



Science in Society Series

# RECONSTRUCTING SUSTAINABILITY SCIENCE

KNOWLEDGE AND ACTION FOR  
A SUSTAINABLE FUTURE

THADDEUS R. MILLER

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# Reconstructing Sustainability Science

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The growing urgency, complexity and ‘wickedness’ of sustainability problems – from climate change and biodiversity loss to ecosystem degradation and persistent poverty and inequality – present fundamental challenges to the production and use of scientific knowledge. While there is little doubt that science has a crucial role to play in our ability to pursue sustainability goals, critical questions remain as to how to organize research most effectively and connect it to actions that advance social and natural well-being.

Drawing on interviews with leading sustainability scientists, this book examines how researchers in the emerging, interdisciplinary field of sustainability science are attempting to define sustainability, establish research agendas and link the knowledge they produce to societal action. Pairing these insights with case studies of innovative sustainability research centres, the book reformulates the sustainability science research agenda and its relationship to decision-making and social action. It repositions the field as a ‘science of design’ that aims to enrich public reasoning and deliberation while also working to generate social and technological innovations for a more sustainable future.

This timely book gives students, researchers and practitioners a valuable and unique analysis of the emergence of sustainability science, and both the opportunities and barriers faced by scientific efforts to contribute to a more sustainable world.

**Thaddeus R. Miller** is Assistant Professor at the Nohad A. Toulan School of Urban Studies and Planning and a Faculty Fellow at the Institute for Sustainable Solutions at Portland State University, USA. He is also an affiliate of the Consortium for Science, Policy, and Outcomes at Arizona State University, USA. His research explores the social, ethical and political dimensions of science, technology and sustainability.

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**Reconstructing Sustainability Science**  
*Knowledge and action for a sustainable future*

Thaddeus R. Miller

# RECONSTRUCTING SUSTAINABILITY SCIENCE

Knowledge and action for a sustainable future

*Thaddeus R. Miller*

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To Britt and Zadie

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'A new generation of students and scholars has embraced sustainability as a concept and is eager to explore more thoughtful, more integrative and better scientifically grounded ways to approach it. Thad Miller's new book is just what they are looking for.'

Paul B. Thompson, Michigan State University, US

'Thad Miller's book presents a sophisticated, nuanced and insightful analysis of the emerging field of sustainability science. Particularly welcome is his analysis of the normative, ethical and epistemological underpinnings of different approaches to sustainability. His proposal for an explicitly normative, solutions-oriented approach to sustainability is exactly right.'

John Robinson, University of British Columbia, Canada

'Thad Miller, in this new conceptualization of how to restructure sustainability science, outlines the logic and mechanisms by which an action-oriented, outcome-driven science might emerge. His book serves as a guide for what all sophisticated future-oriented knowledge enterprises should have as a part of their teaching, learning and discovery agendas in order to pursue a more sustainable future.'

Michael M. Crow, Arizona State University, US



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# PREFACE

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In the spring of 2007, I was among a handful of graduate students to enroll in the inaugural class of the first School of Sustainability at Arizona State University. We had in common a deep concern for the state of our planet's ecology and its implications for human well-being, a desire to do something about that, and a collective excitement to be a part of a new program. Self-proclaimed guinea pigs, we eagerly signed up for this somewhat radical experiment in the reorganization of research and education to understand and address the complex problems of sustainability.

The School of Sustainability is on the bleeding edge of efforts to transform our research and educational institutions to break down disciplinary divides and tackle real-world sustainability problems. From the University of Tokyo to Stellenbosch University in South Africa and, my current home, Portland State University, universities around the globe are shifting to reshape research and education in the face of rapid global environmental change. As they do so, they reveal the limitations of traditional disciplinary approaches and the barriers to transformative change in academia (Crow 2010; Miller *et al.* 2008).

In these changes and others, including the National Science Foundation's recent Science, Engineering and Education for Sustainability initiative and the International Council for Science (ICSU) *Future Earth*, there is a recognition that the ways in which we have come to organize research and education limit our ability both to understand and resolve sustainability problems. The challenges and roadblocks run from the seemingly mundane – such as how the distribution of student credit hours impedes interdisciplinary course offerings – to deep normative and epistemic divides between academic disciplines and assumptions about the relationship between scientific knowledge and social action.

Being a naïve yet willing participant in this upheaval as a doctoral student, I became interested in understanding how sustainability challenges were reshaping academic programs and emerging interdisciplinary fields. How are disciplines merging? How are the normative goals of sustainability incorporated into supposedly 'value-free' scientific research? How will the knowledge produced by sustainability research be utilized? How are sustainability problems framed? By whom? For my dissertation research, I took up these questions and others to examine the emergence of sustainability science – an interdisciplinary, problem-driven field at the forefront of efforts by the US National Academies of Science and the American Association for the Advancement of Science to address real-world sustainability problems. Sustainability and scientific efforts to contribute to it are rich territory for analyzing the complex interplay between science and society and how scientists are responding to twenty-first century sustainability challenges.

At the core of these and similar efforts is a critical question: How can science and technology more effectively inform and foster social action for sustainability? How is knowledge to be connected to actions and decision making that advance collective visions of natural and social well-being (Bocking 2004; Jasanoff 1997)? This book examines how sustainability science aims to contribute to social action for sustainability and the implications of emerging research agendas for societal discourse on sustainability. The results will help move sustainability science forward through a better understanding of how science might contribute to social outcomes more effectively. It will provide an opportunity to create more reflexive sustainability science research agendas and demonstrate the necessity of addressing the social, political and normative dimensions of sustainability in order to contribute to social action. I hope to lay the foundation for a sustainability science that is evaluated based on its ability to frame sustainability

problems and solutions in ways that make them amenable to democratic and pragmatic social action.

This book has also been a deeply personal project. It began with reflections on what kind of student the School of Sustainability was trying to produce. How would we – those guinea pigs – be different? How can places like the School of Sustainability contribute to more sustainable communities? How would these experiments change the way we organize research and education institutions? These initial reflections transformed into my research agenda owing in large part to an incredibly fruitful and creative intellectual environment at Arizona State – particularly around the School of Sustainability, the National Integrative Graduate Education and Research Training (IGERT) program in Urban Ecology and the Consortium for Science, Policy, and Outcomes (CSPO).

After receiving my doctorate in Sustainability in Spring 2011, I accepted my current position as Assistant Professor in the Nohad A. Toulan School of Urban Studies and Planning at Portland State University. Portland State has made sustainability one of its campus-wide strategic initiatives. At Portland State, this effort is led by the Institute for Sustainable Solutions, where I am now a Faculty Fellow. Faculty, administration, staff and students at universities around the world are actively working to transform research and education to produce knowledge, technologies and people that will meet the challenges of sustainability. Arizona State, Portland State and other colleges and universities I've encountered in my research and through colleagues have met their fair share of barriers as well as successes. From this work and experience, it is clear that sustainability's 'wicked' problems (which I discuss in [Chapter 1](#)) present fundamental challenges to knowledge production and our ability to link research to beneficial outcomes.

This project is the result of empirical and theoretical research and deep personal and professional reflection on these challenges. It creates an opportunity for the emergence of a more reflexive sustainability science and demonstrates the necessity of addressing the social, political and normative dimensions of sustainability in order to contribute to social action. The ongoing transformations in research and education for sustainability throughout the world make this an especially exciting time to be involved in this work. However, the challenges are significant and carry risks for the students, faculty and administration involved. This book contributes to our understanding of the successes and limitations of such transformations and develops a pathway forward for a more radically interdisciplinary, solution-oriented design science for sustainability.

## References

- Bocking, S. 2004. *Nature's experts: Science, politics, and the environment*. New Brunswick, NJ: Rutgers University Press.
- Jasanoff, S. 1997. NGOs and the environment: From knowledge to action. *Third World Quarterly* 18(3): 579–94.
- Miller, T.R., T.D. Baird, C.M. Littlefield, G. Kofinas, F.S. Chapin, III and C.L. Redman. 2008. Epistemological pluralism: Reorganizing interdisciplinary research. *Ecology and Society* 13(2): 46. Available at: [www.ecologyandsociety.org/vol13/iss2/art46/](http://www.ecologyandsociety.org/vol13/iss2/art46/). [Accessed 31 July 2014.]

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This project began as my dissertation project as a doctoral student at Arizona State University's School of Sustainability. If the dissertation process were not long and arduous enough, the long haul to the manuscript was that and more. Throughout this project, I have been incredibly lucky to have the support and cooperation of many colleagues, friends and family. Though long, it has been a socially and intellectually rewarding process.

First, I would like to thank all of those I interviewed throughout the course of my research for their responsiveness and for their generosity with their time. One of the highlights of my work has been the opportunity to meet such intelligent and dedicated individuals and discuss the core problems of sustainability.

This research would not have been possible without funding from the National Science Foundation Integrative Graduate Education and Research Training Program (IGERT), the Graduate Student Professional Association at Arizona State University and the Institute for Sustainable Solutions at Portland State University. This material is based upon work supported by the National Science Foundation under Grant No. 0504248, IGERT in Urban Ecology. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

The IGERT Program in particular and the opportunities it affords have been instrumental in my development as a scholar. I would like especially to thank the IGERT Principal Investigators, Stuart Fisher, Ann Kinzig, Margaret Nelson and Charles Redman, as well as the program administrator, Gary Ryser, for all of their help and support throughout my time as an IGERT Fellow.

As a graduate student at Arizona State University, I was fortunate to be surrounded by a group of intelligent, dynamic and committed students and faculty, particularly in the IGERT Program, the School of Sustainability and the Consortium for Science, Policy and Outcomes (CSPO). I would like particularly thank the following colleagues for their input and support: Kate Darby, Ann Kinzig, Clara Miller, Tischa Muñoz-Erickson, Mark Neff and Zachary Pirtle.

I would like to thank my dissertation committee – Ben Minter, Charles Redman, Daniel Sarewitz and Arnim Wiek. They have always been and continue to be available, responsive and supportive. Most importantly, I thoroughly enjoy working with each of them on this project and others, and hope to continue to find opportunities to do so in the years to come. Each of them set a high bar for scholarship, mentorship and friendship.

I would also like to thank the editorial team at Routledge. They have been incredibly supportive and enthusiastic about this work from the beginning. In particular, I would like to thank Khanam Virje, Charlotte Russell and Bethany Wright. I am also grateful to Steve Rayner, editor of the Science in Society series. I am truly humbled to be a part of this series.

Last, but certainly not least, I would like to thank my family for their support and enthusiasm. Thank you Mom, Dad and Cam for checking in with words of encouragement and, sometimes, incomprehension. Most especially, my wife, Britt Crow-Miller, has helped me through this in more ways than she knows. Not only is she a great editor but, more importantly, she is tolerant, loving, supportive – and a great travel companion on research trips. This process has been long enough to see us get married and welcome our daughter, Zadie Avalyn Miller, into the world. And to Zadie – thank you for showing me

what matters in life.

~~As usual, all faults are my own, and everything worthwhile is in part a result of working with the~~  
mentioned above.

# PART I

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## Constructing sustainability science



# PLANET UNDER PRESSURE

In the spring of 2012, during a run of unseasonably warm weather, 3,000 scientific experts and decision makers gathered in London at the ‘Planet under Pressure: New Knowledge towards Solutions’ conference. Convened by the Global Environmental Change Programmes and the International Council for Science, the goal of the conference was ‘to assess the state of the planet and explore solutions to impending global crises’ (Brito and Smith 2012: 1). ‘Planet under Pressure’ was timed to deliver a powerful message to the United Nations Conference on Sustainable Development, or Rio+20, to be held that summer. The ‘State of the Planet Declaration’, summarizing the key messages from the proceedings, was issued at the conference. The declaration provided a clear and urgent call to global action to meet the world’s sustainability challenges. New scientific understandings of the Earth system, it declared, ‘demand a new perception of responsibilities and accountabilities of nation states to support planetary stewardship’ (ibid.: 2). Recent research and the large-scale action required by society, urge the authors of the declaration, require drastic changes in political and scientific organization:

The scientific community must rapidly reorganize to focus on global sustainability solutions. We must develop a new strategy for creating and rapidly translating knowledge into action, which will form part of a new contract between science and society, with commitments from both sides

*(ibid.: 4)*

I begin with this brief dispatch from London to illustrate the ways in which scientific discourse and knowledge claims, particularly around sustainability concerns, are intertwined with socio-political and normative claims and visions of social, political and ecological order. This gathering of scientific delegates sought to bring the power of scientific knowledge to bear on the social and political barriers to achieving sustainability. Insights provided by scientific knowledge, according to the Declaration, are a cause to reconsider our ethical and moral positions. In this case, a call for ‘planetary stewardship’ that requires radical changes to social and political organization to be put into practice. Both normative claims about what we *ought* to value and how, and visions of social and political order – ‘interconnected problems require interconnected solutions’ (ibid.: 2) – are positioned as stemming from insights gained through the acquisition of scientific knowledge.

The Declaration contends that financial and political support for a reorganization of scientific research are necessary. Knowledge must be more rapidly generated and translated to social and political action. This requires a focus on solutions to global sustainability by scientists. They cite the International Council for Science *Future Earth* research initiative, which will ‘develop the knowledge... for supporting transformation toward global sustainability’ (Future Earth 2013), as the type of support and organization that is needed. Global sustainability challenges, then, should drive changes in research organization and priorities and to the more effective use of scientific knowledge.

Scientific discourse and knowledge making are inextricably linked to visions of social, political and ecological order (Jasanoff 2010; Latour 1988). The State of the Planet Declaration and the proceedings

the 'Planet under Pressure' conference demonstrate how knowledge claims about the sustainability of interconnected, socio-ecological systems are also claims to the proper social, political and scientific organization that is necessary to promote sustainability. These knowledge claims are also claims to norms and values that ought to be pursued and upheld. This relationship between science and society is not unique to the sustainability arena and has been explored extensively by science and technology studies (STS) scholars (e.g. Jasanoff 2005; Latour 2004; Shapin and Schaffer 1985). Science produces beliefs not only about how the world is, but also how it *ought* to be (Jasanoff 2004; Latour 1993). As scientists describe social or ecological dynamics, they influence beliefs about what dynamics are sustainable – what society *ought* to do in order to be sustainable. Scientists attempt to respond to social and environmental concerns by researching problems identified by society as important. How sustainability science influences the social, political and normative dimensions of sustainability may render the concept of sustainability and the problems it encapsulates more or less tractable in terms of social action.

Sustainability challenges are reshaping scientific research and education at multiple scales, yet global science and policy organizations and national and regional research and education institutions are ill-equipped to deal with integrative knowledge generation and the management of complex science-policy interfaces (Crow 2007; Reid *et al.* 2010; Miller *et al.* 2011). From well-established disciplines such as ecology and geography to emerging, interdisciplinary fields such as earth systems science and sustainability science, scientists are moving to find ways to contribute more directly to the resolution of society's most pressing problems (Lubchenco 1998; NRC 1999). Central to these efforts is the following question: How can science and technology inform and foster social action for sustainability? Or, put slightly differently, how is scientific knowledge to be connected to actions and decision making that advance our visions of natural and social well-being?

This question has spawned a variety of efforts by members of the scientific community to contribute to the resolution of pressing social and environmental problems (Lubchenco 1998; NRC 1999; Palmer *et al.* 2005; Reid *et al.* 2010). Perhaps the most prominent and wide-ranging of these efforts, and the one that this book will focus on, has been sustainability science – an interdisciplinary, problem-driven field that addresses fundamental questions on human – environment interactions (Clark 2007; Clark and Dickson 2003; Kates *et al.* 2001; Levin and Clark 2010). Sustainability scientists aim to support sustainability transitions by linking scientific knowledge to societal action (Cash *et al.* 2003; Clark and Dickson 2003). The field is both problem-oriented and 'focus[ed]... on understanding the complex dynamics that arise from interactions between human and environmental systems' (Clark 2007: 1737). Carpenter *et al.* (2001: 1305) note that sustainability science 'is motivated by fundamental questions about interactions of nature and society as well as compelling and urgent social needs.' They define progress in sustainability science as those areas where 'scientific inquiry and practical application are comingled.' Carpenter *et al.* (2001) go on to stress 'the urgency and importance of an accelerated effort to understand the dynamics of coupled human – natural systems.' This argument is representative of a major theme in sustainability science: The fundamental understanding of the dynamics of human – environment interactions (e.g. Turner *et al.* 2003a, b).

Sustainability and scientific efforts to contribute to it are rich territory for analyzing the complex interplay between science and society and examining how scientists are responding to twenty-first century sustainability challenges. This analysis, then, will provide insight into how to develop a more effective role for science in pursuing sustainability goals. Utilizing theories and insights from STS, this book explores the construction of a new, and to some, radically interdisciplinary, use-inspired field of scientific research – sustainability science. Sustainability science provides an important window through which to examine how scientific knowledge production – its organization and institutions – are being

(re)shaped to respond to complex, urgent and value-laden problems related to sustainability. Through interviews and discourse analysis, I explore how sustainability scientists perform boundary work (Gier 1983), establishing credibility and epistemic claims and demarcating areas of normative and social political concern. This will contribute to STS analyses of the relationship between science and society as well as inform developments in sustainability science and allied fields. In so doing, the purpose is not simply critique sustainability science, but to lay the foundation for a deeper dialogue among sustainability scientists, decision makers and other concerned stakeholders over the role of science in sustainability and future directions for the field.

This book will also explore the implications of transforming the contested and value-laden concept of sustainability into the subject of fundamental scientific analysis. Sustainability can act as a platform for communities to articulate visions of social and natural well-being, including responsibilities to nature and future generations (Norton 2005; Thompson 2010). In its broadest sense, one can view sustainability as an effort to formulate visions of the collective good. Science has, on one hand, brought many environmental problems to the world's attention, including ozone depletion, acid rain and climate change, which have in turn become the subject of normative and political concern. On the other hand, in offering objective and epistemically powerful explanations of natural phenomena, science can also constrain what is considered appropriate, legitimate or necessary discourse and debate. Exploring these issues, this work will contribute to our understanding of the complex relationship between science and the normative dimensions of sustainability and point to areas where dialogue may be 'opened up' to allow for discussion of alternative pathways to and meanings of sustainability (Stirling 2008).

Finally, I will explore the following question: How can science shift from identifying and describing problems in the biophysical realm to contributing to potential solutions in the social and political realm? It is this issue as well as the nature of sustainability problems as complex and contested that challenge the practice of sustainability science and its usefulness. In [Part II](#), I develop a framework that pushes sustainability science toward focusing on the study and design of solutions, rather than the identification of problems. This is a new, explicitly normative vision of sustainability science that, I argue, will be more effective in advancing visions of natural and social well-being.

Before reviewing the structure of the book, I briefly discuss how the *wickedness* of sustainability problems presents specific challenges to the production and utilization of scientific knowledge, and how this analysis can provide an opportunity for sustainability science to address these challenges more effectively.

## Wicked sustainability

Sustainability issues are often *wicked* – that is, they are problems the solutions to which are not obvious wherein complexity is high, uncertainty is rampant, values are in dispute and trade-offs are the norm (Funtowicz and Ravetz 1993; Miller *et al.* 2011; Rittel and Webber 1973). Many of the problems that fall under the rubric of sustainability – ensuring adequate access to clean water supplies, developing alternative energy systems, evaluating intergenerational trade-offs in natural resource use, and advancing solutions to widespread poverty – not only are difficult to define but rarely yield to simple, one-time solutions. As the coiners of the term, Rittel and Webber (1973: 161) note: 'The formulation of a wicked problem *is* the problem! The process of formulating the problem and of conceiving a solution (or rather solution) are identical, since every specification of the problem is a specification of the direction in which a treatment is considered.'<sup>1</sup> Tame or benign problems, on the other hand, are those in which the goal

clear and it is easy to determine whether the problem has been solved (Norton 2005; Rittel and Webb 1973). Often, as we will see below, tame problems may be amenable to scientific or technological fixes.

Wicked problems are not just empirically challenging, they are linked to normative criteria (Fischhoff 2000; Hoppe and Peterse 1993). A central characteristic of such problems is that they are defined by value pluralism and that these values are highly contested. Consensus over problem definitions or the identification of solutions is very difficult. In the case of tame or benign problems, convergence on political and technical solutions is possible in part because the proposed solutions can satisfy multiple value positions (at least for a time). In other words, wicked problems are just as political as they are scientific or technical. In order to understand such problems conceptually, we must consider how scientific or technical inputs allow for or impede the convergence of divergent and conflicting values on pathways that lead to resolution, even if it is momentary or unstable.

Richard Nelson's (1977) moon and the ghetto metaphor highlights why distinguishing between tame and wicked problems is critical. Though technologically complicated, landing on the moon is a relative tame problem. The mission is straightforward and it is clear when the objective has been achieved. It is a matter of economic investment and technological capability. Success here is a testament to the capacities of science and technology to solve such problems. When there is broad agreement on the nature of the problem and what will comprise a satisfactory solution, science and technology can be powerful tools to inform our decisions and generate action (Allenby and Sarewitz 2011).

Nelson then asks, '[i]f we can land a man on the moon, why can't we solve the problems of the ghetto?' The problems of the ghetto are difficult to define and rarely give way to scientific or technological applications. How can we provide decent and affordable health care? How can high school graduation rates be improved? Addressing these issues is infinitely more complex. The solutions to such problems are often highly contextual and contingent on social, cultural, political and economic factors. In order to understand how science and technology might contribute to sustainability, scientists, engineers, practitioners and decision makers would do well to consider the degree to which a given problem is more like the moon or the ghetto – that is, is it amenable to a technological solution or does the problem lie in socio-political complexity? If the latter, are there elements of the issue that might be clarified with additional scientific knowledge?

This should not, however, be taken to mean that technological solutions are always overly simplistic or insufficient since they are perceived, particularly by the environmentalist community, as avoiding more meaningful value changes. In fact, as Sarewitz and Nelson (2008) illustrate, so-called technological fixes can be incredibly effective in enhancing human well-being and achieving specific and agreed goals. The challenge is not to avoid technological solutions in favor of genuine changes in values and worldview; instead, it is to understand the problem context and what solution pathways – from technological fixes (which are rarely as simple as the critics would have one believe) to the long, but perhaps more meaningful, slog of social and political change – are most appropriate and effective in achieving desirable outcomes.

Many of the environmental problems that society has been successful in solving to some degree have been tame. Sewage treatment facilities and sanitation networks led to vast improvements in water quality and public health throughout western Europe and North America in the mid-nineteenth century (Melosi 2008). Likewise, the invention and eventual widespread use of the catalytic converter in the 1950s and 1960s substantially reduced the toxicity of automobile emissions, contributing to improve air quality in heavily congested cities. A key point is that these tame problems are amenable to technical applications that are relatively uncontroversial and help to settle potential value debates. This is possible because the goal is clear and does not involve significant trade-off between various interests (Lindblom

1959). For wicked problems, this process is not possible. Potential technological or policy solutions to wicked problems such as climate change often divide as many interests as they bring together. Furthermore, owing to normative and empirical complexity, solutions to wicked problems often end up leading to the proliferation of additional, unforeseen problems (Latour 1993; Scott 1998).

Yet it is also the case that, before modern sewage and sanitation systems, the problems of water-borne disease, water quality and public health were wicked.<sup>2</sup> This is an example in which a wicked problem was tamed by technological developments, political will and institutional change. Such developments can occur in the absence of necessary scientific understanding or even despite incorrect scientific understandings. For example, in the case of sanitation the miasmatic theory, which associated disease with bad smells, dominated contemporary thinking as new methods for sanitation and disease prevention were first implemented.

Additional scientific knowledge may not necessarily be the tool to help solve or settle a wicked problem. Calls for mode-2 knowledge production (Nowotny *et al.* 2001) and post-normal science (Funtowicz and Ravetz 1993) have recognized and thoughtfully explored this dynamic. In fact, additional knowledge will likely be contested by conflicting scientific findings or political positions and reveal additional uncertainties, rather than eliminating them (Sarewitz 2004). To what degree does sustainability science grapple with these issues? How do sustainability scientists navigate normative and epistemological issues at the science – policy interface and then address the social, political and ethical challenges posed by sustainability problems? Sustainability science serves as an example to explore how far sustainability concerns are reshaping scientific research agendas, if at all. If sustainability scientists are to facilitate social learning and link knowledge to action, they must be able to differentiate between these various types of problems and provide the knowledge or tools appropriate for a given context. This book analyzes how sustainability scientists currently approach these dynamics and develops a framework for the field that incorporates these insights.

## Book structure

The point of departure for this analysis is itself an openly normative one – sustainability is a valuable and value-laden concept that may allow communities and society writ large to articulate and represent visions of human and natural well-being. In a search for a new path for progress, sustainability links concerns for the value(s) of nature, social justice and poverty with responsibilities to future generations. It attempts to demarcate a desirable space in which humans would like to exist; a path in which societies should develop in a way that limits the negative human impacts (or even seeks to produce positive impacts) on ecological support systems, reduces social injustices such as hunger and poverty, and takes a long-term, multigenerational perspective. Sustainability is a normative claim about how the world is (i.e. unsustainable) and how it *ought* to be. Sustainability offers the potential for constructing a new and improved discourse for discussion of environmental problems because it is both descriptive and evaluative (Norton 2005). As Norton (2005) argues, it is a ‘thick’ concept that can encapsulate a great deal of information about how humans interact with the environment and present that information in a way that is transparent, important to widely held social values and helps move communities toward adopting more sustainable practices.

The book is organized in two parts. The first – [Chapters 2, 3 and 4](#) – is an empirical and theoretical analysis of the emergence of sustainability science. [Chapter 2](#) provides a detailed discussion of the theoretical and methodological approach taken in the book, drawing mostly from STS. It also provides

brief overview of the emergence of sustainability science. [Chapter 3](#) discusses the results of 28 in-depth interviews conducted with leading sustainability scientists. This chapter draws from a content analysis of the relevant literature in sustainability science, examining how scientists are constructing research agendas for sustainability. More specifically, it addresses three core questions: (1) How do sustainability scientists define and bound sustainability? (2) How and why are various research agendas being constructed to address these notions of sustainability? (3) How do scientists see their research contributing to societal efforts to move toward sustainability? Following Thomas Gieryn's (1983, 1999) concept of boundary work, this chapter analyzes how sustainability scientists demarcate areas of normative, epistemic and socio-political concern.

Based on these results, [Chapter 4](#) explores the tensions that arise between the approach of sustainability scientists and societal efforts to articulate and pursue sustainability goals, addressing three sets of questions: (1) How does sustainability science address the normative commitments of the sustainability discourse? What are the implications for science and for societal understandings of sustainability? (2) What are the epistemic challenges posed by sustainability problems? How do sustainability science address these? (3) What are the barriers to and opportunities for linking knowledge with action for sustainability? How does sustainability science as a field address these issues? The purpose of this analysis is to illuminate these often hidden tensions so that future research efforts in sustainability science might navigate them more effectively and contribute to positive social outcomes.

Based on the empirical and conceptual work done in [Part I](#), [Part II](#) maps out an alternative, or perhaps complementary, pathway for sustainability science. [Chapter 5](#) marks a shift from the empirical exploration of sustainability science to this conceptual project. It examines the epistemic and normative limitations of scientific approaches to sustainability in order to open the pathway for a framework centered on the articulation and pursuit of shared visions of social and natural well-being.

[Chapter 6](#) borrows from the work of Nobel Laureate Herbert Simon and repositions sustainability science as a 'science of design' – that is, a normative science of what *ought* to be in order to achieve certain goals – rather than a science of what *is*. It will develop a foundation for a sustainability science that is solutions-oriented – one that aims to enrich public reasoning and deliberation while also working to generate social and technological innovations for a more sustainable future. This chapter then develops a set of design imperatives for sustainability science that aim to overcome the limitations of other approaches and focus research on the generation of positive, more sustainable, social outcomes. A sustainability science of design requires thinking beyond the current state of affairs to explore how preferred, more sustainable, futures can be developed and pursued. This requires that we rethink research priorities, the role of science in society and the training of the next generation of sustainability scientists.

Finally, [Chapter 7](#) concludes with a discussion of the implications of a design science for sustainability for how we organize research agendas, knowledge-producing organizations and the relationship between science and society. As environmental philosopher Dale Jamieson (1998: 191) aptly notes, '[w]hat is needed are simple and compelling stories that show us how to practically participate in creating the future in our daily lives, and how to engage in ongoing dialogue with others about how our everyday actions help to produce global realities.' Science alone cannot *make* a future happen; yet, it can help us identify the potential implications of such futures and their plausibility. As various research agendas for sustainability continue to emerge and develop, this project offers an opportunity to consider how science is informing and shaping societal efforts to pursue sustainability and an avenue for a more broad-based, reflexive and deliberative research program for sustainability regarding how knowledge is appropriated and the public purposes it serves.

# Notes

- 1 Rittel and Weber (1973) identify ten distinguishing characteristics of wicked problems: (1) There is no definitive formulation of a wicked problem; (2) wicked problems have no stopping rule; (3) solutions to wicked problems are not true-or-false, but good-or-bad; (4) there is no immediate and no ultimate test of a solution to a wicked problem; (5) every solution of a wicked problem is a 'one-shot operation'; (6) wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions; (7) every wicked problem is essentially unique; (8) every wicked problem can be considered to be a symptom of another problem; (9) the existence of a discrepancy representing a wicked problem can be explained in numerous ways; the choice of explanation determines the nature of the problem; (10) the planner has no right to be wrong.
- 2 Of course, such problems are *still* wicked in many parts of the world. In large part the contextual variability of problems and the differential presence of technology, know-how and the institutions necessary to regulate or deal with such problems can determine whether a problem is wicked or not. Whether a problem is tame or wicked is contextual.

## References

- Allenby, B.R., and D. Sarewitz. 2011. *The techno-human condition*. Cambridge, MA: MIT Press.
- Brito L., and M.S. Smith. 2012. The state of the planet declaration. Planet Under Pressure Conference, London, UK. Available at [www.planetunderpressure2012.net/pdf/state\\_of\\_planet\\_declaration.pdf](http://www.planetunderpressure2012.net/pdf/state_of_planet_declaration.pdf). [Accessed 24 May 2012.]
- Carpenter, S.R., H.A. Mooney, J. Agard, D. Capistrano, R.S. DeFries, S. Diaz, T. Dietz, A.K. Duraiappah, A. Oteng-Yeboah, H.M. Pereira, C. Perrings, W.V. Reid, J. Sarukhan, R.J. Scholes, and A. Whyte. 2009. Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences* 106(5): 1305–12.
- Cash, D.W., W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D.H. Guston, J. Jäger, and R.B. Mitchell. 2003. Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America* 100(14): 8086–91.
- Clark, W.C. 2007. Sustainability science: A room of its own. *Proceedings of the National Academy of Sciences* 104(6): 1737–8.
- Clark, W.C., and N.M. Dickson. 2003. Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences of the United States of America* 100(14): 8059–61
- Crow, M.M. 2007. None dare call it hubris: The limits of knowledge. *Issues in Science and Technology* Winter, 1–4.
- Fischer, F. 2000. *Citizens, experts and the environment*. Durham, NC: Duke University Press.
- Funtowicz, S.O., and J.R. Ravetz. 1993. Science for the post-normal age. *Futures* (257): 739–55.
- Future Earth. 2013. *Future earth*. Available at: [www.icsu.org/future-earth](http://www.icsu.org/future-earth). [Accessed 24 July 2014.]
- Gieryn, T.F. 1981. The aging of a science and its exploitation of innovation: Lessons from X-ray and radio astronomy. *Scientometrics*, 3: 325–34.
- Gieryn, T.F. 1983. Boundary-work and the demarcation of science from non-science: Trains and interests in professional interests of scientists. *American Sociological Review* 48: 781–95.
- Gieryn, T.F. 1995. Boundaries of science. In Sheila Jasanoff, Gerald E. Markle, James C. Petersen, and Trevor Pinch, (eds), rev. ed. *Handbook of science and technology studies*. Thousand Oaks, CA: Sage Publications.
- Hoppe, R., and A. Peterse. 1993. *Handling frozen fire*. Boulder, CO: Westview Press.
- Jamieson, D. 1998. Sustainability and beyond. *Ecological Economics* 24: 183–92.
- Jasanoff, S. 2004. Ordering knowledge, ordering society. In Sheila Jasanoff, (ed.), *States of knowledge: The co-production of science and social order*, pp 13–45. New York: Routledge.
- Jasanoff, S. 2005. *Designs on nature: Science and democracy in Europe and the United States*. Princeton, NJ: Princeton University Press
- Jasanoff, S. 2010. Testing time for climate science. *Science* 328(5979): 695–6.
- Kates, R.W., W.C. Clark, R. Corell, J.M. Hall, C.C. Jaeger, I. Lowe, J.J. McCarthy, H.J. Schellnhuber, B. Bolin, N.M. Dickson, S. Fauchoux, G.C. Gallopín, A. Grübler, B. Huntley, J. Jäger, N.S. Jodha, R.E. Kaspersen, A. Mabogunje, P. Matson, H. Mooney, B. Moore III, M. O'Riordan, and U. Svedin. 2001. Sustainability science. *Science* 292(5517): 641–2.
- Latour, B. 1988. The politics of explanation: An alternative. *Knowledge and reflexivity: New frontiers in the sociology of knowledge* 155–76.
- Latour, B. 1993. *We have never been modern*. Cambridge, MA: Harvard University Press.
- Latour, B. 2004. *Politics of nature: How to bring the sciences into democracy*. Cambridge, MA: Harvard University Press.
- Levin, S.A., and W.C. Clark. 2010. *Toward a science of sustainability*. Report from Toward a science of sustainability Conference, Air Force Research Center, Warrenton, VA, 29 November–2 December 2009.
- Lindblom, C. 1959. The science of muddling through. *Public Administration Review* 19(2): 79–88.
- Lubchenco, J. 1998. Entering the century of the environment: A new social contract for science. *Science* 279(5350): 491.
- Melosi, M.V. 2008. *The sanitary city: Environmental services in urban America from colonial times to the present*, abridged ed. Pittsburgh, PA: University of Pittsburgh Press.
- Miller, T.R., B.A. Minter, and L.C. Malan. 2011. The new conservation debate: The view from practical ethics. *Biological Conservation*

- Miller, T.R., T.A. Muñoz-Erickson, and C.L. Redman. 2011. *Transforming knowledge for sustainability: Fostering adaptability in academic institutions*. *International Journal for Sustainability in Higher Education* 12(2): 177–92.
- National Research Council. 1999. *Our common journey. A transition toward sustainability*. Washington, DC: National Academy Press.
- Nelson, R.R. 1977. *The moon and the ghetto: An essay on public policy analysis*. The Fels Lectures on Public Policy Analysis. New York: W.W. Norton & Company.
- Norton, B.G. 2005. *Sustainability. A philosophy of adaptive ecosystem management*. Chicago: University of Chicago Press.
- Nowotny, H., P. Scott, and M. Gibbons. 2001. *Re-thinking science: Knowledge and the public in an age of uncertainty*. London: Polity Press.
- Palmer, M., E. Bernhardt, E. Chornesky, S. Collins, A. Dobson, C. Duke, B. Gold, R. Jacobson, S. Kingsland, R. Kranz, M. Mappin, M. Martinez, F. Micheli, J. Morse, M. Pace, M. Pascual, S. Palumbi, O.J. Reichman, A. Simons, A. Townsend, M. Turner. 2005. Ecological science and sustainability for the 21st century. *Frontiers in Ecology and the Environment* 3(1): 4–11.
- Reid, W.V., D. Chen, L. Goldfarb, H. Hackman, Y.T. Lee, K. Mokhele, E. Ostrom, K. Raivio, J. Rockström, H.J. Schellnhuber, and A. Whyte. 2010. Earth system science for global sustainability: Grand challenges. *Science* 330: 916–17.
- Rittel, H.W.J., and M.M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4: 155–69.
- Sarewitz, D. 2004. How science makes environmental controversies worse. *Environmental Science & Policy* 7(5): 385–403.
- Sarewitz, D., and R.R. Nelson. 2008. Progress in know-how: Its origins and limits. *innovations*, 3(1), 101–17.
- Scott, J.C. 1998. *Seeing like a state: How certain schemes to improve the human condition have failed*. New Haven, CT: Yale University Press.
- Shapin, S. and S. Schaffer. 1985. *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life*. Princeton, NJ: Princeton University Press.
- Stirling, A. 2008. ‘Opening up’ and ‘closing down’ power, participation, and pluralism in the social appraisal of technology. *Science, Technology & Human Values*, 33(2): 262–94.
- Thompson, P.B. 2010. *The agrarian vision: Sustainability and environmental ethics*. Lexington, KY: University of Kentucky Press.
- Turner, B.L. II, Pamela A. Matson, James J. McCarthy, Robert W. Corell, Lindsey Christensen, Noelle Eckley, Grete K. Hovelsrud-Bronck, Jeanne X. Kasperson, Roger E. Kasperson, Amy Luers, Marybeth L. Martello, Svein Mathiesen, Rosamond Naylor, Colin Polsky, Alexander Pulsipher, Andrew Schiller, Henrik Selin, and Nicholas Tyler. 2003a. Illustrating the coupled human – environment system for vulnerability analysis: Three case studies. *Proceedings of the National Academy of Sciences* 100(14): 8080–5.
- Turner, B.L. II, Roger E. Kasperson, Pamela A. Matson, James J. McCarthy, Robert W. Corell, Lindsey Christensen, Noelle Eckley, Jeanne X. Kasperson, Amy Luers, Marybeth L. Martello, Colin Polsky, Alexander Pulsipher, and Andrew Schiller. 2003b. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* 100(14): 8074–9.



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