Viability: A Priority Criterion for the Mitigation of Climate Change and other Complex Socio-Ecological Issues

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Abstract

At present many researchers are exploring ways to improve the resilience of the global system, prevent catastrophic failure, and support the transition to a sustainable global system. This paper makes two interlinked proposals for developing better—and more credible—tools for modeling critical global issues and identifying and managing threats. First, proven risk management methods from other fields can be usefully applied to the assessment and mitigation of large, complex socio-ecological problems. Second, using viability as the priority criterion for the design of our models will not only highlight systemic threats, but also help us develop constructive interventions.

Keywords: socio-ecological, risk management, viability, modeling, non-linear, systems, safety, critical, causal diagrams, Bayesian networks

The need for new models and methods

Critical global problems like climate change, growing shortages of essential resources (such as water, food, energy and critical minerals) and the loss of biodiversity are getting worse. Many experts (Bierbaum et al., 2007) believe that humanity's greatest challenge is to find ways to keep these problems from becoming catastrophic.

Attention is increasingly focusing on risk assessment and management. Christopher Field, co-chair of the 2014 Intergovernmental Panel on Climate Change (IPCC) report on the impacts of rising temperatures, states: "The IPCC has transitioned to what I consider to be a full and rich recognition that the climate change problem is about managing risk" (Reuters, 2013).

Awareness is growing also that better methods are needed to assess global risks and ensuring desirable outcomes. For example, in the financial sector Bloomberg is now trialing a carbon-risk evaluation tool for investors (Bloomberg, 2013), and the Investor Network on Climate Risk (a network of 100 institutional investors representing more than $11 trillion in assets) is advising insurance companies to develop catastrophic models capable of anticipating the probable effects of climate change on extreme weather events (Leurig & Dlugolecki, 2013).

At the same time there is increasing concern that current models dangerously underestimate global risks. British economist Nicholas Stern says:

> Scientists describe the scale of the risks from unmanaged climate change as potentially immense. However, the scientific models, because they omit key factors that are hard to capture precisely, appear to substantially underestimate these risks. Many economic models add further gross underassessment of risk because the assumptions built into the economic modeling on growth, damages and risks, come… close to excluding the possibility catastrophic outcomes. A new generation of models is needed in all three of climate science, impact and economics...(Stern, 2013).

The lack of clarity regarding risks and remedies confuses public discourse and delays constructive action. However, large socio-ecological problems are difficult to model, analyse and mitigate because they involve interacting environmental, economic and social systems with complex, non-linear dynamics (Gunderson & Holling, 2002).

This is not to say that these issues have not been studied. Over the last fifty years systems thinkers have developed sophisticated theories of how natural and social systems develop and change. These include theories of how societies evolve (e.g. Taylor, 1972) and/or collapse (Tainter, 1988); how paradigms shift (Capra, 1982); the panarchy cycle of transformation (Gunderson and Holling, 2002); studies of major socio-ecological problems and their interactions (Homer-Dixon, 2006), and proposals for systemic redesign (Beddoe et al., 2009).

At present researchers from many disciplines are exploring ways to improve the resilience of the global system, prevent catastrophic failure, and support the transition to a sustainable global system (Markley, 2011). Nevertheless, these discussions are not yet part of mainstream political and economic thinking.

This paper examines this problem and makes two interlinked proposals for developing better—and more credible—tools for modeling critical global issues and identifying and managing threats. First, proven risk management methods from other fields can be usefully applied to the assessment and mitigation of large, complex socio-ecological problems. Second, using viability as the priority criterion for the design of our models will not only highlight systemic threats, but also help us develop constructive interventions.

The growing threat of climate change

Climate change is an example of a difficult ("wicked") socio-ecological problem. UN Secretary-General Ban-Ki Moon warns:

> Scientists have long sounded the alarm. Top-ranking military commanders and security experts have now joined the chorus. Yet the political class seems far behind…. Too many leaders seem content to keep climate change at arm's length, and in its policy silo. Too few grasp the need to bring the threat to the center of global security, economic and financial management (Moon, 2013).

Adaptation, although necessary, will not prevent dangerous climate change (Ackerman & Stanton, 2013a). We risk passing irreversible tipping points, such as the release of vast quantities of methane from melting permafrost (Schuur & Abbott, 2011) and the extinction of major marine ecosystems due to acidifying oceans (Hönisch et al., 2012).

Figure 1 illustrates three future scenarios. If we continue with business as usual we will soon reach a critical threshold—the tipping point where positive feedbacks trigger a self-amplifying process of runaway global warming (red zone on left). Eventually this could make our planet uninhabitable (Hansen et al., 2013). Current international agreements will fail to stabilize the global climate (Anderson & Bows, 2011)—they will only delay disaster (Sherwood et al., 2014). As a consequence, the only safe course is to take quick action to not only stop further pollution, but also to draw carbon out of the atmosphere and restore global temperatures to a stable level (green zone on right).

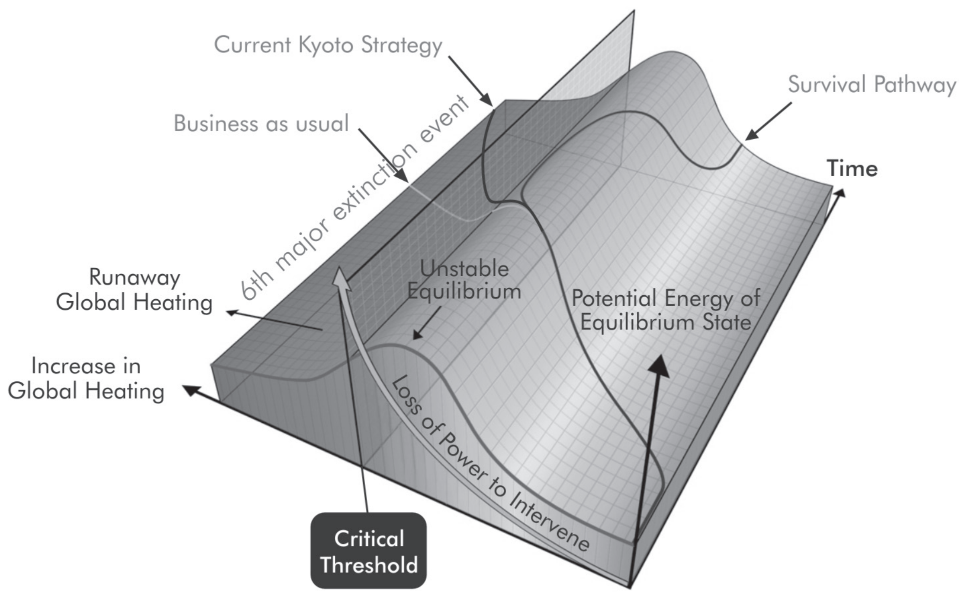

Figure 1. An illustration of the dynamics and risks of non-linear climate change. (Wasdell, 2006)

With mitigation options rapidly shrinking (Stocker, 2013), concerted international intervention is urgently required. However, because most decision-makers fail to understand the gravity of the global emergency, the political will to act is missing.

Using a safety-critical approach

Analyzing and managing large, complex risks

Sophisticated tools for assessing and managing risk are used in many arenas. Why are we are not applying the same methods and standards to manage humanity's biggest risks—the potentially catastrophic threats posed by climate change and other major socio-ecological problems?

Large global problems are frequently viewed as too complex to allow risk to be accurately evaluated, let alone managed. But Nick Mabey and his colleagues argue:

> Public policy decisions (ranging from military procurement, to interest rates, to financial system regulation) are taken under higher levels of uncertainty than exists over climate change science, impacts or policy choices. In fact the range of uncertainty in climate change is generally smaller than that common in long-term security analysis (Mabey et al., 2011).

The enormous cost of mitigation is also seen to be a barrier to managing climate change risk. This view is countered by Frank Ackerman and Elizabeth Stanton:

> Protection against threats of incalculable magnitude – such as military defense of a nation's borders, or airport screening to keep terrorists off of planes – is rarely described as "too expensive." The conclusion that climate policy is too expensive thus implies that it is an option we can do without, rather than a response to an existential threat to our way of life. (Ackerman & Stanton, 2013)

Political priorities can rapidly shift when leaders believe that there is a threat to national security. Whole economies can be mobilized to meet emergencies, as occurred in the Second World War, when many nations allocated 40%-75% of their GDP to military production. Following the "911" attack on the United States, and the global financial crisis of 2008, politicians quickly overcame normal budgetary constraints, allowing trillions of dollars of new funds to be accessed.

Most political and business leaders are unlikely to take urgent action on climate change unless it is framed as a security threat (i.e. reframed from being a primarily environmental issue). Decision-makers need to understand that runaway climate change will damage more than the environment: because it will progressively destroy economic and social stability, it is a growing threat to the long-term survival of their societies.

To frame climate change (and other interacting socio-ecological problems) as a security emergency, policy advisors will have to focus on risk assessment and management: on identifying both dangerous threats and the requirements for safe outcomes. This will require a change of approach from reducing risks and damages and maximizing adaptation (e.g. US Department of Homeland Security 2012) to ensuring the long-term viability and safe functioning of critical socio-ecological systems.

Ensuring safe outcomes

Fields such as aerospace, medicine, business, energy and defense have proven methods for analyzing complex problems, managing risk and ensuring safe outcomes (Bowen & Stavridou, 1993; Fowler, 2004; U.S. Department of Defense, 1993). These methods focus on managing dangerous risks and ensuring safe, viable outcomes. Many of these "best practices" can be usefully applied to managing complex socio-ecological issues where safe, viable outcomes are essential.

For example, when designing an airplane or space vehicle, aerospace engineers take a safety-critical (or "life-critical") approach: they work on the assumption that the failure of any key component could have unacceptable consequences. Developing a fail-safe system begins with establishing the critical parameters for its safe operation – the "Safety Case". The Safety Case determines the design requirements. "Mission Assurance" methodologies are then used to build, operate and maintain the vehicle to standards that ensure that essential human and mechanical systems always function within wide safety margins (Gregory, 1996; Alberts & Dorofee, 2005).

We should take a similar safety-critical approach to designing a safe future for humanity. The starting point is to establish the critical biophysical and social parameters of a sustainable global system. These parameters will then determine the Safety Case--the structures and processes needed to develop and maintain a viable planetary system. Then Mission Assurance methods can be used to make the necessary changes needed to prevent catastrophic failures, strengthen systemic resilience (Evans & Steven, 2009) and ensure that every critical element always functions within wide safety margins (Smith, 2006).

Managing crises—the Apollo 13 example

The story of the 1970 Apollo 13 moon mission demonstrates how a safety-critical approach can be used to manage an emergency (NASA, 2001). After an oxygen tank exploded, the spacecraft's life-support systems began to fail. NASA's challenge was to devise a way to keep the astronauts alive and return them safely to Earth. Their successful crisis management approach can be summarized as:

- First determine the essential requirements for mission viability;
- Then determine critical timelines;
- Then determine available resources;
- Then design a solution that restructures available resources within the required timeframe to meet critical mission requirements.

The current global emergency is similar in nature to the Apollo 13 crisis. Spaceship Earth's life-support systems are failing and we also need to rapidly reconfigure existing resources in order to re-establish a safe, livable environment.

Unfortunately, unlike Apollo 13, Spaceship Earth does not have a proactive management team that is united around the goal of ensuring safe outcomes. Reactive, piecemeal methods based on obsolete mental models prevent us from recognizing the severity and immanence of the global emergency, let alone managing it (Taylor & Taylor, 2007a; Evans & Steven, 2009).

Applying a safety-critical approach to socio-ecological systems

Proactive, whole-systems thinking

Global risk management must be proactive because future environmental and social conditions will be different from anything humanity has experienced. Ian Dunlop warns: "It should not rely on backward-looking historical analysis as a guide to action, as we are currently doing, otherwise it will be too late to prevent irreversible catastrophic outcomes" (Dunlop, 2013).

It must also be holistic. A National Science Foundation (2009) report advises:

> To address the environmental challenges that confront us we must find ways to integrate and synthesize data from diverse fields into a whole-systems perspective.… Natural and human systems alike are changing in ways that are poorly understood. How far and in what ways can these systems be stressed before they reach tipping points, i.e., undergo rapid

transition to new states with unforeseen consequences?

Developing a whole-systems perspective on global problems is not as daunting as it sounds! It does not involve modeling everything (Sterman, 2000), but only modeling the environmental, economic and social factors that are required to maintain systemic viability and understand and manage dangerous risks.

Using probabilistic diagnostic tools

The use of safety-critical/life-critical methods is not restricted to the design and operation of mechanical systems. They are also used to ensure the sustainability of living systems: e.g. to diagnose and treat medical problems.

To facilitate their diagnosis of complex emergent problems, medical practitioners use diagnostic algorithms (decision trees) based on criticality analysis (Bosker et al., 1996). This is possible because the parameters of physical and mental health are well established. Patients are tested (e.g. for blood chemistry) and the results evaluated to both discover immediate problems and determine how constellations of risk factors are likely to affect long-term health. For example, blood pressure is not examined as an isolated, fixed set of data, but looked at in terms of both (a) ranges (dangerously low, low, safe, high, and dangerously high); and (b) associated risk factors (overall health, age, family history, etc.).

A similar risk management approach can be used to integrate and analyse multiple socio-ecological forces and issues in terms of critical system parameters, risks, timelines and options.

Modeling viability

The priority is to discover what is required to ensure safe, viable outcomes. In ecology, population viability analyses use models that simulate the likely future numbers of a species based on an understanding of the ecological and demographical parameters of sustainable populations (Akçakaya, 2000). Similarly, when modeling complex global problems, the first step is to define the critical biophysical and social parameters of a sustainable global system (Folke, 2013; Raworth, 2012). We can then use probabilistic methods to assess the likelihood of critical trends threatening systemic viability.

Dynamic risk assessment models can be developed once critical trends and thresholds are determined (e.g. the probable increase in ocean acidification with current policies, and the point at which increasing acidification will prevent a species of coral from growing and reproducing). These will indicate the likelihood of essential parameters being breached and the probable timelines and impacts of these tipping points. After the individual factors associated with an issue (e.g. major factors affecting the sustainability of the world's coral reefs) have been identified, their associated risks and tipping points can be determined. These findings can then be combined into composite models to give an overall picture of systemic health.

Figure 2 shows the total impact of multiple factors on a system's viability (in this example, coral reefs). The trend lines represent minimum and maximum estimates and timelines. The dark green at the bottom represents optimal conditions for coral growth (although at this stage corals are still dying due to overfishing, pollution, reef destruction, etc.). Yellow areas represent the range of boundary conditions where various reef species are compromised due to bleaching, increasing storms, etc.). The red zone at the top represents areas where life for most species becomes unviable (due to factors such as ocean acidification and rising sea levels).

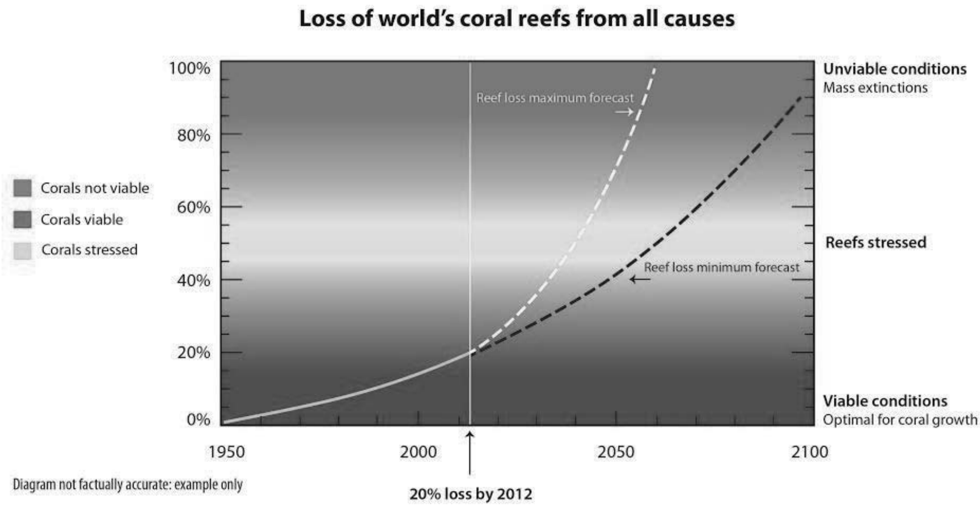

Figure 2. An example of a Multiple Factors Viability Chart

Understanding probable trends, timelines, tipping points and consequences will allow us to evaluate possible policy options and their costs and benefits; and from this determine priorities, discover high leverage points, and develop optimal intervention strategies (Marten, 2005).

Global dynamics and boundaries

Steady progress is being made on determining the critical thresholds of major biophysical systems. Less research has been done on determining the boundary conditions of socio-ecological systems, possibly because their more complex and chaotic dynamics are even more difficult to model. However, without a better understanding of how environmental, economic and social factors interact we will not be able to analyze and manage climate change and other complex socio-ecological problems.

Social scientists have general theories of how societies interact with their environments (e.g. structural functionalism relates social structure to a society's means of production, and conflict theorists believe that competition over scarce resources is a major cause of conflict). The boundary conditions of social sub-systems (e.g. market tipping points, group behavior under stress, the differences between successful and unsuccessful businesses, etc.) have also been extensively studied, while other research has explored various aspects of social viability: e.g. Stafford Beer's Viable Systems Model outlines the organizational requirements for viability (Hoverstadt, 2008).

Nevertheless relatively little research has been done on the critical environmental, economic and political dynamics and parameters of major socio-ecological systems. As a consequence we have been unable to develop integrative socio-ecological models of the global system and its major sub-systems, particularly under conditions of systematic transformation such as tipping points leading to systemic collapse or to transitions to new political/economic regimes.

To discover the boundary conditions and tipping points of societal systems, it is necessary to understand the relationships between societies and their environments. Human societies maintain and reproduce themselves through processing information, resources and energy from their environments. They are complex cybernetic systems with feedback loops that take in inputs from the biosphere and from other societal systems, and convert these inputs into the material and societal outputs necessary for the system's maintenance, self-stabilization and reproduction - as pictured in the schematic of Figure 3 (Taylor, 1999).

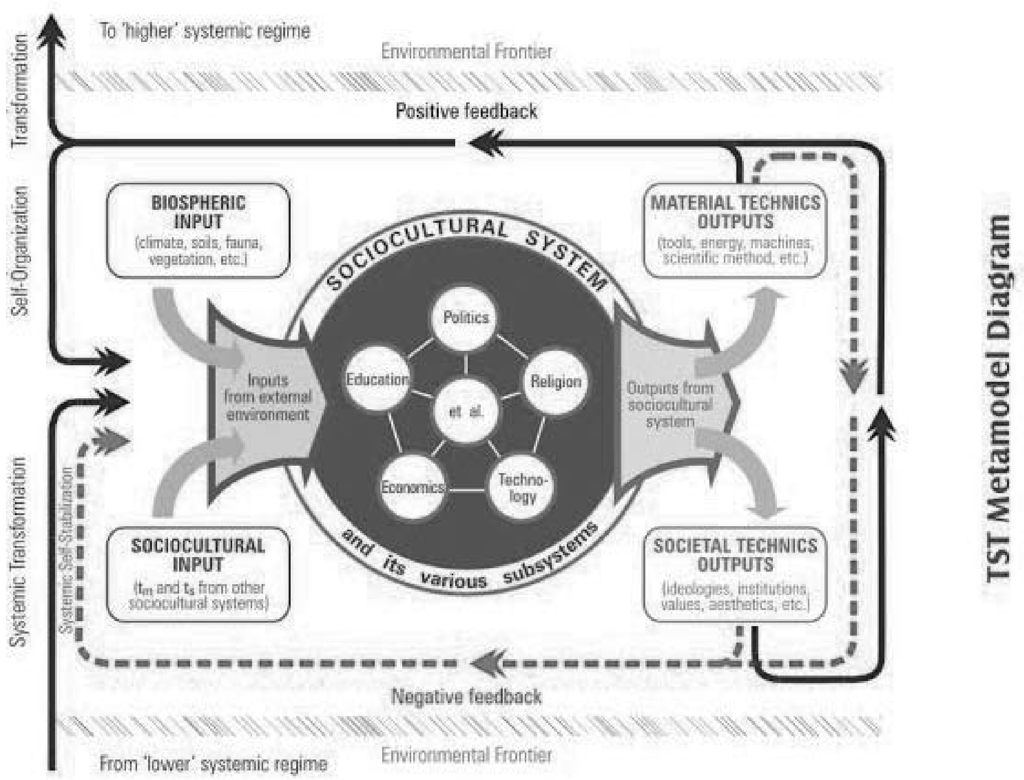

Figure 3. How societal systems function in relationship to their environments (t_s= societal technics; t_m = material technics). (Taylor, 1999)

Because human societies are open systems, they exist in dynamic equilibrium with their environments. Societal and material feedbacks normally combine to promote systemic self- stabilization: increasing imbalances between positive feedback and negative feedback will result in either systemic transformation or collapse.

For societies to survive over time (to be sustainable), they must have structures and technologies that are internally functional and externally appropriate (i.e. environmentally fit). They must be able to maintain and reproduce themselves while avoiding both social collapse (e.g. caused by catastrophic famines and/or warfare) [An even better example might be global economic meltdown, governance failures, and people dying due to malnutrition, and suicide.] and environmental collapse (e.g. through irreversible ecological degradation and/or resource depletion).

The sustainability of a living biological and social system is determined by its ability to meet its essential needs on an ongoing basis (Taylor & Taylor, 2007b). These enable it to maintain itself over a relative time period with sufficient resilience to withstand normal environmental and social perturbations and stresses and to reorganize in healthy ways in response to changing conditions.

A corollary is that the boundaries of living systems are determined by the ability of critical internal processes and external conditions to meet essential needs. For example, the biological Law of the Minimum (Liebig's Law) states that the population of any species (including ours) is limited by the necessity (e.g. water, food, suitable climate) in least supply. The sustainability of ecosystems and social systems can be evaluated once we discover the critical thresholds at which system failure occurs (e.g. if the populations of keystone species are stable or declining, or if supplies of critical resources are increasing or decreasing).

Figure 4 illustrates the biophysical and social boundaries of viable human societies. In the diagram inner green areas = viable conditions; outside red areas = unviable conditions; D = societal development, E = environmental conditions. The viable state space (safe operating conditions) in which societal systems can exist are constrained by environmental conditions on one hand (e.g. weather extremes or a lack of resources), and by societal functionality on the other (e.g. a lack of environmentally and socially appropriate worldviews, institutions and technologies due to either underdevelopment or overdevelopment/maldevelopment). Note that high levels of complexity are not necessarily correlated with environmental or social fitness (e.g. dysfunctional development can result in unsustainable resource consumption and/or unmanageable social conflicts).

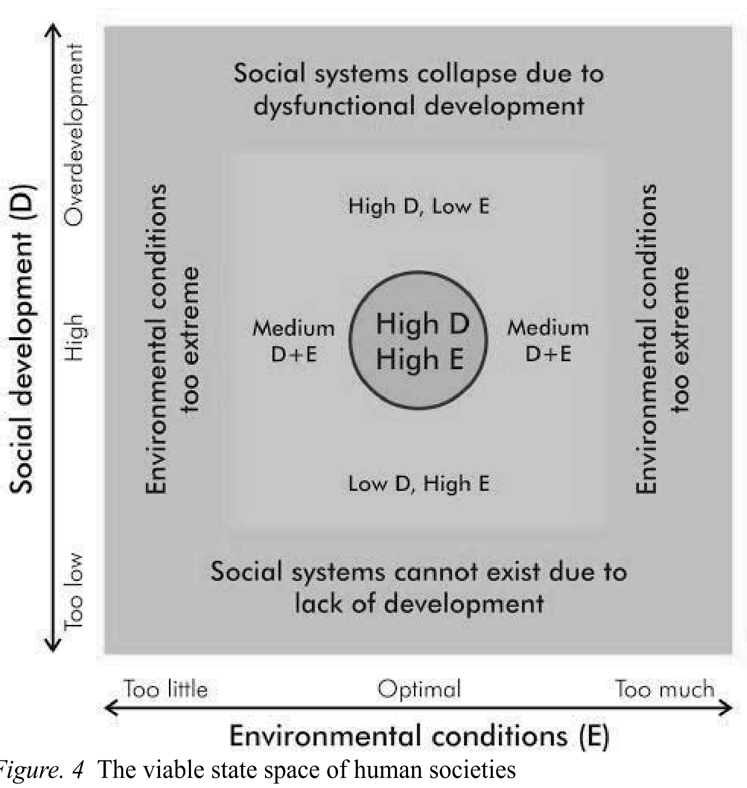

Figure. 4 The viable state space of human societies

The dark green circular area represents optimal states where the worldviews, social structures, economic processes and technologies of societal systems exist in sustainable equilibrium with their environments. Different types of societal systems can be sustainable: for example, many types of hunter-gatherer or agricultural societies survived for millennia, and it is conceivable that an extremely complex sustainable post-industrial societal system could evolve in the near future. Sustainable quantitative development (more material goods) could be achieved through the increasingly efficient use of renewable and recyclable inputs (Daly, 1996); there are no limits to sustainable qualitative development.

Ultimately societal sustainability is not (per se) a moral question, but a matter of functionality and resilience within biophysical and social parameters. However, this does not mean that sustainability is a separate issue from ethics. Because worldviews and values motivate and organize social structures and economic processes, the economic and environmental outcomes of human activities are culturally determined.

It is important to remember that human needs are more than material needs for food, shelter and safety: they are also emotional, intellectual and spiritual needs—for meaning and belonging, for relationship to both community and nature. Identity and resource conflicts occur when people believe that their needs are not being met or are being threatened. People compete and fight over material goods when they fear material scarcity, and people compete and fight over religious, ethnic and national issues when they fear the loss of cultural identities (Deutsch, 1973).

Determining social tipping points

One difficulty in modeling societal dynamics is the unpredictable role of individual and institutional actors. The question of whether individual actors or social conditions create social, economic and technological tipping points has been widely debated. For example, would the Internet have been developed if the people who invented it had not existed? We can safely say that the Internet could not have been invented until key components (telecommunications and personal computers) had reached a sufficient level of development. Once enabling conditions existed (the IT technological wave), it was highly probable that the Internet would be invented. However, exactly how or when would have been impossible to predict.

P.J. Lamberson and Scott Page point out that:

> [T]he tendency [is] to focus on direct tipping points rather than contextual ones when explaining how events unfold, despite the fact that…contextual tips often make direct tips possible…. A leader wishing to prevent protests in a nation cannot do so effectively by focusing on the direct tips. Like so many sparks in a pile of dry leaves, if the context is set eventually one will start a fire. (Lamberson & Page, 2012)

Social tipping processes usually have both endogenous and exogenous triggers (Grimm & Schneider, 2011)—e.g. rising food prices have a disproportionate impact on the poor and are most likely to result in social unrest where vulnerability is combined with inequity. A United Nations University study on societal tipping points argues that it is useful to focus on situations where groups and states are not only exposed to stressful environmental, economic and social changes, but are extremely limited in their capacity to respond. The researchers recommend collecting and analyzing existing vulnerability indexes to establish the baselines of current social and biophysical vulnerability and create a framework for risk assessment:

> A new rigorous vulnerability index to identify hot systems would select and integrate the existing methods that are most reflective of the current and future needs and conditions of populations, thereby creating a novel, innovative and cross-cutting decision-making frame. (Lynn et al., 2010, p. 16)

The Failed States Index is an example of how a multisectoral approach can be used to develop metrics for determining parameters for social viability and analyzing social risk (Failed States Index, 2013).

Modeling socio-ecological dynamics

Understanding complex causal relationships

The difficulties with analysing and resolving 'wicked' socio-ecological issues like climate change are not primarily biophysical in nature, but economic and political. Traditional statistical modeling fails to adequately analyse their complex dynamics and risks, which are often non-linear. Although some very useful work is being done in this area (e.g. Lagi et al., 2011 identify a threshold where rising food prices cause social unrest), quantitative measurements and targets are not enough: we also need to understand the trends and system dynamics that threaten sustainability. Here hard and soft systems methods can be combined to model complex environmental and social dynamics and determine their probable impacts on systemic viability (Jackson, 2003).

The challenge is to differentiate constructive from destructive dynamics and then devise interventions capable of changing vicious cycles into virtuous cycles. For this we need cross-sectoral causal models that will allow us to determine the probability of events and their likely consequences. This can be done by using causal loop diagrams (to explain system dynamics) in combination with stock and flow models (to quantify dynamics and determine dominant trends) (Sterman, 2000; Maani & Cavana, 2004). Bayesian networks can then be used to assess the probabilities of multiple non-additive interactions (Leidloff & Smith, 2010)

Figure 5 is an example of how a causal relationship diagram can be used to provide a simplified overview of a problem. Depending on the focus of the analysis additional feedbacks can be added and/or factors can be expanded to show further dynamics (e.g. economic factors supporting action include new 'green' technologies as well as activities adversely affected by climate change; political factors resisting action include mechanistic worldviews, institutional resistance, interest groups, etc.). This diagram helps to identify the most effective intervention point: actions that make pollution unprofitable (e.g. pollution taxes) will reduce both emissions and resistance to mitigation.

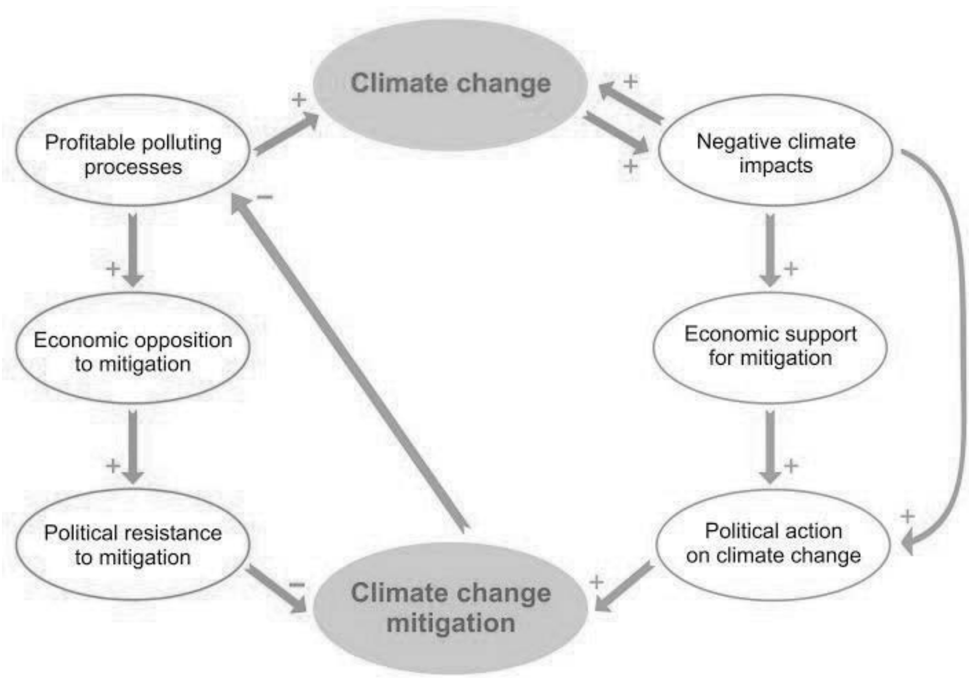

Figure 5. Some of the key causal relationships among factors supporting or obstructing policies mitigating climate change [+ = increases; - = decreases]

Cross-sectoral causal models can be combined with probabilistic risk models to help determine critical trends, timelines, tipping points, consequences, and options. While this approach will not overcome all uncertainty, it will improve our ability to analyse and manage complex socio-ecological problems.

For example, investors and governments need to know if and when thermal coal sales are likely to decline in order to manage risk and avoid making bad investment decisions that result in stranded assets. For this reason it will be very useful for investors, corporations, governments and NGOs to have a better understanding of trends and tipping points in the energy sector. Figure 6 examines future thermal coal share prices in terms of long-term trends and the causal relationships between various environmental, economic and political tipping points.

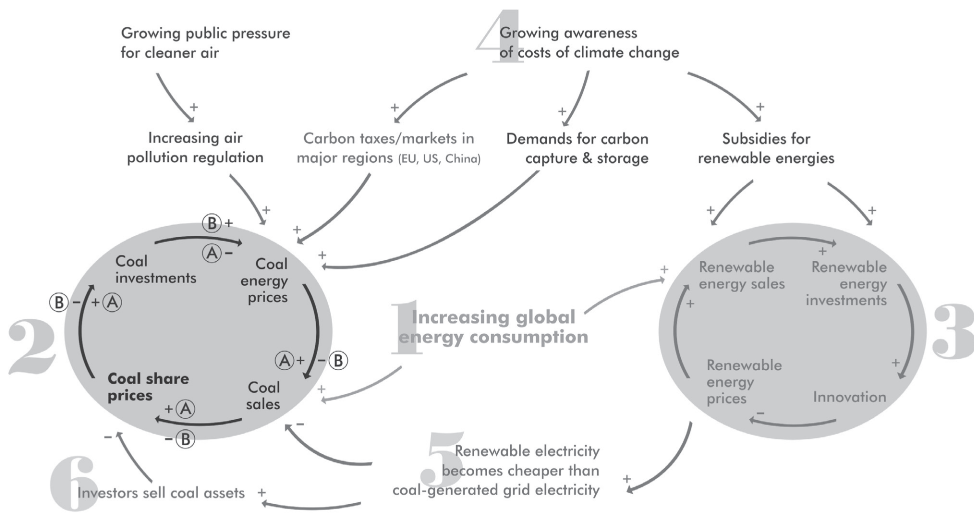

Figure 6. Major thermal coal share price trends and tipping points [+ = increases; - = decreases]

The diagram illustrates the following dynamics:

1) Global energy demand is rapidly rising due to increasing population and rising consumption.

2) In the short- to medium- term this creates a growing demand for thermal coal, a low-cost source of energy, and creates a virtuous circle (A) of increasing coal sales, which increase coal profits and share prices, which result in increasing investments in coal production and power generation, which keep coal prices relatively low, guaranteeing expanding coal sales. [Note that the coal price circle has two phases: the initial virtuous circle is marked with (A), and the later vicious circle is marked with (B).]

3) Although sales of renewables are also stimulated by growing global demand, they start off as high-cost sources of energies that are only competitive in off-grid, niche markets. However, renewable energies also have a virtuous cycle: investments in innovation and large-scale production are rapidly reducing per watt costs, which in turn are increasing sales and encouraging more investments.

4) Other long-term trends are likely to affect the relative prices and market shares of thermal coal and renewable energies. Global awareness of the catastrophic environmental and economic costs of climate change is steadily increasing, with the International Energy Agency warning: "The current trajectory for coal is fundamentally inconsistent with a low-carbon future" and "Global primary coal demand must peak before 2020 [to avoid dangerous climate change]" (IEA 2013). As a consequence pressure is growing on governments to both support a shift to renewable energies and introduce carbon taxes and/or emissions limits. These shifts will progressively reduce the price of renewables while increasing the price of coal generated electricity. Air pollution standards are also likely to steadily increase due to growing public pressure (e.g. in China) for cleaner air. This will increase costs to industries burning thermal coal.

5) As long as coal-generated grid electricity remains cheaper and more reliable

than electricity from renewable sources, sales of thermal coal are likely to remain strong. However, when the cost of electricity generated from renewable sources becomes cheaper than that of coal-generated electricity, thermal coal sales are likely to enter a period of protracted decline (Parkinson, 2014). The virtuous circle (A) that creates rising coal share prices will now become a vicious circle (B) of decreasing coal sales, profits and share prices.

6) Coal share prices will start falling once investors realize that this tipping point is approaching.

Although Fig. 6 only describes a few key causal relationships, it can be used to develop a more sophisticated predictive model (e.g. one that can forecast probable coal share prices over time). This can be done by using a combination of quantitative and qualitative research to analyse the strength and likely impacts of underlying environmental, economic and political factors and dynamics.

Designing constructive interventions

These methods can be integrated with proven business, industrial and defense approaches—e.g. scenario simulations (Gilad, 2008; Herman & Frost, 2008; Schwarz, 2009) to help decision makers better understand complex socio-ecological problems and design sustainable solutions.

After the critical requirements for sustainable socio-ecological outcomes have been determined, backcasting can be used to design structures and processes capable of meeting these requirements. [This approach applies standard outcomes-based architectural and engineering design methods (Smith, 2006; Birkeland, 2008) to the proactive management of socio-ecological problems.]

The need for a transformational narrative

"Wicked" socio-ecological issues are difficult to resolve not only because they are complex, but also because they reflect systemic structural problems such as vicious cycles, entrenched interests and perverse incentives where the solution of one problem leads to the worsening of another. For these reasons problems like climate change cannot be solved by simply setting emission targets: climate mitigation will require a paradigm shift in the way we produce and consume energy and other resources—the complete cultural, economic and technological transformation of our consumer society to a conserver society (Taylor 2008; Beddoe et al., 2009).

This shift will not happen until a critical mass of both leaders and the public become convinced that change is not only necessary, but practical and beneficial. However, research by Feinberg and Willer (2011) indicates that people often reject apocalyptic warnings that threaten their sense of safety and stability. Difficult messages will only be accepted if they contain positive solutions.

This means that it will not be enough to develop better models for evaluating and explaining risks and opportunities; we also need to create a viable alternative to business as usual—to provide a safer and more desirable path to the future (a positive system attractor). Already many people are helping develop a vision of a better world (Porritt, 2013) and a strategy for creating it (The Worldwatch Institute, 2013). Our collective challenge is to integrate these constructive initiatives into clear, coherent narratives capable of inspiring and catalysing transformational global change.

Conclusions

If current methods are ineffective, then new methods are required. Socio-ecological viability modeling will improve our understanding of cross-sectoral interactions, including the probability of disruptive, non-linear events. As well as focusing attention on strategic threats and opportunities, it will help design the constructive interventions needed to prevent catastrophic failures.

This approach is proactive rather than reactive. It starts by examining what is necessary to prevent potentially catastrophic risks rather than what is presently possible. It uses proven methods of risk assessment and project management to analyse and manage critical socio-ecological problems and ensure safe, viable outcomes.

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