Science, Technology, and Sustainability: Building a Research Agenda

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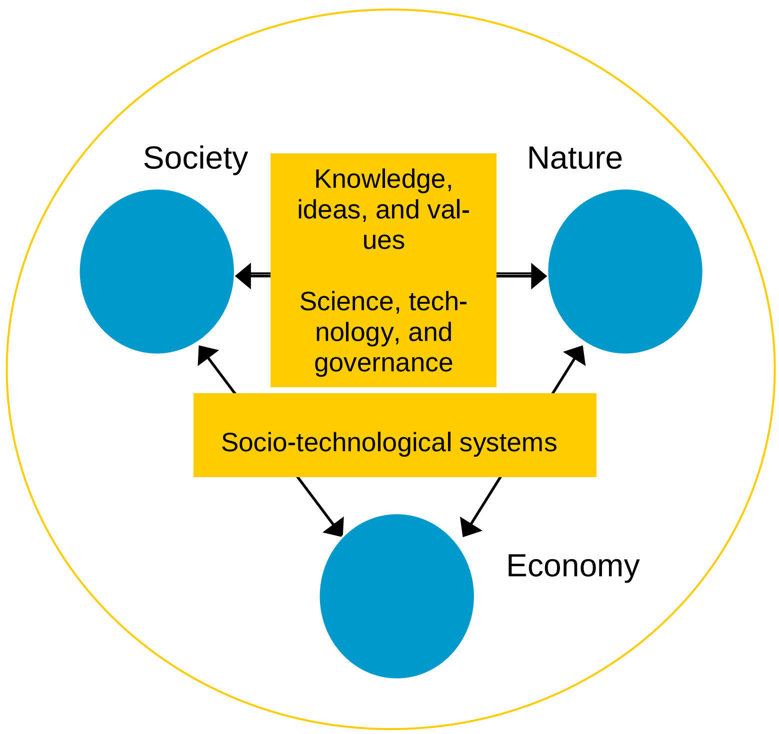
Report Prepared by:

Clark Miller
Arizona State University

Daniel Sarewitz
Arizona State University

Andrew Light
George Mason University



Introduction

Over the last decade, the thesis that scientific and technological research can contribute to overcoming sustainability challenges has become conventional wisdom among policy, business, and research leaders.[1] By contrast, relatively little attention has been given to the question of how a better understanding of the human and social dimensions of science and technology could also contribute to improving both the understanding of sustainability challenges and efforts to solve them. Yet, such analyses would seem central to sustainability research. After all, human applications of science and technology pose arguably the single greatest source of threats to global sustainability, whether we are talking about the energy and transportation systems that underpin global industrial activities or the worldwide expansion of agriculture into forest and savannah ecosystems. These applications arise out of complex social, political, and economic contexts – and they intertwine science, technology, and society in their implementation – making knowledge of both the human and social contexts and elements of science and technology essential to understanding and responding to sustainability challenges. Thus, while science and technology are central to efforts to improve human health and wellbeing,[2] the application of science and technology has not always contributed as anticipated in past efforts to improve the human condition.[3] It is essential, therefore, that research on the relationships between science, technology, and society be integrated into the broader sustainability research agenda.

This is the central conclusion of the workshop *Science, Technology, and Sustainability: Building a Research Agenda*, held at the US National Science Foundation on September 8-9, 2008. The workshop brought together national leaders in research on science, technology, and society (STS) to explore how the field could contribute to sustainability research. In this report, we use the identifier "STS" to refer broadly to researchers working in the full range of intellectual arenas encompassed by the NSF Program in Science, Technology, and Society.[4] Workshop participants were drawn from a wide range of disciplinary perspectives, including environmental history, sociology, philosophy, and ethics; history of science and technology; science, technology, and environmental policy; disability studies; and social studies of science and technology. Participants at the workshop also included representatives from federal science and technology agencies and the National Science Foundation.

Participants in the workshop were asked to address the following three questions:

- What unique perspectives are brought by research on science, technology, and society to understanding concepts of sustainability, challenges to sustainability, and sustainability solutions?

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[1] See, for example, the draft National Science Board report, *Building a Sustainable Energy Future* (2009).
[2] John Holdren, "Presidential Address: Science and Technology for Sustainable Well-being," *Science* 319 (5862): 424-434, 2008.
[3] James Scott, *Seeing Like a State: How Certain Conditions to Improve the Human Condition Have Failed* (New Haven: Yale University Press, 1998).
[4] This usage is deliberately broader than the sometimes narrower reference to sociology of science and technology or science and technology studies.

- What are the central research challenges or areas of research where STS scholars can make significant contributions to the broader sustainability research agenda?
- What infrastructure investments would improve the ability of researchers in the full range of STS fields to meet these research challenges and more effectively contribute to improving sustainability outcomes?

This report synthesizes discussions at the workshop that sought to address these questions. The report is divided into four parts. The first three describe what workshop participants identified as core perspectives brought by STS to the study of sustainability, as well an agenda for future STS research that emerged from that perspective for that would contribute to advance sustainability research and practice. The fourth highlights areas where investments in research infrastructure could significantly enhance the ability of STS to contribute meaningfully to improving sustainability research and outcomes. Here we offer a brief summary of each part:

Part I. Socio-technical systems: More than any other research domain, work in the fields of STS research focuses on the coupled systems that link human and social values, behavior, relationships, and institutions to science and technology. Like coupled human-natural systems or socio-ecological systems, socio-technical systems are central to understanding the nature and dynamics of sustainability problems and solutions. Key research questions include: How do the structure and dynamics of socio-technical systems contribute to unsustainable outcomes? How did socio-technical systems that contribute to unsustainable outcomes come to be constructed as they are, and how are those systems maintained over time? How are aspects of people's lives and livelihoods that are valued as integral to the meaning of sustainability impacted by the design and operation of socio-technical systems? How might sustainability be defined and understood in the context of socio-technical systems?

Part II. Knowledge, ideas, and values: A second central area of STS research that contributes directly to sustainability research are inquiries into the human and social practices and arrangements and conceptual and ethical frameworks that provide foundations for particular ways of knowing and valuing aspects of society and the environment that are critical to sustainability problems and solutions. Key research questions include: What ideas (concepts, beliefs, knowledges, ethics, and values) underpin people's understandings of nature, environment, science, technology, and society as they relate to sustainability? What social practices (behaviors, relationships, arrangements, and institutions) underpin the construction and maintenance of these ideas? In turn, how do these ideas shape social practices and relationships? What are the conceptual and ethical foundations of sustainability, in terms of both how diverse groups currently understand sustainability and how it might be better understood in the future?

Part III. Science, technology, and governance: The third core conceptual focal point of sustainability research in STS is its focus on strategies and institutions for governing science and technology in society. Sustainability solutions are likely to require fundamental changes in science and technology policy, management, and regulation that STS research can valuably inform. Key research questions include: How can change be brought about in existing socio-technical systems and systems of knowledge and valuation to create more sustainable alternatives? How can practices of design and innovation be conducted so as to enhance the ability to fashion in the future more sustainable socio-technical systems or systems of knowledge and information from the outset? What governance arrangements might enhance the ability of societies to achieve more sustainable socio-technical systems or systems of knowledge and valuation?

Part IV. Infrastructure needs: The final section of the report discusses the infrastructure challenges and needs if research in STS is to effectively contribute to broader research on sustainability. These include:

- **Opportunities for networking and field-building**: To address the research needs described in this report will require support for the establishment of both interdisciplinary research teams and a broader interdisciplinary field of researchers who can exchange ideas, data, methods, and models; construct and pursue a collaborative research agenda; and build the human capacity to address the long-term challenges of sustainability.
- **Long-term, systematic, interdisciplinary research initiatives**: The scale and complexity of sustainability problems demands a larger scale of research effort and support for systematic research efforts over a longer period of time than can currently be funded under existing grants from the NSF Program in Science, Technology, and Society.
- **Cyberinfrastructure**: To support the envisioned research efforts will require new investments in cyberinfrastructure that can support virtual interdisciplinary and collaborative work environments, large-scale professional networking platforms, storage and dissemination of data and other materials; and monitoring and feedback regarding the field's research and its impacts.
- **Graduate and postdoctoral training initiatives**: Opportunities in the field for advanced conceptual and methodological training for graduate students and postdoctoral researchers is essential, yet sparse, at best, ad hoc, and localized, while existing graduate programs are highly specialized and do not always afford opportunities for broad cross-training of the next generation of scholars in the kinds of skills and knowledges necessary for grappling with sustainability.
- **Enhancing diversity**: Participants also identified enhancing the diversity of STS researchers as a key priority, especially among underrepresented groups. Framings of sustainability and potential responses are strongly related to worldviews, ways of knowing, and socio-cultural and historical contexts, so diversity is not only important for obvious equity reasons, but also to help ensure a sufficiently rich array of problem framings and identification and elucidation of diverse sensibilities about the environment, technology, justice, and sustainability.
- **Support for international research, training, and collaboration**: Sustainability problems are, in many cases, fundamentally transnational, requiring significant investments in opportunities for international research and education of US researchers and the preparation of an STS workforce that has the skills, contacts, and experience necessary to pursue research on international and global phenomena.
- **Focal points for engagement and application of research**: Participants identified the establishment of institutional capacities for engaging with leaders in science and engineering, policy, business, and civil society in order to help apply insights from STS research to practical sustainability problems as a key gap in existing infrastructure.

I. Socio-technological systems

At the core of many of the globe's most critical sustainability challenges lie large-scale technological systems deployed in the service of human goals and objectives. Worldwide, the mining, production, distribution, and consumption of fossil fuels contribute not only to rising atmospheric concentrations of carbon dioxide but also to the transformation of landscapes, the release of particulate matter that causes asthma, the creation of smogs that have turned cities and their local airspace dirty brown worldwide, and numerous other sustainability challenges. In many cities, the urban built environment now expands outwards from city centers so far that it is no longer labeled suburban but exurban sprawl, contributing to conversion of land use, commute times, highway and other infrastructure construction, and continued increases in per capita automobile ownership. Water consumption in the cities of the American West is both facilitated and exacerbated by technological systems, from vast canal and pumping systems that move water hundreds of miles to large-scale agriculture, industry, and energy systems that consume it.

Research in the field of science, technology, and society is well positioned to contribute valuable insights into the study of the human dimensions of large-scale technological systems. Within STS, major research advances have identified the diverse and complex ways that human ideas, interests, values, relationships, and institutions are closely intertwined with technological systems to form what the field calls socio-technological systems. The human elements of socio-technological systems are critical to understanding how and why these systems take the forms that they do, how they are maintained, and how they get taken apart and replaced with alternatives. The complex challenges of sustainability facing 21st century societies are thus bound up, in other words, not just in technological systems and their impacts on the environment and society but more importantly in the ways in which technological systems are integrated into the ways individuals and groups live, their designs and ambitions, and their goals for themselves and for the their children's futures.

Put in its simplest form, then, the sustainability challenge is largely about how human societies in the 21st century choose to build, maintain, and reform the socio-technological systems of the future. To understand how those choices are being made, now, and to provide critical insights into their consequences and how they might be made better, requires the kinds of insights into socio-technological systems that STS research can provide. Sustainability will demand critical insights into how people design, value, and use technologies, as well as how technological appetites and practices come about, are sustained, and might be altered in more sustainable ways. At the same time, it requires a focus on questions of what sustainability means in the context of socio-technological systems and how socio-technological systems distribute risk, vulnerability, and responsibility among their component parts. Finally, sustainability raises complex questions about the meaning and practices of technological globalization. Described below are several illustrations of where STS research might contribute to the broader sustainability agenda.

Sustainability in socio-technological systems

What makes for a sustainable socio-technical system? How might one approach the question of sustainability as a feature of how people inhabit socio-technological systems? The workshop identified these and other closely related questions as crucial parts of an agenda for STS research exploring sustainability. Sustainability science often approaches questions of sustainability via place-based analyses, but socio-technological systems often transcend place to encompass multiple communities across the globe, with different interests, goals, and desires. Much as environmental policy recognizes that features of nature, such as watersheds, join upstream and downstream communities in a shared environmental challenge, so, too, socio-technological systems link the problems of sustainability of coffee drinkers in the United States and Europe to coffee producers in dozens of remote mountain locations around the globe. STS research offers potentially unique insights into how these systems work and also into the effectiveness of possible strategies, such as certification systems and other kinds of standards for making such systems more sustainable.

STS research could also significantly address the challenge of anticipating what it might mean to define sustainability within socio-technological systems. While a great deal of sustainability research has focused on the environmental impacts of new technologies, far less has attended to their human impacts: what it means to live meaningfully when a part of one's life is bound up with the functioning of a large-scale technological system. Once systems become pervasive, securing their continued functioning can lead to widespread consequences for ecological and human communities, as has become clear in the case of the petroleum industry worldwide. What would it mean for a socio-technological system to be socially sustainable? Are social and ecological sustainability always aligned, or are there trade-offs between them? At the same time, environmental and health legacies can also create complex challenges that live in spaces that are or perhaps once were deeply bound up with technological systems.

Distributions of risk, vulnerability, and responsibility

While the vulnerability of New Orleans to hurricanes was well understood by atmospheric and environmental scientists, Hurricane Katrina revealed fundamental socio-ecological vulnerabilities built into the large-scale technological systems that were supposed to protect the city. Such systems, designed to protect from mid- to low-level threats, exacerbated the consequences of an event that overwhelmed them. People, seeing the protections offered by the levies, built a city in low-lying areas. Water that overtopped the levies had nowhere to go and remained for months. Insurance policies reimbursed people for wind damage to their properties but not water damage, preventing them from rebuilding due to a lack of funds. Citywide destruction overwhelmed the capacity of the construction industry to rapidly rebuild. Large-scale chemical facilities dumped toxic chemicals into flood waters, which in turn distributed them in patterns across the city determined by both landforms (many of which were artificial) and technological barriers. Overlapping jurisdictions and confused responsibilities contributed, before the disaster, to delays in repairs and maintenance.

Complex socio-technological systems inevitably distribute risks, vulnerabilities, and responsibilities across diverse human communities and geographies. Understanding these distributions, their links to system design and operation, and possibilities for reform is another area where STS research could significantly contribute to research on sustainability. What makes for a sustainable city? That question faced New Orleans, pre-Katrina and post-Katrina, just as it faces many cities around the globe. Who has responsibility for ensuring its sustainability? What risks and vulnerabilities does the system distribute, and to whom? Similar questions might be asked about risks associated with transportation systems. What makes for a safe automobile? Is that even the right question? Should we instead ask what makes for a safe system for transporting people and goods where we need them to go? Who has responsibility for making sure that automobiles are safe: industry, government, automobile owners? How do we choose to ensure safety, and how does that, in turn, distribute new risks and vulnerabilities?

Sustainability and the globalization of technological systems

Another area where STS research could perhaps uniquely contribute to sustainability is in analyzing the processes and consequences of the globalization of socio-technological systems. Underpinning global markets is an equally global expansion of the technological infrastructures – communications, transportation, production – that make markets possible. Surprisingly little attention has been given to these socio-technological systems in sustainability research, except perhaps in a few highly symbolic and politically salient cases, such as the mining industry. Almost no one paid attention, for example, until food riots were occurring around the world, that there might be potential consequences to large-scale shifts away from fossil fuels toward biofuels produced on croplands. Likewise, little thought was given to what operating chemical facilities in different cultures might mean for safety practices in those facilities until after the catastrophic methyl isocynate leak at Bhopal.

Precisely because STS research examines how people interact with technological systems it is uniquely poised to critically examine what the export of large-scale technological systems from one social context to another might mean. How do communities give meaning to new technologies that they encounter? Under what conditions do social values, relationships, and institutions get reorganized to accommodate new technological systems, and how does this take place? Likewise, under what conditions do communities resist new technologies or adopt them in ways unanticipated by their designers or differently than in other countries? What are the potential consequences of these transformations, adoptions, and resistances for the sustainability of both the communities involved and the larger-scale socio-technological systems of which they now find themselves a part? Questions such as these might be asked of a wide range of innovations being expanded globally, from information and communication technologies to carbon markets.

Sustainable design of socio-technological systems

Finally, STS research has the potential to aid significantly in enhancing the possibilities for sustainable design of socio-technological systems. STS research offers, first and foremost, unique perspectives on technological systems that could allow for investigations into dimensions of system design that may not always factor in to design decisions. While STS researchers have shown that engineering design work is often simultaneously technical, economic, political, and social – what has been labeled heterogeneous engineering – a more reflexive attentiveness to these dimensions in the design process, with a particular focus on how people will live and work within socio-technological systems, could potentially add valuable insights into both successes and failures of sustainability. In this sense, STS research provides methods that could inform the evolution of institutions and settings where designs occur, as well as design processes themselves, by bringing new kinds of expertise into design decisions.

At the same time, STS research could help better understand the social dynamics of design processes and thus help to refashion design decisionmaking. STS research, for example, is beginning to grapple with the challenge of designing strategies for engaging publics in processes of imagining and deliberating technological futures. In collaboration with designers, planners, and engineers, STS scholars could help use such approaches to help communities reflect more purposively on the kinds of technological societies they would like to inhabit in the future and how those societies might be designed to be more sustainable from the outset.

II. Knowledge, ideas, and values

In his masterpiece *Nature's Metropolis*, William Cronon speaks of second nature: the nature humans imagine and fashion. Through their work, STS scholars in a wide range of fields including environmental history, feminist scholarship, science studies, and environmental ethics have put significant efforts into understanding how diverse individuals and communities understand and value nature and the environment across cultures, contexts, places, and historical eras. At the same time, this work has examined how humans have translated their ideas about nature into the shaping of landscapes, parks, zoos, forests, and other natures. European empires fundamentally transformed ecologies around the globe in the service of creating productive colonial enterprises. Cities captured the resources of their hinterlands, at the same time creating radically different landscapes from what existed prior. Governments protected certain landscapes, often removing humans from within their boundaries and fashioning them into putative wilderness spaces.

Today, similar work is beginning to flesh out the conceptual and ethical foundations of sustainability. In a not entirely dissimilar fashion as their historical counterparts, today's sustainability researchers are building models of nature and the environment that once again are determining where and how people, animals, and plants may and may not inhabit. STS researchers are critically examining the social, epistemic, and ethical foundations of sustainability research. Environmental philosophers are exploring how questions of equity, fairness, property, and value are being worked out in sustainability projects in the service of enhancing the visibility and deliberation of trade-offs among value choices that might otherwise remain tacit and unexamined and, potentially, undo the benefits of the project to humans and the environment.

Conceptual and ethical foundations of sustainability

What is sustainability? Much ink has been spilled on this subject, and many who seek sustainability have increasingly begun to avoid the question altogether, either out of a concern that definitional debates will prevent action or because of growing critiques of the vagueness of broad definitions of the term. By contrast, STS research is beginning to offer new and valuable research approaches to accomplishing at least two important objectives vis-à-vis clarifying the conceptual and ethical foundations of sustainability. First, STS research has begun to examine in depth, clarify, and classify into meaningful categories the diverse definitions and approaches to sustainability. In this fashion, STS research, especially in environmental philosophy and environmental history can help to make sense for sustainability researchers and practitioners, as well as broader publics, of the diverse concepts and values that underpin conflicts over sustainability, their similarities and differences, and possibilities for meaningful deliberation.

At the same time, other STS research offers the potential for advancing novel conceptual and ethical models that could deepen and extend the philosophical foundations of efforts to understand and achieve sustainability. Bryan Norton's recent treatise *Sustainability: A Philosophy of Adaptive Ecosystem Management* offers an example of how work in environmental philosophy can not only clarify diverse understandings of sustainability but advance the moral and intellectual underpinnings of key concepts like adaptive management that underpin a wide range of sustainability practices and programs. In a similar fashion, David Takacs' *The Idea of Biodiversity* helped to create a much richer and more subtle understanding of the epistemic and value foundations of the rapidly growing field of conservation biology. Critical work remains, however, both to explicate and deepen the emergent conceptual and ethical foundations of sustainability work. At the same time, work in environmental history, following in the traditions of works like Cronon's *Changes in the Land* and Gregg Mitman's *Breathing Space* and *Reel Nature*, can significantly advance our understanding of how such conceptual and ethical frameworks came to be and how they have influenced the fashioning of the landscapes and communities humans now inhabit.

Knowledge and valuation systems

STS research is also poised to help explicate, empirically, the social, institutional, epistemic, and valuation practices that characterize existing framing of sustainability problems and solutions and management of natural resources and socio-technological systems. Analysis of knowledge and valuations systems has a long history in STS research, including examinations of the practices and arrangements underpinning the work not only of scientific fields and disciplines but also of government agencies, corporations, social movements, and other actors in struggles over nature and the environment. Such research can help understand how and why problems are framed in certain ways, the social and political work that goes into epistemic and value production, the possibilities of alternate ways of imagining and approaching sustainability problems, and the ways in which certain views and perspectives are systematically excluded. In certain arenas of sustainability, such as climate change, STS research has built extensive understandings of the functioning and organization of knowledge and valuation systems and their strengths and pathologies. In the vast majority of arenas of sustainability, such work is either nascent or non-existent.

Similarly profitable would be STS research that contributed to the fashioning of new conceptual models for understanding and analyzing knowledge and valuation systems and their implications for individual and community decision-making. While sustainability research has begun to engage this topic, it has done so without the rich empirical and conceptual backdrops available in STS research. STS research in this area could substantially enhance the capacity of sustainability efforts to understand the existing knowledge and valuation systems that underpin sustainability challenges as well as to more effectively engage those systems in efforts at reform and revaluation. Similarly, STS has considerable insights to offer into how a wide array of sustainability knowledge systems – including models, indicators, and databases – function to enable and delimit the possibilities of what can be known and acted upon within their frameworks, as well as to potentially envision new approaches to data and modeling that transcend existing limits and create the possibility of more socially and sustainably robust knowledge and valuation systems.

Sustainability, democracy, and justice

A third area where STS approaches and insights can significantly enhance sustainability research is in bringing sustainability into dialogue with other important conceptual and normative concerns in society. STS research in environmental philosophy and ethics, for example, can help illuminate where and how efforts to achieve sustainability converge and diverge with problems of justice. While sustainability is often not understood in terms of justice, questions of justice are often implicit in both sustainability problems and solutions. Environmental refugees, for example, can emerge from both complex sustainability problems, such as the failure to adequately protect communities against natural hazards or to facilitate adaptation to changing climatic conditions, as well as policies designed to enhance sustainability, as when the creation of natural parks excludes from these spaces individuals and communities who have used them historically to provide material resources. The resultant situations raise critical questions about the rights of diverse communities, the potential bases of their claims to justice, and the processes by which such claims are – or are not – adjudicated.

In another example, STS research in socio-technological systems could examine questions of democracy, system design, and management. STS research can offer both critical assessments of whether processes for the design and management of socio-technological systems function or not in ways that comport with important notions of democracy as well as offering models and experimental methods to researching alternative processes and approaches that might enhance the democratization of scientific and technological decision-making.

III. Science, technology, and governance

The third major thematic emphasis of the workshop discussions focused on science, technology, and governance – including both the governance and management of science and technology and the contributions of scientific and technical expertise to governance and policy. Understanding both is crucial to sustainability, and STS has much to offer to both.

On the one hand, the detrimental consequences of large-scale socio-technological systems for sustainability are legion, demanding new models of the governance of science and technology that orient them toward enhancing sustainability outcomes. In the field of emerging technologies, STS research has inquired deeply into existing arrangements for governing science and technology and has begun to articulate and test new, more reflexive and anticipatory approaches to governance. There is now a need to begin to develop and evaluate comparable models regarding the reform of existing scientific and technological systems to render them more sustainable. New experimental approaches will be necessary in ways of developing insights into the human and social dimensions of scientific and technological change and integrating those insights into sustainability decisions through effective engagement with technical, business, policy, and civic communities.

On the other hand, the complexity, uncertainty, and novelty of many sustainability problems challenges existing social and institutional arrangements for producing and applying knowledge to policy decisions. Work in STS has significantly advanced conceptual models of knowledge and decision making that goes well beyond the over-simplistic linear and deficit models that characterized prior research and continues to dominate public policy discussions in the United

States. While this conceptual work must continue, especially with regard to the kinds of complex policy environments frequently reflected in sustainability governance, there is also a strong need to begin to develop more policy-relevant research that can contribute to enhancing or transforming existing approaches to knowledge creation, synthesis, and uptake to cross disciplines and blend scientific and other forms of knowledge, in light of evolving insights into decision making that recognize, incorporate, and take advantage of the full diversity of knowledge and ideas available to guide sustainability policy.

Democratic governance and the fashioning of technological futures

A central challenge for enhancing the social and ecological sustainability is opening up decision-making surrounding the design, creation, and operation of large-scale socio-technological systems to broader deliberation. STS research into the conceptual foundations of sustainability has highlighted the crucial question of identifying what is being sustained: what kinds of ecologies and what kinds of societies? These questions are fundamentally embedded in what kinds of technological systems society chooses to build, whether collectively, via public policy, or through individual decisions by consumers and citizens. Yet, most decision making within such systems assumes a degree of technical essentialism – decisions are made on technical criteria, while questions of societal values and meaning remain tacit and unacknowledged. Arguably, this limited context for decision-making is a key factor underlying unsustainable development paths.

In response, STS researchers have called for upstream engagement of broader publics in scientific and technological decision-making, in which citizens become involved in choices of design and implementation, whether as knowledge holders or authoritative decision-makers. The question of how to achieve robust upstream public engagement, while crucial to the possibility of sustainable governance of science and technology, is ripe for new STS research. A key challenge, for example, is how to enable public participants to understand and make visible the potential technological futures for society that stem from today's choices about how to design new infrastructure or new technologies. Equally challenging is to continue to advance STS research into effective strategies for encouraging effective deliberation of socio-technological options. A third challenge is to structure decision-making processes that ensure that public inputs are meaningful and are effectively integrated into decisions that also entail substantial technical elements. Such processes need to ensure that choices are revisited as the imagined technological futures become concrete as technologies are constructed and used in society. Finally, important research is needed into the training necessary for technical, policy, business, and civic participants to ensure these processes viably inform decision-making, rather than rendering decisions impossible.

Managing large-scale technological transformation

A specific case of democratic governance of science and technology critical to sustainability involves the transformation of large-scale socio-technological systems to more sustainable alternatives. Chief among these are energy systems, which are particularly visible today, but transportation, water, materials, agriculture, and many other technological systems (many of which, of course, are interdependent and overlapping) face equally important transitions. European STS research has already begun to focus systematically on the management of sustainability transitions in a variety of industrial sectors, but US research in this field lags considerably behind.

Because technological systems are deeply embedded in the possibilities of meaningful life and livelihoods for most people in the US, technological transformation is likely to bring significant implications for human wellbeing and welfare. Managing these transitions with an eye toward their human and societal dimensions will be critical to enhancing sustainability, and research into approaches for doing so would be extremely valuable.

Consider energy, for example. It is now generally recognized that, while last year's food price rises were the result of complex causal relations, future speculation on the emergence of biofuels markets, as well as actual diversions of significant amounts of grain from food to fuel to meet EU and prospective US renewable portfolio standards would like have driven food prices to unacceptable levels. In Canada, opening of the Albertan oil sands distorted labor markets throughout the country. In Mexico, oil revenues provide crucial subsidies to the nation's poorest communities, yet those revenues are already declining. Put simply, substantial changes in energy production and consumption may be crucial for sustainability, but they may also entail enormous societal dislocations and implications that are likely to accompany such changes, not to mention the equally significant rearrangement of risks, vulnerabilities, and responsibilities such system changes will also incur. Historical studies of technological systems change offer potentially valuable insights into these kinds of processes, as do contemporary ethnographies of technologies-in-transition.

Enhancing knowledge systems for sustainable governance

Sustainability researchers have identified the development of new knowledge systems – such as novel sets of indicators – as critical to the ability of governance processes to enhance sustainability. In many respects, however, the model used to guide these efforts remains bound up in the fallacies of what STS researchers have identified as the linear model of science-to-decision-making. STS research has much to offer, therefore, to enhancing the capacity to bring diverse knowledges to bear on sustainability policy problems and challenges.

One important arena for future STS research in this field is in expanding theoretical models to take account of the complexity of knowledge and decision-making contexts involved in sustainability. Sustainability problems often involve multiple, diverse producers and consumers of knowledge; multiple organizations that operate fully institutionalized systems for producing, vetting, and applying knowledge to agency choices; complex dynamic interactions among participants; and trade-offs among values associated, e.g., with diverse ecosystem services. Understanding the knowledge and decision-making ecologies that operate in such contexts requires conceptual frameworks and methodological approaches drawn from STS research, as do efforts to reform and improve the functioning of such ecologies to enhance sustainability.

Another important arena for future STS research is in the field of applied knowledge systems analysis and reform. STS research, for example, has worked for over a decade to depict in intimate detail the ways in which the sciences of the global environment have constructed and deployed models of planetary ecological risks, as well as the kinds of expert advisory processes that have been created to synthesize and represent scientific knowledge and ideas in international governance. Part of this analysis has been to critically evaluate the tacit values and social assumptions embedded in global models and expert institutions and networks, how problems are framed within them (and where alternate frames have been neglected or suppressed), the styles of reasoning and evidentiary norms adopted, how they manage uncertainties, and numerous other aspects of both their epistemic foundations and the co-production of epistemic and social order within them. Future STS research will need to build on these insights with more applied research that examines how the global environmental sciences – which could in many respects be understood as the new human sciences of the 21st century – and their roles in international governance can be reformed in ways that facilitate more explicit and broader deliberation over the epistemic foundations of decisions that impact every individual and community on the planet.

Application of sustainability ethics and values in decisionmaking

Another area where novel opportunities exist for use-oriented STS research is in the field of environmental and sustainability ethics. Here, too, research in environmental ethics and philosophy has made significant contributions to eliciting the normative underpinnings of the idea of sustainability. For this research to contribute significantly to sustainability outcomes will require new insights into how normative and ethical considerations can be applied meaningfully in the complex and contested contexts that comprise the most difficult of sustainability challenges. This offers exciting opportunities not only to continue to advance ethical theory but also to fashion new fields of applied ethical practice or what Robert Frodeman has called field philosophy, the pursuit of philosophy not simply as an academic exercise but as a critical component of complex policy deliberations, analyses, and developments.

Infrastructure Needs

STS researchers are already beginning to tackle the agenda described in the prior three sections and to translate their work into concrete contributions to enhancing broader sustainability research and its application. At the University of Texas-Austin, for example, Dr. Stephen Moore has developed a unique research and educational effort that works to integrate STS ideas and approaches into the practice of architecture and design. One of his research projects examines city building codes to determine the potential for incorporating considerations of social equity and sustainability. This work recognizes, as described above, the value of understanding that sustainability is deeply embedded within socio-technological systems and that only by understanding those systems in an integrated way that grapples simultaneously with their societal and technical dimensions can we identify useful approaches to enhancing sustainability. Dr. Moore has also successfully launched a new graduate program in sustainable design, again integrating STS ideas and concepts into design practice, oriented toward sustainability.

A second example of existing STS research in this tradition is that of Dr. Phil Brown of Brown University. Dr. Brown is an environmental sociologist whose work is closely integrated with epidemiology and toxicology in the analysis of community health challenges created by industrial waste. Through community-based research, working closely with impacted individuals and groups, this work inquires into the sociology of environmental disputes and the formation of environmental health movements in response to the environmental legacies of technological systems. At the same time, it seeks to aid communities in improving their understanding of industrial systems and their consequences for environmental health and to enhance their ability to effectively govern and regulate technological industries in their midst to create healthier and more sustainable lives and livelihoods.

A final example of current STS research is that of Dr. Sheila Jasanoff, who has worked for much of the past two decades to examine the institutionalization of risk assessment the US federal government. This aspect of Dr. Jasanoff's work focused on the epistemic construction of risks analysis and the institutionalized processes by which government agencies solicit, conduct, standardize, and use risk analyses to shape regulatory decisions. For this work, she was selected to serve on the Committee on Risk Assessment of Hazardous Air Pollutants of the National Academy of Sciences and, subsequently, to be a member of the National Academy of Sciences Committee on Risk Characterization in its work on *Understand Risk: Informing Decisions in a Democratic Society*. The latter report revisited and fundamentally revised the way federal agencies approach risk assessment and its relationship to policy decisions. Dr. Jasanoff has also served as an advisor to the European Union and other European governments in addressing the risks of genetically modified organisms.

While these and other individuals have been successful in certain instances in bringing STS research to bear on efforts to enhance sustainable outcomes in society, infrastructural shortcomings seriously limit the fields' broader capacity to pursue the kind of sophisticated, interdisciplinary research necessary to grapple effectively with the complexity of sustainability challenges. If the field is to reach its full potential, in this regard, new infrastructure support will be necessary across a range of important areas, including opportunities for advanced graduate training, international research and education experience, long-term support for complex, dynamic research programs, and many others. Participants at the workshop stressed the critical importance of new kinds of interdisciplinary, multi-university collaborations that can help overcome a number of key weaknesses in existing research infrastructure.

STS research on sustainability has an enormous potential to contribute fundamental insights into not only the character and dynamics of threats to sustainability but also robust solutions that fully address the integrated social, epistemic, technological, and ecological dimensions of contemporary sustainability challenges. Without significant new investments in research infrastructure, however, these ambitious and necessary goals will be difficult to realize. Specific infrastructural needs identified by the workshop included:

Opportunities for networking and field-building

As discussed in the introduction to this report, a key challenge for STS researchers in the United States is the absence of regular, systematized opportunities for fashioning networks and building research communities around the topic of STS and sustainability. While annual professional society meetings bring together sub-groups of the potential community of researchers, they do so largely within disciplinary communities. Even the Society for Social Studies of Science (4S) meetings draw only a fraction of STS researchers working in this area, often not including historians or philosophers of science, technology, or the environment. Nor do 4S or other professional society meetings traditionally include significant opportunities for engaging with either science and engineering communities pursuing research on sustainability or practitioners involved with policy or management of sustainability. Finally, such meetings often provide poor environments for engaging thoroughly and systematically with particular research topics. The rapid growth of such meetings has generally resulted in more frequent sessions of shorter duration, with shorter and less rich papers, sometimes even no more than 10-12 minutes in length, and also with multiple, overlapping sessions that fragment attention and offer relatively little opportunity for coordinated scheduling.

Rectifying these deficiencies will require multiple strategies. The field of STS and sustainability would benefit substantially from regular opportunities for researchers to share and explore new ideas in depth and from a variety of disciplinary perspectives, to examine and plan opportunities for collaborative, multi-disciplinary research projects, and to bring together not only senior scholars but also graduate students, postdocs, and young faculty to create genuine community and mentorship required to ensure the continuity, growth, and intellectual development of the field. Regular meetings would also offer an opportunity to invite key scientists, engineers, and practitioners to engage in cross-disciplinary planning and exchange of ideas. The field would also benefit from a coordinated effort to build intellectual ties with relevant science, engineering, and practitioner communities through systematic efforts to send representatives to other professional meetings, such as the Ecological Society of America. While individuals already pursue these kinds of interactions, a coordinated effort would allow these efforts to build on one another in a genuine form of field building.

In recent years, the European Union has pursued a targeted strategy of building research networks that address similar needs to those described here. In doing so, the EU recognized that researchers across Europe are often poorly networked, especially outside of France, Germany, and Britain, and that network and community-building efforts could significantly enhance European research productivity and the European research environment, thus ideally slowing a brain drain to the United States. While the current state of STS and sustainability differs from the European case in some respects, in others it is remarkably similar. Pockets of scholarship, divided by geography and discipline, need to be brought together and integrated to achieve the objectives of significantly enhancing research productivity and advancing the application of that research to help achieve sustainability goals.

Long-term, systematic, interdisciplinary research initiatives

The complex sustainability challenges facing contemporary societies are dynamic, long-term problems that have evolved over decades or centuries and will be solved only through decades of social, policy, and technical innovation. In several areas, sustainability research has taken advantage of investments in long-term data collection and synthesis efforts, such as demographic trends from Census data, energy production and consumption patterns sampled by the Energy Information Agency, or NSF's Long-Term Ecological Research network, to produce critical insights into sustainability problems. With respect to the dynamic evolution of knowledge and valuation systems, socio-technological systems, and governance systems, however, long-term data is rare, especially vis-à-vis contemporary sustainability challenges. Some such data is available, of course, for example, through historical studies or, in the case of anthropology, when senior scholars have had the opportunity to visit research sites over decades. Such glimpses of long-term dynamics can provide highly valuable insights, but are infrequent, at best, and often limited to the work of a single individual.

STS research in sustainability would significantly benefit from opportunities for longer-term, interdisciplinary teams of researchers to systematically engage in a coordinated research agenda over longer periods of time than are conventionally available through the STS program at NSF. STS researchers have had extremely limited opportunities to seek funding for longer-term research such as those that are routinely available in other fields, such as research centers in science and engineering fields (which typically run 5-10 years on NSF support, followed by other avenues of funding) or the multi-decadal survey instruments that NSF has funded in sociology and political science. To be sure, STS research in sustainability will likely follow quite different methods and approaches from the other kinds of longer-term studies NSF has funded. Nonetheless, the long-term objectives are the same: to be able to understand long-term dynamics and phenomena that have significant bearing on our nation's ability to solve critical sustainability challenges.

One approach discussed at the workshop in some detail focused on the establishment of long-term research sites that could focus as focal points for infrastructure development, including the development of interdisciplinary research teams; long-term data collection, storage, analysis, and dissemination efforts; development of systematic ties with science, engineering, practitioner, and civic communities; and the application of research to enhancing sustainability outcomes. A few research groups in the STS and sustainability have fashioned preliminary research sites that illustrate some of the benefits that could emerge from the establishment of long-term research sites. For example, the Contested Illnesses Research Group at Brown University has built a series of projects that, over time, have built collaborations between STS, sociology, and environmental health researchers and community groups that have significantly enhanced our understanding of the health risks communities face from environmental pollution and community-based strategies for reducing those risks. In another example, the Center for STS at Santa Clara has established a multi-year program titled the Global Social Benefit Incubator that brings together experts from STS, business, and engineering to enhance the capacity of social entrepreneurs to scale up and make more sustainable local development projects in a wide range of developing countries.

Another approach to the establishment of long-term research sites could develop through partnership with existing long-term research programs in sustainability science and engineering, such as the University of Massachusetts-Lowell Center for Sustainable Production or the recently established Urban Long-term Ecological Research Sites in Baltimore and Phoenix. Existing limited collaboration between researchers from these initiatives and STS researchers offer both evidence of the potential fruitfulness of longer-term partnerships, e.g., in the development of productive research findings, as well as the foundation for longer-term, more significant collaborative research initiatives.

Cyberinfrastructure

Any effort to significantly upgrade the capacity of the field of STS and sustainability to pursue collaborative, interdisciplinary research and its application to enhancing our understanding of and ability to address sustainability challenges must take advantage of significant advances in cyberinfrastructure. Novel cyberinfrastructure tools, pioneered in other disciplines, have yet to be adequately institutionalized in STS research, yet offer the ability to enable a wide range of capacities that will be essential to advancing STS and sustainability research goals:

- Establishing **virtual work environments** that promote advanced research activities across distributed, multi-institutional research collaborations and teams. From inexpensive, Internet-based video conferencing technologies that allow teams to communicate regularly in cross-site meetings to new, web-based work platforms that allow data, ideas, and work products to be shared and developed in collaborative virtual environments, new tools can greatly facilitate work across dispersed teams. Such platforms have been largely unavailable, however, within STS research communities and could significantly enhance research on STS and sustainability.
- Creating **large-scale professional networking platforms** could also significantly enhance work in the field, especially by enabling individual researchers to have a much greater capacity to identify potentially valuable prior research or opportunities for collaboration, outreach, or application of their work. Crucial to such platforms is in part their ability to represent profiles of individual researchers and research teams, as well as others with an interest in the field, such as funding agencies, science and engineering teams, or practitioners and policy officials. Just as crucial, however, are their intelligence engines, which bring significant added value to platform participants by connecting them to news items, published research outside the field (e.g., through Google Scholar), upcoming conferences and events, and other available resources in a "smart" fashion.
- **Storage and dissemination of data and other materials** is also a critical potential function of cyberinfrastructure. While many fields of research have developed large-scale programs for sharing data across communities, STS has not done so in significant ways, especially in the field of sustainability. As a result, the field has had limited opportunities for researchers to build explicitly on one another's work, to develop comparative projects, and to store and maintain data for long periods of time to facilitate future follow-up research to examine long-term dynamics and change. Development of such infrastructure would require advanced approaches for recording, integrating, and analyzing qualitative data and materials, especially in comparative contexts. Data, analyses, reports, and findings could also be made available broadly to science, engineering, and practitioner communities.
- **Monitoring and feedback** functions of cyberinfrastructure could also provide valuable tools for the community, not only making management and reporting of infrastructure use systematic, straightforward, and relatively less effort intensive, but also highlighting successful patterns of use that can be adopted by others as well as unexploited opportunities the network is not yet taking advantage of.

Graduate and postdoctoral training opportunities

Another area where STS research on sustainability could use substantial infrastructure investment is in the development of advanced training institutes or summer schools for graduate students and postdocs. By and large, the US STS research community has not made widespread use of opportunities to provide advanced training opportunities for graduate students, postdoctoral researchers, or young faculty. Several European universities, for example, offer advanced summer schools in STS research methods and techniques, but there are no counterpart programs in the United States. Especially in the area of sustainability research, workshop participants noted, advanced training opportunities could bring significant benefits, including not only opportunities for research training but also opportunities to provide training in STS skills and ideas to researchers and practitioners outside of the field. Particular areas of emphasis for training might include:

- **Advanced research training**: a signal feature of STS research training as it currently is conducted in graduate training programs is the absence of all but a small handful of programs that are able to provide methods training across the wide range of skills, approaches, and techniques used in STS research. Short courses designed to provide unique methods and skills could substantially enhance the capacity of researchers across the community and expand the community's ability to tackle important research problems. Similarly, research in STS on sustainability would benefit from advanced training opportunities focusing on core research concepts and themes that would ensure that young researchers across the field benefited from highest-level preparation to conduct their research.
- **Professional program development**: in addition to advanced research training, workshop participants identified several new areas where new degree programs would substantially enhance the infrastructure of the field to respond to sustainability challenges. Suggestions focused on professional training programs targeted toward the creation of cadres of professionals trained to apply core ideas from STS research in practical, policy, or technical careers. For example, applied professional training opportunities in ethics related to sustainability and climate change were highlighted as potentially valuable contributions the field could make to broader professional training. Similarly identified were new or revised professional training programs in science and technology policy or design oriented toward enhancing the capacity of policy officials and designers to enhance the sustainability of socio-technological systems.
- **Applied and professional training and networking opportunities for researchers**: Recognizing the importance of effective communication and leadership skills to scientific researchers, a number of fields have begun to develop programs for scholars at various stages in their careers to learn these skills. The field of ecology has developed training programs in media and public communication via the National Center for Ecological Analysis and Synthesis and also through the Aldo Leopold Leadership Program at the Woods Hole Institute for the Environment. The field of STS has lagged, by contrast, in helping prepare researchers for these aspects of their careers. Indeed, relatively few STS scholars are actively engaged in policy leadership activities, and where those activities do occur the community is often unaware and under-appreciative of the importance of this work. Particularly in the area of sustainability, the potential value of STS research will only be realized if greater efforts are taken to prepare researchers to take on significant leadership and communication roles in connecting research to public goals and policy initiatives.

Enhancing diversity

Workshop participants also identified diversity as a critical need. While STS as a field is broadly diversified by gender, representation of underrepresented groups remains less, as it is in the sciences and engineering broadly. Efforts to redress the participation of students from underrepresented groups in other fields of research suggest that the programs that work do so through long-term engagement with students from high school, through college, to graduate, postdoctoral, and faculty stages of student careers. Such efforts must be intensive and transformative, demonstrating to students both the fundamental excitement of research and its potential to achieve important improvements in people's lives or to solve critical problems in society.

Within STS, systematic, long-term efforts to build the diversity of the field have largely not been undertaken. As a field, sustainability would seem to offer a natural opportunity to fashion such an effort, given its appeal to students of younger generations and its specific focus on critical problems in society and in people's lives. An infrastructure effort could provide long-term support for a systematic effort that would involve students over several years in preparing them to be successful in college and graduate school. Such an effort could have a long-term impact on the field of STS as a whole.

Indeed, STS research suggests that the inclusion of perspectives from diverse racial, ethnic, and socio-economic backgrounds in research is likely to be crucial to a full understanding of the human dimensions of sustainability and the potential success of proposed sustainability solutions across diverse contexts of application and implementation. Studies of race, gender, and the environment have shown how the meanings of environmental risks, values, and solutions vary significantly across communities and groups in diverse social, historical, and cultural contexts. Similar findings emerge from literatures examining environmental injustice and vulnerability, as well as the broader relationship between sustainability, justice, and democracy.

While we do not want to fall into the simplistic trap of assuming that women or minorities do research differently, STS research has nonetheless identified important ways in which research is shaped by people's historical and cultural experiences, as well as their training and disciplining. Framings of sustainability and potential responses are strongly related to worldviews, ways of knowing, and socio-cultural and historical contexts, so diversity is not only important for obvious equity reasons, but also to help ensure a sufficiently rich array of problem framings and identification and elucidation of diverse sensibilities about the environment, technology, justice, and sustainability. By bringing people into the dialogue about sustainability research who have very different backgrounds and experiences, the field would strengthen its ability to grapple with the diverse social and cultural dimensions of sustainability challenges across diverse human communities.

Support for international research experience, training, and collaboration

Many of the most important sustainability challenges of the 21st century are global or transnational in scope, as are many of the most important socio-technological systems that contribute to them. Similarly many of the knowledge, valuation, and governance systems that shape human understanding and responses to sustainability challenges likewise span across nations and, increasingly, function at global scales. To address the international dimensions of science, technology, and sustainability will thus require significant new investments in several forms of research infrastructure, including a significant increase in the number of STS researchers trained in appropriate skills and with appropriate experience in conducting international and global research.

In addition, support will be needed for the development of research teams with the capacity to examine the broad and diverse aspects of international sustainability challenges. Global research is, by definition, considerably more extensive in scope and scale than policy research in a single or even a couple of countries. It is, therefore, less amenable to the individual investigator model that dominates traditional social science funding. Only a handful of the most elite social scientists are able to generate sustained research funding at a level of even $100k to $200k per year to support graduate students and postdocs: yet, this level would be a minimum necessary to support systematic STS investigation into many of the most significant global sustainability problems.

Third, international collaborations have an important role to play in global research, but their limitations must be appreciated. First, the pool of potential collaborators is small, all of whom are busy with their own agendas, and hardly coextensive with the planet. Second, coordinating research funds for teams in multiple countries, from multiple national funding agencies, is a problem of high politics—definitely not for the lighthearted. Third, such collaborations come with their own costs, both in money and in time. International collaborations require substantial investments to bring collaborators together on a regular basis to define objectives, to develop protocols, to compare results, and to finalize publications. Such collaborations are expensive and difficult to set up and maintain over time, especially when funded projects typically have durations of only a few years. In cases where training is required to establish a local research presence, considerable expenses are required to bring the person in question to the United States for PhD-level education, if the right person can be found in the first place. Infrastructure that could help facilitate researcher efforts to overcome these challenges and develop productive, long-term international collaborations is essential to advancing the capacity of STS research to contribute to addressing sustainability challenges.

Focal points for engagement and application of research

A final critical area of infrastructure need identified by the workshop was the establishment of focal points for engagement with important communities outside of STS, with an eye to the application of STS research to concrete sustainability problems. Specific reference was made to engaging policy agencies, and especially federal science mission agencies, such as the US Geological Survey and the National Oceanographic and Atmospheric Administration. These agencies have critical missions in the field of sustainability that would benefit from interaction with STS communities, yet no systematic opportunities exist for them to take advantage of STS research. Currently, the only pathways for STS research to reach these agencies lie in one-on-one relationships or encounters between agency and STS researchers. Establishing formal focal points for more systematic engagement could lead to significantly more fruitful exchange of ideas and research analyses, as well as potential future investments in STS research from these agencies. Such focal points could establish clearinghouses of potentially relevant research and information; develop networks of researchers with specific expertise of potential relevance to agency missions; host periodic meetings of agency researchers and officials and STS researchers; work toward more systematic forms of engagement between STS researchers and federal agencies.

Another potentially valuable focal point for engagement is the business community. Businesses have enormous interests in and impacts on sustainability and often are critical to the creation and operation of socio-technological systems. Yet, STS researchers have traditionally had even less systematic interaction with the business community than with federal policy and science agencies. Other possible focal points could include critical fields of science and engineering, such as ecology or civil and environmental engineering; non-profit agencies and non-governmental organizations with significant interest in sustainability, and especially sustainable development in developing countries; and broader publics.

Appendix I – Workshop Participants

Marybeth Bauer, National Oceanographic and Atmospheric Administration
Geof Bowker, Santa Clara University
Phil Brown, Brown University
Robert Figueroa, University of North Texas
Bill Freudenburg, University of California, Santa Barbara
Scott Frickel, Washington State University
Elisabeth Graffy, US Geological Survey
Richard Hirsh, Virginia Tech
Rachelle Hollander - NAE Center for Engineering, Ethics, and Society
Alastair Iles, University of California-Berkeley
Steve Jackson, University of Michigan
Sheila Jasanoff, Harvard University
Myanna Lahsen, International Geosphere-Biosphere Program
Shannon Lidberg, Arizona State University (rapporteur)
Andrew Light, George Mason University
Clark Miller, Arizona State University
Chad Monfreda, Arizona State University (rapporteur)
Steven Moore, University of Texas-Austin
Tischa Munoz-Erickson, Arizona State University (rapporteur)
Claudia Neirenberg, Arizona State University
Bryan Norton, Georgia Institute of Technology
Roopali Phadke, Macalester College
Daniel Sarewitz, Arizona State University
Paul Thompson, Michigan State University
Jameson Wetmore, Arizona State University
Gregor Wolbring, University of Calgary

Appendix II – Participant Statements and Bibliographies

Phil Brown

Professor of Sociology and Environmental Studies

Brown University

My Research

I work on environmental health issues, including disputes on environmental causation, citizen involvement in disease and exposure discovery, citizen-science alliances to study environmental health, and toxics reduction. Currently I am doing much work on biomonitoring and household exposure studies, including ethical issues of reporting back personal data to participants. Other current work is on the social and ethical implications of nanotechnology. I continue to write a lot on health social movements. <u>Toxic Exposures: Contested Illnesses and the Environmental Health Movement</u>, published in 2007, represents a large synthesis of much that I have done over the past decade. Along with my research team, the Contested Illnesses Research Group, I am now preparing a collection, <u>Contested Illnesses: Ethnographic Explorations</u>, which emphasizes our recent approach to "field analysis" and "policy ethnography." I work with interdisciplinary teams, because as a social scientist I realize that in order to do this work effectively I need to be collaborating with public health scientists and advocates to advance the field effectively. My goal is to transform not only the scientific enterprise, but the social sciences as well, in terms of how they theorize and practice their craft.

I view my work as a unique amalgam that connects medical sociology, environmental sociology, STS, and social movements, infused with an environmental justice and community-based participatory research framework. My research has been funded by NIEHS's Environmental Justice Program, NIEHS's Superfund Basic Research Program, NSF's STS Program, NSF's Sociology Program, NSF's Nanoscale Interdisciplinary Research Teams (NIRT) Program, and the Robert Wood Johnson Foundation.

STS has always played an important role in my work. When I shifted from mental health to environmental health in the mid 1980s, the first journal article I published in that field was in <u>Science, Technology, and Human Values</u>, and I have published two other pieces in STHV and one in <u>Science as Culture</u>. When my colleagues and I presented papers at the Society for the Social Study of Science in 2001, as part of a stream on social movements, we returned with much enthusiasm and began a project to develop a theoretical and analytic framework for studying health social movements, and wrote articles and books in that area. I believe that much of the best work in social scientific analysis of environmental health and in health social movement is being done by scholars who are centered in STS, especially those who have strong ties to the public health field or who collaborate a lot with public health scientists.

Although I have not mainly thought that my work fits under the rubric of sustainability, upon reflection I can appreciate the value of that framework. We can consider a variety of types of sustainability for: 1) the larger environment, up to the planetary level, 2) natural resources and the agricultural and industrial productive apparatus, 3) air, water, and soil, 4) livable and harmonious environments, whether rural, suburban, or urban, and both built environments and landscapes/waterscapes, 5) food and nourishment, 6) the healthy growth and development of people. Sustainability in the context of environmental justice/environmental health means connecting human health to habitat. This is a critical idea that says it is not enough to ensure health and prosperity of people, if it threatens the basic life systems upon which we all depend. This raises new opportunities for merging environmental justice and sustainability movements.

The toxic contaminants that I study threaten all those levels of sustainability, starting at the point of production and flowing through the life-cycle of consumer use, residential exposure, disposal, and persistence. Persistent organic pollutants (those in the POPS Treaty as well as those considered for addition) move through air and water all over the globe, affecting pristine areas and altering the climate. They sap our natural resources and trash our bounteous habitat. They commit toxic trespass on our air, water, soil, and food. They make our communities and environs into dangerous locales. They stunt our growth, alter our neurological, sexual, and other development, and create fear and distress. I seek a holistic approach that takes this all into account, so that the study of original causes of the problem, current assessment, ongoing remediation, and future prevention can be part of a total engagement.

Key Research Questions for STS Sustainability Research

Emerging Contaminants

With hindsight, we have learned the "late lessons from early warnings" in which toxics like DDT, PCBs, chlordane, and dieldrin have harmed humans, wildlife, and ecosystems, and have persisted for decades after banning. Indeed, the wealth of biomonitoring programs from CDC, states, academics, and advocates has rapidly brought to widespread attention the legacy contaminants, while demonstrating a new range of emerging contaminants. It is important to understand how knowledge is derived to understand these emerging contaminants (e.g. PBDE flame retardants and PFOAs used in non-stick coatings and other applications), and how relevant new science is funded and then applied toward policy. There is much to learn about the recent expansion of knowledge about the many dangers of endocrine disrupting compounds. This major paradigm shift came about after much resistance from elements of science and government, and with widespread public pressure became broadly accepted as a significant research enterprise.

One particularly interesting question is how do state-level approaches to restricting, phasing out, and banning emergent contaminants arise, and how do they impact further science and federal policy. Maine's restrictions on PBDE flame retardants are an example where state chemicals policy leads to creative biomonitoring initiatives. Calilfornia's shifts in allowable forms of PBDEs have led to national ramifications in discussions of new federal fire prevention policy.
Among other questions we need to ask are: What are the facilitators and obstacles to further regulation of current POPs chemicals (persistent organic pollutants) through the UN's POPs Treaty? What are the facilitators and obstacles to adding new toxics to the POPs list (e.g. PBDEs and PFOAs)? How does the EU REACH policy of chemical regulation effect potential US regulation? What are the barriers to effective interagency collaboration concerning emerging contaminants, e.g. between EPA, FDA, NIOSH, and CDC? Should toxic effects of nanoparticles be included as emerging contaminants? Nanotechnology is perhaps the best example of the impor-

tance of interagency research and policy-making, and one that deserves much attention from social scientists and ethicists.

Expanding Public Participation

Public participation is both an area of scholarship in itself (e.g. understanding how laypeople understand science, how they engage in scientific work, and how they interact with science and government), as well as an overarching framework for carrying out many kinds of research. Both these facets deserve attention for new directions on sustainability.

STS scholarship has long been a leader in work on public participation, and can play a major role in developing it further. The NRC's August 2008 report Public Participation in Environmental Assessment and Decision Making provides a major review of a growing literature on how public participation advances scientific knowledge, and lends important credentials to an already well-established approach. Recent interest in "science cafes" has been noticeable. Lay consensus conferences are also gaining attention as a powerful mechanism.

It will be helpful to learn from NIEHS in understanding a research agenda for public participation. NIEHS' long-standing support of citizen involvement and collaboration, through its Environmental Justice and Community-Based Participatory Research Programs, has nurtured a significant corps of community-based organizations with solid research capacity, academics with strong credentials in collaborative research, and graduate students being trained in a milieu that values such work. Those NIEHS programs have fostered some of the most effective and "sustainable" interdisciplinary collaborations bringing scientists and social scientists together to research and address cutting-edge environmental health problems. In addition, NIEHS includes public participation and various forms of lay engagement in outreach cores of other of its major programs -- Breast Cancer and the Environment Research Centers and Superfund Basic Research Program. Annual grantee conferences for each NIEHS program have further fostered the development of a community of scholars, government officials, and advocates that can take the lessons from those programs and take if further beyond the element of NIEHS funding. In spring 2008, NIEHS convened a workshop to help design its new Partnerships in Environmental Public Health Program (PEPH), which will take the lessons from its history of lay involvement and bring it to more institute-wide level. Importantly, NIEHS Acting Director Sam Wilson was present for the entire two-day workshop, indicating strong support for this approach.

A lesson from that PEPH workshop, and from all the programs that led up to it, is that we need more social scientists to put their theories to work in the realm of public health science research and practice. NIEHS programs offer this opportunity and NSF can also supplement the social science side of this work. As an example, my project on "Linking Breast Cancer Advocacy and Environmental Justice" got funding from both NIEHS and NSF to support our Household Exposure Study work, which was critical to the success of this project and our capacity to effectively disseminate our results to the scientific community as well as the social scientists.

Developing, applying, and evaluating alternative technologies

Alternative technologies are rapidly increasing, especially alternative energy sources, alternative vehicles, green chemistry, and environmentally-friendly products. STS scholars can apply a social scientific approach to understand processes of innovation and diffusion of alternative technologies, as well as how those technologies affect institutions, professions, and communities. Innovation and development of alternative technologies are often the result of public pressure, and we need to better understand how seemingly impossible leaps of realization and innovation have happened (e.g. alternative fuels, alternative vehicles).

Some key questions to address are: How quickly can alternative technologies replace older ones? What effects does alternative technology development have on the existing labor force and on training/education? Do alternative technologies bring with them more democratic forms of work environments, dissemination, and application? How do we use the precautionary principle to assess the potential hazards of even the most well-meaning alternative technologies? How can we understand public experience of risk and hazard in relation to alternative technologies? To what extent are new technologies necessarily alternative technologies (e.g. nanotechnology)? Will alternative technologies make it more likely that the US will join treaties such as Kyoto, play more progressive roles in regimes it belongs to (e.g. WTO), and develop major innovations such as the EU's REACH program for chemical regulation?

Health and Equity Outcomes of Climate Change

WHO and other sources estimate that climate change has major effects on health, including deaths due to climate-driven alterations in vector borne diseases, food insecurity, heatwaves, and other extreme-weather events, and forced migration and the plight of environmental refugees. While much attention has focused on other nations, circumpolar scientists and Alaska Natives have pointed to major health effects of shifts in food supply and to health and psychological results from threats to the continued existence of traditional villages. Health outcomes have been overshadowed by many other climate change issues, and require more attention. STS, medical sociology, environmental sociology, risk research, and disaster research can play an important role, perhaps in tandem with NSF's Arctic Social Sciences Program and its Human and Social Dynamics cross-cutting initiative.

At the same time, we must pay attention to the equity impacts of climate change mitigations themselves. Climate change has become a very significant issue for human rights, public health, and social equity because is has a disproportionate impact on vulnerable and socially marginalized populations. Scholars and activists have raised concern about disparities in the abilities of different groups to adapt to climate change, and pointed to likely inequities in the costs and benefits of climate change mitigation strategies. For example, will pollutant reductions be directed toward environmental justice communities with the most significant emission sources? Will more marginalized communities receive sufficient attention in job retraining resulting from employment shifts that will occur because of mitigation efforts? How will some of the alternative energy technologies in the prior section be distributed more equitably?

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William Freudenburg

Dehlsen Professor of Environmental Studies

University of California-Santa Barbara

I begin with an apology for length. These comments are behind schedule, which means that I need to hurry to get them into the packet. Since it always takes me longer to produce something shorter, that means I will be going past the official page limits.

I will try to compensate by being less personal and more substantive. I will focus on two issues. The first, which gets the most space, is the need to extend the analysis of social construction processes to areas of science and technology where they are most urgently needed – some of the least prestigious areas of STS. Growing evidence indicates that surprisingly small fractions of technological activity creates disproportionately severe threats to sustainability, *in part because of consistently successful efforts to construct just the opposite belief*. The second and shorter issue will involve the need for more research on scientific efforts to estimate "sustainability" – in part because the few findings to date suggest such estimates to be seriously biased in a direction that, again, threatens sustainability.

Disproportionality. I start with a deliberately provocative assertion: Roughly speaking, scholarly status within Science and Technology Studies (S&TS) can be reckoned as a function the status of the scientists being studied. A concern for status can get in the way of intellectual progress under any circumstances, but it is particularly important to confront for purposes of this workshop. To deal with sustainability questions, NSF needs to emphasize the less-prestigious end of what I still call ST&S – Science, Technology *and Society* – and for two reasons. One is that the grubbier end of the STS spectrum – the place where science and technology come into contact with society – is where the most important implications for sustainability are to be found. The other is that presently low-status subfields of STS offer not just the best opportunities for social sciences to contribute to sustainability, but also the for studies of sustainability to contribute to the social sciences.

When Latour and Woolgar began their now-classic study (1979) of Salk's neuroendocrinology lab, focusing on the micro-politics of laboratory science in a "pure" science setting made good sense. For arguing that “scientific facts” are socially constructed, rather than divinely revealed, there was a good deal to be said for focusing on a tough case. At that time, if they had concentrated instead on studies of the effects of smoking on human health, for example, a finding that the scientific results were being "socially constructed" might have seemed a good deal less compelling, let alone original.

Now that the initial points from the constructivist school of the sociology of science have been made repeatedly, however, it is time for more attention to the challenge that was initially bypassed – and that may actually be tougher. After a study of a basic-science setting, a laboratory manager such as Jonas Salk might even write a preface saying that he did not necessarily agree with the depiction, but that he thought it to be worthwhile (Salk, 1986). The matter might not be so straightforward for a lab manager with access to lawyers, a large budget, and public relations expertise – and whose corporate survival depends on destroying the credibility of such a study. In fact, it may be precisely when studies of social construction move out of the "apolitical" world of basic-science labs that challenges become most sharply defined: Here is where the stakes of having a social construction accepted as legitimate are the highest, and thus where we are likely to find some of the practitioners who are the very best at it. In such "non-pure" settings, accordingly, the analysis may need to be more thorough, the standards for evidence tougher, and the margin for error much narrower

We need to take on the more challenging work, however, to build an appropriate research agenda for a newer "ST&S" – studies of "Science, Technology and Sustainability." A small but growing body of research suggests that – as any version of STS would predict – the social scientists who first started taking environmental issues seriously (again) in the 1970s-80s made a mistake in following the examples of the biophysical scientists who first drew attention to environmental problems. Perhaps because those natural scientists were worried about being accused of "being political," they nearly always framed environmental quality and sustainability as matters of shared responsibility. Some of them focused on global population numbers – even though an average American consumed more than thirty times as much of the earth's resources as the average citizen of India. Most of them focused on what Hardin called a "tragedy of the commons" – a reference to shared pastures in which any one sheep, for example, could be expected to have about as much impact as any other sheep.

Today – forty years after *Science* published Hardin's essay – issues of equity and social structure still receive almost the same level of (in)attention. One of the reasons may be that even the best-known social science theories on environment-society relationships – from the most conservative to the most radical – essentially reduce down to "there are too many of us and we all use too much," almost as interchangeably as the sheep in Hardin's pastures. Such approaches, in short, focus on individual consumers, not organized producers.

Organized producers, however, use up roughly 90% of the raw materials in the U.S. economy. Only 3% of those raw materials actually get to consumers – and 2/3 of the 3% is food (Ayres 2001). To focus on "post-consumer waste" is thus to focus on 1% of the resources. We *should* all try to recycle consumer products, because 300 million times anything is a pretty big number. But it makes very little sense to focus on the 1% while ignoring the 90% – especially since growing evidence indicates that much of the waste in industry is *not* "necessary."

The best numbers for the U.S. come from EPA's Toxic Releases Inventory. What fraction of the economy gives us the majority of all toxic emissions – is it anything like 50%? No – it's less than 5%, and if we calculate in terms of "jobs," it's closer to 1% (Freudenburg 2005a).

It's not even plausible to argue that such high levels of harm are "necessary" *within* specific industries. We can even ignore the most toxic industry in America, namely mining – with 83% of all toxic releases in 2000 and less than 1% of the jobs. Focusing on the rest of the economy, and using EPA's numbers to convert from tons of pollution to expected risks, America's most toxic industry is SIC 333, "primary nonferrous metals" (those that don't include iron, such as copper, zinc, and lead). That industry is responsible for more than a third of the toxic risks from the entire economy. Of the 62 facilities in that industry tracked by the EPA, however, 61 did *not* find it "necessary" to put out such high levels of toxic emissions. Just one – Magnesium Corporation of America, in Rowley, Utah – accounted for over 95% of the toxic risk from the entire industry.

In Hardin's grazing commons, removing *any* 10% of the sheep would reduce grazing pressure by about 10%. In the case of the Primary Nonferrous Metals Industry, taking away the most heavily polluting 10% of firms – or *just getting them to match the median level of emissions to for their own industry* – would have reduced total toxic risks from the *entire* industry by well over 90%.

To repeat, then, the first grand challenge I see for a new STS is to extend the constructivist project to *critical* analyses of specific aspects of science and technology that tend not to be prestigious, but that have important impacts on sustainability. The analyses need to be "critical" in including independent examinations of the actual numbers, as well as of the ways in which environmental impacts are described to policymakers, the press, and the public.

Toxic emissions, of course, are "outputs," while many concerns about sustainability have to do with the use of "inputs," such as fossil fuels. Although inputs/outputs are clearly related, there are likely to be substantial variations across industries in the *degree* to which the harms to sustainability are disproportionate to economic importance. In particular, I've always said that, if there's any area where I'd expect the disproportionality to be the lowest, it would be CO_2 emissions. Now, I'm not even so sure of that. A quarter of all the African-American households in America don't even have access to automobiles, while many commuters still drive 100+ miles a day in big SUVs. Beyond that, the vehicles themselves vary widely in their emissions. At least in terms of pollution, roughly half of the harm comes from just 10% of the automobiles – "41% of which were found to have evidence of tampering with emission control systems and 25% of which had defective or missing equipment" (Harris 2003: 461). Just today (9/9/08), a new NOAA-led report (part of the series of Synthesis and Assessment Reports coordinated by the U.S. Climate Change Science Program) is announcing that short-lived gases and particle pollutants – those that stay in the atmosphere for just days or weeks – have more influence on Earth's climate than previously thought. Even in the case of "traditional" greenhouse gas emissions, it is important not to overlook the importance of producers. Work by the World Bank indicates that the "flaring" of natural gas – burning off the natural gas in commercial oil fields – "adds about 390 million tons of CO_2 in annual emissions" (Kaldany 2006: 5). That's more than the sum total of all the projects currently registered under the Clean Development Mechanism of the Kyoto Protocol for reducing greenhouse gas emissions.

I see particular potential for research on one of the most important resources for anyone concerned with sustainability – water, and its use/abuse. In practically every western state, roughly 80% of all water goes to one industry – one that generally makes up about 2-3% of the economy. A hint is that it also uses about 50% of all the water in the Phoenix region. It's not golf, but agriculture. When we get more specific (I've only been able to find crop-specific numbers for California so far), we find that about half of all agricultural water – or 40% of all the water used by humans in the nation's most populous state – goes not to high-value crops such as almonds or wine grapes, but to hay, grass and alfalfa (Gleick 2004). If we add rice and cotton (being grown in the desert), then we're up to 70% of the water, plus or minus 10%. California uses less TOTAL water today than it did in 1982, even though there are millions more people and the economy has grown by multiples. In contrast to what politicians have been saying, I'd be hard-pressed to find any evidence that "the inability to get water" has been any significant drag on economic sustainability. Instead, a tiny amount of water that used to go into growing hay has been diverted to other uses, and the economy has improved as a result.

At the other end of the spectrum, the issue of "too much water" can also be informative. We have known since 1943 that, the more the U.S. spends on "flood control" structures, the *higher* the subsequent flood losses, even after controlling for inflation (White 1945). Hazard managers call that "the levee effect," but closer examination suggests that the true culprits are humans, not levees. After the 1993 Mississippi River floods – the most expensive in history – FEMA removed more than 12,000 homes from the floodplains, at a cost of over $150 million. Unfortunately, by 2005, those same floodplains had become the location of some 28,000 *new* homes, in the St. Louis metro area alone – accompanied by strip malls, office and industrial parks, and flood-exacerbating impervious surfaces or formerly flood-absorbing bottom lands, all of which had been under 10-15 feet of water in the 1993 floods (Pinter 2005; Gertz 2008). Carefully written laws provided "protection" from liability suits for the very developers who profited from putting over $2 billion of new investments into the floodplains – protections that come far closer to being "leak-proof" than are the literal levees. As we have now known for 65 years, these kinds of developments don't *help* the economy – they *hurt* the economy. Yet almost everyone who matters, at least in the U.S. policy world, still seems to assume the opposite.

Once the water goes downstream, it enters the oceans, where we see even stronger implications for sustainability. In the states of Ohio, Indiana, Illinois, and Iowa, this kind of "development" has destroyed 80% of river-bottom wetlands that once helped convert fertilizer runoff into plant matter and atmospheric nitrogen (NRC 2006: 59). Partly because some farmers use up to 9000% of the recommended levels of fertilizer, those "nutrients" now create a huge "dead zone" in the Gulf of Mexico – and 250 other such dead zones around the world (Society of Environmental Journalists 2008). Meanwhile, we are fishing well past the point of sustainability. In California, "Cannery Row" is now just a tourist attraction, real-estate developers no longer advertise the fine fishing nearby, all salmon fishing was cancelled this year, for the first time ever, and for eight of the last ten years, the #1 commercial fish species hasn't even been a fish – it's the "market squid," which is about a foot long. About 150 commercial fishing operations target the squid, but 85% of the catch goes to just 11 of them – and those 11 operations are actually controlled by just two families (McGinnes 2008).

Studying Science that Serves "Sustainability." Given that every prior commercially valuable fish species in the (Anglo) history of the state has been overfished – to or past the point of exhaustion – one might expect that regulatory agencies would now be tempted to err on the side of caution. For the market squid, however, the "sustainable yield" limit has been set at 140 million tons per year – curiously, a figure that is roughly identical to the highest catch in history, which has not been matched since 1998. That proves to be an example of a much broader pattern.

By contrast, ironically, Hardin's grazers actually *were* "sustainable." Many commons areas in Europe have been in continuous use for 500 or even 1000+ years, or far longer than industrial civilization has thus far survived. The true "tragedy" came from the policy world, which helped a few rich landowners to "enclose" the commons and evict the grazers. Something similar, as suggested above, appears to be happening for many kinds of environmental resources today – a tragedy not of "the commons," but of the "un-commons," or what historians have called the "enclosure movement."

The pattern of using science to aid "sustainable resource management," meanwhile, is what has often turned "tragic." In recent decades, over two-thirds of the world's commercially valuable fish species have become threatened or endangered – a tremendous threat to sustainability, given the high fraction of humans who depend on fish for protein. The pattern has even had an official name for more than half a century – "the fisherman's problem" (Gordon 1954; McEvoy 1986). A similar pattern is evident in forest management: The U.S. Forest Service has long been required to manage its forest lands for "sustainable yield," and it has long claimed to be doing so. For decades, however, estimates of "sustainable" rates of harvest stayed above 20 million board-feet per year. Actual harvests never approached those levels, instead rarely exceeding 10-12 million board feet per year. In retrospect, however, those "low" levels proved to be far too high to be sustainable – partly because industry spending on research, but also elected policymakers, tended to favor the estimates that were higher. Hirt (1994) called this pattern a *Conspiracy of Optimism.*

Past analyses of efforts by the tobacco industry to influence the scientific literature, similarly, have emphasized deliberate attempts to support the kinds of work that the industry wanted to see (e.g. Glantz et al. 1996; see also Michaels 2008). Recent work on global climate disruption, however, suggests that industrial interests have discovered a much more efficient way to distort the scientific literature – not so much by supporting the kind of research they like, but by challenging the findings they dislike (see e.g. McCright and Dunlap 2000; but see Freudenburg 2005b). Jaques et al. (2008) examine the supposed "controversy" over global warming, finding that, of the 141 English-language books they could find that criticized the "Scientific Consensus on Climate Change" (Oreskes 2004), 130 or 92%, came straight out of a small number of conservative "think tanks." It is rare to consider the possibility that "debates" in the mass media might influence scientific conclusions, but highly preliminary findings from ongoing research with a student (Freudenburg and Muselli 2008) suggest that Hirt's work might better be seen as an example of a broader phenomenon –l "The Asymmetry of Scientific Challenge" – suggesting that, rather than being "too pessimistic," as critics charge, current consensus views toward global climate disruption may not be pessimistic enough.

Other recent research suggests that "debates" over the science of global warming, cigarette smoking, and possibly estimates of "sustainable" yields of fish and forests, may again be examples of a broader challenge – in this case, a pattern so consistent, at least since the 1920s, that it deserves its own name. That research (Freudenburg et al. 2008) draws heavily on existing STS literature, particularly on the fact that science commonly provides "grey area" answers rather than black/white certainty, as well as drawing on extensive observations of (grubby) technological controversies, to note a pattern: If 90%+ of the relevant scientific answers are not yes or no, but "maybe," and if one side can rig the rules so that it wins whenever the answer is "maybe," then about 90% of the time, that side can expect to win. Since the pattern needs a name, we suggest calling it the "Scientific Certainty" Argumentation Method – or SCAM. We would strongly encourage a new generation of colleagues from the new ST&S community to test, refute, or refine our observations to date.

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Scott Frickel

Assistant Professor of Sociology

Washington State University

In an era marked by economic globalization and widespread recognition of environmental degradation, questions pertaining to sustainability, and the potential role for STS in achieving that goal, loom large. My own work falls under the rubric of the political sociology of science (Frickel and Moore 2006) and focuses on environmental knowledge politics, or political constructions of environmental knowledge (e.g. Frickel 2004). In that vein, my comments here target two topics that tie knowledge politics to sustainability, but which have received comparatively little attention in STS: interdisciplinarity and ignorance.

Interdisciplinarity

As a policy goal, sustainability implicates the failures of modern science and technology to meet basic societal and ecological requirements. Accordingly, achieving sustainability—at any meaningful level—will likely require different kinds of knowledge, harnessed by new types of institutions, both characterized to varying degrees by interdisciplinarity. Efforts to develop interdisciplinary knowledge forms such as "sustainability science," "vulnerability sciences," and studies of "resiliency" speak to this need. They also join a sustained chorus of university administrators, federal funding agencies, private foundations, and non-governmental organizations in promoting interdisciplinary research and education (for a review, see Jacobs and Frickel 2009).

Whether basic or applied, interdisciplinary research is seen as integrating knowledge and solving problems that individual disciplines cannot solve alone. Yet, advocates worry that the potential of interdisciplinary research is not being translated efficiently or effectively into practice. This is largely because intellectual, organizational, and institutional barriers impede interdisciplinary communication and collaboration. The stakes in overcoming these barriers are high and pressing. According to a recent National Academy of Sciences (2004:25) report, "To hinder [interdisciplinary] activity is to diminish our ability to address the great questions of science and to hesitate before the scientific and societal challenges of our time."

One avenue for STS scholarship to take toward resolving the apparent dilemma is to identify the assumptions underlying calls for more interdisciplinarity and examine those assumptions systematically. Assumptions such as:

- Interdisciplinary knowledge succeeds where disciplinary knowledge fails
- The historical success of disciplines is implicated in the failure of interdisciplinary research to thrive
- The growth of interdisciplinary research is fundamental to the health of the scientific enterprise
- Reducing institutional barriers to interdisciplinary research will enhance the efficient production of socially and ecologically useful knowledge

These assumptions powerfully undergird the idea that interdisciplinarity is a key piece of the sustainability puzzle. Yet, rarely have researchers subjected these assumptions to systematic empirical investigation. The historical promise of interdisciplinarity to meet pressing socio-environmental challenges through the unification of knowledge may be producing just the opposite—a condition that some disparage as amplifying rather than resolving "the level of babble in the academy" (Fuller 1993:40).

Does more interdisciplinarity lead to integration of knowledge systems? Does that integration in turn reliably feed the elements of sustainable solutions to policy makers? Conversely, does more interdisciplinarity induce more fragmentation, more competition, more instability, and ultimately more disparity? Or, to rephrase a question Geoff Bowker raised in our discussion, is interdisciplinarity "really good for the planet?" While advocates of sustainability hang their hopes on the promises of a more unified knowledge system, systematic research on the causes and consequences of cross-disciplinary interaction remains limited. We do not in fact know whether interdisciplinary knowledge translates better than disciplinary knowledge into deeper socio-ecological understanding and more meaningful environmental reform. Scholars such as Diana Rhoten and colleagues (2008) are taking leading roles in designing empirical studies to address these and related issues head on, but much work remains.

Ignorance

When it comes to sustainability, we know very little. STS should seek to understand why. STS should take our ecological ignorance seriously.

Ignorance is often presented as a truism, as in "the more we know, the less we know," or "any way of seeing is also a way of not seeing." But it is important to problematize ignorance as a subject for historical and sociological inquiry. Ignorance is the absence of knowledge. But this simple definition belies a deeper complexity and implicates an institutional politics of knowledge. Ignorance is not only the absence of knowledge, but also of knowers, their practices, and their networks. The forms ignorance takes are varied, and these forms do not emerge sui generis. Rather, they are the result of historical processes and institutional arrangements that structure what is known and what is not known. In this way ignorance is like knowledge. It overlaps, entwines, and accumulates.

On one hand, STS's ignorance of ignorance seems to me pretty straightforward. As a rule, historians, philosophers, and sociologists of scientific knowledge study knowledge *making*; seldom do scholars study the nonproduction of knowledge. On this accounting, we can chalk our ignorance of ignorance up to the normative expectations and organizational routines of academic life. We are required to study something and it is easier to study what is than what is not.

On the other hand, STS knowledge politics may also play a role here. To the extent that science stands ideologically opposed to ignorance, the term carries a critical—and for some perhaps a dangerous—meaning for a field whose entire existence is based on Science Itself. In this context, ignorance implies failure—either a failure to understand (a negative epistemic outcome) or a failure to investigate (a negative organizational outcome). Either way, ignorance is an outcome that calls for explanation. So it is puzzling to me why past efforts to generate sustained interest in the topic have repeatedly fallen flat (Stocking 1998).

In contrast, considerably more attention in STS has been paid to scientific uncertainty—a related but distinct problem. Uncertainty describes a condition of existing knowledge rather than its absence. Unlike ignorance, uncertainty is embraced by scientists and STSers alike as an expected outcome of scientific work. Because it is expected, the STS research on uncertainty rings a normative tone: studies tend to examine uncertainty as a negotiated accomplishment, in terms of how it comes about, rather than why. And unlike the failed attempts to ignite scholarly interest in ignorance, European and North American researchers have for years successfully tapped steady streams of government funding to study uncertainty, not least in the areas that are consonant with sustainability concerns, such as environmental risk and climate change. The imbalance is striking.

Despite all this, a growing body of empirical work has begun to document the various ways that scientific and technical understanding is not produced. This scholarship includes studies of scientific secrecy in the domain of national security (Galison 2008), the suppression of occupational health knowledge (Markowitz and Rosner 2002), the destabilization of scientific consensus (Michaels 2008), the delegitimation of local or subaltern knowledge (Tuana 2008), and the loss of knowledge through historical processes of epistemic drift (Wylie 2008) and through the political shaping of scientific research agendas (Hess 2007, Nash 2006).

From these case studies we learn, for example, that the social production of ignorance can be intentional or unintentional. It can come about because knowledge is mistakenly lost or purposefully hidden, or because knowledge in plain view is ignored, or because knowledge is never made. Ignorance can take different epistemic forms—a fact, a general understanding of things, a set of unanswered questions, an entire area of inquiry left fallow. Institutions order ignorance in different ways. The national security apparatus studied by Galison generates ignorance through rule-making, while the chemical industry scientists studied by Markowitz and Rosner created ignorance by rule-breaking. And ignorance influences different social outcomes—national security secrets may (arguably) forestall international conflict, while chemical industry secrets widen disparities between corporations and their employees.

STS should do more to understand ignorance. This will require effort and creativity, and will vex the hardcore empiricists among us because it means studying what for the most part is not there. Studying ignorance entails a moral challenge as well, since some things are best left unknown and because there is some knowledge society would be better off without (e.g. MacKenzie and Spinardi 1995). Where do we draw these lines and who gets to make those decisions?

I keep coming back to the question Sheila Jasanoff posed in the workshop: "What is it we want to sustain?" It seems to me that we cannot begin to answer that question responsibly without sober consideration of what we do not know and why.

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Richard F. Hirsch

Director, Consortium on Energy Restructuring and Professor of History

Virginia Tech

STS accomplishments in my area relating to sustainability

My STS field of history of technology offers a body of work—specifically dealing with energy systems and the environment—that has great value to sustainability studies. Moreover, it has produced an array of tools for analyzing technological systems that have significance to policy makers dealing with sustainability.

For several decades, historians of technology Lynn White, Jr., Joel Tarr, Thomas Hughes, Martin Melosi, Edmund Russell, and others have described the way humans developed technology to create a new "natural" world. They have focused on cities and the environment, public health, the impact of industry and manufacturing, the extraction and use of natural resources, government policy, and energy systems.[5] In the last category, Thomas Hughes provided a detailed history of electric power systems in three countries that adopted them—albeit differently, resulting from political and institutional variations—in the period from 1880 to 1930.[6] David Nye pursued work on electrical and other energy systems, examining the role of culture and social circumstances on the ways Americans adopted and integrated power into their lives.[7] Speaking personally, I have performed research on the social construction of the American electric utility system. My work deals with sustainability in that it examines, among other things, the transformation of values among institutions and individuals concerning the notions of growth, energy efficiency, and renewable-energy technologies.

The history of technology as a discipline can also help policy makers manage real-world problems. First, the field deals with a subject—technology—that plays important roles in society, and people in business and government want to understand it better. Because the history of technology focuses on the nature of technology and its relationship to science, business, and society, the field can therefore offer insight to decision makers.[8] Second, the discipline's participants have developed a useful set of tools to analyze technology within society. These tools in-

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[5] See Jeffrey K. Stine and Joel A. Tarr, "At the Intersection of Histories: Technology and the Environment," *Technology and Culture* 39 (1998): 601-40 for a review (up to 1997) of such works.
[6] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983).
[7] David E. Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940* (Cambridge, MA: MIT Press, 1990); and David E. Nye, *Consuming Power: A Social History of American Energies* (Cambridge, MA: MIT Press, 1998).
[8] Mel Kranzberg pointed out in 1986 that technology has become so important that even its history is important. His fifth "law" states that "[a]ll history is relevant, but the history of technology is most relevant."Melvin Kranzberg, "Technology and History: 'Kranzberg's Laws," *Technology and Culture* 27 (1986): 553.

clude contextual methodologies such as Hughes' systems approach. Besides making prominent the social nature of technological momentum, Hughes (and others) emphasized the nontechnical conditions that make technologies either "radical" or "conservative." Identifying these factors can be especially useful in developing a deeper (and practically oriented) understanding of why certain technologies have succeeded or failed in the past. Comprehending those same circumstances can help policy makers as they deal with analogous situations today.[9]

Key research questions as important opportunities for STS research on sustainability

Among the important questions that STS practitioners can ask are:

1. How can STS research provide insight into the social conditions that inhibit modern societies from choosing sustainable technologies and practices?

As I have suggested above, I think STS research can highlight a large number of often-overlooked social considerations that need to be addressed when making decisions involving science and technology. Too often, those decisions have been made in ways that discourage the use of sustainable technologies and practices. Why is that the case? Are we simply dealing with systems (such as the petroleum-based transportation system) that have huge momentum that cannot be altered? And even if that is the case, can't STS researchers identify the social elements that might effect a change in that momentum?

2. What social, cultural, and political conditions exist in countries that have adopted more sustainable policies, and can those conditions be "exported" to other countries?

STS researchers have sometimes used cross-national studies as the rough equivalent to controlled experiments in the sciences. They could do so profitably when studying the circumstances that have existed (or exist today) in European countries, for example, that had adopted the Kyoto Protocol or other sustainable policies dealing with large technological systems. Comparative research might identify ways in which the United States and other countries could gain support for technologies and practices that are more energy-efficient and sustainable.

3. On a highly focused level, we could ask "what are the proper ways of looking at the future?"

Since the study of sustainability deals (at least in part) with the conceptualization of problems and solutions occurring in the future, STS practitioners could look more critically at the nature of forecasting. We need to understand explicitly how different entities make and value forecasts because of advantages that such forecasts offer to affected parties. We should investigate inherent biases of forecasts and the subtle cultural and philosophical reasons that different individuals and groups make predictions as they do. Moreover, STS scholars could investigate questions dealing with making plans today that will affect people in distant future generations (i.e., inter-

[9] Of course, this contribution of history of technology was also discussed by Mel Kranzberg, who pointed out in his fourth "law" that although technology might be a prime element in many public issues, nontechnical factors take precedence in technology-policy decisions." Ibid., 550.

generational ethics). We could also examine (historically and otherwise) the development of technologies and the effects of social movements that can confound forecasts—for good or for ill.

4. From a practical point of view, perhaps the most significant question we can ask is "how do we make our expertise as STS researchers more accessible (and acceptable) to the people outside academia who plan the future of technological systems?"

I believe that STS research has potentially great value for informing policy makers in business and government as they address issues of energy and sustainability. I have been doing policy research for decades, and I have been fortunate to gain the attention of some policy makers, though I can't claim to have made as much impact as I would have hoped for. I would like to know why that's the case. Do policy makers pay so little attention to our work because they view it as a time consuming exercise that offers few dividends? Or is it because STS researchers haven't made a strong case for their subject's value? Do those of us who do policy research feel content to talk to each other rather than to try to engage policy makers directly?

I don't have answers to these questions, but I'm happy that this workshop has begun to address them. Of course, academic researchers do not need to justify their work on the basis of practical value. But much of what we STS researchers do in the realm of energy and sustainability inherently has value to people who make real-world decisions. We would be remiss if we didn't try to offer our insights to help deal with important issues of the day.

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Alastair Iles

Assistant Professor, Department of Environmental Science, Policy & Management

University of California-Berkeley

Scholars working in the Science and Technology Studies field (defined broadly) have made a number of compelling contributions to understanding sustainability, which can be encompassed in the phrase "environmental STS". These contributions include:

- *Insights into the nature and role of regulatory science.* Much research has examined quantification, standards of proof, and risk assessment in the processes of generating regulatory science, primarily in chemicals, pollution, and climate change. Inspired by Sheila Jasanoff among others, this research emphasizes that science, policy, and law are shaping each other (rather than science directing policy-makers what to do), and that institutions, cultural contexts, and processes for making environmental decisions are important to understand. The changing roles, philosophies, and character of governments are also central.

- *Analysis of the development, roles, and impacts of the tools and methods of sustainability science.* Cases have included computer modeling especially for climate change, ecological measurements, GIS, and satellite imaging (i.e., largely for global environmental change purposes). Led by Simon Shackley, Clark Miller, Paul Edwards, Peter Taylor, and others, this research has revealed the politics, values, and epistemologies embodied in the tools, highlighting the need to avoid "black-boxing" sustainability science.

- *A deeper understanding of the importance of expert politics* in a wide range of sustainability issues including biological diversity, hazardous waste, energy, climate change, and environmental health. Brian Wynne, Frank Fischer, Steven Yearley, and Phil Brown have helped instigate this research. This has been one of the most active areas for research, generating insights into the promises and challenges of participatory policy-making, environmental NGOs, and citizen science. Among other themes, the nature of "citizenship" in increasingly technological societies has been investigated.

- *Recognition of the societal influences on technological development*. Beginning with Bijker and Winner's work among other sources, this research has questioned how technologies (particularly energy systems, transport systems, and certain industrial products) come to be established and made stable in particular forms, and has highlighted the challenges of democratizing new technological trajectories. Technology assessment alternatives have been much explored. A variety of projects have investigated institutions and processes for facilitating societal dialogues, on topics such as climate change, nanotechnology, and energy technologies.

- *Evaluation of the construction of experiments in managing and acting on sustainability*. Early STS scholarship focused on the laboratory as a primary setting for knowledge production; in part due to environmental STS, there has been an expansion from the laboratory into ecosystems and neighborhoods. There is growing interest in the nature and politics of experimentation, and in the epistemology of generating knowledge, for sustainability purposes.

- *A critique of knowledge production in helping define "sustainability" and "sustainability problems"*. This research has investigated the nature of agenda setting and the politics of defining problems: how humans come to be conscious of the existence of problems and how their understandings may be revised over time, often using framing as an interpretive approach. Much research also examines conventional and critical frameworks for public understandings of science, including the importance of ethnography in understanding cultural differences in using and protecting resources.

While many rich, exhilarating insights have been generated, I personally think that environmental STS continues to be on the margins of sustainability politics and science. In part, this is because the field has not matured sufficiently to illuminate many critical questions regarding the meanings and practices of sustainability in the early 21st century. For instance, environmental STS has largely failed to address the nature, politics, and formation of contemporary industry as well as complex technological systems. How do environment, science, and technology intersect conceptually and empirically? Environmental STS has also neglected many topic areas. Soil sustainability may well become a critical research area that STS concepts and methods can help enrich. Yet, it has remained absent from not only policy debates but STS research. Similarly, resource extraction and consumption seem to be peripheral, along with critiquing development and distributive justice.

This lack of innovative discussion is manifested in the latest edition of the STS Handbook. Only one chapter is dedicated to environmental issues, primarily the politics of climate change to the exclusion of many other 21st century environmental issues. This also highlights the tendency among scholars, activists, and policy-makers to magnify climate change whereas other issues continue to be equally pressing.

Environmental STS needs to move away from relying on historical analyses to focus more on contemporary problem framing in progress. History and policy need to be integrated more creatively. To some extent, STS also needs to move beyond using scientific and policy controversies as a base for investigation. An equally interesting question is why there is an apparent lack of controversy underlying many areas that could well be "sustainability issues". Is controversy truly absent, or is there hidden subversion where scholars are not looking? How are "unsustainable" technological systems dependent on widespread tolerance and particular public understandings of science?

Three of the most important research questions that environmental STS can investigate in the next decade are:

1. The measurement and explanation of "sustainability". One issue with sustainability science is that many researchers assume that there is ready agreement on what "sustainability" means and on how to measure progress in attaining a sustainable society. Nonetheless, many cases of debates and controversies over sustainability exist.

One strand of research needs to focus on the processes and politics of deciding on what sustainability means. In many areas ranging from fisheries, energy, green chemistry, to environmental health, there are intense debates over the kinds of sustainability that different corporate, governmental, academic, and non-governmental actors are pursuing. How do we know that a fishery is depleted, chemicals are entering human bodies, biodiversity exists in hot spots, plastic bags are biodegradable, and materials recycling is occurring? Relatively few institutions and procedures have been established to arbitrate on "sustainability". Conversely, a growing variety of metrics and measurement activities are being used to define and track "progress", helping constitute sustainability without critiquing what these do. There needs to be an extended critique of drivers, life cycles, impacts, indicators, and other ideas that are commonly invoked to analyze sustainability.

Another strand of research needs to investigate the explanations of how sustainability develops, and how emerging evidence for change is accommodated or challenged. Policy-makers commonly assume that they can develop rules and tools that will instruct people to practice "sustainable" behavior. They rely on implicit theories of the transition to sustainability. For example, deforestation has been understood by many actors to involve uncontrolled clearing of land, so that policies should try to restrain landowners. In the late 1990s, Fairhead and Leach published research suggesting that dominant framings of deforestation in West Africa could be flawed by ignoring local efforts to replenish ecosystems. In the early 2000s, some NGO and academic voices began arguing that farmers in Africa have been much more successful in restoring soil and vegetation than many international organizations and scientific experts have recognized. How are the histories of knowing about environmental and social impacts built and integrated into explanations of how sustainability comes about?

2. The analysis of agency and power within technological systems and cities. Contemporary societies worldwide are dependent on complex technological systems that mediate their sustainability. Cities cannot be separated from technological systems. Infrastructures for food, water, energy, transport, production, and other human activities are closely tied together in urban areas, and extend across the entire planet. Transportation, for instance, consumes energy and reshapes geographies on a vast scale. What are the challenges and opportunities for changing entrenched systems to become more sustainable? What resources and epistemologies are needed to make change appear feasible? Who are the agents that can help change technological systems, and what does agency mean? How do technologies take on specific forms of life, and how do technological innovations displace existing systems under the guise of increasing "sustainability"? How can greater traceability, transparency, and accountability be fostered – and what do these ideas mean in the context of technology?

Countless systems could be investigated. For example, plug-in electric cars offer the promise of significant sustainability gains. General Motors, along with several other companies, is currently engaged in the "gamble" of developing such cars. A suite of technological developments are underway, including the design of a battery that can meet energy delivery specifications. The company assumes that achieving technical changes will suffice for a successful transition to the "new" car configuration, but omits the societal changes that may be needed to allow take-up to occur. For instance, how are the specifications formulated, and by whom? Will consumers need to modify their driving habits, or are technologies expected to change rather than human behavior? Why is it that the private sector is being entrusted to develop the plug-in car?

Another interesting example is water technology politics, which will increasingly become vital as water becomes less reliable in the US and many regions of the world. Why do governments favor some technologies (dams, desalinization plants, pipelines) over others (rainwater tanks, conservation)? Why are large private users of water often left invisible, whereas water use restrictions are imposed on consumers? Why are citizens often unwilling to challenge government and industry on water scarcity? Are citizens reshaping cities by installing their own rainwater tanks?

3. The politics and modes of resource allocation. Resource use has long been recognized as a leading variable in causing sustainability problems. Manufacturing and consumption both generate pressures on resources (including energy, materials, water, and land). Yet, little STS research has critically evaluated the ways in which systems and practices for resource extraction and use have developed, and are continuing to evolve in the context of globalization and more local politics.

For example, since the 1950s, consuming cultures have come to dominate much of the world, as consumers develop life style expectations and industry seeks out new markets. What does consumption mean, and how has consumption developed as a set of societal practices? The emergence of energy-eating water bottles and plasma TV sets are only two examples of consumer products with significant environmental impacts. Why is obsolescence designed into products, and why do consumers accept this situation? What does "human forcing" of environmental impacts mean, and why do most policy-makers ignore consumption as a major sustainability challenge?

Conversely, the production sides are critical to understand more. Why, where, and how do companies and markets make allocations of resources to products rather than other societal purposes? Procedural justice is almost wholly missing from the analysis of resource extraction and use, since the private sector is assumed to have the freedom to decide on sourcing and production. The roles and impacts of markets need to be investigated at length. Eco-debts have recently emerged as a lens through which to understand the global transfers of wealth and resources between countries. Similarly, the concept of ecological services has been promoted as a way to marketize previously unvalued ecosystem features. But are these ideas helpful to restore procedural justice to resource allocations?

I would also suggest that the place of non-human actors (animals, ecosystems, the earth) will likely deserve much more critical assessment. Humans have long acted on the assumption that their needs are to be met above all other potential demands for recognition. That is, human exceptionalism has become a dominant premise, still pervading sustainability science and policy despite the advocacy of some environmental philosophers. Sustainable food and animal rights are among the fastest growing sustainability themes, yet STS has not yet addressed these in depth. Latour has begun to ask about the role of non-human agents and their rights, but this is not a critique of the ethics of sustainability.

It will become increasingly important to include Asian perspectives and experiences on science, technology, and environment. China, India, South Korea, Taiwan, and Singapore are emerging as major actors in their own right. The U.S. and Europe are no longer the only leading producers of science and technology. Recently, a report disclosed that China is not just growing quickly in its industry and carbon emissions but in its transition to renewable energy systems. Development and sustainability are closely intertwined. The next 4S conference is to be convened in Tokyo in 2009. Ideally, this would provide the genesis for a much greater engagement with Asian researchers interested in environmental STS. Collaborations need to be nurtured for the future.

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I also think that much can be learned from critiquing a range of sustainability texts. For example, CS Holling. Ecological science fiction might also be a fruitful source of inspiration (Kim Stanley Robinson; Sheri Tepper; John Barnes; Ursula LeGuin; Dan Simmons).

Steven Jackson

Assistant Professor, School of Information

University of Michigan

Strengths and contributions of STS to sustainability research to date

These are of course numerous and multifaceted (and extend no doubt beyond the points listed below). Vis-à-vis other approaches to the study of sustainability, core STS (or STS-flavored) work has been particularly good at analyzing and understanding:

The *constitution, bounding, and proper limits of expertise*, including in relation to other bodies / forms / practices of knowledge. This includes important thinking around the interface between expertise and formal structures and processes of governance (e.g. state-based decision-making processes, public policy, etc.), and expertise and publics (including but extending beyond those organized as semi-formalized 'stakeholders' in well-formed policy domains). [I'm thinking here of classic work by Jasanoff, Wynne, Epstein, etc.]. STS work has been particularly good and important at extending the scope of analysis (beyond, e.g., work in the decision sciences) to emergent phenomena, and to core issues of ethics and politics that go beyond narrowly proceduralist approaches. STS work around such questions has also begun in recent years to move beyond western sites and publics, connecting with the field's increasingly rich scholarship around post-colonialism and international development.

Sites and materialities of knowledge production. This maps generally to some of the earliest work in STS (e.g. laboratory studies), though in the case of sustainability science the sites of knowledge production are: a) a good deal more diffuse (i.e. harder to center on a single privileged site); b) typically located in closer proximity to social decision-making processes (environmental policy, etc.); and c) arguably more socially heterogeneous in composition. It's also possible that the link between sustainability policy and the sciences that constitute (a part of the) basic knowledge of sustainability science (e.g. ecological science, hydrological research, etc.) has been underexplored, and there remains considerable room for something like a 'lab studies' of the component fields within sustainability science (though given the shifting scale and organization of things like ecological research, I think these may be better described and approached as 'network studies' than discrete, bounded, and site-centered 'lab studies'). STS emphases on materiality and material practice/culture, both around the 'stuff' sustainability science deals with in the world (plants, bodies, landscapes, etc.) and the 'stuff' used to produce and circulate knowledge (tools, inscriptions, samples, etc.) seems an additional and distinctive strength of the field vis-à-vis other approaches to sustainability. In the world of sustainability science in particular, such STS work lines up potentially with work around space, place and landscape that has been usefully explored by (in this regard) adjacent fields like social and cultural geography and environmental history. Such connections, arguably more robust in places like the UK than the U.S., represent additional opportunities for the field, and I think any STS-centered take on sustainability science would do well to develop these further.

Partly connecting to the above point, but deserving of separate mention, is STS work around the *representation of knowledge*, including explorations of the accomplishment of vision in both a direct sense (e.g. strategies for the visualization of data, mapping, etc.) and somewhat more metaphorically (e.g. how does one get to "see big", i.e. assemble vast and vastly distributed phenomena in a way that gives some sort of cognitive purchase on the whole, e.g. through mechanisms like statistics). STS has been historically good at exploring the mechanisms and consequences of such vision/representation (including negative or power-laden ones). Insofar as sustainability science writ large is dedicated in part to the accomplishment of new forms of representational scale (indicators, new forms of environmental mapping, etc.), STS traditions of work in this area should continue to constitute central contributions.

Some strategic bridges / research areas between STS and sustainability science moving forward

These are undoubtedly multiple and possibly diffuse. A couple that I have particular interest in are listed here.

Building sustainable knowledge infrastructures for the sustainability sciences, including through development, shaping and appropriate governance of emergent collaborative scientific networks. This relates to increasing activity and investment within the NSF and other science funders around cyberinfrastructure (or elsewhere, 'e-Science' or 'e-Research'), with a central focus on advanced computational infrastructure meant to transform the practice and application of science in various ways (new modes of data storage, reuse, and exchange, new forms and styles of collaborative work, new modes of access to / participation in scientific research by students, citizens, and public decision-makers, etc.). Work from other disciplinary traditions and other locations within the NSF and similar bodies has centered primarily on computationally-driven tool development (the vast bulk of CI investment to date), and to lesser extent narrowly-focused evaluation studies (i.e. measuring the efficacy of existing CI investments according to usually narrow and/or quantitative sets of criteria). A robust STS-centered engagement would significantly extend and broaden current thinking around cyberinfrastructure, carrying pragmatic lessons for design (of both artifacts and policies), and asking larger questions around inclusion and exclusion, meaningful public participation in the shaping of research practice and priorities, and appropriate bridges or linkages between cyberinfrastructure-supported sustainability research and the fields and practices of public decision it informs.

Methodological innovation. As a gross generalization, STS has been and arguably remains a field centered on thick descriptions of single case studies. This has been a great source of strength, and central to the complexity and sophistication of the field's treatment of the dynamics of science and technology in society. An STS-flavored sustainability science should carry this strength forward, but ought also to explore other methodological formulations and/or strategies. One important axis of development, beginning to be explored (cf. Jasanoff 2005) is comparative (multi-site, multi-domain, multi-national, etc.). STS studies of sustainability might also usefully draw on, experiment with, and/or couple its traditional methodological tools (ethnographic, historiographic, etc.) with things the field has to date shown less interest in (or in some cases, like scientometrics, relegated to a positivist past). Examples here might include amended forms of network analysis (cf. Cambrosio et. al. 2004), or some forms of indicator development and statistical analysis. Such methods arguably sit uneasily with the general orientation of the field, but new and creative combinations (including ones that take on board STS's historical suspicions around such efforts at metrication) may be possible and worth exploring. In addition to its other benefits, STS engagements with the field of sustainability science may supply new and hopefully productive challenges to the practice of STS 'at scale'.

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Myanna Lahsen

Science Officer for Social Sciences, International Geosphere-Biosphere Programme

Brazilian Institute of Space Research and University of Colorado

Research area in focus

The impact of cultures of science and decision-making (political cultures) on environmental politics and policy outcomes; Theoretical and practical understanding of the science-policy interface in general, and in the global South and Brazil in particular.

Accomplishments and research needs

Important accomplishments of the subfield of STS studies focused on environmental policy and politics include the deep challenge it has mounted against dominant assumptions related to science policy and the nature of science, and its empirical studies of the role of science and power in environmental policy and related assessment processes. The linear model of the science-policy interface has been thoroughly debunked by empirical studies, yielding new theoretical frameworks and practical steps for improving the interface (see, among many others, Cash, et al. 2003; Funtowicz and Ravetz 1993; Gibbons, et al. 1994; Lahsen and Nobre 2007; Jasanoff and Wynne 1998; Miller 2001; Sarewitz and Pielke 2007). This work has spread recognition that more knowledge is needed to enhance the science-policy interface.

How do knowledge systems work?

STS and policy analysts have come to appreciate the importance of the design and dynamics of the science-policy interface to successful linkage of science with environmental decision making. They have found the impact of science to depend on many factors, including how it is produced, distributed and adjudicated, and the nature of decision makers' interpretive frameworks and political agendas (Bradshaw and Borchers 2000; Cash, et al. 2003; Cash and Moser 2000; Dilling, et al. 2007; Jasanoff and Wynne 1998; Juma and Yee-Cheong 2005; Global Environmental Assessment Project 1997; Lahsen 2004; McNie 2007; Miller 1998; Mitchell, et al. 2005; Sarewitz and Pielke 2007; Stern and Easterling 1999). Yet there is little consensus on how to bridge the gap between science and policy (McNie 2007; Smith and Kelly 2003). A comprehensive conceptualization of the science-policy interface at national and global levels is not easily forthcoming because of insufficient, empirically-based analysis of how knowledge systems work and how they might be integrated with decision making to facilitate sustainability. Especially lacking is knowledge related to inter-subjective dimensions, trust or lack thereof (Lahsen 2007; Litfin 2000; McNie 2007) – even while the few studies that do exist suggest the important shaping influence of these dimensions for the uptake of scientific knowledge and environmental policy (Fogel 2002; Lahsen 1999; Lahsen 2004; Lahsen 2007; Lahsen 2008; Litfin 1994).

There is an important need is for empirically-based analysis of how knowledge systems work and how they might be integrated with decision making to facilitate sustainability.

Another important accomplishment of recent research has been to highlight the need for participatory approaches in science production, assessments and policy efforts, while also calling attention to short-comings and deeper challenges to present efforts (or purported efforts) to ensure participation, equity and democracy.

What is the nature and causes of the social formations driving and inhibiting sustainability efforts?

A related needed area of study involves mapping and analyzing social formations which are shaping sustainability efforts, not the least the so-called epistemic communities. Recognition of this need also underpins the emergent Earth System Governance project under the International Human Dimensions Programme (Biermann 2007). Research might locate scientists in terms of their links to social movements and governmental and business actors, links that are presently understudied and overlooked, partly due to tendencies to speak of governments, civil society and scientists as separate rather than deeply and complexly networked actors. Like related concepts, such as transnational advocacy networks (Keck and Sikkink 1998) and advocacy coalitions (Sabatier and Jenkins-Smith 1993), the empirical foundations for such theorized entities need to be better identified and understood, as do the specificity of their existence. Such work can press present studies beyond merely identifying the existence of such social formations towards actually empirically mapping and analyzing the factors that make them form in the first place. Work along these lines can shed needed insight into mechanisms for and against social change bearing on sustainability efforts, and the understudied links between science and social movements (Breyman 1993; Hess 2007; Jamison 2006; Yearley 1993).

What is the role of science in environmental policy?

When strong beliefs and interests are at stake, scientific uncertainties related to environmental risks tend to be highlighted as actors impugn the quality of countervailing science. The practical importance of science in environmental policy at the national and international levels, including the actual mechanisms shaping its impact, remains insufficiently known and needs to be further examined. Some studies suggest that science plays a minimal role in issue definition, fact-finding, bargaining, and regime strengthening (Andresen, et al. 2000; Susskind 1994), while others conclude that acceptance of science greatly enhances the strength of national environmental policy (see for instance the comparative study by Fischer (2004)) .

How to reconcile development, equity and sustainability?

Global, regional and local environmental change has long been a concern of a number of global environmental change (GEC) research programs, such as IGBP, IHDP, WCRP and DIVERSITAS. A growing number of scientists from developing countries have participated in GEC research projects and capacity building activities. More recently, under the Earth System Science Partnership (ESSP), joint projects on food, water and health were initiated to address questions of direct relevance for developing regions. ESSP also promotes and facilitates Integrated Regional Studies (IRS) focused on a few regional 'hot spots' of environmental change. New research needs to further specify what kinds of knowledge can make a difference to actual sustainability-related decision making. Such research needs to identify and target root problems and it must ensure that the resulting knowledge is both usable and actually used: What are the sustainability-inhibiting factors at the levels of the funding and production of science and its use in governmental decision making and "on the ground" in local settings? What kinds of knowledge are objectively needed? Is it being produced and used and, if not, how might it be produced and used? How might S&T be shaped to help meet the United Nations Millennium Development Goals (MDGs) around the world? For instance, how might science and technology facilitate sustainability in the Amazon region in ways that also ensure equity and successful livelihoods and quality of life in the region? What kinds of new discourses, institutions, combinations of orientations, values, analytical angles, skills and approaches are needed, and how might they be nurtured? Such research might start by identifying the mistakes of past development efforts such as the Pilot Project for Protection of Tropical Forests in Brazil (PPG-7), in particular why efforts to invent and finance sustainable development on the basis of the region's natural resources failed, and what can be done to avoid such failure in the future?

Sociologies of environmental knowledge and knowledge-producers.

At the level of the production of science, STS research has shed some light onto how socio-political factors shape environmental knowledge. It has begun to open the black box around scientific environmental knowledge, including the central technology of modeling (Ashley 1983; Edwards 1996; Edwards 2001; Lahsen 2005; Shackley and Wynne 1995; Shackley 1995; Shackley and Wynne 1996). Studies have probed how socio-cultural dynamics among different subsets of scientists are reflected in controversies around climate science (Lahsen 1998a; Lahsen 2005; Lahsen 2008). However, STS-informed studies of many important, specific scientific controversies within the area of climate change are still lacking (e.g., around the temperature record). Such studies are needed to deepen insight into the role of technologies and differences in social networks, geography, historical experience, disciplinary training and scientific and socio-cultural and political values in controversies involving environmental science and sustainability, and provide insights that might facilitate calibration of competing expert claims.

Thick analyses of environmental decision-making

Empirical/ethnographic studies of business leaders and policy makers' perceptions of science are perhaps especially needed, and presently limited due to the tendencies dominating the respective fields. Such empirical research focused on decision-makers can help reduce the prevalence of the long-standing assumptions among political scientists, e.g. the assumption that policy-makers, as a whole, tend to believe that science operates in a realm separate from the influence of politics (as an example, see Litfin 2000). STS scholars have produced studies which suggest a different, more complex picture (Biermann 2000; Biermann 2002; Fogel 2002; Kandlikar and Sagar 1999; Lahsen 2004; Lahsen 2007). Such studies are still scant, however, and need to be enhanced. They should provide "thick' analysis of environmental decision-making" along the lines advocated by Adger et al (2003).

There is a need to study patterns and trends in how science is understood and integrated into decision-making in different national, subnational and transnational arenas and networks, and to provide richly textured accounts of the shaping impact of cultural, institutional, economic and political factors: What kinds of knowledge appear most influential, and why? To what extent and in what ways are various strands of scientific evidence and discourses variously believed, disbelieved, used or ignored, portrayed/conceptualized as dependent or independent of politics? What sociological sense can be made of the identified patterns? What factors limit the uptake of knowledge, and what would have to be changed to improve the uptake? It is especially important to understand this at the level of national and international decision-makers, and to identify the role of socio-cultural and political factors, including structural ones such as global disparities in scientific capacity. Is the trend towards greater questioning of scientific facts, as posited by some (Jasanoff 1990b) or towards a growing strengthening of scientific authority relative to political authority, as posited by others (Litfin 2000)?

Environmental policy in tropical countries

There is an especially important lack of empirical studies of the dynamics of environmental policy in countries of the tropics, despite the latter's vital importance to global environmental policy outcomes because they subsume the majority of the world's population, natural resources, and biological diversity.

Comparative studies

There is an important need for *comparative* studies of how science is integrated differently into policy processes in different national and regional contexts, and how the differences – in conjunction with particularities of political cultures - bear on sustainability policy. Cross-national and cross-cultural, comparative studies can also help enrich and broaden the scope of the STS, which, as a field, has tended to narrow in scope and methodologies in recent decades (Fischer 2003; Jasanoff 2005; Hess 2007).

A study integrating many of the elements identified above is Paul F. Steinberg's (2001) work on the role of scientists and their national and transnational networks for biodiversity policy in Costa Rica and Bolivia. However, his framework has notable short-comings, most centrally the lacking integration of STS and critical theory insights into the relationship between knowledge and power. Steel et al.'s (2000-1, 2004) works also are examples. All three examples lack the needed context-sensitive thickness of description, however.

How explain and overcome the dearth of sustainability research in the social sciences?
Considering common, present-day framings of global environmental problems such as climate change and depletion of natural resources and life-supporting eco-systems as the greatest threat facing humankind, it is astonishing how scarce work on these problems is in fields such as STS, anthropology and sociology. The factors explaining this state of affairs may be a research problem in itself whose full range of causal factors needs to be identified and eliminated, perhaps through intra-field discussion and changed academic incentive structures.

How overcome the gap between the natural and social sciences?

How might natural and social scientists learn to better work together? In other words, how might we reduce/overcome the divide between natural and social sciences? What structural factors need to be changed, e.g., what incentive structures need to be built? Should the social sciences strive to increase its involvement and contribution to quantitative modeling? One of the areas in which enhanced social scientific involvement is wanted is in Earth System modeling. Natural scientists are increasingly looking to include social scientists in integrated research focused on issues such as bioenergy and climate change, but are having difficulty finding and engaging social scientists. Are social scientists amenable to such collaborations, and if not, why? If they should be, what can and should be done to optimize the results of their engagement? We may start by revisiting STS scholars' examinations as to whether modeling is the best tool for studying global environmental phenomena (Shackley, et al. 1998), and work towards an informed position as to the extent to which social systems and decision-making processes can and should be integrated into Earth System models.

To summarize, an overarching question in need of research is: how do knowledge systems work and how might they be structured to best facilitate sustainability in line with core principles related to fairness, equity, and democracy?

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Steven A. Moore

Bartlett Cocke Regents Professor of Architecture and Director, Graduate Program in Sustainable Design

University of Texas-Austin

To discuss STS accomplishments and challenges related to sustainable development in concrete terms it is helpful to narrow the scope of discussion to the built environment. According to the U.S. Department of Energy the production and operation of buildings accounts for almost half of all greenhouse gas (GHG) emissions and more than half of North America's annual energy consumption. This amount is significantly greater than the contribution made by the transportation sector, the source popularly associated with environmental degradation and climate change. These general statistics are put in a critical context by a Brookings Institution study conducted by Arthur C. Nelson which projects that by 2030, the US will need a total of approximately 427 billion square feet of built space to accommodate growth. About 82 billion of that will be replacement of existing space and 131 billion will be new space. In other words, by 2030, about half of the buildings in which Americans live, work and shop will be built after 2000. If we assume that these projections are even reasonably reliable, it suggests that the construction and operation of architecture could ironically become the nation's single largest threat to the health, safety, and welfare of human and nonhuman communities.

Although poignant, the problem with these statistics is three-fold: First, they conflate the concept of sustainability with that of climate change and thereby ignore social equity as a dimension of sustainability (WCED 1987). Second, they suggest that a technological fix is possible. And third, they document a pattern of neglect by STS scholars toward design of the built environment--with the notable exception of engineering design (Buchanan and Margolin, 1995).

One reason for such neglect may be the conventional association of design fields such as architecture, landscape architecture and industrial design with the fine arts rather than with the sciences. However, leaving the built environment to be interpreted solely through lenses constructed in the philosophy of art, rather than in the philosophy of technology or STS, is problematic at best because such optics tend to filter out the social and political consequences of design choices in favor of other criteria (Moore, 2001; Guy and Moore, 2005). A second reason for the neglect of design by social scientists may be because design is often understood by scientists to be the "application of knowledge created in their own discipline" (Buchanan, 1995: 18). From this perspective design is only the materialization and assembly of previously known truths. But, no matter the reason, the absence of a systematic study of design is troubling because design is best understood, not as the fashioning of trendy objects or the application of abstract knowledge, but as the principal method used by society to envision how we want to live in the future.

This is not to say that STS scholars have neglected sustainability (Bijker, 2004; Hess, 2007), or design as a whole but that the topic tends to lurk in the background of famous studies such as Langdon Winner's bridges, Wiebe Bijker's bicycles, Bruno Latour's personal rapid transit system, and so on. The most explicit treatment of design has been in engineering studies where researchers often use ethnographic methods to follow engineering teams as they produce technical artifacts (e.g., Noble, 1977; MacKenzie, 1990; Ferguson, 1992; Bucciarelli, 1994; Henderson, 1999; Law, 2002; Vinck, 2003). Here, design is characterized as a messy, active form of socio-technical production with experts being influenced by a variety of technical and non-technical constraints. Conversely, a smaller number of STS studies have focused on the design of the built environment (e.g., Brain, 1994; Aibar and Bijker 1997; Moore, 2001; Gieryn, 2002; Brand, 2005; Guy and Moore, 2005; Yaneva, 2005; Henderson, 2006). Most significantly in this arena, Guy and Farmer (2001) have used STS methods to examine the multiple and often conflicting "logics of sustainability" employed by architects. In spite of this encouraging beginning, the field remains under-developed.

A few brave philosophers of technology, notably Albert Borgmann, Carl Mitcham, and Langdon Winner, have trespassed the porous boundaries of STS to participate in the relatively new field of Design Studies. Historian Victor Margolin founded the field (along with a journal by the same name) in 1984 as a response to the public skepticism of professionals after World War II. Margolin (1989: 28) holds that "design is the result of choices," prompting him to ask "Who makes these choices and why? What view of the world underlies them and in what ways do designers expect a worldview to be manifest in their work?" This parallels Langdon Winner's (1977) famous argument that choosing a technology is not choosing a thing, it is choosing a "form of life" that necessarily favors living in one way over another. Design choices are, in this collective view, far from innocent or autonomous aesthetic preferences. The built environment embodies human intentions and understandings of the world and design is about shaping the world, one artifact at a time. But it is also much more. The work of engineers, architects, and other designers of urban environments "provide stage settings upon which the ongoing dramas of political action are mounted" (Winner, 1995: 150). STS might be considered, then, an underutilized design tool that can help citizens to craft the settings appropriate to the dramas we desire to enact.

Directions for research

1) But timing, as they say, is everything. The doctrines of path dependency and technological momentum warn us that we are not as free as we might like to think in constructing ideal or even functional settings for the lives we desire. We have been continually building and rebuilding our cities, and the institutions that inhabit them, for several thousand years and these "obdurate" interests will not be easily displaced (Hommels 2005). But as I noted above, because demographers insist that in only a few decades economic and population growth will double the size of our cities, we are provided with a very mixed blessing—the opportunity to deflect the trajectory of history. Put another way, Winner (1995: 150-151) argues that, "Speculation about design … can be especially fruitful because it pushes attention … back to a point before choices have hardened in cement." STS, then, offers the design disciplines a way of thinking critically and analytically about the consequences of design choices. In a special edition of *Design Issues*, Ned Woodhouse and colleagues at Rensselaer Polytechnic Institute directly considered how STS might help others to "think systematically about how design can help shape a commendable society" (Woodhouse and Patton, 2004: 1). Where other STS inspired projects have examined how built environments serve particular social interests, Woodhouse and his collaborators are intent upon examining the political implications of normative design practice itself. The research gap that remains is to focus more narrowly on the (un)sustainable city as a giant sociotechnical artifact.

2) If, however, our goal is to create and sustain functional eco-socio-technical systems, analyzing the practices of others from a distance will not be enough. STS scholars must not only encourage more STS-style analysis of urban design practices, but STS practice might itself benefit by adopting a type of "design thinking". Following Aristotle, C.S. Peirce argued that abductive reasoning, as distinct from inductive and deductive reasoning, is a distinct epistemological disposition. This not to say that abductive reasoning and design are the same activity, only that, like William James, we too might productively link future-oriented action to knowledge production. More recently, Design Studies scholars (Margolin and Buchanan in particular) have followed this path. I will also argue that the *phronetic* approach to social science advocated by Haraway (1995) and Flyvbjerg (2001) points in the direction of an activist social science that necessarily blurs the historical division between *analysis* (the realm of social science) and *action* (the realm of design). A second research question is, then, to ask: What is the relationship between STS analysis and design thinking with respect to a sustainable built environment? (Moore and Karvonen, in press). Research in this area might produce surprising new hybrid practices. If a building design proposal can be said to hypothesize a way if living, how might STS scholars collaborate with environmental designers and citizens in testing a given hypothesis and then make the analysis available to future collaborative groups? The existing practice of "post-occupancy analysis" is only foreshadows the possibilities.

3) As recent STS research has demonstrated (Woodhouse, 2004; and Winner, 2004), design practice is not the existential struggle of individualistic designers impugned by some philosophers of technology (Borgmann and Mitchum). Rather, design is a social and highly regulated activity. To date, however, no STS analysis has been conducted (except Moore and Engstrom 2005; and Henderson, 2006) of those codes that seek to define what it means to build "sustainably." In the very brief period of ten years the LEED code, developed by the US Green Building Council has become the dominant standard, yet no scholar has investigated the politics of codifying "green building". Scholars from Landscape Architecture (Ben Joseph 2005) and architecture (Davis 2005) have investigated the historical relationship between "place-making" and "code-making", but these studies do not adequately consider the political consequences of technological standardization—nor do they investigate sustainable design as a distinct design problem. Likewise, scholars from geography (Imrie, 2007) have examined codification related to architectural production and handicap accessibility, but not sustainability. In addition to the historical and geographic works by Ben Joseph, Davis, and Imrie related to codification, *Technology and Place* (Moore 2001), and *Building Codes* (Moore 2005) provide a starting point for STS research concerning the standardization of sustainable technologies for the built environment.

The built environment is not, of course, the only area of sustainability research that must be pursued. It is, however, the one with which I am most familiar. I look forward to hearing the proposals made by other Workshop participants.

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Tischa A. Muñoz-Erickson

PhD Student, School of Sustainability

Arizona State University

STS Research Accomplishments

My involvement in STS scholarship is relatively recent, yet my academic and practical experiences in environmental and sustainability issues have long exposed and directed me to questions and interests that are central to STS. For the last 10 years I have conducted research and applied projects in the U.S. and Latin America aimed at understanding the role of alternative institutions arrangements in integrating various types of knowledge, values and attitudes, into decision-making, and evaluating their impacts on sustainability. I have a M.S. in Environmental Science and Policy from Northern Arizona University and my master's thesis evaluated the ecological and social outcomes of collaborative management with implementation of place-based sustainability indicators. This project evolved into the Integrated Monitoring for Sustainability (IMfoS) program and continues to support managers and stakeholders in fostering learning and adaptive capacity. I attribute the success of this program in large part to the long-term social relationships that my colleague scientists and I built with local stakeholders to obtain trust and legitimacy in using science in support of their management needs. This work prompted many questions about the value of recognizing different knowledge systems in sustainability problems, and about the effects that our research and indicators had on decision-making, and vice-versa.

Recognizing this two-way relationship between science and society, I worked as a Research Associate with NAU's Forest Ecosystem Restoration Analysis (ForestERA) Project in evaluating how scientific modeling tools and participatory processes influence discourses in forest policy and sustainability. As sort of a 'boundary spanner' I helped build linkages between scientists and stakeholders in collaboratively developing a research agenda to bring about useful and relevant scientific modeling information for local communities, managers and policy-makers to reduce vulnerabilities. To evaluate the effectiveness of this process and its impact on the local discourse, I implemented a Q methodology at three different times of the process (before and after) and evaluated how much do the different discourses converge or diverge as a result of this collaboration. Results are still underway, but already we found that, while time intensive, this process helped link governance networks and greatly influenced the scientific and management process.

I am now working on my PhD at Arizona State University's School of Sustainability in which I'm incorporating STS ideas with environment governance approaches to analyze of knowledge systems for sustainable governance, with a particular focus on the urban systems. My central question is: what is the knowledge system and institutional network coming bear on urban environmental governance, and how does it influence the city's capacity to learn, adapt and build reflexivity in the face of socio-ecological vulnerabilities and sustainability? The academic STS training that supports this research comes mostly from courses and interactions with STS scholars at ASU's Consortium for Science, Policy and Outcomes (CSPO), and through a Social Science Research Council DPDF (Dissertation Proposal Development Fellowship) on Critical Studies of Science and Technology Policy with Sheila Jasanoff and Clark Miller as advisors. I am also a an IGERT Fellow in Urban Ecology and Research Assistant to Clark Miller on a project to synthesize knowledge system literature for the Advancing Conservation in a Social Context (ACSC) of the John D. and Catherine T. MacArthur Foundation. My hope is that this research will result in a useful framework to analyze knowledge systems and build institutional capacities for sustainable governance.

STS Research Questions

I offer two suggestions that extend from the inquiries I described above, but more importantly, from the perspective of a student in sustainability, the issues I see emerging in the sustainability research agenda, and how I think STS insights can help. One of my main concerns that, while much has been advanced exploring how to best link knowledge and action for sustainability, we are just beginning to understand the cultural and institutional dynamics that are emerging between research and society, specially involving bottom-up efforts that integrate citizens in defining goals. What are the conditions that lead to fruitful and democratic interactions between knowledge and policy in problems involving multiple trade-offs and not simple alternatives? STS has contributed substantially to our understanding and appreciation for the dynamics of framing, boundary work, and agenda-setting in scientific communities. The public policy scholarship has achieved a parallel understanding for policy communities. I think though that now we should focus these efforts to the spaces where these communities interact in practice. How are priorities negotiated and what rules emerge to manage this joint action arena between science and society? What type of network and institutional arrangements are most conducive to allow flow of information and knowledge in a transparent manner and across multiple scales? How to we evaluate the impacts of these? I think these questions relate to the point that Elizabeth Graffy brought up recently in an email exchange where she was concerned that “that we just don't have methods and institutional processes in place to integrate the various kinds of "meaning" into the public discourses that set social goals and the means to ends, etc. We don't really know how to do it, and it matters...”

Along these lines, in my view, one of the least advanced aspects of the sustainability agenda, or that it runs the danger of being a marginal perspective, is the trade-off involved between development and vulnerability and social justice. In this sense the climate shift that Elizabeth Graffy and Brian Wynne describe may not be that bad as this area has tended to look at vulnerability and justice issues more closely. But as the sustainability discourse continues, how can STS help inform and infuse back a sense of justice, values, and vulnerabilities into the sustainability agenda? Can we develop evaluative criteria to track social and democratic trade-offs and contradictions of sustainability in a way that is critically constructive to the scientific and technological discourses? If sustainability is a “normative science”, which I believe it is, then can we help develop decision-making tools or frameworks to assist the research agenda in a achieving a better integration of normative aspects into their decision functions? I think that while much as been done with decision-making tools and frameworks, it is still separate from the actual scientific process in academic institutions.

Put in a more practical note, can we take what we know already and suggest conceptual and methodological approaches to sustainability scholars, students, and practitioners to work in science-society spaces and be aware of the conditions that are or are not rendering to effective relationship between the science they develop and society? As one of the first students in the School of Sustainability, I'm very aware at the fast speed in which the research agenda for sustainability is developing and being implemented in practice, while those of us that are trying to instill reflexive modes of knowledge production that take STS lessons into practice are barely trying to catch up because we lack the synthesized tools and frameworks to do so. There are lists of "things to watch for" or "things to do" in the business organization and knowledge management literature to help practitioners, can we think of an analogous but more-nuanced list of 'principles' from STS, without the danger of being prescriptive?

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Bryan G. Norton

Distinguished Professor, School of Public Policy

Georgia Institute of Technology

I have tried in my own research and writing on sustainability and adaptive management to follow problems across disciplinary boundaries, and this makes it difficult to respond to the request for an account of my "area of research". I fear that my response will be as idiosyncratic as my own halting path across intellectual boundaries toward (a) a basic definition of "sustainability" that reveals the full range of *values* that must be protected if we are to live sustainably and (b) a focus on problems of "scale," which can be viewed from the perspectives of ecology, psychology, geography, philosophy/ethics, and politics (Norton, 2005).

Having apologized for the idiosyncratic perspective I take, I will try to sketch one research focus—highly relevant to STS—that I believe can improve the integration of scientific knowledge from multiple disciplines and, in turn, the integration of that knowledge with processes of policy evaluation and decision making. Beginning with (b), above, I have (from my perspective as a philosopher) engaged with social scientists who are pursuing ***spatial social science***. The goal of our research has been to examine, using multiple methodologies, the interaction of model-building in efforts to understand and respond to threats to endangered systems and the very slippery problem of problem formulation. In particular, we believe that problem formulation can be highly controversial and that boundaries of a given problem and the scale at which we respond too it are essential aspects of problem formulation. Emphasis on spatial scale is important for another key reason: since Adaptive Management embodies *hierarchy theory* as its framework for understanding scalar problems (larger systems change more rapidly across time than do smaller subsystems that compose them), this approach provides a useful basis for correlating temporal and spatial aspects of systems.

What is unusually fruitful about this nest of problems is that they reveal two foundational truths about sustainability: (1) Sustainability must, ultimately, be characterized as protecting a plurality of values; and (2) The models we build for understanding and responding to environmental problems are not "descriptive science", they embody our values insofar as they respond to a problematic situation—a situation in which values are threatened. Once these two truths are accepted, the concept of sustainability becomes a truly "big-tent" idea: Understanding "sustainability" as a concept requires the integration of scientific models into evaluative projections of how to live so as to protect the values and aspirations of the relevant community.

These realizations, in turn, create the possibility of a truly post-positivist science. Environmental sciences exemplify what Funtowicz and Ravetz call "mission-oriented science." Science is pursued in the context of values and social goals; sustainability is an aspirational notion that guides environmental science; it can never itself *be* a science. If this rather bold statement is true, then would it not follow that, as mentioned in the first paragraph above, articulation of a pluralistic set of values that can define sustainability goals is a most urgent need. Given that we operate in social systems in which individuals are highly diverse in the values they embrace and defend, a research program responsive to this need must involve public participation in goal-setting and an empirical methodology that is capable of guiding public discussions toward goals that protect multiple and varied values. A key aspect of this interaction of public discourse and empirical study is to focus attention on the choice of indicators that can be expected to track important social values. This pluralistic approach, that is, does not seek to enforce one or a small number of values (such as economic efficiency), but rather encourages open discussion and negotiation in which diverse values are appealed to in attempts to identify indicators which, if maintained at target levels, can protect the range of values favored by the collective individuals engaged in the adaptive management discourse.

This general approach points toward three very important areas of research.

1. By accepting that nature is valued in many ways and that there can be no synoptic, "substantive" characterization of a "best" outcome of sustainability planning, the emphasis shifts to *procedural rationality*. Rather than attempting synoptic, totalistic calculations of costs, benefits and ecological services over indefinite time, research should focus on how to develop better processes. According to Herbert Simon, a decision is *procedurally rational* if it is arrived at by an "appropriate procedure," and this shifts the focus to the problem of developing effective discourse and creating "appropriate procedures" for making important decisions. This research might lead into research on communicative ethics and the characteristics of "ideal speech communities" as explored by Jurgen Habermas (1984) and by institutional economists such as Bromley (2006). One can study, for example, whether a given partnership or collaboration is progressing toward an ideal and it might in some circumstances be possible to infer that certain decisions are "rational" in the sense that they are the decisions that would be made by an ideal procedure in an ideal speech community. These hypothetical judgments can function to clarify goals and possible outcomes, and also focus attention on what kinds of actual procedures seem to work in various situations.

2. An important aspect of understanding values within a diverse community is to understand how the values of individuals and groups can affect problem formulation. Most environmental problems are "wicked problems" in the sense that individuals with different values and perspectives tend to formulate problems differently (Rittel and Weber, 1973). In our research we have found that in many particular cases problems become intractable and discourse breaks down because, given different perspectives, they tend to construct "models" of the problem at different scales and different temporal horizons. It is possible, then, to learn a lot about how individuals and groups conceive problems by bounding the system which they see as problematic. Here, then, is a locus at which the interaction of values, choices of physical models, and problem formulation can be studied.

3. It is well known that environmental problems, including sustainability projections, very seldom have a spatial extent that corresponds to any political jurisdiction (Hajer, 2003. As suggested in 2., however, a major aspect of problem formulation is to "bound" a problem in space and time. But how does one "bound" a problem before one, for example, knows who is affected by it? Therefore the creation of "models" of problems appears to be inseparable from the evolution of *institutions* that address those problems: Problem formulation and the development of institutions to address these problems are closely related and hold the key to developing a sustainability agenda. As noted in 1., then, developing an appropriate procedure links to the develop-

ment of institutions—sometimes called “boundary institutions” (Guston, et,al., 2000; Ingram and White, 1993) that can initiate a “discourse” about a problem or set of problems and then evolve into more formal organizations that link decision processes across multiple scales. Understanding how the specification of sustainability goals is, on this view, often best studied by studying the evolution of institutions of appropriate size, scale, and receptivity to plural values.

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Roopali Phadke

Assistant Professor of Environmental Studies

Macalester College

STS and Environmental Politics

As an environmental studies scholar, my interests over the last decade have focused on the intersection of participatory democracy, technology development and sustainability.
My research aims to constructively engage two fields of academic inquiry: political ecology and science and technology studies (STS). Scholars who work at the intersections of these fields are often situated in the disciplines of geography, cultural and ecological anthropology, environmental history, development studies, history of science, or postcolonial science studies. My research builds upon the work of scholars, such as Tim Forsyth, Timothy Mitchell, Diane Rocheleau, Arturo Escobar, and Anna Tsing, who have sought to engage these two fields of inquiry.

Political ecology and STS have addressed the politics around conservation, development and environmental change through different lenses. As a field of study, political ecology has been concerned with how the landscape imagination is shaped by the structural dynamics of poverty, underdevelopment, and environmental inequity. Research in political ecology has been characterized by fieldwork that bridges local cases of resource use with political and economic structures at national and international scales. Political ecologists have been concerned with the ways in which local knowledge and state development expertise interface. Their attention has been drawn to how alternative, and often subaltern, ways of knowing and seeing the world are mobilized by NGOs and radical social movements defensively against a state appropriation of natural resources.

In contrast to political ecology, STS scholarship has more often focused on revealing and understanding the social relationships and networks that produce, transmit and sustain forms of scientific knowledge and technological artifacts. STS scholars have been particularly interested in the emergence of new categories, systems and disciplines that value and represent nature and society. Analytical approaches in STS theory have focused on participatory and democratic technology development. Within this genre, STS concerns include the social construction of technology, local knowledge, accountable scientific expertise and the mobilization of citizen science. Compared to political ecology's predominant focus on the "third world", STS work has more often privileged European and American case studies and intellectual currents.

There are important common points of engagement between political ecology and science studies that help elucidate how landscape and technological imaginaries come together. Scholars working at the nexus of political ecology and STS have been interested in the constitution of the "green state" and the mobilization of "green knowledge" in diverse settings and among diverse stakeholders.[10] They have asked how sustainability expertise is constituted and by whom? How

[10] I would include here the word of Michael Goldman, Andrew Jamison, Tim Forsyth and

are local knowledges asserted and mobilized toward sustainability? What skills and technologies enable local governance of sustainability interests? How do social movements function as knowledge producers, brokers and assimilators in the face of environmental conflict?

These are questions without simple answers and worthy of continued exploration. They also warrant the attention of the STS community in ways that frame knowledge politics and governance as central to the sustainable development problematic.

STS and Sustainability

Over the last five years, sustainability concerns have blossomed on college campuses and universities in North America. Supported by extensive academic investments in environmental studies departments and programs, sustainability initiatives are ubiquitous in and out of the classroom. For example, my small liberal arts college campus has an Office of Sustainability and a full-time senior Sustainability Manager who oversees that the professed goals of the college are implemented throughout our various operational units. Many universities, including Harvard, Stanford, UW Madison and Arizona State, have established Sustainability Science departments and majors.

Despite this advance of environment and sustainability concerns, these issues still lag among the STS community. Biomedical and IT issues still dominate STS research. One important question to ask is: How do we stimulate greater interest in using STS analytics to produce a wider and more nuanced understanding of sustainability work? There are several important opportunities for extending STS concerns toward understanding the discourses and mechanics of sustainability. I want to highlight three such topics: 1) core principles of sustainability science 2) the technologies of sustainability, and 3) the climate change framing

1) Sustainability Science

Sustainability science has recently emerged as an academic space for examining nature-society interactions. Harvard’s Sustainability Science Program professes its goals are to “advance scientific understanding of human-environment systems; to improve linkages between relevant research and innovation communities on the one hand, and relevant policy and management communities on the other; and, more broadly, to build capacity for linking knowledge with action to promote sustainability.”[11] The field is supported by an online, peer reviewed, free access journal called ***Sustainability: Science, Practice, & Policy***. Arizona State University now offers a BS and BA in Sustainability Science.

STS scholars have often examined emerging disciplines as sites of contested knowledge and power formation. Some have argued that a sustainability science paradigm requires “re-engineering” the very fabric of science. This is an important juncture to examine not only the espoused benefits of a “sustainability” science, but its opportunity costs.

[11] See http://www.cid.harvard.edu/sustsci/

Some key questions to ask

- What separates sustainability science from its predecessors cultural ecology, human ecology and environmental studies?
- Does sustainability science aim to achieve the stability and legitimacy of a "normal science" or cast itself as a reflexive and "post-normal" science? Which framing in gaining ground and why?
- Does a "solutions oriented" science help produce a form of scientific expertise that is more democratic and inclusive?
- Does sustainability science transform the broader institutions of science in ways that impact norms, methods and practices?
- Does sustainability science provide the underpinning necessary for advancing the political goals of sustainable development?
- Does sustainability science provide a better model for transcending and connecting data generated in local and context specific sites to trends and challenges at the global scale?

2) Technologies of Sustainability

STS scholars are in an ideal position to interrogate the new technologies of sustainability – the carbon offsets projects, mitigation models and tools, and carbon markets that dominate current sustainability work. This is not new terrain for STS scholars.[12] Yet, it is important to move beyond the theoretical implications of this work toward understanding how mitigation and adaptation mechanisms are impacting livelihoods on the ground. It is vital that STS scholars examine not only the technologies themselves but the forms of public deliberation and participation that either produce or limit bottom-up agency. This is as important in first world contexts as in developing countries, where exercises of democracy have often been limited to forced participation in development projects that have measurable climate change outcomes. How does participatory democracy become a tool for sustainable development? How are the expanded roles of international and local NGOs affecting their reliance on scientific knowledge and scientific authority within a shifting political arena? What are the metrics of accountability in sustainability projects and programs?

3) Climate Change as Umbrella Category

As a result of the current interest in global warming issues, many more general environmental sustainability topics have fallen under the umbrella of climate change policy. There are clearly issues which require different kinds of social, political and scientific framings than a climate change orientation enables. For example, can endangered species management, wilderness protection, hazardous wastes, and water scarcity be reasonably subsumed as climate change initiatives? Are these sustainability concerns receiving lesser treatment as climate change concerns

[12] See Clark A. Miller and Paul N. Edwards, eds., *Changing the Atmosphere: Expert Knowledge and Environmental Governance*. MIT Press. Cambridge, MA. July 2001

gain traction? What are the limitations and opportunities that the climate change framing offers? In which cases and contests is it advantageous to take a more “silo” approach to environmental sustainability?

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Daniel Sarewitz

Co-Director of the Consortium for Science, Policy & Outcomes and Professor of Life Sciences and Sustainability

Arizona State University

Two developments in U.S. federal policy create potential opportunities for STS (here I mean STS to be broadly inclusive of academic work in the general area of science, technology, and society). The first is an opening up of discussions about the social value of public investments in science and technology. While varieties of the linear model, and simplistic notions of how R&D contribute to social goals, are still strongly present in science policy discussions, there is also a growing skepticism to claims that investments in R&D will automatically lead to desired social outcomes. As unsatisfactory or incomplete as NSF's criterion II, or NIH's broadening of study group participants might be, they are nevertheless indicators of a growing openness to new visions of how science and technology can be governed. Similarly, the evolution from a rather detached ELSI approach to genomics and society, to a somewhat more engaged program in the "Human Dimensions" of climate change, and still greater engagement in nanotechnology in society, seem to be steps in an STS-ish direction.

The second development is of course the legitimization of sustainability itself as a matter of urgent concern, as especially embodied in the challenge of climate change. And while the general response to sustainability challenges from a federal science policy perspective has largely conformed to the standard "do more research so we will know how to solve the problem" approach, there are some developments that are broadly consistent with (if not actually informed by) STS work, including the Regional Integrated Science Assessment program at NOAA, the Decision Making Under Uncertainty program at NSF, and a wide recognition that standard disciplinary approaches to knowledge creation are insufficient to the task at hand.

These developments offer opportunities for increased investments in STS work itself, and they also offer opportunities for STS to contribute productively to political and policy processes. These two opportunities may be mutually reinforcing, though this is not necessarily the case. In some ways, the insights of STS for addressing sustainability offer direct challenges to fundamental political and policy assumptions about science and society, including beliefs about the value of information for decision making, and the appropriate institutional structures for creating useful knowledge (and even the notion of "useful knowledge" itself). Embodying STS in sustainability politics and policy thus represents a potential threat to present ways of doing business, which could translate into opposition to STS. Yet, examples from science policy related to climate change and nanotechnology do show that change consistent with STS understandings is possible, even if it is, so far, pretty much at the margins. Can such insights be mainstreamed?

Paul B. Thompson

W. K. Kellogg Chair in Agriculture, Food, and Community Ethics

Michigan State University

Findings from Previous Work

My prior work on sustainability has focused on three questions.

1. *What implicit and explicit values are associated with sustainability as the term is utilized, especially with respect to food and agriculture?*

Prior to the Brundtland report in 1987, the term was used frequently in conjunction with agriculture, and in three primary senses outlined by Gordon Douglass in 1983. First, it was associated with food security, especially when understood in as an aggregate function of population and productivity. Second, it was used to call attention to agriculture's impact on ecosystem functions, especially with respect to water quality and availability, but also habitat. Finally, it was used to reference the stability of rural communities and community institutions under alternative systems of land tenure. Brundtland shifted the discourse significantly, and should be viewed in contrast to the Brandt report of 1982. In Brandt, development priorities were framed in terms of human rights, and the report stressed obligations owed by North to South. Brundtland substituted the phrase "sustainable development" and suggested that global development should be based on interests shared by rich and poor nations.

2. *How are the empirical dimensions of sustainability characterized?*

Most approaches can be fit into one of two models. *Resource sufficiency* suggests that a practice or process is sustainable to the extent that the inputs needed to continue it are foreseeably available. This approach fits well with welfare economics models of development that stress the savings rate or production economics models that specify input-output relationships. *Functional integrity* suggests that an autopoietic system is sustainable to the extent that it is invulnerable to internal threats. This approach fits well with models stressing ecosystem processes and renewable resources, and is implicit in some approaches to social systems which either explain or presume the continuous reproduction of institutions such as the family, social norms or social infrastructure. Recent work that utilizes social movement theory addresses may apply functional explanations to account for the success or failure of social movements, but in maintaining that sustainability can simply be *defined* as a social movement (some hold this view), analysts fail to stipulate empirical criteria for sustainability as such.

3. *How are normative criteria linked to empirical criteria?*

Sustainability in the sense of resource sufficiency presupposes independent normative justification of the process or practice to be sustained. Key questions involve the goals and beneficiaries of the process. In the case of functional integrity, some autopoietic systems may be thought to have intrinsic value, hence their sustainability may be thought an intrinsic value as well. Key value judgments involve system boundaries. Social movement theory tends to treat normative criteria as theoretically arbitrary commitments or goals to which the social movement may (or may not) be committed. Thus, one can be "for" or "against" sustainability to the extent that goals such as fair trade or human rights are covered by it.

Key Research Questions

The literature on sustainability suggests very little attempt to examine or evaluate alternative models and approaches to sustainability on a multi-disciplinary basis. As such, robust debates occur amongst advocates of economics-based resource sufficiency approaches and (primarily) ecologically based functional integrity approaches, but there is very little cross-fertilization or comparison of the two. There may be an assumption that the apparent conceptual contrast to these approaches is resolved when either is quantified. That is, quantification of either resource sufficiency *or* functional integrity will rely on similar if not identical mathematical models. Even if this is true (and one good research question is to find out), the distinct way in which each viewpoint suggests different normative questions suggests that a) mathematical models may be parameterized differently, even when they are in other respects similar; and b) the translation of model results into ordinary language for the purpose of consensus seeking or decision making may be highly sensitive to the framing in broad resource sufficiency vs. functional integrity terms. These possibilities warrant further investigation.

Regarding social movement theory, while I do not question that sustainability can be conceptualized as a social movement, the relationship between doing so and the substantive social goals implied by various ways of operationalizing resource sufficiency or functional integrity approaches is entirely mysterious. In many quarters, "sustainability as social movement" comes very close to an old wine in new bottles phenomenon. There thus is a serious need for underlying logical analysis of *how* sustainability as a social movement is being conceptualized, and what rationale is associated with the particular normative goals to which this social movement is committed.

Beyond that, I think there are serious questions about what might be called the "surveyability" of sustainability. The economic and ecological concepts deployed in both resource sufficiency and functional integrity models are so complex that these professionals have mostly been unable to talk to one another. How can we possibly think that such concepts could become widely accepted by non-specialists as political and social goals? Yet it is clear that much of the public rhetoric about sustainability holds that "being more sustainable" is something that we, as a society, should try to achieve. If we can get clear about what sustainability means in these relatively technical areas, we should undertake research to determine what would be needed in order to more effectively express such goals broadly. Artistic and narrative modes, as well as mythical expressions, should be included as possible communication modalities in this research.

More practically, there are a number of forces at work to develop standards or specifications of sustainability as the term might relate to production or commercial practice. Thus we can expect to see product claims to the effect that a good has been sustainably produced, and there are currently efforts underway by organizations such as ANSI and ISO to develop and market technical standards that would provide a basis for such claims. These standards may be based on technical methods such as life-cycle analysis (fits well with resource sufficiency) or carbon footprint (implies functional integrity), but to the extent that sustainability is conceptualized as a social movement, they are just as likely to include criteria such as “fair trade” or “humanely produced”. Indeed, they may rely on such criteria *instead* of criteria such as those that might follow from life-cycle analysis or carbon footprints. There are thus absolutely huge questions about what these standards should actually say.

Once standards are written, there will presumably be commercial certifiers cropping up who will visit one’s factory, farm or establishment to certify that, indeed, one is sustainable (in the eyes of ANSI or ISO). Then we will have a competition between, say ANSI-sustainable or ISO-sustainable that will make the paper vs. plastic controversy look like child’s play. Huge questions loom. Do we want to settle the issue of what sustainability is the same way we settled the question of HD-DVD vs. Blue-Ray?

An answer to this question presupposes a much better understanding of the power issues involved in sorting out a standards competition, as well as some good empirical analysis of where the power lies in this looming competition. We know that the shape of standards can often be decisive in determining who has access to a given market, what types of products will emerge in markets, and the extent to which consumers (much less citizens as third parties) are able to influence either question.

There are also critical questions to ask about the way that these standards-setting competitions relate to evolving notions of non-state governance. Some questions will be philosophical in the sense that they will raise critical questions about the legitimacy of such processes and their standing with respect to longstanding traditions such as utilitarianism, libertarianism and the like. But frankly we just need a much clearer empirical picture of how these processes work, what economic, social and political principles seem to determine their shape and outcome. With that in hand, it may be possible to then ask what role states might play in shaping these processes.
As these processes relate to the general question of sustainability, my gut feeling is that standardization is premature. There is, thus, a research question implicit: Is Thompson’s gut feeling correct? And how would we even frame or stipulate when a technical standards-setting process for sustainability *is* mature. These are, I realize, rather open questions, but we are moving so rapidly into a world more substantially governed by the non-state actors who control these processes that we need some serious theory building simply to know what kind of questions it is worthwhile to ask.

None of this even begins to get into questions such as how sustainability relates to questions of risk and uncertainty. I think the implication of most sustainability rhetoric is that concern about risk, uncertainty and precaution is in a different ballpark altogether. Sustainability is warm and fuzzy; risk is cold and sharp. But of course, there will be tremendous overlap between the sustainable society and the risk society. Hopefully someone else has raised these questions in their two pages.

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Jameson Wetmore

Assistant Professor, Consortium for Science, Policy & Outcomes and School of Human Evolution and Social Change

Arizona State University

My research broadly examines how values get built into technological systems and how those technological systems in turn impact values. I have explored a number of case studies including automobile safety in the United States, the Amish use of technology, the New Orleans flood hazard mitigation leading up to Katrina, and religious views of technology. Much of this work is summed up in the forthcoming book I co-edited with Deborah Johnson: *Technology & Society: Building Our Sociotechnical Future*.

Key Research Questions

How can we as a society rethink the idea of responsibility in a world of complex and interrelated socio-technical-natural systems?

In much of my work I look at how vast sociotechnical systems are constructed, maintained, fall apart, and get replaced. What I've found is that there has to be something tying all the different nodes together. This is done in a variety of ways, but one of the most powerful ways is a shared understanding of how the responsibilities required for sustaining a system are distributed throughout the system. Sometimes these responsibilities are enforced by concerns about public opinion (i.e. Coca-Cola doesn't put arsenic in it's product for fear of losing all it's customers), sometimes they are enforced by regulations/laws/enforcement (i.e. many of us drive close to the speed limit not because we want to but because we're afraid of getting a ticket, losing insurance, etc.), and sometimes there is no system of oversight or accountability and the system falls apart.

In order to tackle the sustainability issue some dramatic changes are going to be needed. The existing sociotechnical systems as presently constructed will not get us there and will have to be changed. Figuring out how to shift the momentum of these enormous systems will be incredibly difficult. [Incidentally I'm an organizer of a project at the School of Human Evolution & Social Change at ASU entitled "Change is Hard: The Challenge of Path Dependence" which seeks to tackle this precise issue.] Just as difficult will be figuring out how to convince corporations, governments, NGOs, and individuals to change. Because it is easy to avoid having to take responsibility in a large sociotechnical system, many people do. Katrina is a perfect example of numerous people and organizations passing the buck and saying "I don't have to be thorough… someone else will do it." Or "no one will notice if I don't make this perfect." Sustainability goals are not attainable if individual entities can avoid having to play the role they are assigned in a sociotechnical system.

How can scientists and engineers be helped to recognize the social, political, and environmental implications of their work and adjust their behavior/projects/research to further the goals of sustainability?

It is reasonably clear that a great number of social and political changes will be required to grapple with the issues surrounding sustainability. It is also reasonably clear that science and technology hold great promise for contributing to sustainable solutions. These endeavors also hold the potential to make sustainable efforts much more difficult. There are a variety of ways to mobilize science and technology to help ensure that they further the goals of sustainability. One of the most important of these methods will be to get scientists and engineers themselves – the individuals on the front lines of these endeavors – to play a conscious role in furthering sustainability.

To make this possible, scientists and engineers must be able to think beyond their laboratories. The traditional scientific and engineering training at the PhD level in the United States focuses on the lab. They are supposed to produce knowledge and ideas that open up the possibilities for new technologies outside the lab. This existing system is not very efficient. Sustainable solutions will likely require complex sociotechnical systems. To best contribute to these systems, scientists and engineers will need a nuanced view of the world. They must not lose sight of their technical work, but to best contribute to sustainable solutions they need an understanding of the role their work plays in this world, what is more and less useful, and how to fine tune at least some of their research to best meet society's needs. This will require a new system of education, or at least a major patch to the existing system of education. We need leaders of science and engineering that can see the big picture so that we can solve the big problems.

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Gregor Wolbring

Assistant Professor of Community Health Sciences

University of Calgary

Work So Far

Most of my work is somehow related to "science and technology studies (STS) if STS is understood to be about how social, political, and cultural values affect scientific research and technological innovation, and how these in turn affect society, politics, and culture" http://en.wikipedia.org/wiki/Science_and_technology_studies. In regards to sustainability I would describe many of my writings to cover the area of 'social sustainability' even if they do not use the term per se.

1) Impact of Ableism on scientific research and technological innovation

Ableism in its general form is a set of beliefs, processes and practices that produces based on ones abilities a particular kind of understanding of oneself, one's body and one's relationship with others of one's species, other species and one's environment and includes one being judged by others. Ableism exhibits a favouritism for certain abilities that are projected as essential while at the same time labelling real or perceived deviation from or lack of these essential abilities as a diminished state of being leading or contributing to the justification of a variety of other isms. One can identify many different forms of ableism such as biological structure-based ableism (B), cognition-based ableism (C), social structure-based ableism (S) and ableism inherent to a given economic system (E). Science and technology research and development and different forms of ableism have always been and will continue to be inter-related. The desire and expectation for certain abilities has led to science and technology research and development that promise the fulfillment of these desires and expectations. And science and technology research and development led to products that enabled new abilities and new expectations and desires for new forms of abilities and ableism. Emerging forms of science and technology, in particular the converging of nanotechnology, biotechnology, information technology, cognitive sciences and synthetic biology (NBICS), increasingly enable the modification of appearance and functioning of biological structures including the human body and the bodies of other species beyond existing norms and inter and intra species-typical boundaries. This leads to a changed understanding of the self, the body relationships with others of the species, and with other species and the environment, accompanying changes in anticipated, desired and rejected abilities and will enable the transhumanization of ableism. The transhumanized form of ableism (human related) is the set of beliefs, processes and practices that perceive the 'improvement' of human body abilities beyond typical Homo sapiens boundaries as essential. It exhibits the favouritism of beyond Homo sapiens typical abilities and perceived human bodies as limited, defective, in need of constant improvement, as being in a diminished state of being human if they are not enhanced beyond Homo sapiens typical abilities. In its general form it is a set of beliefs, processes and practices that perceive the improvement of biological structures beyond species typical boundaries as essential. It perceives species typical biological structures as deficient as being, in need of constant improvement, as a diminished state of being.

2) Animal Farm Philosophy

Bioethics theories are supposed to develop ethical principles, which allow for the governance of science, technology and biomedical research. I presented evidence in a variety of my writings that a double system of morality/ethics an “animal farm” philosophy appears to dominate the debate around bioethics issues, the development of bioethics theories as they pertain to as ‘impaired labelled people’ and the governance of science, technology and biomedical research . In this philosophy, characteristics labelled as ‘medical problems’ are treated different from characteristics labelled as ‘societal problems. I used in particular the animal farm philosophy evident in the debate over sex selection and so called impairment “deselection”. Every argument used to justify sex selection prohibition could also be used to demand impairment deselection prohibition. Furthermore any arguments used to denounce the demand for the prohibition of impairment deselection can be used just as well to denounce the arguments used to demand the prohibition of sex selection. The only possible way to justify impairment deselection but not sex selection is by arbitrarily defining certain characteristics as impairments and with that as medical problems in need of medical solutions and seeing them in a different moral light based on the medical label whereby sex would be seen as a non medical characteristic and therefore any intervention would be seen as done for social reasons. One would merely have to define something as a medical problem and the acceptable acting would broaden. The argument that ‘It’s a medical problem’ trumps all other arguments. This kind of discourse is of course one driver for the medicalization of the healthy underway today and for the transhumanization of health where every species and sub species typical biological subject is medical ill and that subject only gains health if the subject obtains the newest enhancements/upgrade to the body moving it beyond species typical boundaries.

3) Animal Farm S&T engagement processes

The discourses around biotechnology products, laws, policies, goals, processes and applications are perceived by many as highly flawed. In the same way that the ‘God in white,’ the all-knowing, knowing-best and in-charge role of physicians is increasingly questioned, and in the same way that ‘patients’ demand to be more involved in decisions they perceive is impacting on themselves, so is the ‘God in white’ behaviour of the industry, academics and policy-makers, as the ones who know what is best for the public with regard to the development of science and technology and its governance, questioned. The ‘patients’ in this case, many different social groups, demand to be more involved, consulted and listened to by the ‘God in white’, which in this case is academia, industry and policy-makers. The nanotechnology discourse is seen as being able to avoid the ‘God in white’ and other problem attached to the biotech discourse. However, in order to do so, the nanotechnology engagement has to fulfill a few prerequisites. It has to involve all the relevant stakeholders, which entails that one has to have a matrix, a tool which allows one to identify *all* the relevant stakeholders for any given topic and geographical and cultural setting, the willingness to involve them and the financial means to be able to involve them. It furthermore requires that the stakeholders are knowledgeable in how their knowledge intersects impacts and is impacted by any given investigated nanotechnology, and in the end, by any science and technology. It requires that the instigators of the stakeholder meeting know how their prime issue up for investigation is impacted by other issues. So far, nanoengagements show a lack of diversity of stakeholders and many nanoengagements are too narrowly focused. Indeed, most of these engagements would have a hard time to cover social justice, social safety and social risk due to the limited diversity in the background of people involved and the lack of presence of marginalised groups. One has to draw the conclusion that the nanoengagements (public, academic, or government wise) of today is not much different from the bio-engagement of the past. Much more work has to be done to develop frameworks, tools and practices to identify and eliminate exclusionary biased practices within the engagement. As the discourse stands at the moment, it seems to be rather useless for marginalised populations. It's an animal farm S&T engagement process again with some groups issues seen as more important.

Future Research Streams/questions

1) Disabled People, the law, S&T and social sustainability

Often science and technology is seen as the salvation to sustainable development and the solving of problems of low income countries. However so far no strategy exist from the proponents of such approach as to how these approaches really help disabled people and indeed do not make it worse. Indeed within these approaches it's often about prevention of impairments not social integration of the as impaired labelled people:

Disability Prevention: Disability can be integrated in Health, Population and Nutrition sector (diseases and conditions that cause or exacerbate disability such as polio, measles, micronutrient deficiencies, malnutrition, etc.); Water and Sanitation sector(prevention of fecal or water borne diseases, etc.); Environment and Social Sustainability Network (air and water quality, agricultural and industrial pollution, usability and sustainability of the built environment, etc.); and Social Protection and Labor sector (worker safety, child labor, etc.)(1).

Wording of the Convention on the rights of persons with disabilities (CRDP) such as "*Emphasizing* the importance of mainstreaming disability issues as an integral part of relevant strategies of sustainable development" (Preamble g)(2) "*Considering* that persons with disabilities should have the opportunity to be actively involved in decision-making processes about policies and programmes, including those directly concerning them," (Preamble o)(2) "*Highlighting* the fact that the majority of persons with disabilities live in conditions of poverty, and in this regard recognizing the critical need to address the negative impact of poverty on persons with disabilities," (Preamble t)(2) clearly outline certain demands from the science and technology as solution crowd, and the sustainable development crowd, demands which are not met as of yet. The below Worldbank Disability and the Millennium Development Goals excerpt demands much more action under the language of the CRPD.

Ensure Environmental Sustainability: Environmental dangers can lead to the onset of many types of disabilities, and inaccessible environments prevent disabled people from taking part in economic and social activities.(3)

2) Ableism and sustainability

Beside the ableism and social sustainability issue attached to the body enhancement debate in general there is a linkage of ableism to the environment and environmental sustainability discourse. The disregard for nature reflects another form of ableism (4,5): humans are here to use nature as they see fit, as they are superior to nature because of their abilities. Humans would treat nature with more respect if they understood the ensuing negative consequences for themselves. We might treat nature better when we can't treat it badly anymore, due to the ensuing negative consequences for humans. The second report by the Intergovernmental Panel on Climate Change released on April 6 predicts the 'highway to extinction' however it's still up in the air whether move will be fast enough. Furthermore we might see another movement to develop soon. We might see a climate change-driven appeal for a transhumanized version of ableism, where transhumanization of humans is seen as a solution for coping with climate change. This could become especially popular if we reach a point of no return', where severe climate change consequences can no longer be prevented (4).

3) Consumerism and Sustainability

Consumerism is based on the desire to have the ability to consume. This form of ableism has an influence on many other isms. It also changes our perception of needs – the notion of human wellbeing and fulfilment of potential is replaced by the right to experience instant gratification (4,5). Consumerism is one of the forces to move the body beyond species typical boundaries (4,5). Consumerism is also one reason for the energy crisis not just the 'dependency on oil'. There is some interesting work out by "Thomas Princen's *The Logic of Sufficiency* that provides an in-depth analysis of why global production, distribution, and consumption systems are resistant to sustainable development plans and continue exacerbating the ecological situation. Princen's main argument is that to adequately deal with growing environmental problems, we need to move from an economy built around the principles of profit maximization and efficiency to that of sufficiency". http://ejournal.nbii.org/archives/vol3iss1/book.princen.html

4) Sustainability Health and Climate Change

The below is a conference announcement that highlights some research questions one could address under especially social sustainability:

"Welcome to the official e-Forum for Bamako 2008
The e-Forum discussion on HR4D-net looks forward to your views and comments on the main objectives and key themes of the 2008 Global Ministerial Forum on Research for Health, which will be held from 17-19 November in Bamako, Mali. The conference will address key issues in intersectoral research for
health, including :

- How can research for health help people in both developing and developed countries to adapt to climate change? What are the key research areas which need to be expanded in order to address the various challenges to health and health security posed by climate change?
- How can interdisciplinary research be stimulated to tackle other

- intersectoral challenges such as issues of food security and nutrition? or the growing burden of chronic non-communicable diseases in developing countries?
- How can research and innovation systems be best organised for health and health equity in developing countries?
- What mechanisms are needed to make the funding of research more accountable to countries' real needs?
- How can civil society organisations become more involved both in the process of research, and the broader question of which research issues are prioritised and addressed, given limited resources?

Please visit the conference website (at http://www.bamako2008.org/)."

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I do not really feel I can give key bibliographies but these links might be useful.

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2) DISABILITY AND DEVELOPMENT IN KOSOVO: THE CASE FOR COMMUNITY BASED REHABILITATION
Majid Turmusani*http://www.aifo.it/english/resources/online/apdrj/apdrj102/kosovo.pdf (one example related to disabled people)

3) Thomas Princen's *The Logic of Sufficiency*
http://www.amazon.com/Logic-Sufficiency-Thomas Princen/dp/0262162326
http://ejournal.nbii.org/archives/vol3iss1/book.princen.html

4) Valuing the Earth: Economics, Ecology, Ethics By Herman E. Daly, Kenneth N. Townsend
Contributor Herman E. Daly, Kenneth N. Townsend Published by MIT Press, 1993
ISBN 0262540681, 9780262540681 387 pages
http://books.google.ca/books?id=h1JUarFE1bYC&dq=Valuing+the+Earth&pg=PP1&ots=8_QRYeebVG&sig=wZ7aIAOEZ5XGgF5hAzYay8XJFhw&hl=en&sa=X&oi=book_result&resnum=1&ct=result#PPP1,M1

5) Social Sustainability The "soft infrastructure" of a Healthy Community Trevor Ha**ncock**
http://newcity.ca/Pages/social_sustainability.html

6) Some links
- http://www.sustainablemeasures.com/
- http://www.rprogress.org/sustainability_indicators/about_sustainability_indicators.htm#top

- Hawke Research Institute for Sustainable Societies University of South Australia
  http://www.unisa.edu.au/hawkeinstitute/
  Sustainability links http://www.unisa.edu.au/hawkeinstitute/research/ecosocial/eco-links.asp
  1. International sites
  2. Australian sites
  3. Selected definitions of social sustainability
  4. Text bibliography