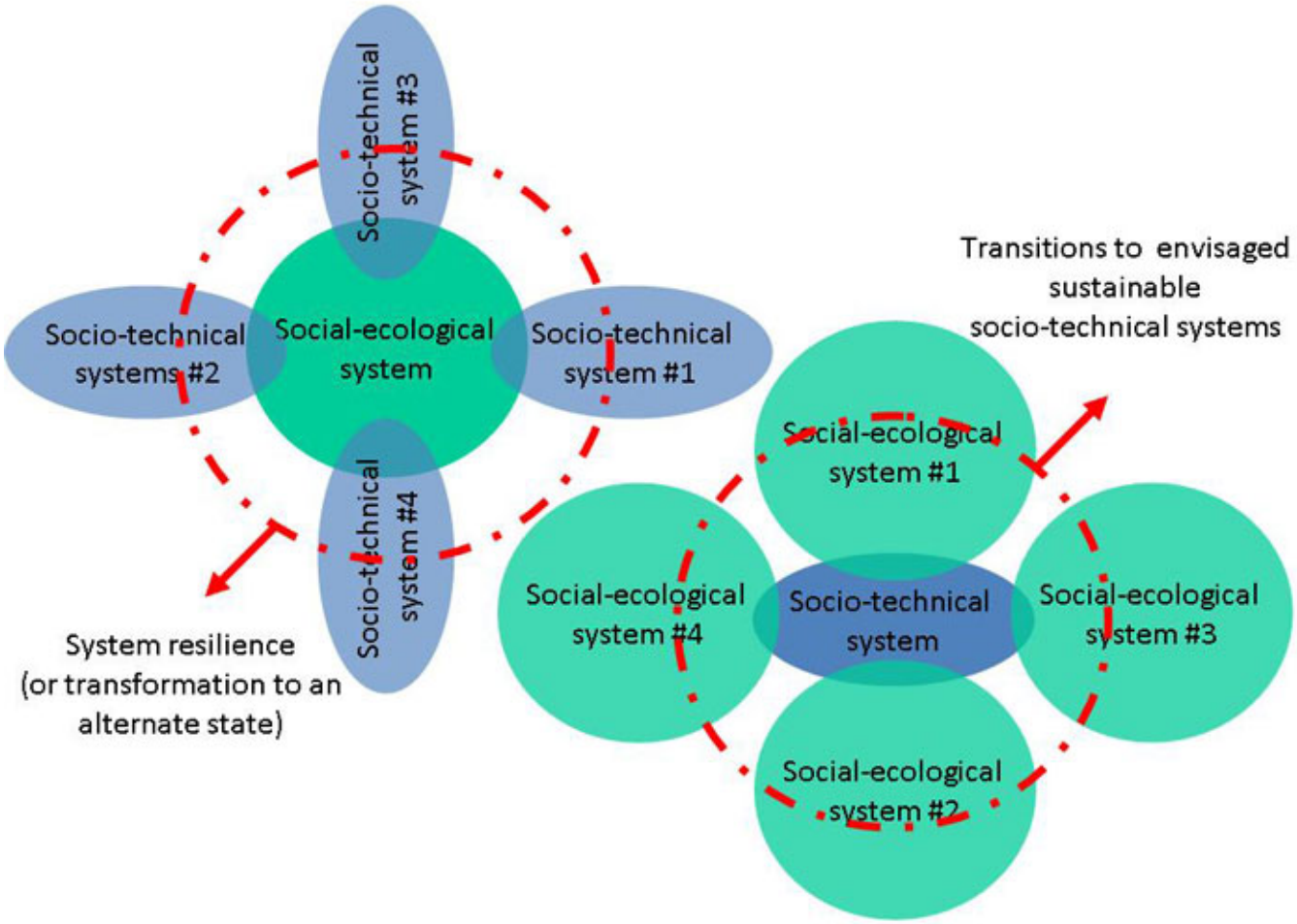
Transition management debates in socio-technical research focus directly on this problem. The particular socio-technical structures that are judged best in delivering requisite sustainability functions are often emphatically not the existing structures. It is thus intrinsic to socio-technical transitions that functional sustainability is best achieved through structural transformation. Incumbent socio-technical regimes are, by definition, structurally resilient. When regimes are no longer able to withstand shocks and stresses, they become destabilized (Smith et al. 2005). This process of decline and susceptibility to transformation renders them no longer regime-like. This intrinsic separability of structural and functional resilience remains to be fully appreciated in social-ecological research.

Resilience and transformation

A final area in which there exists a particular need for careful translation between socio-technical and social-ecological research concerns the contrasting circumstances of resilience in the face of disturbance vs. the robustness under a process of transformation. Each predicament may equally be intractable to control in ways that are well recognized in the social-ecological literature, demanding instead more open, humble, adaptive, response-based strategies (Berkes et al. 2003). However, although divergent contexts of disturbance and transformation are often acknowledged incidentally (Walker et al. 2006), many formal general definitions of social-ecological resilience continue to conflate responses to shock and stress (Berkes et al. 2003).

In socio-technical regimes, considerable investment is made in sustaining the performance of particular structures in the face of possible short-term episodic shocks, including safety margins, improved

Fig. 1. A schematic representation of differences and overlaps in the analysis and governance of social-ecological systems and socio-technical systems



communications, infrastructure maintenance, contingency planning, redundant capacity, personnel training, and regulatory provisions. However, where the focus shifts to structural transitions in the face of long-term secular stress, as with many sustainability threats, many of these measures can have the effect of inhibiting adaptability and transformability (Leach et al. 2010*a*; A. Stirling, *unpublished manuscript*). Take the case of strategies for the development of an agronomic system based on maize in the face of possible climate threats. When the challenge is conceived as one of increased frequency in intermittent droughts, then responses might best be seen in terms of the development of new drought-tolerant maize varieties and cultivation practices and in measures such as increased water and food storage capacity. When the challenge is conceived instead in terms of a secular shift toward a drier climate, then the response might best be seen as a transition away from a maize-based agronomy. In this event, investments in maize-focused provision can present serious opportunity costs, or actively consolidate the commitment to maize. When definitions of resilience fail to discriminate between responses to shock and stress, this kind of dilemma is obscured (Leach et al. 2010*b*).

When a socio-technical perspective prompts greater attention to these kinds of issues, there arises a need

to discriminate more systematically between strategies aimed at maintaining performance under short-term episodic shocks, and policies oriented toward transformations in the face of long-term secular stresses. In each case, the object is to maintain requisite levels of functionality. It is the configurations of the structures in question that are subject to resilience or transformation. Recognizing that each may involve control- or response-based interventions, these contexts might involve significantly contrasting dynamic properties (A. Stirling, *unpublished manuscript*). It is in keeping with much colloquial and technical usage of the term, including in the social-ecological literature (Walker et al. 2006), that a strictly defined property of resilience be held properly to refer to response-based strategies under shock. The contrasting property fostered by response-based strategies under stress might better be referred to by a different term such as robustness (A. Stirling, *unpublished manuscript*). This insight context seems as relevant to the social-ecological as the socio-technical context (Dawson et al., *in press*).

Having positioned technology in social-ecological change and noted important but neglected differences with social-technical systems research, we turn to our third aim. Whatever the precise meaning and purpose of building resilience or promoting transformation in systems, it is clear that questions of governance will be central to achieving one's aims. We next address to what extent critical issues in transition management are relevant to adaptive governance.

TRANSITION MANAGEMENT

Few historical regime transitions were explicitly directed by collective, socially deliberated, long-term goals like sustainability (Smith et al. 2005). Public health and sanitation in industrialized countries in the late 19th century is a comparable historical example. Nevertheless, historical studies that trace the emergence of new regimes back to originating niches (e.g., Geels 2005) inspire ideas for purposive sustainability transitions. Transition management focuses on facilitating an evolution of sustainable regimes out of green niches. This includes favoring the selection environment for green niches by putting incumbent regimes under significant sustainability pressure.

Niches provide protective settings that reduce susceptibility to prevailing market pressures. Radical sustainable innovations that carry systemic implications typically need this kind of space to develop, improve, and enroll support (Kemp et al. 1998, Smith 2007). Transition management puts this niche-based, evolutionary view of change within an iterative, four-stage cyclical governance framework (Rotmans et al. 2001, Kemp et al. 2007, Loorbach 2007). Advocates envisage greater interaction than the sequence presented below, which appears linear only for purposes of presentation.

1. **Problem structuring and goal envisioning**
   Multistakeholder transition arenas, usually facilitated by a government department, develop a shared vision for attaining sustainability goals (van der Brugge and Van Raak 2007). Scenario-building techniques turn sustainability goals into practical visions for future sustainable socio-technical systems (Sondeijker et al. 2006). Visions provide a promising orientation for subsequent governance activities.

2. **Transition pathways and experiments**
   Participants identify pathways toward transition visions using back-casting methods (Quist 2007). Pathways provide a framework for the subsequent development of niche experiments. A portfolio of niches is created. Successful niche pre-development is followed by a period of take-off and acceleration, before culminating in stabilization within a more sustainable regime (Rotmans et al. 2001).

3. **Learning and adaptation**
   Learning and adaptation provide the essential links among long-term goals, socio-technical pathways, and short-term actions in niche experiments. Lessons are drawn not just for instrumental improvement of the niche, but also institutional reforms. A better understanding of the institutional constraints and opportunities for the sustainable practices is at the heart of niche experiments (Hoogma et al. 2002).

4. **Institutionalization**
   Acknowledged to be the most important element, institutionalization is considered least in the transition management literature (Smith and Kern 2009). This is the point at which serious commitments are needed, to such an extent that the incumbent regime

suffers and is undermined if they are not made (Smith et al. 2005, Shove and Walker 2007). Politically and economically, institutionalization is very difficult. It involves mobilizing serious selection pressures against the incumbent regime and redirecting vast institutional, economic, and political commitments into promising niches along desired pathways.

Overall, transition management injects goal-directing processes into socio-technical transformations.

CRITICAL CHALLENGES FOR TRANSITION MANAGEMENT

In practice, different socio-political constituencies within and beyond regimes adopt strongly divergent positions over different socio-technical possibilities, even when these are thought of as equally sustainable. These critical political dynamics challenge straightforward managerial understandings of transition management (Smith et al. 2005, Smith and Stirling 2007). We next consider a number of difficulties that flow from this and that are of relevance to adaptive governance: Who governs? Whose system counts? Whose sustainability gets prioritized?

Who governs?

An obvious initial question concerns the locus of transition-governing activities and who is involved. The multilevel socio-technical perspective cuts across policy sectors, involving multiple government agencies, institutions, and policy networks. A state actor may be the facilitating agent, but transition initiatives must primarily be implemented within business communities and civil society (Kemp and Loorbach 2006).

In terms of participation, advocates argue that transition management should initially comprise visionary forerunners. Such individuals are seen as empathetic to sustainability goals, open-minded, able to convey the transition vision back to their constituency, and able to influence their constituency's behavior. They are willing to put time, energy, and resources into the challenges of: collectively envisioning viable sustainability goals; nurturing promising niches; building supportive constituencies of actors, institutions, and markets; and continually anticipating, learning, and adapting (Kemp and Loorbach 2006). Transition arenas thus build a network of change agents that are partly independent from the normal policy-making networks dominated by incumbent interests (Kemp and Loorbach 2006).

Transition managers appear as a vanguard sitting apart from governance actors within incumbent socio-technical regimes, but nonetheless seeking to intervene and transform (Smith and Stirling 2007). Deliberations over structural transformations of socio-technical regimes affecting the lives of millions of people are seen as led by an elite group of visionary forerunners. Critics interpret this as a highly technocratic vision (Hendriks 2008, Scrase and Smith 2009). It is unclear how transition management processes sit in relation to prevailing policy institutions and political activities. Transition management is not unique in this regard, as other participatory approaches share this dilemma. However, given ambitions to transform the structures of our everyday lives, this unclear relationship is especially problematic because the basis for authority, legitimacy, and accountability in transition governance will ultimately rest on the way it engages with other political processes and institutions.

Relations with wider democratic politics become significant here (Hendriks 2008). Sustainability goals derive from conventional public policy arenas and associated institutions for democratic and accountable oversight. However, it remains unclear how involved these institutions are in the development of specific visions and pathways. Should institutions of representative democracy become more directing toward the content of the visions and experiments followed? Some argue that it can be difficult for parliaments to engage in the long-term, specialist deliberations involved in transition management (Meadowcroft 2005). This prompts some analysts to consider the novel sources of direct democratic legitimacy that are prevalent in debates about networked governance (Hendriks 2008).

Many processes contributing to the reproduction or transformation of socio-technical regimes operate across jurisdictional boundaries. They exist in increasingly globalized networks of capital, knowledge, people, skills, and resources. Multilevel and polycentric governance imperatives are critical

to transition management, as they are to social-ecological systems research. However, this is easier said than done. In recognizing the necessity to operate across many polities, there emerges a considerable challenge in influencing critical nodes of intervention that are not only highly distributed, both spatially and temporally, but are also intrinsically inaccessible and subject to divergent interests.

Whose system counts?

Transition management has to bound, partition, and order the system under consideration. Delineations among niches, regimes, and landscapes can be unclear (Smith et al. 2005, Smith 2007). The empirical operation of key concepts is ambiguous across cases in the literature (Genus and Coles 2008). Of course, transition research is not unique in its sensitivity to analytical framings, but the high stakes in transition management, its instrumental purpose, and the pressing timelines accentuate these analytical difficulties (Smith and Stirling 2007, Walker and Shove 2007).

Various participants in the transition arena will carry their own mental model of the socio-technical system, its key components, major processes of development, their own positioning, and favored strategies for sustainable transformations, whether proactive or resistant. Actors are situated in diverse contexts, bring contrasting knowledge or experience, and hold contending interests and purposes. Different groups will bring disparate framings of the system, both in terms of its structure and its function (Scoones et al. 2007).

Part of the purpose of transition governance is to negotiate these divergent framings and attain a shared formulation of the system and commitment to common transition pathways. The question of who governs gets re-emphasized, not simply for democratic reasons, but also because it has a material effect on the construction of the socio-technical system in question (Smith and Stirling 2007). It demands an open reflexivity on the part of participants, including analysts (Stirling 2006). It also requires transition management to be as attentive to the opening up of alternative system framings and norms as to closing down around a subset of pathways (Stirling 2008).

Whose sustainability gets prioritized?

The political nature of systems boundary work is underscored when we consider the inherent ambiguity, and thus contestability, of sustainable development itself (Voss et al. 2007). Specific goals are often far from self-evident, seldom clear, and susceptible to highly variable rankings (Smith et al. 2005). Headline goals for sustainability, such as carbon reduction, can command broad rhetorical consensus. However, more specific environmental, economic, and social criteria are hotly contested, with profound implications for favored pathways. In the case of low-carbon energy systems, attitudes to radioactive waste, nuclear proliferation, landscape effects, and biodiversity loss condition the rankings of visions for nuclear, wind, tidal energy, and biofuels. Even on occasions in which there is no significant scientific uncertainty over physical effects, emissions, or their consequences, there may typically be strong ambiguities over the choice of indicators (Shove and Walker 2007), the framing of metrics (Stirling 1999), the setting of satisfactory levels of protection, and the relative weighting to place on different forms of harm (Dreyer and Renn 2008). This leaves crucial questions as to whose judgments should prevail at any point in time, especially because shifts and learning in social values or interests can reverse perceptions of hitherto favored socio-technical pathways (Voss et al. 2007).

Many of the above criticisms are readily apparent to transition management advocates. Transition management is clear in encouraging reflexive and adaptable learning over uncertainties and the passage of time. However, this tends to focus on the micro level modalities through which given visions are realized, not to shifts or pluralities in the visions themselves. Concerns tend to be interpreted as challenges requiring refinement to processes of engagement and negotiation within the transition management framework, rather than necessitating fundamental reconceptualizations of how structural change originates and proceeds, for example, via class-based or counter-hegemonic perspectives in political economy (Scrase and Smith 2009).

The point is not that transition management imposes some fixed, prior view of the socio-technical regime, sustainability goals, or desirable pathways. It is clear how these can be negotiated and realized through better transition arenas. Rather, the issue is that governing transitions is more complex than

simply negotiating closure around a particular vision of sustainability. The driving aims, orientations, and modalities of sustainability itself, not just the managerial instrumentalities, are much more plural in practice and are continually open to radical reformulation. Questions over the political conditions for the kinds of consensus and coordination implied by transition management, and how these conditions are to be achieved, have yet to be addressed fully.

Power and politics

Interlinked with, but even less tractable than this, is the question of agency and power in and over incumbent socio-technical regimes. With notions of sustainability displaying such malleability to strategic interpretation, how credible is it that a transition management process that begins within a vanguard of elite visionary forerunners can really overturn structurally embedded regimes? How realistic is it to expect the pervasive infrastructures of these regimes to be responsive to the more challenging lessons generated in transition management?

Moreover, long-lived decisions such as which kinds of power station to invest in, what forms of housing to provide, or which transport infrastructure to develop may be susceptible to future adaptation only around the edges. It might be possible to attend to 'future-proofing' and adaptation, but the typical picture in socio-technical regimes is one of obduracy. It cannot be assumed that existing institutions and infrastructures will afford the requisite space and resources for the kinds of continual adaptations and social learning necessary for effective transition governance (Meadowcroft 2005). Transition management has to consider how to engage with these power relations to realize the envisaged transitions and boost the development of promising niches.

Power and agency are not as straightforward as they might first appear. The investment decisions of an infrastructure business like an energy utility, as well as those of its regulator, are each significant for the continuing development of the socio-technical regime. However, the regime is also effectively reproduced by millions of small, routine decisions taken by end users, often invisibly. Although a utility company or political authority clearly has the capacity to introduce greater changes than everyday users, the latter's responses complicate the ability of the former to anticipate outcomes precisely (Shove and Walker 2007). For instance, European Union policy for enhanced producer responsibility for electronic waste intended to promote the greener design of inherently less wasteful electronic products. However, this intervention actually prompted producers to develop waste management systems instead, including dumping low-grade waste in poorer countries (Hagelskjær Lauridsen and Jørgensen 2010).

Structural change in something as pervasive as a socio-technical regime entails both losers and winners. In considering what a transition to sustainability actually means, the stakes are typically very high (Meadowcroft 2005). Targeted socio-technical interventions carry implications for the kinds of innovation that are valued in transition experiments, and subsequently attain a marketable and political significance, compared to those innovations that do not. What gets written into and out of transition management has distributional consequences. Inevitably, regime incumbents have to become involved in socio-technical transitions because they occupy a critical position in regime reproduction and change. This is the pragmatic position. However, the fear is that this requires more powerful countervailing constituency-seeking changes of a kind opposed by incumbents, thus risking capture of the transition management process (Smith and Kern 2009).

An important source of countervailing pressure lies in favorable events beyond the transition arena. This includes the mass mobilization of a social movement demanding greater sustainability or a series of environmental or economic crises bestowing greater credibility on radical arguments within a transition arena. At these moments, the interdependencies that made the regime so enduring can become problematic because they constrain responses to these significant new pressures.

It is under such circumstances that transition management may be able to harness more powerful support. However, this is beyond the agency of those engaged in the transition arena itself. Rather, it requires the arena to develop a capacity for positioning itself favorably in the light of ongoing political processes, mobilizing support, influencing agendas, and redirecting investments and other commitments away from incremental repair work and toward more radical transition goals. Although

some of the above challenges can be addressed by 'doing transition management better', these questions of power reinforce the complementary need for a broader political project (Scrase and Smith 2009). This kind of reflexive governance is already practiced on a day-to-day basis by the social groups and movements who lobby to get their social-ecological priorities heard by political and economic elites and who create alternative niches offering inspiring solutions for others to adopt and adapt (Stirling 2006). They contribute pressures that constantly interrogate particular framings of socio-technical regimes and transition management, and which reopens those framings for debate.

CONCLUSIONS

Socio-technical regimes shape social-ecological systems in positive and negative ways. Socio-technical regimes are constituted by a form of resilience that is formally congruent with this same dynamic property in social-ecological systems. However, the contrasting normative and substantive context of technology means that the implications of resilience may contrast strongly between these areas. Researchers must reflect on what precisely it is that is being made resilient, in the face of which specific dynamics, for whom and by what criteria this is good or bad, and whether such resilience is consequently problematic or not.

It is important to translate ideas carefully between the two areas of study. It is therefore incumbent upon us to do so by interpreting how critical issues in transition management speak to future research in the adaptive governance of social-ecological systems.

On first inspection, the anchoring of social-ecological systems in specific places makes the delineation of governance structures and processes appear more straightforward. A place-based political jurisdiction will sit at the heart of the polycentric governance arenas relevant to the structure and function of a social-ecological system. Because many jurisdictions are drawn along territorial lines, one might expect a higher degree of congruency between objects and governance than is the case for transition management, in which the core system is composed of those distributed social and technological processes constituting a societal function. Perhaps the critical issues of bounding the system, coordinating governance, and ensuring effective links to democratic politics are less onerous?

We are not so sure. Criticisms about insufficient attention to the interests, framings, and power relations among the various actors complicate these practical considerations. The recognition that drawing boundaries and understanding the stakes involved is far from self-evident begs questions about whose system counts even for spatially rooted systems in clearly delineated jurisdictions. As many authors point out, places are actually governed by multilevel processes, which opens this question to an even wider set of interests and constituencies (Folke et al. 2005, Lebel et al. 2006). The governance of social-ecological systems confronts similar normative, epistemic, and ontological challenges to transition management.

In our view, the opening up of explicit analyses of power and politics is just as salient to social-ecological systems as to sustainability transitions (Stirling 2008). This opens up a host of vitally important questions. How do challenging bottom-up governance initiatives confront the deeply structural forms of economic power vested in current global patterns of system reproduction? How are different bodies of knowledge and interests in social-ecological systems negotiated? How is consent achieved, and how is dissent reconciled? To what extent are plural development pathways tolerated, and how is dialogue between their advocates and constituents maintained? How should these problem-focused, adaptive, and reflexive governance activities link to the more general-purpose and formal institutions of political authority and democracy? What alternate forms of direct democracy can be brought into adaptive governance and transition management?

This suggests a further final line of inquiry. It hinges on recognition that the wider politics of sustainability already exercise a form of reflexive governance, however imperfectly, by challenging governance appraisals and commitments and introducing pressure to open up the ways that current socio-technical and social-ecological systems are governed. The essence of reflexivity is that research is not just a means to understand the wider politics, but also helps to constitute it.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol15/iss1/art11/responses/

Acknowledgments:

We are grateful to the Economic and Social Research Council for funding the STEPS Centre and the Sussex Energy Group, which provided the space for us to develop the ideas in this paper. Our thinking benefited from discussing earlier versions of this work with participants at the IHDP Berlin Conference and the Resilience Alliance Conference in 2008. We also thank Jan-Peter Voss, Per Olsson, Victor Galaz, and two anonymous referees for comments on an earlier version of this article.

LITERATURE CITED

Anderies, J. M., M. A. Janssen, and E. Ostrom. 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society* **9**(1): 18. [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art18.

Arthur, W.B. 1989. Competing technologies, increasing returns, and lock-in by historical events. *Economics Journal* **99**(394):116-131.

Berkes, F., J. F. Colding, and C. Folke, editors. 2003. *Navigating nature's dynamics: building resilience for complexity and change.* Cambridge University Press, New York, New York, USA.

Berkhout, F., and A. Gouldson. 2003. Inducing, shaping, modulating: perspectives on technology and environmental policy. Pages 231-260 *in* F. Berkhout, M. Leach, and I. Scoones, editors. *Negotiating environmental change.* Edward Elgar, Cheltenham, UK.

Bijker, W. E. 1997. *Of bicycles, bakelites and bulbs: toward a theory of sociotechnical change.* MIT Press, Cambridge, Massachusetts, USA.

Dawson, T., M. Rounsevell, T. Kluvánková-Oravská, V. Chobotová, and A. Stirling. *In press.* Dynamics of complex adaptive ecosystems for service provision. *Biodiversity and Conservation.*

Dreyer M., and O. Renn, editors. 2008. *Food safety governance: integrating science, precaution and public involvement.* Springer, Berlin, Germany.

Folke, C., T. Hahn, P. Olsson, and J. Norberg. 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* **30**:441-473.

Foxon, T. J., M. S. Reed, and L. C. Stringer. 2009. Governing long-term social-ecological change: What can the resilience and transitions approaches learn from each other? *Environmental Policy and Governance* **19**(1):3-20. Available online at: http://www3.interscience.wiley.com/cgi-bin/fulltext/121659841/PDFSTART.

Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multilevel perspective and a case-study. *Research Policy* **31** (8-9):1257-1274.

Geels, F.W. 2005. *Technological transitions and system innovations: a co-evolutionary and sociotechnical analysis.* Edward Elgar, Camberley, UK.

Geels, F. W., and J. Schot. 2007. Typology of sociotechnical transition pathways. *Research Policy* **36**:399-417.

Genus, A., and A-M. Coles. 2008. Rethinking the multi-level perspective of technological transitions. *Research Policy* **37**:1436-1445.

Hagelskjær Lauridsen, E., and U. Jørgensen. 2010. Sustainable transition of electronic products through waste policy. *Research Policy, in press.*

Hendriks, C. 2008. On inclusion and network governance: the democratic disconnect of Dutch energy transitions. *Public Administration* **86** (4):1009-1031.

Hoogma, R., R. Kemp, J. Schot, and B. Truffer. 2002. *Experimenting for sustainable transport: the approach of strategic niche management.* Spon Press, London, UK.

Hughes, T.P. 1983. *Networks of power: electrification in Western society, 1880-1930.* Johns Hopkins University Press, Baltimore, Maryland, USA.

Kemp, R., and D. Loorbach. 2006. Transition management: a reflexive governance approach. Pages 103-130 *in* J-P. Voss, D. Bauknecht, and R. Kemp, editors. *Reflexive governance and sustainable development.* Edward Elgar, Camberley, UK.

Kemp, R., J. Rotmans, and D. Loorbach. 2007. Assessing the Dutch energy transition policy: how does it deal with dilemmas of managing transitions? *Journal of Environmental Policy & Planning* **9** (3):315-331.

Kemp, R., J. Schot, and R. Hoogma. 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology Analysis and Strategic Management* **10**(2):175-195.

Langridge, R., J. Christian-Smith, and K. A. Lohse. 2006. Access and resilience: analyzing the construction of social resilience to the threat of water scarcity. *Ecology and Society* **11**(2): 18. [online] URL: www.ecologyandsociety.org/vol11/iss2/art18/.

Leach, M., I. Scoones, and A. Stirling. *2010a.* Governing epidemics in an age of complexity: narratives, politics and pathways to sustainability. *Global Environmental Change* **20**, *in press.*

Leach, M., I. Scoones, and A. Stirling. *2010b. Dynamic sustainabilities: technology, environment, social justice.* Earthscan, London, UK, *in press.*

Lebel, L., J. M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. Hughs, and J. Wilson. 2006. Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society* **11**(1): 19. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art19.

Loorbach, D. 2007. *Transition management: new mode of governance for sustainable development.* International Books, Utrecht, The Netherlands.

Meadowcroft, J. 2005. Environmental political economy, technological transitions and the state. *New Political Economy* **10**(4):479-498.

Olsson, P., L. H. Gunderson, S. R. Carpenter, P. Ryan, L. Lebel, C. Folke, and C. S. Holling. 2006. Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. *Ecology and Society* **11**(1): 18. [online] URL: www.ecologyandsociety.org/vol11/iss1/art18/.

Quist, J. 2007. *Backcasting for a sustainable future: the impact after 10 years.* Eburon, Delft, Netherlands.

Raven, R. P. J. M. 2004. Towards alternative trajectories? Reconfigurations in the Dutch electricity regime. *Research Policy* **35:**581-595.

Rip, A., and R. Kemp. 1998. Technological change. Pages 327-399 *in* S. Rayner and E. Malone, editors. *Human Choices and Climate Change 2*. Battelle, Columbus, Ohio, USA.

Rotmans, J., R. Kemp, and M. van Asselt. 2001. More evolution than revolution: transition management in public policy. *Foresight* **3**(1):15-31.

Russell, S., and R. Williams. 2002. Social shaping of technology: frameworks, findings and implications for policy with glossary of social shaping concepts. Pages 37-132 *in* K. H. Sørensen and R. Williams, editors. *Shaping technology, guiding policy: concepts, spaces and tools.* Edward Elgar, Camberley, UK.

Scoones, I., M. Leach, A. Smith, S. Stagl, A. Stirling, and J. Thompson. 2007. *Dynamic systems and the challenge of sustainability.* STEPS Working Paper 1, STEPS Centre, Brighton, UK.

Scrase, I., and A. Smith. 2009. The (non-) politics of managing low carbon sociotechnical transitions. *Environmental Politics* **18**(5):707-726.

Shove, E., and G. Walker. 2007. CAUTION! Transitions ahead: politics, practice and sustainable transition management. *Environment and Planning A* **39**(4):763-770.

Smith, A. 2007. Translating sustainabilities between green niches and sociotechnical regimes. *Technology Analysis & Strategic Management* **19** (4):427-450.

Smith, A., and F. Kern. 2009. The transitions storyline in Dutch environmental policy. *Environmental Politics* **18**(1):78-99.

Smith, A., and A. Stirling. 2007. Moving outside or inside? Objectification and reflexivity in the

governance of sociotechnical systems. *Journal of Environmental Policy & Planning* **9**(3-4):351-373.

Smith, A., A. Stirling, and F. Berkhout. 2005. The governance of sustainable sociotechnical transitions. *Research Policy* **34**:1491-1510.

Sondeijker, S., J. Geurts, J. Rotmans, and A. Tukker. 2006. Imagining sustainability: the added value of transition scenarios in transition management. *Foresight* **8**(5):15-30.

Stirling, A. 1999. The appraisal of sustainability: some problems and possible responses. *Local Environment* **4** (2):111-135.

Stirling, A. 2006. Uncertainty, precaution and sustainability: towards more reflective governance of technology. Pages 225-272 *in* J. Voss and R. Kemp, editors. *Sustainability and reflexive governance.* Edward Elgar, Cheltenham, UK.

Stirling, A. 2008. Opening up and closing down: power, participation and pluralism in the social appraisal of technology. *Science Technology and Human Values* **33**(2):262-294.

Stirling, A. *In press.* Precaution, robustness and diversity in governance of technological vulnerabilities. *In* W. Bijker, J. Mesman, editors. *Technological vulnerability,* Oxford University Press, Oxford, UK.

van der Brugge, R., and R. van Raak. 2007. Facing the adaptive management challenge: insights from transition management. *Ecology and Society* **12**(2): 33. [online] URL: http://www.ecologyandsociety.org/vol12/iss2/art33.

Voss, J.-P., J. Newig, B. Kastens, J. Monstadt, and B. Nölting. 2007. Steering for sustainable development: a typology of problems and strategies with respect to ambivalence, uncertainty and distributed power. *Journal of Environmental Policy & Planning* **9**(3-4):193-212.

Walker, B., L. Gunderson, A. Kinzig, C. Folke, S. Carpenter, and L. Schultz. 2006. A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society* **11**(1): 13. [online] URL: www.ecologyandsociety.org/vol11/iss1/art13/.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzing. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* **9**(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5.

Walker, G., and E. Shove. 2007. Ambivalence, sustainability and the governance of socio-technical transitions. *Journal of Environmental Policy & Planning* **9**(3-4):213-225.

World Commission on Environment and Development (WCED). 1987. *Our Common Future.* Oxford University Press, Oxford, UK.

Winner, L. 1978. *Autonomous Technology.* MIT Press, Cambridge, Massachusetts, USA.

Young, O., F. Berkhout, G. C. Gallopin, M. A. Janssen, E. Ostrom, and S. van der Leeuw. 2006. The globalization of social-ecological systems: an agenda for scientific research. *Global Environmental Change* **16**:304-316.