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EDITORIAL

Maurie J. Cohen
Editor

Sustainability social science at the applied science and engineering universities

The applied science and engineering universities have long occupied an enigmatic niche in the spectrum of higher education. Many of these institutions trace their lineage to the mechanics’ institutes that played a formative role in the Industrial Revolution. From early on, supercilious Victorian elites derided technical instruction as inappropria te for hallowed academic halls and incompatible with classical education. As a result, the established universities spurned technical training and proponents of these insurgent pedagogies, often with the support of local manufacturing interests, created their own institutions.1

By the latter decades of the nineteenth century, most major industrial centers had a technical institute. In the United States, these institutions experienced heady growth during, and especially after, World War II.2 Administrators seeking resources with which to realize newfound ambitions while serving national political objectives encouraged close collaboration with the rapidly expanding military-industrial complex. During the 1960s, the applied science and engineering universities became frequent targets of social critics who denounced them as handmaidens of militarization. The following decades, though, brought forth the end of the Cold War, the dawn of the Internet age, the advent of increasingly ubiquitous computing, and, most recently, the onset of a challenging economy. These circumstances have given the applied science and engineering universities new—and in some cases spectacular—appeal.

In short, the so-called STEM (science, technology, engineering, and math) disciplines have become cool, or at least a source of personal competitive advantage. There is a palpable sense among students—and I see it every day at the New Jersey Institute of Technology—that a diploma that discretely communicates that a job candidate has passed multiple courses in calculus, as well as physics and organic chemistry, offers a valuable leg up, even in fields that do not require such skills. Combine these circumstances with public awareness of the extent to which crony capitalism—and outright criminality—bedevils the once-lauded financial sectors and it becomes apparent why even a beneficiary of Wall Street largesse like New York City mayor Michael Bloomberg has championed establishment of a new applied science and engineering university, Cornell NYC Tech.

It is difficult to get a firm grip on the number of these institutions in the United States—or for that matter the world—as most compilations (e.g., US News and World Report and Shanghai Jiao Tong University’s Academic Ranking of World Universities) comingle them with colleges and schools of engineering that are constituent parts of comprehensive universities. A list that I did obtain counts approximately 30 applied science and engineering universities in the United States; internationally the number is probably in the vicinity of 100.3

1 I summarize some of this history in Cohen (1999).
2 Because of the distressed financial condition of the country after World War II, most former British polytechnics could not effectively position themselves for military research and either evolved into more comprehensive universities or merged with existing institutions of higher education. Even the venerable University of Manchester Institute of Science and Technology (UMIST)—founded in 1824 and formerly known at different times as the Manchester Mechanics’ Institute, the Manchester Municipal School of Technology, and the Manchester College of Science and Technology—was absorbed in 2004 by the Victoria University of Manchester (more commonly known as the University of Manchester).
3 See http://www.payscale.com/college-salary-report-2013/engineering-schools. What I describe here does not pertain to all applied science and engineering universities, in part because all of them do not have social science researchers actively engaged in publishing for an international audience. The list of relevant institutions in the United States comprises (in alphabetical order) California Institute of Technology, Carnegie Mellon University, Case Western Reserve University, Clarkson University, Colorado School of Mines, Cooper Union for the Advancement of Science and Art, Florida Institute of Technology, Georgia Institute of Technology, Harvey Mudd College, Illinois Institute of Technology, Kettering University, Lawrence Technological University, Massachusetts Institute of Technology, Massachusetts Maritime Academy, Michigan Technological University, Milwaukee School of Engineering,
Given the outsized role that these institutions have played as crucibles of industrialization over nearly two centuries, it is ironic that they have today become notable havens for sustainability social science.

The incipient field integrates across ecological economics, science and technology studies, environmental sociology, environmental political economy, and innovation and foresight studies and applies these perspectives against a background understanding of earth system science—in particular the notion of planetary limits—and the need for a more globally equitable distribution of resources. Research focuses on the design of sustainable systems of production and consumption, the formulation of transition strategies for complex sociotechnical systems, the scaling up of grassroots social innovations, and the fostering of solidaristic and sustainable local living economies. Seminal contributions to this emergent field include Daly (1997), Raskin et al. (2002), Speth (2008), Boyle & Simms (2009), and Jackson (2010). Sustainability social scientists are increasingly questioning the warrant of continuous economic growth and are seeking to chart alternative models of societal organization predicated on sufficiency (as opposed to merely materials and energy efficiency) and high regard for individual and collective well-being.

While scholars working on these issues are not predominantly based in the applied science and engineering universities (this would be unlikely given the relatively small number of these institutions), their extensive presence is striking and raises questions about why this might be the case.

One possible explanation begins with the observation that the social sciences occupy a peripheral orbit at the applied science and engineering universities and this combination of tolerance and benign neglect creates a hospitable home for interdisciplinary social science scholarship. Unlike “normal” institutions of higher education, these institutions do not typically maintain a full array of social-science specializations and do not imbue discipline-bound social scientific knowledge with especially privileged status. Recruitment, promotion, and other personnel decisions are guided by institutional requirements that the social sciences complement a rigorous technical education and shed light on issues at the interface between technoscience and society. Disciplinary social scientists are apt to regard such circumstances as an affront because their brand of knowledge is not, as in the small worlds of, say, sociology or political science, regarded as having exceptional value. However, interdisciplinary social scientists are likely to find relaxation of disciplinary constraints quite refreshing and to take advantage of the intellectual freedom provided to pursue integrative, systemic, and, above all, problem-focused research.

So which applied science and engineering universities are particularly favorable contexts for sustainability social science? In the United States, the most prominent examples are the Massachusetts Institute of Technology and Rensselaer Polytechnic Institute. In Europe, there are thriving groups of sustainability social scientists in the Netherlands (TU Delft and Eindhoven University of Technology), Switzerland (Swiss Federal Institute of Technology Zurich and Swiss Federal Institute of Aquatic Science and Technology-Dübendorf), and Austria (Inter-University Research Centre for Technology, Work and Culture and the Institute of Technology Assessment of the Austrian Academy of Sciences). In addition, the Norwegian University of Science and Technology, the University of Surrey (UK), Aalborg University (Denmark), and KTH–Royal Institute of Technology (Sweden) support prominent programs.

The exercise that I have engaged in here is admittedly fuzzy and disposed to errors of both omission and commission and I readily acknowledge that I have probably missed a few relevant institutions.

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6 It is also probably fair to say, as a general characterization, that social scientists at the applied science and engineering universities are more circumspect than their engineering colleagues about the efficacy of technological interventions (particularly with respect to the management of biophysical systems) and this division further subordinates the status of the social sciences at these institutions.

7 Institutions specializing in agricultural education and research have afforded similar opportunities for sustainability social science. Although the general pattern over the past century has been for former agricultural institutes to become constituent entities of more comprehensive universities, where some autonomy has been afforded, sustainability social science has flourished. The most notable example of this phenomenon is Wageningen University in the Netherlands which has been for the past two decades an important center of innovation in sustainability social science.
For these blunders, I apologize while also encouraging wider engagement in this conversation. The intent is to initiate a process of more expansive inclusion as the incipient field of sustainability social science takes steps toward further institutionalization.

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ARTICLE

The global sustainability transition: it is more than changing light bulbs

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Current policies and norms to reconcile human demands for resources with the Earth’s ability to supply them have resulted in practices that mainly treat the symptoms of unsustainability rather than their underlying causes. Moreover, the increase in our knowledge about humankind’s role in ecosystems is not keeping pace with our understanding of the consequences of our actions, resulting in a deepening inability to address sustainability issues. The extreme complexity and intricate workings of the world require the expansion of our mental models in a systems-thinking framework if we are to realize a sustainable place for humans in it. The challenge of the emerging transdiscipline of sustainability science lies in developing specific tools and processes, including curriculum development and a new generation of systems models, to help us better understand complexity—uncertainty and surprise, scale, hierarchy, and feedback loops—and to educate a new generation of sustainability scientists to design better policies, to facilitate social learning, and to catalyze the technical, economic, social, political, and personal changes needed to create a sustainable world.

KEYWORDS: sustainable development, rights of future generations, interdisciplinary research, technology, education, public policy

Introduction

Un-sustainability is an inevitable emergent property of the systemic interaction between contemporary global society and the ecosphere.

William Rees (2012)

Humankind has become a dominant force of nature, shaping the global landscape, exerting unprecedented pressures on the planet’s resources, and pushing the Earth’s biophysical system far outside of its historic operating range (Steffen et al. 2005). It is not just the patterns and functions of many ecosystems that have changed during the Anthropocene era (Crutzen, 2006), it is that they are also increasingly framed within the context of climate change, habitat degradation, globalization of species distribution, and loss of biodiversity, all caused by the evolving suite of intense human activities. Peterson-Meyers & Reichert (1997) ask, “[H]ow much of the Earth’s ecological integrity can we disrupt before we pass a threshold in the loss of life support services?” In fact, “threshold behavior” may already be a pervasive characteristic of key global social-ecological systems, including trade (e.g., market “bubbles”), finance (stock-market collapses), food (famine), and resource extraction (supply-demand cycles) (Westley et al. 2011).

Defying our best intentions, the future consequences of these changes will likely be to dehumanize and stratify society and to create catastrophic instabilities, but unfortunately, not to effect a transition toward qualitatively desirable sustainability. Although important, the “sustainable practices” that society increasingly engages in are insufficient to create sustainable systems because, as Sterman (2012) notes,

[M]ost efforts by firms, individuals, and governments in the name of sustainability are directed at symptoms of unsustainability rather than causes…policies to reduce waste, cut energy and material use, reduce greenhouse gas emissions, promote green products and local consumption…fail to address the underlying source of the unsustainable world we have created…[a] focus on symptoms and low-leverage policies reflects a widespread failure of systems thinking.

In other words, we seem to be moving along a path where innovation is primarily leading to optimi-
zation of the status quo rather than to system innovation. As van der Leeuw (2010) comments, there are warning signs that technological innovation, “far from serving human needs, is driving development in directions potentially opposed to sustainability.” Clearly, the transition to sustainability will require more than changing light bulbs!

The issues of sustainability are, therefore, broad, interrelated, and all-encompassing. This situation is problematic because opinions about how to transition to a sustainable world are about as diverse as their proponents! We adopt here a systemic approach to building capacity for the necessary transition by: 1) providing a general overview summarizing six major challenges; 2) addressing these challenges within the context of the nascent field of sustainability science; and 3) providing suggestions for key areas of attention. We do not claim that these are the only ways forward, but rather that they are essential, fertile components in bringing an obvious set of conclusions within the sustainability community to the general population and to various governance institutions and functions.

Knowing the Challenges

Challenge 1: Naiveté and the Bretton Woods Conference

World leaders assembled in Bretton Woods, New Hampshire in the waning days of World War II to plan the aftermath of the most devastating conflict in human history. In his concluding remarks at the conference, Henry Morgenthau, then Secretary of the Treasury of the United States, commented that the goal was to rebuild Europe and Asia by recreating:

A dynamic world economy in which the peoples of every nation will be able to realize their potentialities in peace…and enjoy increasingly the fruits of material progress on an earth infinitely blessed with natural riches [emphasis added] (quoted in Daly & Farley, 2004).

During the intervening years, the world’s population has roughly tripled, per-capita resource throughput has increased more than nine-fold, and billions of people have been unable to overcome poverty. Morgenthau’s first goal, realizing our human potential, was directly linked to economic prosperity perceived as having no fixed limits. The coupling of human potential (above a minimum need) with economic development was an acceptable premise in the 1940s, and today remains the dominant development paradigm. We treat the world’s material resources and ecological systems as infinitely regenerative. However, as William Rees (2012) notes, “the growth-oriented values and assumptions underpinning contemporary economic models and consequent ‘environmental’ behavior are fundamentally at odds with the biophysical laws and dynamics governing vital ecosystem and geophysical processes.” It is difficult to envision any politically acceptable reform of the prevailing paradigm that would produce a sustainable relationship between the modern human enterprise and “nature” if we are to have shared governance. Rees and many others have also suggested that the global human enterprise is currently in a state of overshoot. Our aggregate energy and material consumption and waste production have begun to exceed the ecosphere’s regenerative and -assimilative capacities. Thus, the magnanimity of Morgenthau’s goal for humanity is compromised by the naiveté of the linked economic paradigm.

Moreover, decision makers throughout society increasingly recognize that the policies we implement have not only failed to solve our persistent sustainability problems but are, in fact, causing them (Sterman, 2012). Well-intentioned programs, for example, may create unanticipated “side effects.” The pesticide DDT and polychlorinated biphenyls (PCBs), for instance, have wondrous industrial properties that dramatically improved human health, safety, and quality of life in the short term, but the result has been “policy resistance,” the tendency for interventions to be defeated by the system’s response to the intervention itself (Sterman, 2012). The challenge, therefore, is to embrace a new narrative about human well-being without the slavish attachment to illusory economic compromises.

Challenge 2: Earth Demands in the Anthropocene

How do we reconcile human use of the Earth’s natural resources with the planet’s ability to provide them at sustainable levels? The challenge is to learn how to make the transition from the threatening set of present circumstances to a sustainable Earth system that encourages, not just allows, realization of Morgenthau’s human potential. One way is to examine the assumptions and outcomes of our own decisions. Even though human society cannot be manipulated as if in a laboratory experiment, the interactions between humans and their environment are, as many have suggested, suitable subjects of rigorous scientific analysis and advancement to improve our understanding of the threats to, and opportunities for, sustainable development (NRC, 2002). Tradeoffs, sacrifices, and compromises will be needed to make use of this improved understanding, and so learning about the consequences of how we manage the global commons is essential. Successful conflict manage-
ment and consensus building is also important. Both require innovative approaches and the rediscovery of proven ones. A successful transition to sustainability will involve critical advances both in new knowledge and in humankind’s social and technological capacity to turn that knowledge into action (NRC, 2002). This is the essence of the emerging field of sustainability science (Kates et al. 2001; Clark & Dickson, 2003), and is the core fabric of the modern institution that seeks the knowledge, experiential base, and wisdom necessary to maintain human-environment interactions on sustainable trajectories.

The sustainability transition must, therefore, consider the dynamics of evolution and the complex interplay of social, economic, and natural systems. The required integration of disciplines goes beyond individual areas of study—population, economy, water, food, energy, and climate—to identify the common threads and drivers of systemic change.

**Challenge 3: Economies and Energy Use**

An example of these integrative biophysical-social dynamics is the dependence of the world’s economy on energy and other resources to manufacture goods, to provide services, and to create capital. The direct relationship between energy use and Gross Domestic Product (GDP) reveals the central role of energy in the economies of nations and underscores the limits imposed on any global economic growth model.

Several emergent properties of the relationship are shown in Figure 1. First, the ecological footprint of humans on Earth, or the aggregate influence of per capita resource consumption and waste production, increases with energy use and GDP. It has not been possible to increase socially desirable goods and services without raising the use of resources or increasing environmental degradation, i.e., climate change, habitat loss, pollution, and reduced biodiversity. Second, to support the projected global population of 9.5 billion by mid-century with a standard of living approaching that of the United States would require about 268 terawatts (1 terawatt = 10^{15} watts) of energy, or about sixteen times current global energy use (Brown et al. 2011). Third, of the eleven recessions in the United States since World War II, ten, including the most recent, were preceded by a spike in oil prices (Murray & King, 2012). Finally, although some economists have dismissed warnings that energy shortages might ultimately limit economic growth because of the belief that technological innovations will always meet demand, there is little or no scientific support for the latter proposition (Brown et al. 2011).

Ominously, there is evidence of threshold changes appearing. Since 2005, for example, the oil market has tipped into a new “system state” that is similar to a phase transition in physics: oil production is now “inelastic” and unable to respond to rising demand (Murray & King, 2012). Among the challenges we have to recognize and address are the subtleties and compromises of our relationships with nonrenewable energy, to optimize what we use, and to prepare for pending scarcities.

**Challenge 4: Urbanization**

The climate crisis won’t be solved by changing light bulbs and inflating your tires more, planting a tree and driving a little less. It’s going to require a truly fundamental shift in how we build our cities and live in them.

Richard Register (2009)

A second example of these complexities is a worldwide process of urbanization that increasingly defines the human ecological niche and its planetary “footprint” (Rees, 1992). Cities comprise the major habitat of the dominant species on the planet and make unmatched biophysical demands on the ecosphere. The future organization and functions of cities will demonstrate how well we are creating sustainable systems. Urbanization is the greatest mass migration of people in history, and its pace is accelerating. The United Nations projects that the world’s cities will add 2.9 billion people over the next 40 years, which is more than had accumulated on Earth in the entire history of H. sapiens up until 1957, and...
more than the anticipated increase in total human numbers of 2.3 billion (Rees, 2012). Like the ecosphere, cities are self-organizing dissipative structures existing far from thermodynamic equilibrium. They are open, growing, dependent subsystems of the materially closed, non-growing finite ecosphere. Yet, while the ecosphere evolves and maintains itself by “feeding” on an extraterrestrial source of energy and by continuously recycling matter, cities grow and maintain themselves by “feeding” on the rest of the ecosphere and ejecting their wastes back into it (Rees, 1992; 2012). Cities are heterotrophic nodes of intense energy/material consumption and waste generation that are entirely dependent on the productive and assimilative capacities of complementary producer ecosystems often located at great distances from the cities themselves. They are urban parasites of the rural landscapes. In other words, cities can grow and increase their internal order only by “disordering” the ecosphere and increasing global entropy (disorder) elsewhere.

Importantly, this process of urbanization creates a dramatic shift in city-dwellers’ spatial/psychological relationships to the land, but there is no corresponding change in eco-functional relationships. Despite this psychological shift, decoupling people from nature, in a material sense, urbanization generally increases human per capita “load” on the cities’ surrounding ecosystems. Failure to understand the basic facts of urban human ecology may doom our quest for sustainability and increase the vulnerability of cities to global ecological change. Understanding the ecology and management of cities and their dependent relationships with the countryside is a fundamental challenge of sustainability science.

**Challenge 5: Controlling Nature**

*Humans have a duty to restructure nature for their survival.*

Freeman Dyson (quoted in Dawdoff, 2009)

This anthropocentrism expresses humankind’s faith in its technology and knowledge to manage nature, with the supposition that “survival” is sufficient. We are a product of evolution and have been “trained” to do whatever it takes to survive, which is perhaps the “duty” that Dyson refers to. The polar opposite to this knowledge-based worldview is an ignorance-based one that holds we know very little about many things, and not much about most (e.g., Vitek & Jackson, 2008; Turner, 2009). The problem is not whether natural systems are going to change because of human influences—but how this happens and to what end. There was more than just survival in mind when Morgenthau spoke of the human “potentials in peace.” Because fluctuations in nature impose problems in meeting production goals, the strategies for controlling environmental variability and natural disturbance become essential for managing nature. Unfortunately, such practices create a model in which humans attempt to dominate nature in the sense that nature is to be conquered, controlled, and ruled (sensu Holling & Meffe, 1996; Folke et al. 1998).

This “command and control” approach to environmental management is still today’s *modus operandi* and has not been effective in keeping global growth tracking along sustainable trajectories. In fact, a case can be made that reducing uncertainties in natural systems themselves damages the values that we aim to preserve. The “paradox of the dual mandate” remains at the very heart of the matter (Roe & van Eeten, 2001): whereas complexity, interdependence, high levels of uncertainty, unpredictability, and dynamism characterize natural systems—traits that prevent competitive dominance by any one species—human-dominated systems seek predictability and stability to ensure uninterrupted provision of resources for human use. The need for resolution of the paradox arises from society’s desire to preserve, restore, and rehabilitate natural ecosystems that are defined by disorder in key factors (see below), *while at the same time* ensuring the provision of reliable, predictable, and stable supplies of goods and services (Roe & van Eeten, 2001; Weinstein et al. 2007). The acceptance and/or resolution of this paradox is at the forefront of the sustainability transition.

**Challenge 6: Ecosystem Resilience**

Sustainability implies maintaining the capacity of ecosystems to support social and economic systems over the long term. This capacity for ecosystem resilience is an underlying feature of sustainable systems (Gunderson & Holling, 2002) that cannot be predicted or understood simply by understanding its parts. As Berkes et al. (2003) note, it has three defining features: 1) the change that a system can experience, but still retain the previous controls on structure and function and degree of attraction within a sustainable trajectory; 2) the capability of the system for self-organization; and, 3) the ability to optimize capacity for learning and adapting. Resilience is a promising concept because it provides a framework for maintaining stability in the face of change, and as Berkes et al. (2003) comment, “[I]t’s synonymous with ecological, economic and social stability.” But it is also important to note that ecosystem resilience is not defined as a return to equilibrium; rather as a consequence of complexity, multiple states, or domains of attraction and multiple equilibria coexist *simultaneously* in ecosystems. Understanding and promoting ecosystem resilience is another key chal-
lenge of the sustainability transition.

These six challenges (C1–C6) together constitute a substitute narrative for the present paradigm. The new paradigm effectively confines a worthwhile goal of developing human potentials with a shallow economic framework (C1) functioning within present (and frequently unknown) complexities (C2) that involve precarious dependencies on energy (C3) that in turn drive massive urbanization at the planetary scale (C4). Working our way toward a high-quality sustainable system requires the acceptance of uncertainties of the natural system, even as predictability in the social goals is sought (C5), along with formal appreciation in the governance structure and function of ecosystem resilience as a precondition for societal well-being (C6).

**Meeting the Challenge(s): Systems Thinking**

*Because of the complex relationships among people, ecosystems, and the biosphere, human health and well-being are closely linked to the integrity of local, regional and global ecosystems.*

National Science Foundation (2002)

The challenges described herein are significant and deeply-rooted, so that any worthwhile sustainability transition will require a comprehensive understanding of the complexity and interactions within coupled human-environment systems (CH-ESs), and an ability to forecast the consequences of our actions. Knowing the challenges is one thing, but addressing them makes it necessary to develop the specific tools and processes that will help us design better policies, facilitate social learning, and catalyze the technical, economic, social, political, and personal changes needed to create a desirable and sustainable society.

It is a challenge to synthesize new knowledge emanating from sustainability science in policy-relevant ways (Carpenter et al. 2009), because this requires problem solvers at all levels to harness science and technology from anywhere in the world (Steffen et al. 2005). Synthesizing new knowledge also addresses the widely recognized problem of the application of scientific results for decision support and decision making. The decision process itself needs analysis (Anderties et al. 2010) and it is absolutely essential to understand what kinds of institutions can best perform these complex bridging roles, i.e., act as *boundary organizations* between science and policy across multiple scales and across the social and natural science disciplines and do this under a wide range of social circumstances (Steffen et al. 2005).

Partnerships are needed to facilitate the engagement of scientific, technological, and political and social sectors to support environmentally sustainable human development globally and to build a truly international community for sustainable development. It is important to engage nontechnical with technical fields and lay and professional communities in ways that allow all to participate meaningfully and at different scales and dimensions. Doing this is a task of sustainability science, a new field of formal inquiry with immediate relevance. It is worthwhile, we think, to look at its origins to understand its potential for further development.

**The Emergence of Sustainability Science and Systems Thinking**

*Today’s challenges are the result of systems that we have created...it is the unanticipated side-effects of our own actions, side-effects created by our inability to understand and act in consonance with our long-term goals and aspirations...* [To address this issue] system dynamics will help us expand the boundaries of our mental models...help people see themselves as part of a larger system, so that we become aware of and take responsibility for the feedbacks created by our decisions...that shape the world in ways large and small, desired and undesired.

John Sterman (2002)

Two insightful and influential reports from workshops held at Fribergh (Sweden) and at the Air- lie Center, Warrenton, Virginia (United States), in 2000 and 2009, respectively, summarized the global sustainability challenges and led to a formal definition of sustainability science (Kates et al. 2001; Levin & Clark, 2010). The discussion at Fribergh revealed profound differences in perspectives among scientists in developed countries versus those in developing countries (Kates, 2012). Scientists in the former focused primarily on global issues, whereas their colleagues in the latter addressed principally local matters. The two groups were separated by a variety of economic, technological, and capacity divides. Northern scientists worried about the effects of affluence and consumption as well as climate change and its causes, and undertook theory-driven research. Southern scientists, in contrast, worried about the effects of poverty and underconsumption and the impacts of climate change, and pursued action-driven investigations. Such differences notwithstanding, the workshop also reflected broad agreement that science and technology have an enormous potential to facilitate a sustainability transition. As Kates (2012) notes, realizing that potential will require serious efforts to promote a science for sustainability.

At the more recent event in Virginia (Levin & Clark, 2010), six sets of thematic research were iden-
System Theory and Complex Adaptive Systems

Systems theory is concerned with both wholes and wholeness. It emphasizes connectedness, context, and feedback as underlying components and processes. The understanding arising from systems theory comes from integrating knowledge of how parts of the system work together, rather than how they work in isolation. Of particular interest to sustainability scientists is the observation that complex adaptive systems (CAS) also have emergent properties and phase transitions not normally observed in simpler systems: nonlinearity, uncertainty, multiscale interactions, emergence, hierarchy, and self-organization (Levin, 1998; Anderies et al. 2010; Solé, 2011). CAS structure is often hierarchical or nested. Phenomena at each level tend to have their own emergent properties that are coupled by feedback loops and allow the system to be self-organizing and buffered against external forcing. Most importantly, because of the multiplicity of scales, there is no one “correct” perspective on a complex system. CASs are comprised of agents that interact locally based on information they use to adaptively respond to their environment. Behaviors typically emerge from such interaction that are not imposed or predetermined (Levin, 1998; 2010). Unlike their linear counterparts, numerous potential equilibria may co-occur as multiple stable states or stability domains in CASs (Holling, 2001).

The concept of CASs may be extended further to address the interrelationships between humankind and nature in CH-ESs (Gunderson & Holling, 2002; Berkes et al. 2003; Anderies et al. 2010). CH-ESs can also organize around one of several equilibrium states (or “attractors”). When conditions change, feedback loops act to maintain the current state, but at a certain threshold the system may move to a new stable state. Like any CAS, CH-ESs are often unpredictable. An important observation of the behaviors in CH-ESs is that they cannot be understood, let alone managed, because of the multiplicity of scales, there is no one buffer against external forcing. Most importantly, because of the multiplicity of scales, there is no one “correct” perspective on a complex system. CASs are comprised of agents that interact locally based on information they use to adaptively respond to their environment. Behaviors typically emerge from such interaction that are not imposed or predetermined (Levin, 1998; 2010). Unlike their linear counterparts, numerous potential equilibria may co-occur as multiple stable states or stability domains in CASs (Holling, 2001).

Where Do We Go From Here?

If the “naïve” narrative is abandoned by governance institutions and decision makers, as it should be, then a stronger, more appealing sustainability narrative must take its place. A potent vision is needed, therefore, to maintain the compass heading, and there is nothing quite like an “unfair” system to undermine cooperation and a sense of community (Turner, 2012). For instance, Wilkinson & Pickett (2009a; 2009b) have shown in myriad of ways how economic stratification is correlated with social dysfunction, e.g., teenage pregnancies, imprisonment, health problems, educational disparities, and other social problems including mental illness, incarceration, obe-
Wilkinson & Pickett (2009a; 2009b) discuss numerous direct relationships between the scale of income disparity and negative social attributes. Source: http://www.slideshare.net/equalitytrust/the-spirit-level-slides-from-the-equality-trust.

Figure 2 Wilkinson & Pickett (2009a; 2009b) discuss numerous direct relationships between the scale of income disparity and negative social attributes. Source: http://www.slideshare.net/equalitytrust/the-spirit-level-slides-from-the-equality-trust.

At some threshold, or series of thresholds, we lose the time and resources to make wise choices. There is no learning without feedback or without knowledge of the results of our actions. Traditionally, scientists generate that feedback through controlled experimentation, an iterative process through which intuitions are challenged, hypotheses tested, insights generated, and new experiments run. However, reductionist methods and experiments are impossible to deploy in many of the most important complex systems, including several critical for sustainability. When actual experimentation is impossible, scientists rely on models and simulations that enable controlled investigations in virtual worlds (Steffen et al. 2005; Andersson et al. 2010). Our inability to accurately predict the weather or economic trends without improved models are just two examples.

Simulation models have long been central in sustainability and environmental research; however, simulations are not only useful in knowledge creation, but must also become a main tool in knowledge communication. They are already powerful tools to support management approaches. Integrated earth-system models, for example, allow many scenarios of interacting natural and human-driven changes to be developed and evaluated. In addition, the models and scenario development that follow from them must evolve further through integrated transdisciplinary research and in continuing dialogues between the scientific community and policy makers at a variety of levels (NRC, 2002; Steffen et al. 2005; Kates, 2012). More use-inspired research is needed, however, to support sustainable development at the global scale (Levin & Clark, 2010; Kates, 2012).

There is much more, of course. Carpenter et al. (2009) summarize studies including the Millennium Ecosystem Assessment’s attempts to synthesize scientific knowledge about the capacity of global ecosystems to support human well-being.1 The authors call for a new generation of integrated quantitative models across a range of coupled social-ecological systems that would be essential for research, synthesis, and projections of the consequences of management actions. Topics would include addressing non-linear changes and improving the assessment and

1 See http://www.maweb.org.
communication of uncertainty. Moreover, these new models would have the capacity to consider spatial boundaries of systems, units of analysis, time horizons, inputs and drivers, scale, as well as key components of the system and their relationships and outputs (Carpenter et al. 2009). Finally, the authors conclude that a great deal of work is still needed to make these models an operational part of the sustainability scientist’s “toolkit” that might also include scenario methods coupled with the evolving models.

To move beyond slogans about interconnectedness and systems, however, we also need specific tools and methods to develop our systems thinking capabilities, methods that avoid both self-defeating pessimism and mindless optimism, while simultaneously embracing the values of the scientific method and ecological realities (Chapin et al. 2010; Graedel, 2010). Interactive, transparent simulations for learning, grounded in the best available science, now exist for a wide range of sustainability issues. To enable learning, Steffen et al. (2005) comment,

[T]hese management flight simulators must give people control over assumptions and scenarios, encourage wide-ranging sensitivity analysis, and run nearly instantly online or on ordinary desktop and laptop computers, so that people receive immediate feedback. When experimentation is too slow, too costly, unethical, or just plain impossible, when the consequences of our decisions take years, decades or centuries to manifest, that is, for most of the important issues we face in building a sustainable world, simulation becomes the main—perhaps the only—way we can discover for ourselves how complex systems work, where the high leverage points may lie.

A new generation of systems models will be required that address 1) spatial and temporal heterogeneity; 2) nonequilibrium properties and scale dependence, and 3) the coupling of pattern and process. In a recent treatise, Liu et al. (2007) review six case studies that explicitly examine complex interactions and feedback in CH-ESs. The authors conclude that future research on complex systems must include not only individual site-specific studies, but also “coordinated, long-term comparative projects across multiple sites [and scales] to capture a full spectrum of variation.”

Education in a Sustainable World

Education is critical for promoting sustainable development and effective public participation in decision-making.

United Nations (1992)

Sustainability science is both problem driven and solution oriented, and is underpinned by “use inspired” research (Stokes, 1997). Grounded by traditional educational goals, among them critical thinking and social learning, sustainability science goes beyond these fundamentals to introduce and apply “new” knowledge as transformational action in participatory, deliberative, and adaptive settings. More than ever, the skill profile of future graduates will be those of problem solvers, change agents, and transition managers. By acquiring “key competencies” for problem solving in a complex world, sustainability science graduates will be set apart from traditional bounded disciplines (Wiek et al. 2011).

Much has been written about emerging sustainability curricula in higher education, but these skills generally fold into a new toolkit that can address multiple interacting stresses on CH-ESs. In addition to “use inspired research” and transdisciplinary curricula, the new education and outreach paradigm will take many forms: 1) improved communication with government, decision makers, the media, and the general public to convey the urgency of sustainability challenges; 2) development of new policy formulation tools, including systems modeling and other simulations, visualization methods, and appropriate metrics, that recognize the complex, interconnected nature of ecological and socioeconomic systems; 3) introduction of an awareness of ecological systems into commerce, as in the emergence of integrated energy-management services and sustainable architectural practices; and 4) development of mechanisms for integrated dialogue among industry, government, and academia, shifting from an adversarial to a cooperative approach.

What Skill Set and Knowledge Do Students Need to Acquire?

First, many scientists and decision makers have suggested that achieving sustainability will require a “solutions orientation” that includes addressing tradeoffs among different solution pathways. A useful description of the difficulty is that when:

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2 Social learning is vetted in the slow, interactive accumulation of scientific knowledge, technical capacity, management institutions, and public concern over extended periods (generations).
[M]ultiple desirable but competing objectives exist, it is not possible to maximize each...[and] in any system with multiple competing objectives, it will not be possible to meet every one.

United States Commission on Ocean Policy (2004)

Second, sustainability science graduates should be skilled in moving beyond a limited focus on immediate problems to constructively reframing challenges within complex systems in terms of overall success (Basile, 2011; Vincent & Focht, 2011). That is, they should be able to address challenges not only in classic ways, such as on the factory floor or within institutional reach, but also in terms of success at increasing scales in both the short and long term.

Finally, the competencies gained will function in complex systems when future graduates are engaged with experts and nonexpert decision makers in contexts with inherent uncertainty, i.e., in almost any real-world situation where one seeks sustainable solutions.

Graduates with this mix of skills can help others understand, think, and act across multiple parts of a system. A graduate in sustainability understands mixing use-inspired research with values and cultural and ethical decision-making perspectives across the natural and social sciences as part of the process of building lasting strategic outcomes in the effort to achieve a sustainable world (Basile, 2011; Vincent & Focht, 2011). Rather than the “silo” mentality that has placed us in this untenable situation in the first place, it becomes a matter of the following:

- Redefining planning boundaries and horizons in terms of sustainable success.
- Understanding and managing resource potentials, and handling tradeoffs and compromises while minimizing new sustainability problems.
- Integrating the growing knowledge and tool base into increasingly robust and flexible strategic pathways.
- Supporting cross-sector collaboration and cooperation.
- Embracing uncertainties inherent in our emerging planning reality.
- Translating all of this into practicality given today’s context of unsustainable concepts and institutions.

To be clear, this transition is not limited to higher education. It can be used spectacularly in the K–12 classroom. Peter Senge (2012) tells the story of a 12-year old, Annalise, and her classmates, who, after gaining approval from the school principal, parents, mayor, and town council, built a wind turbine at her school as part of a sustainability teaching module. Following a four-minute project presentation to 250 local residents, she “set aside her notes and standing calmly, some 75 pounds of fierce determination, said, ‘We children are often hearing that “you children are the future.” We don’t agree with that. We don’t have that much time. We need to make changes now. We kids are ready, are you?’”

**Sustainable Governance Incubators**

Annalise’s sentiment about being “ready” is worthy of further commentary. If a system is too complex to reduce to its component pieces without losing sight of the whole system’s behavior, and if there are more unknowns than knowns, then we are led to the challenges of assembling a new sustainability paradigm. When would we be ready? As we move forward, rather than thinking of a stepwise process of ending one phase (preparation) and beginning another (implementation) we might think of an ongoing integrated process. In other words, we will not be ready all at once, but in stages. Because the clarity of science is an essential component of decision making, and because we are also influenced by our experiences internally and externally, we need to look at the transition as an evolving social contract. The path of transition, therefore, is wide, incorporating social, economic, political, and other fields traditionally engaged less intensely than they need to be.

Numerous initiatives are underway or in planning stages that increase the “what, why, and when” of sustainability in practice as part of this ongoing process (Table 1). The idea is to build something like social incubators, experimental social sets, demonstration organizations, or quality centers that bring all the issues out in the open for the community to work with, and with recognizable consequences. The country of Bhutan, for example, is on a path that seeks to integrate equitable social opportunity and economic development with environmental conservation and participatory governance. The country’s young king has substituted the concept of “gross national happiness” for GDP to indicate priorities in a national program embracing sustainable systems as the goal.

Several watershed-sized agricultural projects in the American Midwest are working on sustainable practices, but with a suite of governance tools restricted by national farm policies, global commodity pricing, and historical precedents. One proposal suggests that society needs to build on the entrepreneurial and innovative energy of Midwestern farm communities by creating examples of shared governance.
that others can follow (Peterson et al. 2011). The participants would have nearly complete oversight over their watershed. This approach can simultaneously address water-quality problems contributing to the “dead zone” in the Gulf of Mexico and increase the productivity and resilience of Midwest agriculture. How might this be accomplished at the level of the whole landscape? Start at a meaningful scale; learn what works; put trust in regional democracy. Do it by creating watershed-scale “incubator” projects that build on the smaller-scale projects. But, at the same time, these projects must be large enough (5,000 square kilometers) to capture the ecological, social, economic, and political complexities of modern farming. They should have watershed-scale governance based on shared responsibilities for clean water, a healthy environment, a robust economy, and equitable access to resources.

**Conclusion**

The underlying principles of sustainability science and the new “social contract” for science (Lubchenco, 1998) contend that a sustainable biosphere is not only necessary, but economically feasible, socially just, and ecologically sound. With “use inspired” research as its underpinning, the discipline must be broadened to encompass the overarching

| Table 1 Examples of programs and experiments in CH-ES system transitions to sustainability. |
|-----------------------------------------------|----------|-----------------------------------------------|
| **Content/Subject**                          | **Scale**                          | **Infrastructure Support**                  |
| Global Visions and Cooperation               | Rio+20 Summit                        | National governments, United Nations        |
| Strategic visions for biodiversity          | Global                               | DIVERSITAS                                  |
| and ecosystem services                      |                                      |                                              |
| Global Visions and Cooperation               | Global                               | Rockefeller Brother’s Fund, Sustainable     |
|                                             |                                      | Development Program                          |
| Global Visions and Cooperation               | Global                               | Tellus Institute, Widening Circle Campaign   |
|                                             |                                      | for a Global Citizen Movement               |
| Consortium on relationships between climate  | Low- and middle-income countries     | Consortium of International Agricultural     |
| change, agriculture and food security       |                                      | Research Centers, United States Agency for   |
|                                             |                                      | International Development, Canadian          |
|                                             |                                      | International Development Agency, European   |
|                                             |                                      | Union, and others                           |
| Gross National Happiness Index               | National                             | Royal Government of Bhutan                  |
| Interdisciplinary research on coupled       | National                             | United States National Science Foundation,   |
| human-environmental systems                  |                                      | CH-ES Program                               |
| Study and understand sustainability issues   | Qualitative and quantitative analysis| United States National Academy of Sciences,  |
|                                             | of the institutions, infrastructure, | Sustainability Science Section               |
|                                             | and developing issues                 |                                              |
| Biophysical couplings within agricultural   | Mississippi River watershed          | United States National Science Foundation,   |
| policy                                       |                                      | CH-ES Program                               |
| Agricultural Landscape: shared governance   | 5,000 km²                            | Pew Foundation Recommendation, Macondo      |
| of sustainable landscapes to restore Gulf of|                                      | Oil Spill                                   |
| Mexico                                       |                                      |                                              |
| Creating community peace at the local level | Newark Peace Education               | Tibet House, Foundations, Office of the     |
|                                           |                                       | Mayor of Newark, New Jersey                  |
| Institutional collaboration for sustainable  | Global                               | Stockholm Resilience Center, Arizona State  |
| systems                                     |                                      | University, Portland State University,      |
|                                           |                                      | Australian National University, and Uppsala  |
|                                           |                                      | University                                  |
| Sustainability programs in higher education | Arizona State University, Portland    | Traditional                                  |
|                                           | State University                      |                                              |
| Multi-institutional courses in sustainability| Arizona State University, Cornell    | National Center for Ecological Analysis and  |
|                                           | University, Florida International     | Synthesis                                    |
|                                           | University, Harvard University,       |                                              |
|                                           | University of Minnesota, National     |                                              |
|                                           | University of Mexico, Princeton       |                                              |
|                                           | University                             |                                              |
| Professional journals                       | Solutions; Current Opinion in        | Foundations, individuals, public agencies,   |
|                                           | Environmental Sustainability;         | professional societies; for profit publishers|
|                                           | Sustainability: Science, Practice, &  |                                              |
|                                           | Policy; International Journal of      |                                              |
|                                           | Agricultural Sustainability           |                                              |
question: at multiple scales and over succeeding generations, how can the Earth, its ecosystems, and its people interact toward the mutual benefit and sustenance of all? Creating an effective science of sustainability and building the public understanding required for action requires us to develop the skills to recognize the boundaries of our mental models and then to expand them so that we become aware of, and take responsibility for, the feedbacks created by our decisions (Sterman, 2012). And these feedbacks are not static. Westley et al. (2011) referred to human shortcomings as an “ingenuity gap” between the increasing seriousness of global sustainability problems and the lagging supply of solutions. We come to the realization that knowledge about our role in the environment cannot keep pace with the presently poorly understood consequences of our actions.

John Sterman (2002) wrote that “overcoming policy resistance and building a sustainable world requires meaningful systems thinking coupled with community engagement in promoting the common good.” It requires new knowledge gained from use-inspired research (Stokes, 1997; Kates, 2012) and rigorous applications of that research to expose our hidden assumptions and biases. It entails engagement of all scientists to face the ethical issues raised by growth and inequality and to speak out for a just, equitable, and sustainable world (NRC, 2002; Steffen et al. 2011). It obliges us to listen with respect and empathy to others. It compels humility and the courage needed to lead in the face of uncertainty. Sterman (2012) said it so very well: “If we devote ourselves to that work we can move past denial and despair to create the future we truly desire—not just for us, but for our children. Not just for our children, but for all the children.”

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ARTICLE

Measuring sustainable development: the promise and difficulties of implementing Inclusive Wealth in the Goulburn-Broken Catchment, Australia

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A difficulty in measuring sustainable development is integrating measures of its key components (environment, economic, and social) in a way that allows comparison and assessment of tradeoffs and communication of results. This article presents a trial implementation of a sustainability measure called Inclusive Wealth. We do this by constructing an experimental model to estimate sustainable development through the measurement of capital stocks (built, human, natural, and resilience) in the Goulburn-Broken Catchment in Australia. By trialing the model over the period 1991–2001, we address practical issues associated with identifying capital stocks, estimating shadow prices, addressing risk, assessing intragenerational equity, and dealing with price changes. Results are presented as the basis for discussing hurdles to the implementation of regional sustainability measures and for highlighting outstanding theoretical and methodological issues that need resolution for sustainability measures to become a practical policy tool.

KEYWORDS: cost analysis, socioeconomic aspects, risks, assessment, sustainable development

Introduction

The assessment of sustainable development is beset by (at least) two key challenges: 1) the philosophical challenge of properly defining what is being measured and 2) the technical challenge of accurately measuring the component parts of the eventual sustainability indicator for the assessment to proceed. The first challenge is an “in principle” one that defines how relevant and plausible a sustainability indicator might be in a policy context, while the second concerns how accurate such an indicator might be.

In this article, we present a relatively new sustainable development measure called Inclusive Wealth (IW) (for more formal derivations and treatments, see Arrow et al. 2003 and Walker et al. 2010) and trial it at regional scale in the Goulburn-Broken Catchment (GBC) in Victoria, Australia. The GBC is one of the country’s most important “food bowls,” with dairy from irrigated pastures, horticulture, dryland wheat and livestock production and, in the higher-altitude, higher rainfall areas, forest production. It is also a region where nature conservation and “lifestyle” are highly valued. In this trial assessment, we included all capital assets contributing to the dairy industry, dryland wheat and livestock production, nature conservation, and carbon sequestration. These sectors were chosen because the tradeoffs among them involve changes in land use.

To show the key contributions of this approach, we outline how we view IW in the context of the two challenges presented above. With regard to the first, philosophical challenge, the IW measure directly targets the “productive base” that generates society’s standard of living, that is, the collected set of “capital stocks” (produced, human, and natural)—or wealth—that provide us with our lifestyles. If the value of the collected set of stocks declines over time (IW falls), society can be deemed to be consuming its capital and risking its own future impoverishment. Thus, a
sustainability rule using IW would, at a minimum, ensure nondeclining IW (i.e., zero or positive wealth). This rule is analogous to defining sustainability as nondeclining social welfare, as operationalized in an economic sense, which is broadly consistent with framing outlined in the Brundtland Report (see WCED, 1987).

IW is an economic framework, which need not be relied on exclusively as a sustainability indicator, but at any given scale it can provide a meaningful policy constraint when considering development options. Moreover, the process of aggregation of stocks allows the direct consideration of policy tradeoffs, as natural assets always face competing uses, and using a capital-based framework allows an assessment of their contributions in alternative uses (and avoids the typical trap of them being treated as “free goods”).

With regard to the second, empirical, challenge, the process of construction of the IW measure uses shadow prices—measuring a capital stock’s marginal contribution to social welfare—to value individual stocks and then to aggregate them into a total wealth measure. Conventional monetary wealth measures are necessarily partial, measuring what can easily be appraised and valued. IW, by contrast, seeks to include “everything that matters”: this makes it difficult to implement, but this challenge is inherent in sustainability assessments, in which everything that matters ought to be included, by definition. The practical estimation of shadow prices is at the heart of the empirical challenge in implementing IW for use in the policy process. Shadow prices serve as social welfare weights in the construction of IW, and if these are significantly inaccurate, IW estimates (and changes in those estimates over time, which is what matters for sustainability) will be biased. For the purposes of this trial study, shadow prices are admittely crude (as outlined later in the article), and the IW estimates provided here are definitely preliminary.

A further innovation in the use of IW presented here is the focus on the resilience of the systems that comprise key natural capital stocks. Many sustainability indicators capture changing quantities of natural resources and environmental assets without looking at the implications of those changes. One such implication can occur when a system is subject to thresholds beyond which it “changes state” in ways that have implications for sustainability. In this study, a food-production system can become unproductive when farmland is salinized, where the threshold involves the level of the water table. Changes in the “resilience stock” of the system—measured as changes in the distance from the threshold value—can be meaningfully captured in changes in the estimates of wealth. Values, or shadow prices, of resilience can be derived theoretically in the manner outlined in Walker et al. (2010).

It is useful to briefly compare IW to another aggregated sustainability measure, the Ecological Footprint (EF) (see, e.g., Wackernagel et al. 2002). While EF is often advocated as a “strong sustainability” measure (see, e.g., Neumayer, 2004), it does, like IW, aggregate different attributes into a single measure, and does not single out particular sets of natural assets that require specific preservation. Like conventional “weak sustainability” measures such as Genuine Savings (see, e.g., Pillarisetti, 2005), the aggregation in the EF is underpinned by an assumption of substitutability (in that attributes can be converted into a common metric, in this case land area). Despite their differences, both measures have aggregation and substitutability in common.

The in-principle value of the wealth approach is that it directly links changes in productive assets now to impacts on human well-being in the future to enable the analysis of environment-development tradeoffs based on impact on stocks of assets and to suggest “reinvestment” policies to improve the overall sustainability picture.

Framework for Measuring Regional Wealth

Formally, IW represents the summation of the real social values of all capital assets—human, manufactured, and natural—in a particular region (Arrow et al. 2003; Dasgupta, 2009). “Real social values” are calculated using shadow prices, which may well diverge from market prices for a variety of reasons (see, e.g., Arrow et al. 2003). We apply the extended IW framework to take account of changes in the risk or resilience of the system as described in Walker et al. (2010). For a point in time (t), these social values are derived as the number of units (Kt) of each asset or stock (i), multiplied by the shadow price of a unit of each stock (pt). Our stocks include three categories of assets: human, natural, and built. In addition, following Walker et al. (2010), we add a fourth stock, resilience. Social capital is explicitly excluded from the calculations on the basis that it is an “integrating” capital: the greater the positive social capital, the more productive and sustainable will be the other capital stocks. Thus, social capital should be reflected in the values assigned to the capitals included in the IW measurement. (Similarly, farmland will be much less valuable in a war-torn or conflict-ridden country than in a well-governed one.) Our trial assumed (not unreasonably) that social capital, including social networks, norms, governance institutions, and so forth remained stable over the period of analysis (see Harris & Pearson, 2004 for further explanation).
The shadow price for any stock is defined as the marginal change in real social value for a marginal change in the current stock quantity. To incorporate resilience in this way, we must be clear about the “resilience of what, to what.” Analogous to how other stocks are treated, we measure both the quantity ($X$) and price ($q$) of the resilience stock today. We use the “distance” a stock is from a threshold level that causes a shift of that stock into a different stability domain (and therefore different value) as the measure of resilience. Not all stocks ($i$) will be affected by a threshold. For stock quantities $K_{hi}$ that are at risk of crossing a threshold at time $t$, we establish the shadow price in each state. Let $p_{hi}$ and $P_{hi}$ be the shadow prices of stock $K_{hi}$ for the two states in which it can exist. We also estimate the cumulative probability ($F_{hi}$) that the resilience stock may cross a threshold ($j$) during the forecast period and ($S_{jt}$) the survival probability that the stock has not flipped before time $t$; therefore $S(X_j,t)=1-F(X_j,t)$.

$$q_j = \frac{\partial S}{\partial X_j} \sum_h \left[ p_{hi}K_{hi} - P_{hi}K_{hi} \right]$$

(1)

Accordingly, the equation for estimating IW at a point in time ($V_t$) is:

$$V_t = \sum_i (p_{it} \times K_{it}) + \sum_j (q_{jt} \times X_{jt})$$

(2)

Sustainability is assessed by calculating the change in IW between two points in time. In other words, it is the net change in real social value, summed across all stocks, where $\bar{p}_i$ and $\bar{q}_j$ represent the constant shadow prices over the time interval [0, $T$]:

$$V_T - V_0 = \sum_i [\bar{p}_i(K_{iT} - K_{i0})] + \sum_j [\bar{q}_j(X_{jT} - X_{j0})]$$

(3)

Where $V_T - V_0$ is not negative (i.e., increasing or stable), the trajectory of change over the interval [0, $T$] is said to be sustainable.

### Process for Estimating Regional Wealth

Calculating change in IW involves five steps.

**Step 1: Identify Critical Capital Stocks**

It is not practically feasible to include all stocks at fine levels of disaggregation. Our approach was to include only critical capital stocks, defined as those that (i) underpin the production of key goods and services (flows) in the region and (ii) are likely to change or (iii) have possible alternate states with significantly different consequences for goods and services. The important production flows for the catchment were clarified by stakeholder workshops, augmented with expert consultation at the policy and scientific level (see Harris & Pearson, 2004 for a further explanation of the workshops and potential biases). The flows included were dairy production (based primarily on irrigated pastures) and processing, dryland agriculture and livestock production, nature conservation, and carbon sequestration. We then determined the natural, built, and human capital stocks that underpin each of these flows. Finally, to identify resilience stocks, we examined each of the natural stocks to determine which of them had or were likely to have thresholds of change in response to particular kinds of shocks. The final list of stocks and their role with respect to each flow is shown in Table 1 (with their associated shadow prices—see Step 3).

**Step 2: Assess Stock Quantities**

The quantity of each stock that contributes to each of the selected flows (e.g., the quantity of natural terrestrial ecosystems that contribute to grazing for livestock production) was determined for the years 1991 and 2001. To derive the total quantity of each stock in the catchment, we aggregated the quantities across the four selected flows, in a manner appropriate to each stock. Figure 1 presents the quantities of natural capital stocks in each of the assessed years.

**Step 3: Estimate Shadow Prices**

Shadow prices are formally defined as the present value of the perturbation to utility that would arise from a marginal increase in the quantity of the asset today (Arrow et al. 2003). We attempted to derive the shadow prices for each critical stock by assessing the value of the asset to each production flow, such as dairy production and nature conservation, and then deriving the total value-per-stock unit by appropriate aggregation across the flows.

Implementing Steps 2 and 3 leads to identifying classes, or quality categories, within a stock that have different flows of social welfare. For example, native vegetation in “good” condition has a higher biodiversity value than that same area of vegetation in “poor” condition (e.g., heavily grazed by domestic livestock or infested with weeds). Similarly, agricultural land in good condition has a much higher value (shadow price) than land that has been salinized (see Harris &
Pearson, 2004 and Pearson, 2005 for further explanation of categories and values).

The Need for Forecasts

Any assessment of the present value of a capital asset takes into account, explicitly or implicitly, a forecast of what is likely to happen to that stock in the future. In the trial assessment of GBC we developed two plausible forecasts based on different expectations of rainfall conditions in the region. The “dry” forecast assumes that the below-average rainfall conditions prevailing in the region during the 1990s will continue over the next three decades. We assume that the per-unit values (shadow prices) of the capital stocks as measured in 1991 and 2001 are based on an expectation that the climatic conditions experienced in the 1990s will persist.

The “wet” forecast assumes above-average rainfall over the coming three decades and has implications for natural ecosystems, agriculture, and livestock production. With respect to natural terrestrial ecosystems, we assume that 30% of the area currently in poor condition will improve to the extent that it can be reclassified as being in good condition. For convenience, and with lack of better knowledge, we assume that this change takes place linearly over the forecast period. Similarly, we assume that 20% of the natural aquatic ecosystems will improve from poor to good condition.

Table 1 The 1991 shadow prices and stocks, not accounting for regime shifts or resilience analysis, that underpin the production flow of valued goods and services in GBC. In the exemplar model, we consider the stocks that underpin a subset of four flows only: dairy production and processing, dryland agriculture and livestock production, nature conservation, and carbon sequestration. Shadow prices are estimated under the dry forecast, business-as-usual (BAU) policy. The overall shadow prices for each stock are derived by weighted summation of the values for each flow, depending on the nature of each stock (e.g., stocks deliver multiple benefits to different flows, such as natural terrestrial ecosystems to carbon sequestration and nature conservation).

| Stock                                      | Unit | Dairy | Dryland Agriculture | Nature Conservation | Carbon Sequestration | Overall   |
|--------------------------------------------|------|-------|---------------------|---------------------|---------------------|-----------|
| HUMAN CAPITAL                              |      |       |                     |                     |                     |           |
| Managers/Specialists: On-farm              |      |       |                     |                     |                     |           |
| Dairy farmers                              | $/person | $1,205,103 | $1,205,103 | $1,913       | $1,205,103           |           |
| Dryland farmers                            | $/person | $1,205,103 | $1,205,103 | $1,913       | $1,205,103           |           |
| Other farmers                              | $/person | $1,205,103 | $1,205,103 | $1,913       | $1,205,103           |           |
| Managers/Specialists: Off-farm             |      |       |                     |                     |                     |           |
| Dairy researchers & NRM                    | $/person | $1,205,103 | $1,205,103 | $1,205,103 |                     |           |
| Dryland NRM workers                        | $/person | $1,205,103 | $1,205,103 | $1,205,103 |                     |           |
| Conservation NRM workers                   | $/person | $1,205,103 | $1,205,103 | $1,205,103 |                     |           |
| Skilled (e.g., trades)                     |      |       |                     |                     |                     |           |
| Dairy technicians & admin                  | $/person | $806,119  |                     |                     |                     | $806,119  |
| Unskilled: On-farm                         |      |       |                     |                     |                     |           |
| Dairy-farm laborers                        | $/person | $666,619  |                     |                     |                     | $666,619  |
| Dryland-farm laborers                      | $/person | $666,619  |                     |                     |                     | $666,619  |
| Unskilled: Off-farm                        |      |       |                     |                     |                     |           |
| Dairy NRM laborers                         | $/person | $666,619  |                     |                     |                     | $666,619  |
| Conservation NRM labor                     | $/person | $666,619  |                     |                     |                     | $666,619  |
| MANUFACTURED CAPITAL                       |      |       |                     |                     |                     |           |
| Public Infrastructure (e.g., power)        |      |       |                     |                     |                     |           |
| Local government assets                    | Total $ | $1,192,024,958 | $1,192,024,958 | $1,192,024,958 | $1,192,024,958 | $1,192,024,958 |
| Railways                                   | $/km | $173,405 | $173,405 | $173,405 |                     | $173,405  |
| Railway sidings                            | $/siding | $1,085,548 | $1,085,548 | $1,085,548 |                     | $1,085,548 |
| Electricity                                | Total $ | $167,889,650 | $167,889,650 | $167,889,650 |                     | $167,889,650 |
| Irrigation System                          |      |       |                     |                     |                     |           |
| Irrigation headworks                       | $/ML | $126   |                     |                     |                     | $126      |
| Irrigation canals                          | $/km | $150,000 |                     |                     |                     | $150,000  |
| Irrigation drains                          | $/km | $28,000 |                     |                     |                     | $28,000   |
| On-farm (e.g., machinery, buildings)       |      |       |                     |                     |                     |           |
| Dairy-farm infrastructure                  | $/farm | $170,467 |                     |                     |                     | $170,467  |
| Dryland-farm infrastructure                | $/farm | $170,467 | $386,815 | $2,035       | $386,815           |           |
| Other farms: infrastructure                | $/farm | $170,467 | $386,815 | $2,035       | $386,815           |           |
| Off-farm (e.g., processing plants)         |      |       |                     |                     |                     |           |
| Dairy-processing plants                    | $/plant | $99,600,000 |                     |                     |                     | $99,600,000 |

Continued
good condition due to the flushing effect of increased rainfall. Under the wet forecast, we further assume that the productivity, and hence shadow price, of nonirrigated agricultural land will be 10% higher compared to continuing dry conditions. This is equivalent to assuming that all nonirrigated agricultural land moves into a higher productivity class, with a higher associated shadow price. Similarly, we assume that the productivity of livestock will decrease by 5% due to the increased incidence of disease, and that there will be a 5% reduction in the shadow price of public infrastructure, such as bridges and roads, and a 10% decrease in the shadow price of irrigation drains due to the destruction and increased maintenance costs associated with flooding.

**Estimating Shadow Prices**

As anticipated, assigning shadow prices proved the most difficult part of the assessment. In the analyses presented for this trial, we used only market prices and benefit-transfer analyses to assign shadow prices, and we concede immediately that for any real assessment this is inadequate. For each stock, an estimate of the price was determined for both 1991 and 2001. Independent sources were used to determine the prices in the two years wherever possible, in order that the prices are related directly to the stock quantities in the respective years (see last column in Table 1 for list of sources). To allow for comparison over time, all prices were then adjusted to 2001 Australian dollar purchasing parity, using either a producer price index (PPI) or the consumer price index (CPI). Different PPIs had to be employed for different stocks. For example, the Price Index of Articles Produced by the Manufacturing Industry was used to adjust prices for stocks produced by the manufacturing industry in GBC. The CPI was used for capital stocks that had significant input into various stages of production industries and were potentially traded directly to consumers. For example, the CPI was used to adjust the 1991 dollar estimate of human capital into 2001 dollar values.

The constant price \( \bar{p}_j \) in Equation 2 over the period 1991 to 2001 was determined as the linear average between the adjusted 1991 and 2001 prices. Ideally \( \bar{p}_j \) should represent the true average price over the time interval, based on information on prices in the intervening years. However, in the absence of this information, we assumed that prices changed linearly over the period. Table 1 gives estimates of the average shadow prices for all assessed stocks in GBC over the period in 1991 under the dry forecast.

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**Table 1 continued**

| Stock                           | Unit | Dairy | Dryland Agriculture | Nature Conservation | Carbon Sequestration | Overall |
|---------------------------------|------|-------|---------------------|---------------------|----------------------|---------|
| **NATURAL CAPITAL**             |      |       |                     |                     |                      |         |
| **Natural Terrestrial Ecosystems (NTE)** |      |       |                     |                     |                      |         |
| Good NTE on dairy land          | $/ha |       |                     | $78                 | $20,626              | $20,704 |
| Poor NTE on dairy land          | $/ha | $0    | $0                  | $52                 | $11,625              | $11,676 |
| Good NTE on dryland ag          | $/ha | $0    | $293               | $78                 | $20,626              | $20,997 |
| Poor NTE on dryland ag          | $/ha |       | $293               | $52                 | $11,625              | $11,969 |
| Good NTE on other land          | $/ha |       |                     | $78                 | $20,626              | $20,704 |
| Poor NTE on other land          | $/ha |       |                     | $52                 | $11,625              | $11,676 |
| **Natural Aquatic Ecosystems**   |      |       |                     |                     |                      |         |
| Good condition                  | $/km | $14   |                     |                     |                      | $14     |
| Poor condition                  | $/km | $2    |                     |                     |                      | $2      |
| **Forest Plantations**          |      |       |                     |                     |                      |         |
| Forest plantations              | $/ha |       | $25,957             | $25,957             |                      |         |
| **Agricultural Land (Non-irrigated)** |      |       |                     |                     |                      |         |
| Dairy pasture                   | $/ha |       | $1,789              | $6,849              | $8,638               |         |
| Dryland agricultural land       | $/ha |       | $1,594              | $6,849              | $8,443               |         |
| Other converted land            | $/ha |       | $1,594              | $6,849              | $6,849               |         |
| **Agricultural Land (Irrigated)** |      |       |                     |                     |                      |         |
| Irrigated dairy pasture         | $/ha |       | $8,944              | $8,215              | $17,158              |         |
| Irrigated horticultural land    | $/ha |       | $8,215              | $8,215              | $17,158              |         |
| **Livestock**                   |      |       |                     |                     |                      |         |
| Dairy cattle                    | $/animal |     | $828               |                     |                      | $828    |
| Beef cattle                     | $/animal |     | $522               |                     |                      | $522    |
| Sheep                           | $/animal |     | $35                |                     |                      | $35     |

Note: AUS$=1.316 US$ at December 1991 exchange rate; natural terrestrial ecosystem (NTE); natural resource management (NRM)
The basic IW framework measures the net impact of changes in the quantity of different stocks over time in a particular region. As the quantity of a stock changes, its shadow price changes, and the net impact of the changes in price and quantity across all stocks is assessed by means of Equation 2. Given the difficulty of assessing prices with only limited data, we have used the constant (average) price between 1991 and 2001 for purposes of the exemplar model. We examine the implications of this assumption in our discussion on accounting for price changes.

**Step 4: Accounting for Risk: Assessing Thresholds and Resilience Effects in Natural Capital**

Two threshold effects are considered. The first is where two different states with different shadow prices exist, but the shift between states is not probabilistic. The value of land for nature conservation is an example. The value to nature conservation depends on the percentage of the landscape covered by native vegetation. The relationship is nonlinear, with a marked jump in the value at around 30% cover (Bennett & Ford, 1997). In this case, we define different categories of condition in which the stock may exist (<30% natural vegetation cover and >30%) with different shadow prices. Under these circumstances, the shadow price does not change as the stock nears the threshold, but only once it crosses the threshold.

Second, and most importantly for the region, is the threshold-related risk of potential salinization of agricultural land and land under native vegetation. Salinization occurs when groundwater tables (GWT) rise to within 2 meters (m) of the soil surface. Once water tables reach the 2m threshold, water is drawn to the soil surface by capillary action. Despite the long-term trend of rising GWT, over the period 1991–2001, GWT have actually dropped by an estimated 0.5m, due to the below average rainfall over the previous decade (further explanation is found in Walker et al. 2010).

We estimated that 60% of the irrigated agricultural land, 40% of the nonirrigated agricultural land, and 25% of the land under native vegetation is susceptible to salinization. These factors make up the critical stocks, h, that would be affected if the 2m water-table threshold was to be exceeded. In each case, the shadow price of the stocks h in the salinized state was assumed to be 1% of the nonsalinized state. The cumulative probability \( F_t \) at time \( t \) of crossing the 2m threshold during the 30-year forecast period was calculated as the product \( I(D) \) of the probability of crossing the 2m threshold in any particular year:

![Figure 1 Estimated quantities of all natural capital stocks in GBC in 1991 and 2001. Note that quantities are only in respect of stocks as they support dairy production and processing, dryland agriculture and livestock production, nature conservation, and carbon sequestration. NTE = natural terrestrial ecosystems; Good = good condition; Poor = poor condition.](image-url)
\[ F_t = 1 - \prod_{t=0}^{T} \left( 1 - 0.4583e^{-2.75X} \right)^{12} \]  

(4)

where \( X \) is the distance at time \( t \) of the GWT from the 2m threshold as shown in Figure 2.

Equation 4 was applied in the exemplar model by forecasting the depth to the water table in 2030 under the two climatic forecasts (wet and dry) and assuming a linear increase between the current depths (1991 and 2001) and the depth in 2030 (Table 2). The cumulative probability of exceeding the threshold (Equation 4) was calculated for a 30-year forecast in each case (i.e., based on forecast increases in water-table depth until 2020 for the 1991 forecast and until 2030 for the 2001 forecast).

**Step 5: Determining the Change in Inclusive Wealth**

The final step is to calculate the change in IW, operationalizing Equation 3 between 1991 and 2001. It is the change in IW over time (not the absolute measure of IW at any point) that provides the assessment of sustainable development. The constant prices identified in Equation 3 change depending on the form of analysis conducted. For example, to determine the change in IW between 1991 and 2001, the constant price is the average of the 1991 and 2001 prices. But if the change in IW associated with a policy option is under investigation, then the constant price is the average of the two prices, for example the average price between Policy 1 (e.g., Business as Usual) and Policy 2 (e.g., Double Production).

**Results: IW in GBC**

Before presenting our results, we stress that our objective was to explore the promise, weaknesses, and difficulties of implementing IW and present the results as a basis for this discussion, not to provide a comprehensive sustainability assessment. This is an illustrative exercise, based on an analysis of the stocks underpinning only four flows and using unrefined shadow-price estimates. We present the results only to show how IW could be used to inform policy and to uncover practical and theoretical hurdles to its use. They cannot be used as the basis for any policy decisions in GBC.

**Monitoring IW Over Time: Was the Pattern of Resource Allocation Sustainable?**

To illustrate IW as a tool for monitoring sustainable development, we calculated the change in IW over the period 1991–2001 for two different climatic forecasts (wet and dry, as described in Step 3). Including resilience considerations, we find that between 1991 and 2001, IW in GBC increased under both forecasts. Notably, under the dry forecast it increased by AUSS6.9 billion (US$5.2 billion), with natural capital contributing 92% of this growth (Figure 3). This difference between 1991 and 2001 under the dry forecast is about 19% of the 1991 IW value. The increase in natural capital under the dry forecast is mainly due to the decreased risk of salinity.

**Table 2** Assumed depths to the water table (m) in 1991 and 2001 and forecast depths in 2030 under different climatic and policy conditions. Cumulative probabilities (%) were calculated through 2030 (i.e., over a 40-year period from 1991 and 30-year period from 2001), assuming a linear increase in the depth to the water table between 1991, 2001, and 2030.

|                           | 1991 | 2001 | 2030                  |
|---------------------------|------|------|-----------------------|
|                           | Business as Usual | Double Production |
|                           | Dry  | Wet  | Dry  | Wet  | Dry  | Wet  |
| Irrigated Agricultural Land | Depth | 3    | 3.5  | 2.5  | 2.1  | 3    | 2.3  |
|                           | F1991 | 100% | 100% | 100% | 100% |
|                           | F2001 | 100% | 100% | 99.96% | 100% |
| Nonirrigated Agricultural Land | Depth | 3.5  | 4    | 4    | 3.5  | 4.5  | 3.7  |
|                           | F1991 | 85.69% | 97.18% | 70.78% | 93.57% |
|                           | F2001 | 59.34% | 85.69% | 38.78% | 75.37% |
| Native Vegetation | Depth | 4.5  | 5    | 5.5  | 4    | 6    | 4.5  |
|                           | F1991 | 7.55% | 38.78% | 5.43% | 20.34% |
|                           | F2001 | 3.09% | 26.70% | 1.97% | 11.66% |
zation in irrigated land, specifically irrigated dairy pasture and horticultural land during this forecast (see Table 2 for GWT depths under forecasts).

The wet forecast also resulted in an increase in wealth, indicating that the resources in GBC were used sustainably between 1991 and 2001. However, the magnitude of change under the wet forecast was only 16% of that found under the dry forecast. The difference between the forecasts illustrates the sensitivity of IW estimates to expectations of the future and shows the care required in interpreting the results.

Built capital is found to have decreased by AUS$270 million (US$210 million) over the period 1991–2001 under both forecasts. These decreases are mainly due to the reduction in dairy-processing plants in the region (arising from individual strategies of international companies) and lack of reinvestment by companies or government into new assets. Under the wet scenario, there are additional losses to public infrastructure and irrigation systems because of increased flooding. Human capital, by contrast, is estimated to have stayed constant with no significant change in human labor over time.

If salinization risk is not included in the estimate, IW is found to increase under both forecasts, by AUS$840 million (US$640 million) under the dry forecast and AUS$830 million (US$630 million) under the wet forecast. This result shows that accounting for the salinization risk delivers the same direction of wealth (i.e., nondeclining), but the magnitude is dramatically different; under the dry scenario, wealth increases by 12% while under the wet scenario, wealth increases by 75%. Consideration of risk can have a marked impact on the IW estimates.

**Policy Application**

We use a proposed policy under discussion in GBC to illustrate the application of IW to the problem of assessing proposed projects or policy changes. We explore the outcome of perturbing the 2001 land-use allocation with a proposal to retire half the agricultural land (primarily in the dryland agricultural area) in the interests of improving natural ecosystems and their functioning, and to double production on the remainder of the agricultural land. We compare the outcome under this scenario—Double Production (DP)—to a continuation of current trends—Business as Usual (BAU). In assessing this policy application, we use constant 2001 prices with predicted 2030 stock quantities, where stock quantities are assumed to be 2001 unless perturbed by the policy as detailed below.

The forecast changes in capital stocks as a result of the DP policy are: i) 50% of the agricultural land is retired by 2030, all of it being nonirrigated dryland agricultural land, which is converted to nature conservation land, and carbon sequestration.

![Figure 3](image-url)

Figure 3 Change in IW in GBC under the “business-as-usual” policy for 2001 comparing two climatic forecasts of the future (wet and dry). Note that the value of capital assets is only with respect to dairy production and processing, dryland agriculture, nature conservation, and carbon sequestration.
remaining 50% of the land is to double in production by 2030.

We also include the impacts of increased native vegetation cover on biodiversity. Once the cover of native vegetation (natural terrestrial ecosystems) gets above 30% for the whole catchment, the nature-conservation value associated with this stock increases significantly (Bennett & Ford, 1997). This native vegetation threshold is a straightforward stepwise function: before the 30% threshold is reached, each additional unit of native vegetation has a relatively low value; once the cover of native vegetation exceeds 30% of the landscape, all further marginal increases have a higher value. We have included the estimated increase (35%) by weighting the pre-threshold and post-threshold prices by the proportion of the forecasted three decades that would be in each state. Assuming a linear retirement of land over the next 30 years, the 30% cover threshold is reached in ten years under the DP scenario.

The GWT were assumed to rise or fall linearly over the 30-year scenario period, assuming depths as given in Table 2. Increased vegetation cover under the DP scenario results in increased transpiration, and therefore lower GWT as compared to the BAU scenario. However, the gains under the DP scenario would be partly offset by a higher rainfall period. The impact of the changed expectations of the future that would occur under the DP scenario is therefore examined under both climatic forecasts.

Under the dry climatic condition, the BAU policy results in a considerably higher IW value. Conversely, under the wet forecast the DP policy results in a higher value of wealth. The difference between the BAU and DP policy results can be interpreted as the maximum amount society could pay to keep the GWT further away from the surface (i.e., at a lower probability of crossing the threshold). The reduction in wealth under the wet forecast is principally related to the decrease in resilience stock associated with a rising GWT. The results again emphasize the sensitivity of the IW estimates to assumptions about the future.

Assessing Intragenerational Equity

IW reflects aggregate social value across the entire population. Estimates of IW used to assess the implications of proposed policies, or alternatives between competing development proposals, will therefore often not adequately reflect the values of particular (often minority) groups. A change in a stock that is deemed favorable by one group may be deemed unfavorable by another. Where such differences are considered important, it is necessary to be able to include them for the approach to be acceptable and to have value to the policy-making process. Therefore, in addition to the IW results based on the aggregate set of shadow prices, we also analyzed IW based on shadow prices that reflect the view of a particular sector of society.

Sectoral IW can be included in a variety of ways; we chose to adjust the aggregate social shadow prices to reflect IW as if the entire current population were composed of the sector under consideration.

We estimated a modified set of shadow prices (for the same changes in stock quantities) for a so-called “green” sector. These prices reflect substantially higher values accorded to nature conservation and related flows than the societal average. We have assumed that the proportional differences in value placed on flows, such as dairy and nature conservation, are equivalent to the proportional differences in the shadow prices of the stocks underpinning those flows. For example, we estimate that the green sector values nature conservation 50% higher than society on average, and have therefore assumed the shadow prices of all stocks with respect of their value to nature conservation to be 50% higher. Analogously, we estimated dairy and dryland agricultural flows to each be 25% lower and carbon sequestration 50% higher.

Our estimates of change in IW between 1991 and 2001 from the perspective of the green sector show a similar pattern to those of the aggregate society, although the values of IW are generally much lower. Significantly, under the dry BAU forecast, the green sector has a slightly higher IW than the aggregate. This is due to the increased weighting placed on natural capital by the green sector and the significant increase in natural capital under the dry forecast (see earlier discussion on change in IW estimates for rationale of why this has occurred). Such an analysis is useful because it confirms that aggregate changes in society can mask major losses or gains for particular sectors.

Accounting for Price Changes: Capital Gains and the Drift Term

When assessing IW between two points in time, changes in both the quantities and the prices need to be considered. Although changes in stock quantities, not prices, are used in determining whether IW is being maintained, two sources of price changes need to be identified when considering how prices should be treated: internal and external to the region of analysis. Internal price changes assume that the region under investigation is large and “powerful” and determines all its shadow prices; therefore, changes in shadow price are regarded as internal, or related to capital gains. External price changes assume a small region with little influence over changes in prices due to the “global” markets in which the stocks are
We propose two practical approaches to implementing a discrete measure of time-dependent IW for a small region. The first is negating the impact of price change by using an average/constant price for the two years, as done in this exemplar model. This negates both internal and external price changes. The change in IW is then given by $V_T - V_0 = \sum \rho_i[K_{iT} - K_{i0}]$ (Equation 2). The second approach assumes all price changes are external, that the region under investigation has little influence over changes in prices. All changes in price are attributed to external impacts, are therefore considered the drift term, and are included in the estimates (i.e., $V_T - V_0 = \sum[p_{iT}K_{iT} - p_{i0}K_{i0}]$).

Alternatively, we could assume that the region under investigation is large and “powerful” and determines all shadow prices. Therefore, all shadow price changes are regarded as internal, or related to capital gains, and are deducted from the IW estimate (i.e., $V_T - V_0 = \sum[p_{iT}K_{iT} - p_{i0}K_{i0}] - \int \left[ \sum \frac{dp_{iT}}{d\tau}K_{iT} \right] d\tau$).

For our trial, we used the first, small-region approach. However, to test the significance and importance of the assumptions held under this procedure, we implemented all three of the above approaches to discrete measures of three stocks: dairy cattle, sheep, and beef cattle, as they relate to dairy production and processing and to dryland agriculture under the BAU scenario. All data were derived from available statistics using market prices and quantities per farm. Although these methods are at the extremes, they are useful in determining the sensitivity of IW estimates to alternate approaches (constructions) of the region under investigation. The legitimacy of estimating capital gains and a drift term on shadow prices, renewable capital stocks, and moveable capital stocks was not addressed in this analysis.

Depending on the method used, the trend and the magnitude of change in IW between 1991 and 2001 can vary for some stocks (Figure 4). For beef cattle, assuming all price change is due to capital gains resulted in an estimated increase in IW, whereas the other methods suggested a reduction in IW. This is because the capital gains for beef were estimated to be negative, and were therefore added, rather than deducted, from IW. The constant prices and drift-term methods yielded similar results in trend and contribution of components stocks (i.e., sheep, beef, and dairy cattle), which is appropriate as they are both considered suitable for small open regional analysis. This result raises concern about the legitimacy of deducting capital gains components from small open regions with highly moveable capital stocks (e.g., cattle) and about the data available to estimate this impact accurately.

**Issues to Consider in Using IW as a Policy Tool**

Our implementation of IW has raised theoretical and methodological issues and some practical hurdles. We discuss them here with some suggestions for how they might be addressed in a full-scale implementation of IW. Fundamentally, the definitions of sustainability, and the construction of measures to assess whether we are acting sustainably or otherwise, are contested territory among scholars, as is highlighted in survey treatments such as Neumayer (2004; 2010) and Pezzey & Toman (2002; 2005). Furthermore, the fundamental subjectivity of sustainability concepts and measures is emphasized by Gasparatos (2010) and Vatn (2005; 2009). The recent report of the Commission on the Measure of Economic Performance and Social Progress (Stiglitz et al. 2009) makes plain the difficulty of settling on one overarching headline indicator, as opposed to taking a “dashboard” approach. Hanley et al. (1999) demonstrate the conflicting diagnoses that emerge from various indicators, including Genuine Savings, the Ecological Footprint, and the Genuine Progress Indicator. However, IW has attained international interest through the UNU-IHDP & UNEP (2012) report *Measuring Progress Toward Sustainability*, ensuring that the issues raised here have direct policy application, as well as academic merit. These valid concerns...
and disagreements notwithstanding, we believe wealth, defined inclusively as per IW, represents a meaningful and robust measure of aggregate sustainability that can be applied at multiple scales and used to meaningfully assess tradeoffs between alternative development/management options. It has been employed in various contexts, including by Lange (2004) in the context of comparing national reinvestment rules aimed at turning resource deposits into sustainable income streams. More ambitiously, Arrow et al. (2004) and Ehrlich & Goulder (2007) indicate that, in terms of consumption flows, the composition is the strongest driver of unsustainability in a number of countries than is the volume (relative to investment back into improving/increasing the stock of valuable assets). Randall (2008), meanwhile, counsels a hybrid approach of savings/wealth-based analysis (not including resilience as per Walker et al. 2010 and this article) and resource-specific biophysical indicators where concerns are raised around legitimacy of “critical capital stocks” and their significance to global functioning ecosystems. Incorporating (changes in) resilience into wealth measures is a potentially significant step in improving the sustainability interpretation provided by such measures.

Despite its contested theoretical standing, IW has been adopted by the United Nations as a potential measure for long-term national sustainability (UNU-IHDP & UNEP, 2012). As such, this article further refines the application of IW by resolving five methodological and practical issues, as discussed below.

Identification of Stocks

The use of a production-systems framework to identify critical capital stocks, based on identified important flows, proves to be useful and workable. The difficult step was to assemble the “right” group of stakeholders, including those who live outside the region. This also relates to the issue of deriving different sectoral IW estimates to address intragenerational equity issues.

Lack of a Methodology and Data for Estimating Shadow Prices

Different approaches to shadow pricing yield different results, and no single method adequately addresses the complex value a shadow price aims to portray. There are no direct data for real, social values ascribed to capital stocks, and prices need to be inferred from various sources. For this exemplar model, used a single estimate derived from either market or benefit-transfer approaches. However, even these price estimates are subject to substantial uncertainties. An acceptable and credible way to estimate shadow prices is a key requirement for the IW approach to become generally useful. An appropriate way might be to use several different price estimates, bounding the shadow price and iterating toward an acceptable value. Whether this results in repeatable and acceptable estimates will determine if change in IW is a useful, practical tool for assessing sustainability.

Sensitivity of Shadow Prices to Forecasts of the Future

Our trial results clearly illustrate the sensitivity of IW to expectations of the future. To address this sensitivity, we suggest that any analysis of IW needs to incorporate multiple forecasts. A remaining research issue is a rigorous way of choosing forecasts that will prove acceptable to all involved and that will enable assessment of the estimates’ sensitivity to future uncertainties.

Sectoral Bias: The Equity Issue Uncovered

The IW technique assesses intragenerational equity under a policy-analysis scenario. We provided one approach, the “sector analysis,” as sectoral distinctions are important for policy makers. Our analyses show that average aggregate assessments of IW, particularly for proposed policy developments, do not make explicit substantial differences in winners and losers within different groups in society. In other words, the method does not fully expose intragenerational equity concerns. We have presented a crude approach for adjusting aggregate shadow prices to reflect those of a particular sector, but how to best do this requires further consideration. Additionally, the question of intergenerational equity is captured in IW through the nondeclining wealth rule. This assumes the use of discount rates, which is controversial in some circles and does not take into account broader equity issues such as justice and freedom (see Goulder & Stavins, 2002).

Incorporating Risk

We applied the theoretical approach for incorporating resilience developed in Walker et al. (2010). Our results suggest that resilience and threshold effects can be important in an assessment of IW and need to be included in the analysis. A practical limitation is the ability to identify which stocks have, or are likely to have, threshold effects, where the thresholds might be, and how to assess the value of the stock in its alternative states. These issues can be dealt with in a probabilistic way, as is done in this article. Incorporating estimates of such probabilities is a significant advance over not considering resilience at all. This approach directly addresses “specified resilience;” however, it does not address
the issue of “general resilience,” which refers to a system’s vulnerability to all threats known and unknown.

Conclusion

In theory, the IW framework uses a single philosophical perspective (based in the economics discipline) to assess a region’s sustainability. In practice, the framework may not address the full criteria necessary for a sustainability assessment. Other philosophical perspectives raise, for example, the importance of intragenerational equity, justice, and freedom. Additionally, a substantial practical problem with the framework is estimating the shadow price of goods and services.

Based on this trial implementation of IW, we have suggested how full-scale IW assessments can overcome some methodological issues and hurdles and highlighted where outstanding theoretical issues need to be resolved. While precise, universally acceptable estimates of IW are impossible in practice, we nevertheless believe that IW is a valuable addition to the policy-making toolkit as it does more than assess the costs and benefits of policy options; it assesses their sustainability. We can only wonder what decisions could have been made over the last 30 years if policy makers were able to test the sustainability of proposals as well as their economic efficiency.

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Local responses to regional mandates: assessing municipal greenhouse gas emissions reduction targets in British Columbia

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Local governments around the world face external and internal pressures to adopt climate change mitigation strategies. Provincial legislation in the Canadian province of British Columbia has recently mandated that all municipalities adopt targets for reducing greenhouse-gas emissions. Lack of specificity in the legislation gives rise to the possibility that even if compliance with the legislation is universal it could nonetheless result in minimal reductions in emissions releases. This article examines the response to the legislation of twenty municipalities in British Columbia’s most populous regions. We hypothesized that noncompliance would be rampant and that cities with large populations, high residential densities, lower growth rates, and prior climate change planning work would set more ambitious targets. However, findings indicate that municipal targets vary widely in terms of intensity, target year, and type of reduction and have little or no relationship to population, residential density, or growth rate. We found 90% compliance and some correlation between prior planning activities related to climate change and target intensity. Findings also indicate that despite the wide range of emissions targets by each municipality, provincial per capita targets would be met if each municipality were to achieve the targets that they have set by the 2050 target year.

KEYWORDS: climatic change, mitigation, emission reduction, legislation, urban planning, government regulations

Introduction

Scholars increasingly emphasize the critical role that municipal governments can play in climate-change mitigation through the adoption and implementation of policies and actions aimed at reducing greenhouse-gas (GHG) emissions (Bulkeley & Betsill, 2003; Brody et al. 2008). While all levels of government can potentially make valuable contributions to mitigation (Collier, 1997; Betsill, 2001), untenable climate-change impacts are likely without the widespread involvement of municipal governments (Betsill, 2000; Lindseth, 2004). This work stresses the particular importance of municipal urban planning for climate-change mitigation, given the traditional role that such planning has played in managing public and private land-use and transportation decisions (Pitt & Randolph, 2009).

In British Columbia (BC), Canada, the provincial government has recently committed to reducing GHG emissions by 33% from 2007 levels by 2020 and 80% by 2050 (Parliament of the Government of British Columbia, 2007a). To help achieve these reductions, the province enacted Bill 27 (also known as “The Green Communities Act” and referred to here as GCA), which mandated that every municipal government in BC incorporate GHG emissions-reduction targets into their official community plans (OCPs) by the end of May 2010 (Parliament of the Government of British Columbia, 2007b). While this directive is unprecedented by North American standards in that it requires all municipalities in the province to set emissions-reduction targets, it does not specify target levels, target years, or base years to which municipalities should adhere; nor does it indicate whether targets should focus on aggregate or per capita emissions. This lack of specificity makes it possible that municipalities could comply with the letter of the law but not its intent. Conformance with GCA requires adopting targets that may ultimately entail such small reductions in GHG emissions that, even if met, would be insufficient to mitigate potentially harmful climate-change impacts. Even worse, the legislation allows the possibility that a municipality could reduce its per capita emissions while actually projecting and planning for an increase in aggregate emissions. Beyond a modest carbon tax rebate program,
GCA provides little disincentive against token compliance.\footnote{The Climate Action Revenue Incentive Program requires local governments to submit targets to receive financial incentives ranging from over CAN$400,000 for the largest municipalities to over CAN$8,000 for the smallest communities in the case study group. These sums, while not negligible, constitute a small fraction of the planning budgets for these jurisdictions.}

In this article, we examine the nature of GHG emissions-reduction targets adopted by a subset of BC municipalities in response to this legislation. In doing so, we address the following question: To what extent do municipal GHG emissions-reduction targets represent a cohesive response that might lead to regional achievement of provincial emissions targets in BC?

We first review the barriers that municipalities can expect in reducing local GHG emissions. The following section describes our variables, data-collection process, and the analytical techniques. We then present our findings and conclude with a discussion of the overall effectiveness of the local-government response to the provincial legislation.

Reducing GHG Emissions at the Municipal Level

Municipal governments are primarily responsible for overseeing a large number of activities that affect GHG-emissions levels, including controlling land use and development through zoning regulations and official plans; issuing building permits and approving major developments; controlling parking supply and rates, roads, and public transit; owning and/or regulating municipal power and natural gas utilities and district-heating systems; coordinating waste management; and managing parks and recreation services (DeAngelo & Harvey, 1998; Robinson & Gore, 2005). A number of scholars have shown that automobile emissions from low-density suburban developments are a particularly important source of GHG emissions (Brownstone, 2008; Ewing & Rong, 2008; Marshall, 2008) and that compact high-density development supported by reliable public transportation is a clear pathway to reduced emissions (Brown & Southworth, 2008; Ewing et al. 2008). We would therefore reasonably expect that cities that already have extensive high-density development would be leaders in both setting and implementing GHG reduction targets.

In the absence of federal or state/provincial mandates, municipal governments have generally been unwilling to voluntarily tackle climate change (Betsill, 2001). One reason for their initial reluctance has been a delay by cities in appreciating the climate-change problem, both in general and as a matter of local concern. Municipal officials often failed to understand how their community contributes to the problem or how they can be affected by it. Even when they have become aware that climate change was a problem at the global level, they have tended not to consider it a legitimate local concern (DeAngelo & Harvey, 1998; Wilbanks & Kate, 1999; Betsill, 2000; 2001; Bulkeley, 2000; Robinson & Gore, 2005). When cities have begun to adopt targets, their planning efforts have often been impeded by variable data, methodological uncertainty, political obstacles, and a general lack of resources (Pitt & Randolph, 2009).

Despite the aversion to climate-change planning and the refusal of the federal government in the United States to sign any climate-protection agreement, by October 2009, 1,000 mayors, representing more than a quarter of the country’s population, had signed such a compact (USCM, 2009). By April 2011, 216 Canadian cities were participating in the Federation of Canadian Municipalities’ Partners for Climate Protection Program (FCM, 2011). While Gore & Robinson (2009) point out that this constitutes only a small fraction of the over 85,000 local governments in the United States and approximately 5,000 in Canada, the numbers are significant, especially when we consider that American signatories grew from 152 in February 2007 (Gore & Robinson, 2009) to over 1,000 in October 2009. This clearly demonstrates a growing trend by cities and local communities to pay attention to the relationship between urban development and climate-change planning.

Numerous scholars have observed that, from a strategic planning perspective, it is difficult to justify municipal governments’ expenditure of resources to control their own GHG emissions (Betsill, 2000; 2001; Engel, 2006; Brody et al. 2008). Any given municipality cannot know for certain that its expenditures will have a measurable impact on mitigating climate change, and even if its efforts did yield positive results, the benefits would not accrue exclusively (if at all) to the municipality that paid the costs. Under these conditions, each municipality has an incentive to “free ride” on the efforts of others.

Municipal governments may also be reluctant to exercise control over their activities because an easy path to emissions reductions is not obvious. Unlike some other environmental problems (e.g., phasing out chlorofluorocarbons to halt depletion of the stratospheric ozone layer), there are no “silver bullet technological solutions” to solving global reliance on GHG-producing activities and scientists believe a wide array of changes is needed (Kosloff et al. 2004). The cities in the United States that are signatories to the climate-protection agreement are clustered in
areas of the country with the highest population concentrations (USCM, 2010) and there is a clear pattern of neighboring cities agreeing to reduce emissions to 7% below 1990 levels by 2012. Because land-use and transportation changes take years and sometimes decades to implement, it is too soon to determine whether cities are successfully executing their emissions-reduction targets, but much is to be learned from examining the potential regional impacts of clusters of cities reducing their emissions. This article attempts to fill this gap with respect to the area of concentrated population in southwestern BC.

For Canadian cities, budget constraints, along with both external and internal pressures, have limited capacity to act (Bradford, 2002; Slack, 2002; Robinson & Gore 2005). These circumstances have impaired municipal ability to handle new climate-related initiatives (i.e., by preventing municipalities from hiring new staff) (Robinson & Gore, 2005). Canadian municipalities, not unlike their counterparts in the United States, also face barriers of competing priorities, lack of information, and limited administrative capacity that have hindered their capacity to respond to climate change (Robinson & Gore, 2005). For some scholars, the existence of such obstacles (which can vary in nature and magnitude across municipalities) suggests that federal and provincial governments should avoid “one-size-fits-all” approaches to encouraging municipal climate-change responses. Instead, they should keep these barriers in mind and make allowances when designing programs to reduce emissions (Robinson & Gore, 2005).

The GCA in BC is a flexible and open-ended approach to bringing about province-wide reductions in GHG emissions (Parliament of Government of British Columbia, 2007b). The legislation requires all municipalities to set and achieve GHG emissions-reduction targets but does not prescribe specific levels. It appears to acknowledge that many municipalities may face significant barriers in both target setting and target achievement. One potential barrier to setting emissions-reduction targets at the local level is relative uncertainty about current emissions levels. Emissions estimates vary depending on the organization that produces them. For example, British Columbia’s Ministry of Environment (2010) estimated that per capita emissions were 15.6 tonnes in 2008. By contrast, the Pacific Institute for Climate Solutions, a research network funded by the same Ministry, calculates total emissions and population figures that indicate per capita emissions to have been 11.4 tonnes in 2008 (Nyboer & Knieuwasser, 2012). This type of significant variation in emissions estimates is a source of ambiguity and confusion for municipalities and impedes the development of a climate protection planning agenda.

An additional barrier to setting targets is the relative uncertainty regarding what the ultimate emissions targets ought to be (Byrne et al. 2007). While absolute emissions values in terms of parts per million by volume of GHGs in the atmosphere are typically used to correspond to global temperature rise values (Metz et al. 2007), there is no consensus in the literature regarding the specific per capita emissions value that municipalities should target. On one hand, authors such as Höhne et al. (2007) estimate that global GHG targets must stabilize at between four and five tonnes per capita to limit temperature rises to two degrees Celsius. The Intergovernmental Panel on Climate Change (IPCC), on the other hand, calculates that per capita emissions must stabilize at approximately one tonne per capita to maintain a temperature rise of this magnitude (Metz et al. 2007). Allison et al. (2009) also state that “the required decline in emissions combined with a growing population will mean that by 2050, annual per capita CO₂ [carbon dioxide] emissions very likely will need to be below 1 ton.” In 2005, the federal government of Canada briefly promoted a “One-Tonne Challenge Program,” encouraging Canadians to reduce their annual per capita emissions to this amount (Environment Canada, 2006). In this context of uncertainty, it would be instructive to identify the range of per capita emissions that local governments in BC are likely to achieve if they are successful in meeting their targets. Knowing what would happen if they continue on the trajectories set by their own targets would help establish a preliminary assessment of the effectiveness of the provincial legislation and the regional response.

This review of the challenges to implementing targets suggests that for cities in BC the specific obstacles are likely to be all or some of the following: lack of power over regional emissions, reluctance to “pay” for the bad habits of “free riders,” uncertainty about current emissions, insufficient information and resources, absence of obvious solutions, and uncertainty about desired target levels. By legislating that every city has to set targets, to take responsibility for its own emissions irrespective of neighbors’ releases, the province has essentially made the lack of power over regional emissions obstacle irrelevant. The provincial legislation also encourages cities to overlook what other cities are doing, although the free-rider problem will persist if some cities choose to set modest targets to avoid high implementation costs with the hope that neighboring cities will shoulder the burden.

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2 One tonne is equal to 1,000 kilograms or 2,204.6 pounds.
In addition to the legislation, the provincial government of BC simultaneously developed a Community Energy and Emissions Inventory (CEEI) program that produces a tabulation of emissions for every municipality in the province. This inventory has provided municipalities with a reference point for both the absolute value of their 2007 baseline emissions, against which reductions can be measured, and the relative volumes contributed by each sector (i.e., buildings, on-road transportation, solid waste). This reduces the uncertainty about current emissions obstacle. While anecdotal evidence from planners’ statements at regional conferences suggests some frustration with the CEEI methodology of calculating emissions, the mere presence of a baseline figure for each municipality alleviates some of the inertia experienced by cities that had not previously planned for climate change.

BC Hydro, the province’s publicly owned electric utility, offers local governments a number of programs that help minimize the lack of information and resources and absence of obvious solutions obstacles. The company provides financial and technical support for the development of community energy and emission plans (CEEPs), funding for hiring a community-energy manager, and financial resources for feasibility studies for district-energy systems. The Power Smart Program, also operated by BC Hydro, offers many incentive programs for energy conservation, including a scoring system for local governments with points given for “enablement” and implementation of energy conservation. Additionally, the Federation of Canadian Municipalities maintains the Partners for Climate Protection program, which is the Canadian network of the Cities for Climate Protection program established by ICLEI—Local Governments for Sustainability. This program helps connect and support cities that have committed to reducing their GHG emissions and tracks achievement of their corporate- and community-reduction milestones. Approximately 40% of BC’s local governments currently participate in the program.

This combination of programs, incentives, and legislation in BC has served to diminish most obstacles to GHG target setting. However, neither the legislation nor any of the programs mentioned above address the uncertainty about desired target levels obstacle. Our research focuses on this final barrier and examines the targets that cities set in this context of uncertainty and whether their cumulative per capita targets would constitute a regional achievement toward the provincial government’s per capita targets. We also explore the relationship between the targets that cities set and population, urban growth rates, density, and prior planning activity exemplified by the cities’ participation in the various programs mentioned above.

Starting Assumptions and Hypotheses

As we began our exploration, we developed a few assumptions based on a reading of the literature and the unique nature of GCA, which, as discussed above, does not have a clear or binding requirement. Our review led to five general assumptions about what we might reasonably expect to find in this study.

Noncompliance Likely Rampant

Our first expectation, and the impetus for this research, was that the rate of compliance by municipalities with the provincial legislation would be low. We anticipated that the relative ambiguity of the law, and the absence of any mechanism for enforcing compliance, would mean that a considerable number of municipal governments would not prioritize expending resources on setting targets and would ignore the mandated deadline. Following the same logic, we expected that some municipalities would simply go through the motions of setting targets without undertaking any rigorous analysis or strategic planning to integrate the targets into their OCPs and other planning documents. The ultimate significance of compliance or noncompliance is that the cumulative effect of local government reduction targets would affect broader provincial goals and the general efficacy of GCA.

The Most Populous Cities Would Have the Most Ambitious Targets

From Robinson & Gore (2005), we know that limited administrative capacity and lack of data hinder climate-change planning. If we assume that the municipalities with the largest populations have more planning resources and the greatest amount of planning experience, then it seems reasonable to assume that these municipalities would be better equipped to tackle the complexity and uncertainty that might come with target setting. We might therefore expect that the most populous cities would have the most ambitious reduction targets.

The Fastest Growing Cities Would Have the Lowest Reduction Targets

Fast growing cities would likely have two constraints on target setting. Local leaders would be reluctant to slow the pace of development with any new

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3 ICLEI—Local Governments for Sustainability, an international organization established in 1990, was previously known as the International Council for Local Environmental Initiatives. See http://www.iclei.org.
policy constraints and planning staff would be too busy trying to keep up with the demands created by growth to concentrate on climate related land-use planning. We therefore expected some negative correlation between the rate of growth and the intensity of the reduction target.

**The Densest Cities Would Have the Highest Reduction Targets**

A fourth assumption was that cities that started off with higher-than-average densities would be most likely to proceed with confidence toward the prospect of more intensive densification. Those cities, such as Vancouver and the City of North Vancouver, are home to populations that have already experienced what it is like to live in more compact communities and would presumably be more amenable to continuing and expanding this development pattern. By contrast, low-density, sprawling cities, such as Abbotsford (located approximately 40 miles east of Vancouver), would have less access to transit infrastructure, be more heavily car dependent, and be least able to move toward ambitious emissions reductions.

**Prior Planning Leads to Aggressive Target Setting**

Our final assumption was that those municipalities that have actively participated in prior climate change planning programs, and have made use of the support provided by the various programs mentioned above, would comply with the law and set targets. We expected that these municipalities would be leaders in the province and set the most ambitious targets.

**Variables, Data Collection, and Analytical Techniques**

In this section, we describe our methods in terms of the variables examined, the kinds and sources of data collected, and the analytical techniques employed. We chose to focus our analysis on BC municipalities with a population greater than 25,000 and a location in one of the province’s three most populous regional districts, Metro Vancouver, Fraser Valley, and the Capital Regional District. Table 1 shows the twenty municipalities that met both criteria and that in aggregate comprise the study group, maps each of the municipalities relative to one another, and provides their 2007 population estimates.

As this is an exploratory study we only review some general characteristics of the case-study municipalities and undertake descriptive analysis and some preliminary correlation analysis of a small set of variables described in Table 2. Our variables are broadly categorized as 1) municipal characteristics such as population and population growth; 2) prior planning activities such as completion of a CEEP, and 3) characteristics of municipal GHG emissions-reduction targets such as the target year and the percentage reduction. Table 2 describes the variables and shows the sources we used to retrieve or generate the data for the series of steps outlined below.

As mentioned above, our primary purpose here is to understand the general characteristics of GHG emissions-reduction targets and to determine the progress they have made toward achieving provincial GHG emissions-reductions targets. To address this question, we undertook the following six steps:

1. **Collected 2007 baseline GHG emissions data.** We used the Updated 2007 CEEI reports for each municipality in the study group, with the exception of Vancouver. Since Vancouver was the only municipality to include emissions-reduction targets with a 1990 baseline, we used the City of Vancouver’s (2009) self-reported 1990 emissions.

2. **Collected current GHG emission-reduction targets for study group.** We then collected data on GHG emissions-reduction targets for each municipality in the study group, many of which have incorporated the targets into their respective OCP (as mandated by Bill 27). However, a few municipalities are still in the process of updating their OCPs and have either included their targets in other documents or do not yet have targets at all. To help us determine the extent of prior climate protection planning work (if any) behind each municipality’s selection of its GHG emissions-reduction target, we also examined corporate and municipal climate-action plans and related documents, including relevant council minutes and documents.

3. **Normalized GHG targets to allow for cross-municipal comparisons.** Our initial review of municipal GHG targets revealed that a number of jurisdictions chose to adopt the province’s emissions-reduction target of 33% of 2007 levels by 2020 and 80% by 2050. However, several municipalities formulated their own targets that vary in terms of the target year and target type. Of the twenty cities, sixteen set targets that specify a reduction amount and target “maturity” year. One specifies a reduction target without a deadline. The final three have not incorporated a target into their OCPs and did not file a target

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4 Many municipalities used either their own baseline-emissions estimates or estimates from the 2007 Draft CEEI report produced by the Ministry of Community and Rural Development in BC.

5 Corporate emissions here refer to the municipality’s internal operations as opposed to policies it enforces through development permits and building permits.
with the BC Ministry of Rural and Community Development by the deadline. As a result of these discrepancies, we found it necessary to normalize the targets for comparability. We used the province’s CEEI data to determine the 2007 emission and population values for all cities except Vancouver, for which we used its base year of 1990 and its self-reported emission and population data for that year. We determined each municipality’s emissions-reduction goal from its OCP or council reports and used the emissions-reduction goals and baseline tonnes of carbon dioxide equivalents (tCO₂e) to calculate the city’s target emissions by reduction-target year. We calculated the rate of total emissions reduction by plotting each city’s emissions-reduction targets and used linear regression to calculate an emissions value for each city for the years 2020 and 2050. For steps 3 and 4 we estimate future emissions for each city based on the assumption that it will succeed in meeting its targets.

4. Estimated per capita GHG emissions for each city in 2050. The per capita emissions for 2020 and 2050 were calculated by dividing the estimated aggregate emissions by estimated population. In all cases, we used historical census data and linear regression of estimates from the years indicated below to approximate future populations for the years 2020 and 2050. For BC’s population we employed provincial government estimates for 2012, 2016, and 2020 (BC Stats, 2011). For municipalities in the Metro Vancouver Regional District, we used population projections for 2021, 2031, and 2041 provided by the Regional District (Metro Vancouver, 2009). For municipalities in the Fraser Valley Regional District, we relied on population estimates made for the District by a consultant’s report for the years 2013, 2016, 2019, 2022, 2025, 2028, and 2031 (Urban Futures, 2005). For municipalities in the Capital Regional District, we used population estimates reported in Victoria’s OCP for 2020 (City of Victoria, 1995) and Saanich’s OCP

### Table 1 British Columbia Municipalities in Study Group.

| Map legend | Municipality            | Population in 2007 | Municipalities in case group (dark red is highest population and light pink is lowest) |
|------------|-------------------------|--------------------|--------------------------------------------------------------------------------------|
|            | **Metro Vancouver Regional District** |                    |                                                                                       |
| 1          | Burnaby                 | 214,919            |                                                                                       |
| 2          | Coquitlam               | 120,249            |                                                                                       |
| 3          | Delta                   | 99,293             |                                                                                       |
| 4          | Langley, City           | 25,167             |                                                                                       |
| 5          | Langley, Township       | 99,012             |                                                                                       |
| 6          | Maple Ridge             | 72,502             |                                                                                       |
| 7          | New Westminster         | 61,778             |                                                                                       |
| 8          | North Vancouver, City   | 47,277             |                                                                                       |
| 9          | North Vancouver, District | 85,966        |                                                                                       |
| 10         | Port Coquitlam          | 54,971             |                                                                                       |
| 11         | Port Moody              | 29,945             |                                                                                       |
| 12         | Richmond                | 186,376            |                                                                                       |
| 13         | Surrey                  | 422,873            |                                                                                       |
| 14         | Vancouver               | 610,136            |                                                                                       |
| 15         | West Vancouver          | 42,973             |                                                                                       |
|            | **Fraser Valley Regional District** |                    |                                                                                       |
| 16         | Abbotsford              | 131,239            |                                                                                       |
| 17         | Chilliwack              | 73,294             |                                                                                       |
| 18         | Mission                 | 36,280             |                                                                                       |
|            | **Capital Regional District** |                  |                                                                                       |
| 19         | Saanich                 | 112,062            |                                                                                       |
| 20         | Victoria                | 81,649             |                                                                                       |
for 2026 (District of Saanich, 2008). Inconsistency in the years for which we have population estimates, as well as the potentially different methods used in arriving at the respective estimates, is a limitation of this per capita calculation. However, 75% of the cities studied are in Metro Vancouver for which we used a single source for estimates, and we have detailed estimates for three of the remaining five cities.

5. **Determined correlation between variables.** We conducted Pearson product moment correlation analyses to measure the linear dependence between each pair of variables. To better understand the overall response of the case-study group to the requirement of having to set targets, we measured associations between most of the variables in Table 1. For the target variables, we only used the baseline emissions, annual reductions, percent of annual reductions, and target

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**Table 2 Variables.**

| Variable Type | Name | Description | Source |
|---------------|------|-------------|--------|
| **Municipal Characteristics Relevant to Emissions** | Population | Municipal population in 2007 |  |
| | Population growth | Population growth from 2001 to 2006 expressed as a percentage of 2001 | Calculated from census |
| | Density population | Number of people per square kilometer | Calculated from 2006 census |
| | Single-family homes | Percentage of homes that are single-family detached dwellings (this is a second indicator of density) | Calculated from 2006 census |
| | Drivers | Percentage of employed persons who drive to work | Calculated from 2006 Census |
| **Prior Planning Related to Emissions Reductions** | CEEP | Community Energy and Emissions Plan | Publicly accessible documents |
| | PSC-Score | BC Hydro’s Power Smart Community Score | Publicly accessible documents |
| | PCP Milestone | Partners for Climate Protection sum of corporate and community milestones | Publicly accessible documents |
| **Characteristics of Municipal Targets** | 2007 emissions | Municipal CO$_2$ emissions from buildings, on-road transportation, and solid-waste sectors in 2007, measured in tonnes of CO$_2$ equivalent (tCO$_2$e) | BC Community Energy Emissions Inventory |
| | Annual reduction | tCO$_2$e per capita per year | Calculated |
| | 2020 emissions | Estimated 2020 emissions, both aggregate and per capita | Either adopted target or projected from nearest target date |
| | 2050 emissions | Estimated 2050 emissions, both aggregate and per capita | Either adopted target or projected from nearest target date |
| | Target type* | Municipal GHG emissions-reduction target. | Publicly accessible documents |
| | | • “Provincial” indicates that the municipality adopted the provincial target (i.e., a 33% reduction from 2007 levels by 2020, and an 80% reduction from 2007 levels by 2050). | |
| | | • Unless otherwise noted, “Modified Provincial” indicates that the municipality adopted only the Province’s 2020 target. | |
| | Reduction type | Whether the target reduction is expressed as an aggregate number for all emissions from the municipality or as a per capita value for each resident | Publicly accessible documents |
| | Date target adopted into OCP | Whether the target has been incorporated in the local governments’ OCP as of September 2010 | Publicly accessible documents |
| | Annual reduction in tCO$_2$e/capita | The value of the annual reduction | Calculated using emissions targets and population projections |
| | Percentage annual reduction | Percentage reduction from 2007 per capita levels (with the exception of Vancouver which references 2000 levels) to either 2020 levels or 2050 levels | Calculated using emissions targets and population projections |

* A related variable is “Reduction value,” which is the manner in which the value of the municipal GHG emissions target is expressed. Because all municipalities used relative values that were expressed as a percentage reduction compared to a base year and only two used absolute values (Langley & Saanich), expressed as a specific number of tCO$_2$e, in addition to the relative value, our analysis did not include this variable.
types and 2050 estimated emissions. Using OpenStat software (Miller, 2012) we ran the following product moment correlation calculation:

\[ r_{x,y} = \frac{\sum_{i=1}^{N} Z_x i Z_y i}{N} \]  

(1)

where \( Z_x \) and \( Z_y \) are the variables converted to z scores. To test the null hypothesis of zero correlation between variables we used:

\[ t = \frac{r}{\sqrt{1 - r^2}} \sqrt{n - 2} \]  

(2)

6. **Calculate cumulative effects of targets in 2050.** We used our estimates for 2050 population figures and per capita emissions for each city to calculate the total emissions across the region and divided by the sum of the population figures to determine what the regional per capita emissions would be if each city achieved its targets. In the case of cities with earlier targets, we assumed a constant linear (arithmetic) progression, with the exception of Victoria and Saanich. These two cities would achieve zero emissions if they continued along the trajectory of their 2020 targets. We therefore assumed that emissions reductions would stop when they reach 80% below the aggregate 2007 levels for Victoria and Saanich. We then compared the regional cumulative per capita emissions to the province’s per capita target as well as the IPCC’s one tonne CO\(_2\)e per capita per year recommendation. The CEEI methodology document warns against comparing community-level emission inventories to the province’s GHG inventory by describing such a comparison as “inappropriate” (British Columbia Ministry of Environment, 2007). For example, some of the province’s industrial- and resource-extraction emissions are not captured by any local government and therefore skew provincial per capita emissions relative to municipal ones. However, the Ministry of Community and Economic Development also expects that a certain share of municipal-emissions reductions would be the responsibility of the provincial and federal governments through their own emissions and energy-performance laws and infrastructure programs. Therefore, the “extra” resource-extraction emissions that the provincial per capita values include, which are not included in municipal-emissions values, might be cancelled out by the “extra” reduction that the provincial and federal governments would enable. Consequently, we judged that a comparison of per capita emissions would be instructive. It would at least reveal the general proximity of the municipal targets to the provincial targets and would help answer our question about the cumulative effectiveness of the targets.

**Findings**

In this section we report our findings in terms of each of the methodological steps outlined above. Table 3 shows the general response to GCA by each of the municipalities in the study group. Responses to the setting of targets range widely, with a number of cities choosing to adopt the province’s own reduction target. Fifteen municipalities adopted emissions targets in their OCPs by the deadline of May 2010. Complete compliance with the legislation was therefore achieved by 75% of the local governments. Another municipality adopted a target one month late. Two more have set targets but have not yet adopted them officially into their OCPs. Only two of the twenty cities did not set any community targets, but one of these set corporate targets for the city’s own operations. Therefore, only one city does not show any public record of any emissions-target planning of any sort. Burnaby stands out as having adopted a target without a target date.

In addition to the wide range of emissions-target setting displayed in Table 3, when we tabulated the baseline releases, calculated emission levels at target years, and normalized for the years 2020 and 2050, we found quite a range of responses. Table 4 shows the normalized values at the provincial target milestones. Comparing the per capita values, we can see that in 2007 emissions ranged from 3.65 tCO\(_2\)e in Saanich to more than twice that amount of 9.22 tCO\(_2\)e in Delta. The 2050 per capita values are also wide-ranging, with the standard deviation of 2.28 being larger than the mean value of 2.18. The annual per capita percentage drop in emissions, which represents the rate of change of emissions, ranges from 0.74% in the City of Langley to 2.92% in the Township of Langley (these are different municipalities, see Table 4). It is noteworthy that these two extremes in annual percentage reductions come from adjacent cities. As Table 1 shows, the City of Langley is nested within the much larger Township of Langley.
The correlation analysis revealed a number of strong associations with low probability of error. The strongest correlations occur within the variable groupings. For example, as one might expect, there is a strong correlation between annual reductions in emissions, percentage reductions in emissions, and ultimate emissions in 2050 (see bottom right portion of Table 5 segments). There is also a strong negative correlation between the percentage of workers who drive to work in a municipality and the density of that municipality, both in terms of people per square kilometer and the percentage of detached houses (see top left segments of Table 5). This confirms expectations from the literature. Similarly, the strong correlation between 2007 emissions and the percentage of workers who drive to work supports general findings that automobile emissions are a significant component of overall community emissions. A strong correlation that confirms our expectations is that if a municipality completes a CEEP it will likely set its own targets and not merely adopt the provincial targets. If communities set and manage to achieve their own targets, they have larger annual reductions and ultimately lower 2050 emissions.

If all the targets set by all the municipalities were met then the cumulative effect would result in regional per capita emissions of 2.15 tCO₂e even if we include no reductions by those municipalities that have not yet set targets. If we exclude those municipalities and only calculate for those that have already set targets, then the cumulative per capita emissions are 1.36 tCO₂e (see Table 6). This number is useful for understanding the regional response in the event that the municipalities without targets eventually set targets in line with those already adopted by others.

**Discussion and Conclusion**

We found no clear pattern linking the characteristics of communities in BC with levels of target setting. More specifically, there is no correlation between baseline emissions, population, rate of growth, density, and the types or intensities of targets. There is therefore no evidence that the relationships we hypothesized exist with the exception of prior planning activity. Those municipalities that completed CEEPs tended to set their own targets. Additionally, there is a significant and high correlation between setting

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**Table 3 Summary of GHG Targets by Municipality.**

| Municipality          | GHG Target                                                                 | Reduction Type | Date Target Adopted in OCP |
|-----------------------|---------------------------------------------------------------------------|----------------|-----------------------------|
| British Columbia      | 33% by 2020 & 80% by 2050 below 2007                                      | A              | N/A                         |
| Metro Vancouver       |                                                                           |                |                             |
| Burnaby               | 5% below 2007 with no target date                                         | A              | May 3 2010                  |
| Coquitlam             | 15% by 2021 & 30% per capita by 2021 below 2007                          | A & PC         | May 10 2010                 |
| Delta                 | Provincial                                                                | A              | May 10 2010                 |
| Langley               | 20,992 tCO₂e below 2017 forecast, 16% below 2007                         | A              | May 31 2010                 |
| Langley, Township of  | 10% below 2007 by 2021                                                   | PC             | May 3 2010                  |
| Maple Ridge           | Provincial                                                                | A              | May 11 2010                 |
| New Westminster       | None (Corporate only)                                                     |                | N/A                         |
| North Vancouver, City | 15% by 2020 and 50% by 2050 below 2007                                    | A              | May 17 2010                 |
| North Vancouver, District | 8% by 2020, 13% by 2030, and 21% by 2050 below 2007                  | A              | Not yet adopted             |
| Port Coquitlam        | 8% below 2007 by 2017                                                    | A              | May 25 2010                 |
| Port Moody            | 10% below 2007 by 2017                                                   | A              | Not yet adopted             |
| Richmond              | Provincial                                                                | A              | May 17 2010                 |
| Surrey                | Modified Provincial¹                                                      | PC             | May 17 2010                 |
| Vancouver             | Modified Provincial²                                                      | A              | May 20 2010                 |
| West Vancouver        | Provincial                                                                | A              | June 21 2010                |
| Fraser Valley         |                                                                           |                |                             |
| Abbotsford            | 20% by 2025 and 45% by 2040 below 2007                                    | PC             | May 10 2010                 |
| Chilliwack            | None                                                                      |                | N/A                         |
| Mission               | Modified Provincial³                                                      | A              | May 17 2010                 |
| Capital               |                                                                           |                |                             |
| Saanich               | Modified Provincial                                                      | A              | May 17 2010                 |
| Victoria              | Modified Provincial                                                      | A              | May 13 2010                 |

¹ Provincial targets on per capita basis: 3.29 tCO₂e per capita by 2020 and less than 0.98 tCO₂e by 2050.
² Reduce community emissions by 33% below 2007 levels by the end of 2020 and 80% below 1990 levels by the end of 2050.
³ Reduce community emissions by 20% below 2007 levels by the end of 2020 and 80% below 2007 levels by the end of 2050.
Victoria and Saanich each set targets of 33% below 2007 by 2020. They did not set additional targets, but if they continued
** Linear trend calculated for 2020 and 2050 emissions and population. Per capita 2020 and 2050 emissions calculated by di
Note: Average rate of emissions reduction for entire study group is 0.12 tCO2e per capita per year.

However, our hypothesis that prior climate protection
Protection Program (PCP participation) had no im-
impact on the targets that cities set in our analysis. Nevertheless, we see from
Table 4 that the City of North Vancouver has the thirteenth highest 2050 per capita target which, out of

| Municipality | 2007 Emissions | 2020 Emissions | 2050 Emissions | % Annual Reduction from 2007 Emissions |
|--------------|---------------|---------------|---------------|--------------------------------------|
|              | Aggregate     | Per Capita    | Aggregate     | Per Capita    | Aggregate     | Per Capita    |                              |
| British Columbia | 1,298,362     | 6.04          | 45,081,000    | 8.76         | 13,460,000    | 1.94          | 0.31                     |
| Metro Vancouver |
| Burnaby      | 650,213       | 5.41          | 621,778       | 3.64         | 509,888       | 1.78          | 0.12 2.22               |
| Coquitlam*   | 915,158       | 9.22          | 613,156       | 5.63         | 183,032       | 1.41          | 0.17 1.84               |
| Delta        | 172,441       | 6.85          | 136,573       | 4.42         | 53,802        | 1.22          | 0.20 2.92               |
| City of Langley* | 805,271     | 8.13          | 1,049,869     | 7.36         | 1,614,327     | 6.63          | 0.06 0.74               |
| Langley, Township of* | 362,616 | 5.00          | 242,953       | 2.57         | 72,523        | 0.49          | 0.10 2.00               |
| Maple Ridge  | 285,135       | 4.62          | 194,635       | 3.91         | 114,491       | 1.56          | 0.08 1.65               |
| New Westminster | 411,908      | 4.79          | 378,955       | 3.92         | 325,409       | 2.68          | 0.05 1.04               |
| North Vancouver, City of | 315,797      | 5.74          | 282,954       | 4.23         | 207,163       | 2.19          | 0.12 2.09               |
| North Vancouver, District of | 130,587      | 4.36          | 113,611       | 3.03         | 74,435        | 1.00          | 0.11 2.52               |
| Port Coquitlam* | 1,153,658    | 6.19          | 772,951       | 3.50         | 230,732       | 0.77          | 0.12 1.94               |
| Port Moody*   | 2,399,002     | 5.67          | 1,826,221     | 3.29         | 820,450       | 0.98          | 0.10 1.76               |
| Richmond     | 2,943,222     | 4.82          | 1,971,959     | 2.98         | 547,000       | 0.70          | 0.08 1.66               |
| Surrey       | 275,405       | 6.41          | 192,784       | 3.77         | 55,081        | 0.86          | 0.12 1.87               |
| Fraser Valley |
| Abbotsford*  | 1,028,472     | 7.84          | 861,392       | 4.70         | 443,222       | 1.00          | 0.17 2.17               |
| Chilliwack   | 534,085       | 7.29          | No set targets |             |               |               |                         |
| Mission      | 239,681       | 6.61          | 191,750       | 3.35         | 47,937        | 0.49          | 0.13 1.97               |
| Capital      |
| Saanich**    | 409,027       | 3.65          | 274,048       | 2.37         | 0            | 0.00          | 0.10 2.74               |
| Victoria**   | 382,412       | 4.68          | 256,216       | 2.95         | 0            | 0.00          | 0.13 2.78               |

Note: Linear trend calculated for 2020 and 2050 emissions and population. Per capita 2020 and 2050 emissions calculated by dividing estimated emissions amount by estimated future population.

** Victoria and Saanich each set targets of 33% below 2007 by 2020. They did not set additional targets, but if they continued this percentage reduction trend then their 2050 emissions would be zero.

independent targets and setting aggressive reduction targets. If those cities that established their own targets managed to achieve those objectives, they are estimated to ultimately have lower emissions in 2050 than cities that adopted the province’s targets. This is somewhat supported by the weak direct correlation of 0.32 at 83% significance between CEEPs and the percentage of 2007 emissions reduced annually (see Table 5).

We found a similar correlation of −0.315 at 82% significance between BC Hydro’s PowerSmart Community Score (PSC-Score) and estimated 2050 emissions. Participation in the Partners for Climate Protection Program (PCP participation) had no impact on the targets that cities set in our analysis. However, our hypothesis that prior climate protection planning activity results in more ambitious targets is somewhat supported by our findings for two of the three programs. This suggests that at least the CEEPs and the PowerSmart Community Score not only helped municipalities overcome initial barriers to target setting, but they may have in fact led to more ambitious objectives. We assume this direction of causality because, while all cities amended their OCPs to include GHG reduction-target amendments in 2010, almost all participation in climate-protection planning occurred prior to the enactment of GCA in 2007. It is therefore more likely that climate-protection planning prompted the setting of more ambitious targets and not the other way around. However, given our small sample size, further research with a larger number of communities is required to test the validity of this correlation.

While we did not test for the quality of prior planning activity, one indication of quality is third-party acknowledgement. The City of North Vancouver has won at least two awards for its climate change planning work (CIP, 2010; CEA, 2010) and, perhaps because of its small geographical area and limited opportunities for low-density growth, has undertaken more emissions-reduction planning than other cities in the region. Nevertheless, we see from Table 4 that the City of North Vancouver has the thirteenth highest 2050 per capita target which, out of
Table 5 Correlation Matrix.

| Correlation | > 0.5 / < -0.5 | > 0.3 / < -0.3 |
|-------------|----------------|----------------|
| Population  | 0.177          | 0.402          |
| % population growth | -0.283 | -0.341 | -0.052 |
| People per square kilometer | 0.748 | 0.468 | 0.044 |
| % detached homes | 0.092 | -0.12 | -0.136 |
| % drivers to work | 0.279 | 0.694 | 0.617 |
| Completed CEEP | 0.32 | -0.386 | 0.051 |
| PSC-Score | 0.873 | 0.406 |
| PCP participation | 0.765 | 1.863 | 1.54 |
| Provincial or own target | 0.026 | 0.169 | 0.978 |
| Per capita or aggregate | 0.605 | 0.694 | 0.617 |
| Annual reduction in emissions | 0.123 | 0.78 | 1.234 |
| % of 2007 reduced annually | 0.751 | 0.559 |
| 2050 estimated emissions | 0.871 | -0.751 |

For probability of correlation > 0 (shading tracks significance from above):

| Population  | 0.765 | 1.863 | 1.54 | 0.22 | 4.789 | 2.25 | 0.188 | 0.394 | 0.513 | 0.58 | 0.4 | 0.509 |
|-------------|-------|-------|------|------|-------|------|-------|-------|-------|------|-----|------|
| % population growth | 0.702 | 0.432 | 0.793 | 1.623 | 0.124 | 0.364 | 0.296 | 2.287 | 0.569 | 1.079 | 0.526 | 0.123 |
| People per square kilometer | 9.46 | 8.44 | 0.291 | 2.17 | 2.919 | 0.832 | 0.854 | 2.231 | 0.738 | 0.092 | 0.572 |
| % detached homes | 0.584 | 0.334 | 2.264 | 2.052 | 0.964 | 1.052 | 2.264 | 0.465 | 1.65 | 0.571 |
| % drivers to work | 0.402 | -0.528 | 0.055 | -0.315 | 0.582 | 0.214 | 0.453 | 1.659 | 0.171 |
| Completed CEEP | 0.293 | 0.187 | 0.289 | -0.038 | 0.162 | 0.157 | -0.315 |
| PSC-Score | 0.377 | 0.300 | -0.313 | -0.14 | 0.012 | -0.142 |
| PCP participation | 0.380 | -0.091 | 0.632 | 0.751 | -0.559 |
| Provincial or own target | 0.279 | -0.181 | 0.279 |
| Per capita or aggregate | 0.187 | 0.72 | 0.137 | 0.473 | 0.497 | -0.418 |
| Annual reduction in emissions | 0.871 | -0.751 |
| % of 2007 reduced annually | 0.873 |
| 2050 estimated emissions | 1 |

For probability of correlation > 0 (shading tracks significance from above):

| Population  | 0.454 | 0.079 | 0.227 | 0.141 | 0.828 | 0 | 0.037 | 0.853 | 0.699 | 0.614 | 0.569 | 0.694 | 0.617 |
|-------------|-------|-------|------|------|------|----|-------|-------|-------|-------|------|------|------|
| % population growth | 0.492 | 0.671 | 0.438 | 0.122 | 0.903 | 0.72 | 0.771 | 0.035 | 0.576 | 0.295 | 0.605 | 0.903 |
| People per square kilometer | 0 | 0 | 0 | 0.774 | 0.044 | 0.009 | 0.417 | 0.405 | 0.039 | 0.47 | 0.927 | 0.575 |
| % detached homes | 0 | 0.042 | 0.036 | 0.055 | 0.346 | 0.307 | 0.036 | 0.647 | 0.871 | 0.575 |
| % drivers to work | 0.055 | 0.691 | 0.176 | 0.007 | 0.297 | 0.978 | 0.472 |
| Completed CEEP | 0.581 | 0.073 | 0.038 | 0.066 | 0.329 | 0.44 | 0.169 | 0.754 |
| PSC-Score | 0.21 | 0.42 | 0.217 | 0.874 | 0.509 | 0.177 |
| PCP participation | 0 | 0.102 | 0.189 | 0.179 | 0.565 | 0.051 |
| Provincial or own target | 0.098 | 0.704 | 0.003 | 0.013 |
| Per capita or aggregate | 0.272 | 0.124 | 0.026 | 0.066 |
| 2007 estimated emissions | 0.233 | 0.446 | 0.233 |
| Annual reduction in emissions | 0 |
| % of 2007 reduced annually | 0 |
| 050 estimated emissions | 0 |

Senbel et al.: Local Responses to Regional GHG Targets

Twenty cities, is arguably not very effective for having invested so much in climate-change planning. This finding suggests that while some prior climate-change planning work may lead to strong target setting, detailed climate-action planning leads to a more conservative and perhaps a more realistic approach to target setting. Future research is needed to test this hypothesis. In addition, since our study did not test the quality of the plans and policies that are intended to help achieve the targets, the relationship between prior planning activity and the ultimate robustness and feasibility of the targets is unknown.
Our finding about compliance with GCA challenges our starting assumptions and disproves our first hypothesis, that noncompliance would be rampant. With 75% of municipalities having complied completely by setting and adopting targets and 90% having complied by setting targets, we can reasonably declare that BC’s legislation has effectively prompted the widespread adoption of targets among the municipal governments in our case-study group. For legislation that has no built-in mechanism of enforcement, this level of compliance is a positive signal for other jurisdictions that might seek to enact flexible legislation that is likely to be politically feasible. However, not all targets set by municipalities in the study group would result in sufficiently low per capita emission levels to help regional targets. For example, the Township of Langley has set per capita targets that would result in only slightly lower per capita emission in 2050 and aggregate emissions that are higher than in 2007. This type of compliance with GCA does nothing to advance provincial emissions reductions and, if it occurred with greater frequency, would call into question the effectiveness of this kind of flexible legislation.

Most municipalities set targets that would result in 2050 emissions lower than two tCO₂e. As Figure 1 shows, fourteen of the twenty municipalities in the case-study group set targets that would result in per capita emissions lower than the province’s 2050 per capita target. While the cumulative effect if each municipality achieved its target does not place the region within the IPCC’s recommendation of one tCO₂e per capita, it would in fact lead to the desired regional goals. The cumulative 2050 emissions of all cities that did set targets is 1.36 tCO₂e, well below the province’s per capita 2050 target of 1.94 tCO₂e.

One of the challenges to the regional response is the disparity of target emissions between adjacent municipalities. As cities attempt to implement emissions reductions through land-use and transportation changes, if adjacent cities are not engaged in similar activities then the effectiveness of the targets may be reduced. This highlights the importance of coordinated regional planning and policy alignment.

Table 6 Cumulative effect on regional per capita emissions.

| Metro Vancouver          | Targeted 2050 Emissions | Estimated 2050 Population* |
|--------------------------|-------------------------|----------------------------|
| Burnaby                  | 2,582,100,427,500       |
| Coquitlam                | 509,888,286,454         |
| Delta                    | 183,032,129,810         |
| Langley                  | 53,802,44,100           |
| Langley, Township of*    | 1,614,327,243,488       |
| Maple Ridge              | 72,523,148,006          |
| New Westminster          | 589,050,127,500         |
| North Vancouver, City of| 114,491,73,392          |
| North Vancouver, District| 325409,121,421          |
| Port Coquitlam           | 207,163,94,595          |
| Port Moody               | 74,435,74,435           |
| Richmond                 | 230,732,299,652         |
| Surrey                   | 820,450,837,194         |
| Vancouver                | 547,000,781,429         |
| West Vancouver           | 55,081,64,048           |

| Fraser Valley            | Targeted 2050 Emissions | Estimated 2050 Population* |
|--------------------------|-------------------------|----------------------------|
| Abbotsford               | 443,222,443,222         |
| Chilliwack               | 1,703,891,233,730       |
| Mission                  | 47,937,97,831           |

| Capital Regional District| Targeted 2050 Emissions | Estimated 2050 Population* |
|--------------------------|-------------------------|----------------------------|
| Saanich**                | 81,805,115,587          |
| Victoria**               | 76,482,156,365          |

Total excluding “No-Target Cities” 5,457,779, 4,011,028
Total assuming “No-Target Cities” maintain 2007 emissions 10,332,821, 4,799,758
Cumulative per capita emissions for 2050 excluding “No-Target Cities” 5,457,779/4,011,028 = 1.36 tCO₂e/capita
Cumulative per capita emissions for 2050 including all cities assuming “No-Target Cities” maintain 2007 Emissions levels 10,332,821/4,799,758 = 2.15 tCO₂e/capita
* Population projections calculated using mean annual growth rates for years included in Metro Vancouver and British Columbia projections.
* Did not set targets by December 2010. Emissions for 2050 were calculated as a product of 2007 per capita emissions and calculated 2050 population projections.
* Comprises Burnaby, Chilliwack and New Westminster.
* 2050 population and emissions were projected from earlier target dates.
** Set 2020 projections only, which, if extended would lead to zero emissions by 2050. Instead, we assumed emissions reduction would stop after reaching 80% below 2007 levels.

Figure 1 Estimated 2007, 2020, and 2050 per capita emissions for studied cities in British Columbia.
and feasibility of transforming transportation patterns is likely to be undermined. This impediment is exemplified by the divergent planning trajectories of the City of Langley and the Township of Langley. This situation also calls for an important next stage in this research; a closer examination of specific implementation strategies by each city and of the regional planning efforts that might facilitate local emissions reductions.

Future research might also address the institutional and political context within which target setting takes place. Why is it that some municipalities chose not to comply with the legislation? Are they simply on a different schedule and taking advantage of the legislation’s flexibility? Do they deliberately ignore it to assert their independence? Or do they disagree with it? What caused the others to set the targets that they did? Was it political expediency or strategic planning? Our initial and informal conversations with planners suggest that all of these factors may have been at work. To answer these questions rigorously would require undertaking qualitative research involving interviews of planning staff and decision makers. Additional investigations could also include a larger sample of cities in BC to enable better statistical analysis.

Upon examining the normalized GHG targets for the twenty municipalities in terms of annual per capita emissions, this research finds that GCA in BC has resulted in discernible progress in climate-change planning. Analyzing the general characteristics of the targets reveals that the flexibility of the legislation is both a strength and a weakness. Its major weakness is that it is so flexible that a number of high-emitting municipalities have made little or no serious effort toward emissions reductions. The strength of this approach is that a majority of local governments have already incorporated language about climate-change mitigation into their OCPs. It appears that the first step toward reduced emissions, that of altering the culture of planning, may have been achieved.

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Biofuels: a contested response to climate change

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Biofuels have received increased attention in recent years as renewable alternatives to fossil fuels in the steadily growing transportation sector. Simultaneously, the impact of biofuel technologies has been highly disputed in public debates, where their introduction is alternately presented as a solution to energy-supply and climate-change problems or as a source of environmental and social difficulties. Through qualitative interviews, this article analyzes the Danish public's attitudes toward biofuels. Particular attention is given to popular perceptions of risks and uncertainties associated with biofuels and to problem-solving responsibilities in relation to climate change. The study illustrates the complexity of the concerns involved with the issue, indicating a positive attitude toward biofuels when respondents perceive them as beneficial for climate and the environment. However, when introduced to problems associated with biofuels, respondents modified their support, conditioning acceptance on the viability of solutions. They also demanded interventions with respect to the problem of climate change and asked for decision making based on factual knowledge and democratic discussions at global and local levels.

KEYWORDS: renewable energy resources, public awareness, transportation, environmental perception

Introduction

Unlike Europe, Brazil has produced ethanol (from sugar cane) for many years, starting in the 1930s. In 1975, Brazil implemented the National Alcohol Program in response to worldwide oil- and sugar-market crises and, in 1979, began mass production of dedicated ethanol vehicles (Soccol et al. 2005; Matsuoka et al. 2009). The United States also has had experience with ethanol production, and over the last decade biofuels have become the most common source of alternative energy in the American transportation sector. In 2008, the United States produced nine billion gallons (one gallon = approximately 3.8 liters) of biofuels, compared to only 1.4 billion gallons in 1998 (Delshad et al. 2010; Sorda et al. 2010).

In Europe, biofuel technologies have received renewed attention over the past few years partly because of their promise to reduce carbon-dioxide (CO₂) emissions from transportation sources and partly because of questions concerning energy-supply security (Ryan et al. 2006). Biofuels have not yet been introduced on a larger scale in either the European Union (EU) or Denmark, but in 2007 EU governments set a target of substituting 10% of all land-based transportation fuels with biofuels by 2020 (European Commission, 2007). In 2009, the European Commission introduced a more moderate EU Renewable Energy Directive, mainly in response to rising concern and criticism regarding the biofuel target and its impacts on sustainable development.

The Directive retained the 10% objective, but also included any renewable energy source (or combination) in total transportation-energy supply (European Union, 2009). To comply, Denmark has introduced mandatory addition of biofuel in all land transport fuels up to 5.75% in 2012 (Klima- og Energiministeriet, 2011). Nevertheless, biofuels and their use for transportation remain debated in Denmark and internationally, with initial public support for biofuel technologies all but given.

The question of how people relate to the prospect of using biofuels to reduce CO₂ emissions from transportation vehicles, and particularly the risks and uncertainties associated with large-scale biofuel production, provides the point of departure for this article. We address issues associated with this energy source through qualitative sociological analysis based on both individual and focus-group interviews.

We begin with a short outline of the study’s background and methodology. This is followed by an analysis in three sections. First, we discuss the issue of biofuels as a response to climate change in relation to perceptions of risk and uncertainty. Second, we take a closer look at how people relate to biofuels as a potential solution to climate change. Third, we examine the ways in which people engage with problem solving and apportion responsibility for biofuels and other potential solutions to the problem of climate change: Who is perceived to be responsible for “doing something,” both for making the complex choices among prospective interventions and for putting...
strategies into practice. The final section consists of a closing analysis and discussion.

Background

The EU targets for biofuel substitution have raised questions about the technology’s advantages and disadvantages, and the targets are still subject to discussion among governments. In Denmark, as in other countries, the debate has appeared regularly in the public media as well. Proponents argue, for instance, that Denmark can cover a large proportion of its energy needs in an increasingly energy-consuming transport sector with biofuels. Although in the long run, hydrogen may be the solution to oil dependence, it may be necessary to opt for other alternatives before then. Biofuel for transport is also a good alternative for the environment (Vedelsby, 2007).

By contrast, opponents fear that millions of hectares of rain forest, natural areas, and farmland will be converted into monocultures with the sole purpose of providing raw materials for [biofuel] plants. This may have disastrous consequences for the climate, the local communities, and especially the security of food supplies (Skøtt, 2007).

Complicating the debate is that the term “biofuel” does not refer to a single, fully developed technology or even a single, uniform type of fuel. All biofuels are energy sources derived from biomass, but the liquid biofuels considered for use in transportation can be divided into several types and subtypes according to the kind of biomass and the technologies used for their production. Biofuels for transportation comprise both bioethanol made from sugar components of plant material as a substitute for gasoline and biodiesel made from plant oils or animal fats as a substitute for fossil diesel. A further distinction can be made between so-called first, second, and third generation biofuels.

First generation biofuels are made from conventional food or feed crops using already existing technologies. The typical feedstock used is sugar cane, wheat grains, or corn seeds for bioethanol and rape, sunflower, or palm oils for biodiesel. Second generation biofuels require development of new technologies where cellulose (and eventually lignin) can be used as raw materials. These biofuels are made from nonfood crops, including organic waste, wheat stalks, wood, and specific energy crops such as willow. A third generation of biofuels made from algae culture is considered promising for the future, but needs to be developed further (Benemann, 2008). The diversity of technologies and crops in question makes it difficult to evaluate the advantages and disadvantages of biofuels in comparison with fossil fuels, as well as with other fuel alternatives, and assessments vary widely.

The debate in Denmark mirrors international discussions. In recent years, a dispute about the sustainability of biofuels has emerged in both Brazil and the United States, where ethanol and biodiesel for transportation have been produced for several decades. Studies of both producers’ responsibility (Huertas et al. 2010) and of the public knowledge of and attitudes toward biofuels (Delshad et al. 2010) suggest that climate and social sustainability are important in the public debate on the continued development and use of biofuels. In Europe, also, the issue of biofuels for transportation is contested and involves several large actors from international political institutions to nongovernmental organizations (NGOs) and private companies with vested economic interests.

The present study looks at how members of the general public relate to arguments for and against biofuels, to the interests behind these arguments, and to the actors involved in the biofuel debate. The aim is not to suggest which specific political and economic decisions need to be made with regard to further biofuel use. Rather, the broader objective is to understand and explain the general public’s reflections and attitudes toward the introduction of a new technology to solve (or at least reduce) climate and other common, often global-scale, problems.

Methodology

As the sociological contribution to a large interdisciplinary project, this study forms part of the broad background for formulation of different biofuel scenarios by exploring perceptions of and attitudes toward the introduction of biofuels for transportation among members of the Danish public. This task presented a major methodological challenge. Biofuel technologies are still at an early stage of practical

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1 All quotes from Danish sources, including the interview material collected as part of the study, have been translated by the authors.

2 This study is part of the project REBECa (Renewable Energy in the Transport Sector Using Biofuels as Energy Carriers), with eight interdisciplinary work packages. Other aspects of this initiative examine various aspects of biofuels including the development of a number of policy scenarios that explicitly seek to address the concerns of political and other decision makers.
implementation in Denmark, and beyond the currently available first generation, second and third generation biofuels are generally at an early stage of technological development. As a result, much uncertainty remains about the various consequences of a large-scale introduction. Moreover, despite policy and media attention, the technologies are still unfamiliar to the general public. Most of the study respondents had little knowledge and meager or no practical or personal experience with biofuels. Against this background, any discussion of responses to a large-scale introduction of biofuels is largely hypothetical.

This situation poses a problem of more general significance concerning the kind of public response or public acceptability studies that seem in high demand whenever political or market stakeholders consider the introduction of new technologies (see Flynn & Bellaby, 2007): How should we investigate public responses to the hypothetical? More specifically, it raises two particularly important questions for this study. First, what are we really studying when interviewing people about biofuel technologies at such an early stage in their domestic implementation? Second, how do we go about asking people about something so uncertain and so unfamiliar to them in a meaningful and scientifically credible way?

**No Pretentions to Fortune Telling**

With regard to the first question, it must be underlined that this study does not aspire to sociological fortune telling. It cannot forecast the development of attitudes toward biofuels among the general public, let alone how and to what extent these attitudes will be reflected in actual fuel-consumption practices. Too many unknown and complicating factors are involved, including the future development of biofuel technologies, the social amplification mechanisms often at work in shaping public opinion (Flynn, 2007), and the everyday dynamics underpinning energy-consumption practices in general (see Shove, 2003). Instead, the study illuminates some of the general mechanisms at play when the public is introduced to a new technology. In fact, the responses to the topic of biofuels we find in this study resemble, to a large extent, reactions to other new technologies, such as those involving hydrogen fuel, described in previous studies (e.g., Ricci et al. 2007).

What we find, then, are general patterns of response to uncertainty of knowledge and technological risk, general relations of trust or distrust, and broad beliefs about influence and responsibility. These patterns are very relevant with regard to understanding public responses to specific technologies in retrospect, and to reflecting critically about whether and how to introduce a new technology, but they are not sufficient to predict public responses with any degree of specificity.

**Data Collection**

With regard to the second question, asking people about something as uncertain and unfamiliar to them as biofuels, an initial choice was made to use qualitative interviews. Valuable attempts have been made to develop quantitative approaches to measuring public perceptions of unfamiliar technologies (see Binder et al. 2012), but a simple, quantitative measure seemed inadequate to capture the full complexity of how the public approaches emerging technologies (see Ricci et al. 2007). While qualitative interviews provide less straightforward answers to issues pertaining to the acceptability or unacceptability of a novel technology, such methods accommodate complexity and ambivalence by allowing room for respondents to explain and clarify the subject matter, the questions asked, and the answers given (see Bellaby, 2007). Moreover, they allow for an open-ended approach in which respondents can give voice to considerations that are not framed by what we or the experts and stakeholders engaged in the biofuel debate would expect or consider critical and relevant (see Ricci et al. 2007).

The choice of qualitative interviews did not, however, eliminate the challenge of eliciting views and perceptions of an uncertain and unfamiliar technology. We deemed it necessary to provide respondents with a presentation of biofuel technologies and the questions and arguments raised in the deliberations over biofuels. This brought to the fore in a very direct way a much-debated question of social enquiry—of whether it is possible to study social “reality” objectively without at the same time shaping this reality (e.g., Blaikie, 2007). Applied to the current case, this becomes a matter of whether it is feasible to conduct research on people’s perceptions of and attitudes toward biofuels without at the same time influencing them on such matters. Interview responses are always created in the interaction between researchers and interviewees, and this is also apparent in the present study. We therefore acknowledge that our presentations and the interview context in general have necessarily framed the responses that we elicited. To avoid shaping responses in a biased way, however, we sought to balance our presentations by giving a fair airing to both positive and negative views of biofuels while at the same time keeping the level of discussion accessible so as not to “blind” respondents with science (see Ricci et al. 2007).

A first step was to form an overview of different biofuel technologies and the diversity of arguments for and against their introduction as an energy source for transportation. As part of this process, we con-
ducted two stakeholder interviews: one with a proponent and the other with an opponent of the large-scale introduction of biofuels for transportation.\(^3\)

For the primary analysis, we convened a focus group and a series of individual interviews with a total of seventeen respondents, selected through telephone screenings based on a random sampling of telephone-book entries. Variation was secured across demographic criteria, including gender, age, household type, educational level, and region of residence.\(^4\)

The overall structure of both the focus group and the individual interviews was the same. The idea of the focus group was to experiment with a more graphic presentation of the interview themes while at the same time encouraging internal debate among the participants (Halkier, 2008)—an obvious choice for a highly contested and controversial subject. During all interviews, respondents were first asked openly about their knowledge and perception of biofuels and their possible experiences with them. Only then were they given a short presentation about biofuel technologies, followed by an introduction to the themes of the interview.

Three main themes concerned possible advantages and disadvantages of a large-scale introduction of biofuels in relation to 1) the environment, 2) security of the energy supply, and 3) social consequences. The respondents were presented with arguments raised in relation to each of these themes. In the focus group, posters showing graphic presentations of biofuel technologies and excerpts of media coverage of the biofuel debate were provided in support. We repeatedly stressed that we were interested in the respondents’ immediate, personal thoughts and views as opposed to those of experts and stakeholders. Two further, more general interview themes were introduced for theoretical and practical perspectives: 1) whom to trust and where to place responsibility with regard to making decisions about the large-scale introduction of biofuels and 2) alternative solutions to the transportation sector’s environmental problems.

The interview material was analyzed thematically according to both the predetermined themes of the interviews and themes that appeared and proved prominent during initial readings of the material. Passages related to each theme were coded and marked in the transcripts for subsequent detailed analysis. In the following, the themes are presented according to their analytical prominence and logic. Focus is on the perceptions and attitudes expressed by participants across the themes as well as how they may be understood in relation to broader theoretical and policy debates.

Finally, the question of representativeness is important when using qualitative methods. The choice of in-depth interviews means that the study is not representative in any statistical sense. Nevertheless, we argue that our findings are analytically generalizable from the standpoint that they reflect broad concerns prominent among members of the public in western societies today and extend beyond the specific Danish context in which we conducted our study. For example, quite concurrent with the findings in this study, a Eurobarometer survey from autumn 2011 reported that 89% of Europeans, an increase from 2009, believe that climate change/global warming is a serious problem. Furthermore, the survey indicated that, like the respondents in the present study, the general public in Europe expects political as well as individual solutions to the problems (Eurobarometer, 2011). Despite differences among EU countries, the similarities are dominant both in this and other environmental questions, and we would argue that our respondents’ concerns are likely to reflect impressions in a broader European context as well. The qualitative approach accommodates the complexity of the subject matter and shows the generality of the specific answers.

**Risk and Uncertainty Under the Prospect of Climate Change**

An important context for the consideration of biofuels for transportation in Denmark, and thus for perceptions and attitudes among the Danish public, is the ever-more urgent question of climate change and the contribution of prevailing mobility practices to it. In recent years, climate-change problems have become increasingly visible and important to people and communities in many parts of the world for a number of reasons.

First, issues pertaining to climate change appear often in the media (Petersen, 2007). We get daily reports on climate disasters, global warming, greenhouse gases, and so forth. Experts of all kinds take part in debates initiated and facilitated by the media. The still more dramatic stories about climate change and the intensive media coverage help to keep climate change on the public agenda (see Carvalho & Burgess, 2005; Petersen, 2007; Jensen, 2011).

Second, politicians and other decision makers in the EU and elsewhere have ventured into the debate. It has become politically expedient to deal with climate change, even in circles that only a few years ago

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\(^3\) Another important step consisted of a literature review to investigate the state of the art in biofuels.

\(^4\) The interviews were conducted in 2008 and the final selection comprised ten women and seven men ranging between 25 and 68 years of age; one student, six with higher educational levels, and ten with lower or no education; three respondents are from Copenhagen, six from the Greater Copenhagen/Zealand area, four from other Danish islands, and four from Jutland.
expressed disdain or indifference. In the scientific community, a general consensus has been established that climate change is at least partly human-induced (see, e.g., Stern, 2007), and this point of awareness, combined with growing public concern, has compelled many leading politicians and other decision makers to seriously address the issue. Agreements are negotiated and meetings held at the highest levels, and only a few political parties reject the problem, although most still find it difficult to identify practical solutions, let alone to implement them.

Finally, tangible phenomena such as warmer weather, exceptionally cold winters, increased precipitation, storms, floods, and so forth have in recent years provided nonexperts with indications that climate change is in fact happening. Climate change is entering a sphere of personal experience for members of the general public when people witness heavier rainfalls, earlier springs, and warmer summers in their own neighborhoods and regions (Petersen, 2007; Jensen, 2011).

The latter point presents an interesting contrast to the observation in German sociologist Ulrich Beck’s (1992) classic work Risk Society, where one important feature characterizing early risk society was that risks were invisible to the senses. Beck based this observation on cases of radioactive pollution, pesticide residues in water and food, and other phenomena that cannot be directly sensed, tasted, smelled, or seen. Against this background, Beck argued that life in early risk society was particularly uncertain because modern risks had been “expropriated from the senses” and people had become dependent on expert knowledge to relate to it (see also Wynne, 1996; Jensen & Blok, 2008). Beck’s point was not that invisible and uncertain risks are ignored, but rather that the basic feature of risk society is the awareness of, or the anxiety about, such hazards.

Although controversial from the start, Beck’s characterization of modern risks as invisible was plausible at the time of its formulation two decades ago when global environmental problems existed mainly in researchers’ observations and measurements and remained largely invisible for members of the general public. Today this has changed, or at least people now interpret phenomena such as record-breaking weather reports as tangible signs of climate change. The interviews in our study illustrate this development. One respondent, for example, expressed her concern about climate change in the following terms:

**Female, 61 years:** But it’s so horrible when we see what it does to our world...Now, with climate change...And that’s more or less a matter of fact now. You know...by now, I’ll say, I have reached a certain age, and...we have seen a lot of water these last few years. And we have seen a lot of heat...Then you start thinking, well there is probably something to it, after all.

For this respondent, the personal experience of changes in weather conditions over the course of her lifetime has given resonance to talk about climate change and prompted a sense of urgency. Later in the interview, she pointed out that it would be in everyone’s interest to deal with the problem, the sooner the better, because, as she put it, “it is our common earth.” Her concern about the consequences of climate change for future generations made her uncertain because she could not see any immediate solutions to the problem. The reason was, she believed, that “we have overconsumption that is totally out of proportion.” In that way she connects (over) consumption with the changes that are happening, but she also expresses uncertainty as to what can be done about the problem while at the same time emphasizing the need to do something. Accordingly, the experience of weather changes is attached to the perception that something is wrong with the environment, and put together this promotes a desire that someone ought to do something about it.

This sensibility of pressing concern was widespread among our respondents. Generally, they talked of climate change as an important and tangible problem, and none of them questioned its reality. Previous uncertainty seemed to a large extent replaced by an awareness of risk and a sense of urgency. However, as the analysis in the following section demonstrates, uncertainty still ruled with regard to what can be done and whether biofuels could be part of a meaningful solution.

**Ambivalence Toward Biofuels**

Given general concern about climate change, most respondents spontaneously reacted with positive associations when the term “biofuels” was introduced to them. Thus, the starting point was positive: “when it starts with ‘bio,’ it must be good,” the rationale seemed to be. One of the respondents put it like this:

**Female, 32 years:** But I think...it is definitely positive that...you give the environment a thought, for example by mixing in 3–5% [biofuels], already now, right? But it’s a good idea!

Particularly, second generation biofuels seemed to appeal to the respondents; they supported the prospect of turning waste into energy. A problem or a
nuiance is converted into a solution. In the words of one respondent:

**Male, 47 years:** Now they’re working on using waste too, right? Then maybe you can solve a waste problem as well, and liq-
uid manure...

However, some of the respondents immediately followed up their initial expressions of optimism about biofuels with comments questioning their viability as a long-term solution, asking what will be the side effects or the drawbacks. Others became increasingly cautious as, over the course of the interview, they were introduced to some of the contested issues in the biofuel debate. As one woman reflected:

**Female, 37 years:** Well, it sounds very easy to think: “Oh, it’s such a good idea” and things like that. And if it can benefit the environment..., but again, if it’s at the expense of something else then maybe you would rather have some other thing that might be more sensible.

This ambivalence between hopefulness and skepticism was in many cases reflected in a demand for more knowledge—and that decisions about whether and how to introduce and implement biofuel technologies should be made on the basis of this knowledge. One respondent put it this way:

**Female, 32 years:** But it seems to me—and this is the alpha and omega—that we have to know things. You know, that you know, maybe not the answer, because there is no final answer, but at least the costs...of things, before you start. No normal people would accept something they didn’t know, or...[if they did not] know what they were getting into.

One can argue that the respondents expressed conditional acceptance of a phenomenon that they hoped could have a positive effect, but that they realized this is associated with such a high level of un-
certainty that the full consequences could not be fore-
seen. That they did express acceptance, although contingent, seems less a result of an informed evaluation than of an expectant faith that biofuels might provide an acceptable solution to an urgent problem—coupled, for some of the respondents, with a general sense of optimism, or a degree of confidence that unanticipated and unwanted consequences could be handled along the way.

**Female, 59 years:** You have to try to look at the nuances and say: “Well, what is this,” right?...Because there’s the skeptics who of course only look at the disadvantages. And there are those who maybe only look at the good sides, right...But it’s my outlook on life in general that I always take a look at both the advantages and the disadvantages.

**Male, 61 years:** We’ve become much better at being aware that what we do also creates new problems. And that takes us back to the United Nations. Overall, it must be up to the UN to try to manage the global problems, right?

The last of these quotes illustrates the perception that political regulation of a complex case such as the use of biofuels should take place at an international level under the jurisdiction of the United Nations. The respondents’ comments also show the phenomenon often found in studies of how people approach contemporary environmental issues (see Blok et al. 2006) that one accepts the use of, for example, pesticides in agriculture, chemicals for daily use, food additives, and so forth both because one suspects that they are necessary and because one has confidence in the intention of authorities to control adverse side-effects. The underlying motto is “what else can we do?” (Wynne, 1996)—ambivalence and uncertainty are basic conditions of modern, everyday life (Halkier, 2001). In our case, with the introduction of a new product with which people have no experience so far, and of which they can only imagine the conse-
quences, ambivalence between hope and skepticism is marked, especially since even the intended effect of biofuels on climate change is uncertain and disputed.

In short, although the immediate reaction of re-
spondents to biofuels was positive, it was followed by some concern as to whether investing in the tech-
nology is the right decision. If the environmental or social consequences outweigh the benefits it might be better to think of alternatives. And if both the full range of benefits and the unintended consequences are unknown, more knowledge is needed before any decision can be made about whether or not to intro-
duce biofuels on a large scale.

**Food Supply and Prices**

One of the unintended consequences of biofuel production discussed in the interviews was their social impact, mainly with respect to land use for production of biofuel crops and the effects on food supply and food prices locally and globally—an issue of particular relevance in relation to first generation
biofuels that are based on conventional food or feed crops. At the time of the interviews, several stories of rising food prices due to competition over land use between fuel crops and food or feed crops were circulating in the media, an issue several respondents referred to without prompting. Asked whether she had followed the discussion about biofuels in the media, one respondent said:

Female, 31 years: Maybe I’m mixing things up, but I have some kind of an idea that it has to do with something about corn?...The problem was that you took in corn for this [biofuel production] and then it was a problem for the poor farmers who couldn’t get enough tortilla flour. But maybe that’s another discussion.

For most of the respondents, the prospect of biofuels causing already poor and disadvantaged people to struggle with dramatically rising food prices was unacceptable. One respondent, for example, was positive toward biofuels, but said:

Female, 32 years: On the condition that people don’t suffer from it. That they aren’t...either going to starve or get stripped of their rights, or...Well, this is always what makes it difficult; because if it were so simple, and you could just say, well that’s just it [the right thing to do]...then it would indeed be a good idea. But there are also some minuses that make it complicated.

Particular concern was expressed about poor residents of developing countries for whom rising food prices could be fatal. Nevertheless, the balancing of concerns about climate change and concerns about food is a real dilemma. One respondent expressed this very clearly:

Female, 25 years: But if in a few years’ time you have people in...who can’t get the food they need, then you have to assess what’s more important. Is it...the environment, or is it the people? And you can’t settle that, can you? Because they affect each other...And if we get a bad environment, well, then there will also be people who...die because of that.

Seen from this perspective, it makes no sense to distinguish between concerns about climate change and the environment on one hand and human beings and social conditions on the other. Humans and the environment are intertwined and both are circumscribed by a sense of social responsibility for distant others—whether in faraway countries or in future generations (see Popke, 2006). Perhaps because of this dilemma, few of the respondents categorically rejected biofuels as part of an answer to climate change despite the prospect of rising food prices. Conversely, some expressed hope that, for example, new farming and biofuel technologies could make biofuel production more efficient in terms of land and that nonfood crops, waste, or other kinds of biomass could be used for biofuel production as promised by second- and third-generation technologies. Other respondents hoped that diets might adapt in acceptable ways to changes in food supply, or that production of biofuels or biomass for biofuels might provide opportunities for economic growth both locally and in developing countries and thus counter the effects of rising food prices. It was a clear condition for respondents that biofuels should not cause people to starve or otherwise cause serious social consequences either domestically or abroad. The respondents expressed a great deal of concern about these social consequences of biofuel production, but some remained relatively hopeful that they might turn out to be less harmful.

**Damage to the Environment**

Related to the social consequences of land use for biofuel crops is the issue of consequences for the environment. An alternative to the direct use of food or feed crops for biofuels, or of existing farmland for biofuel crops, is an expansion of cultivated land. This may diminish the competitive problem of food versus fuel, but introduces instead a dilemma of environmental protection versus agricultural cultivation.

This issue was a cause of concern among the respondents, particularly regarding the cutting of rain forest and the effects that such activities might have on biodiversity or CO₂ levels and thus climate change.

Male, 33 years: So, one can say that if they start felling rain forest to grow fuel, well, that’s...basically that’s a bad thing to do.

Female 32 years: The more one fells the rain forest, the greater the climatic costs.

Opposition to the felling of rain forest is not a new phenomenon. It has been on the public agenda for years, led by environmental groups such as Greenpeace, Friends of the Earth, and so forth. These groups have clearly argued that the cutting down of rain forest endangers biodiversity and that rain forests help mitigate climate change. Thus, the rain forest has almost iconic status for Westerners, as illustrated...
by a comment from one of the respondents: “You immediately hit the red zone” when someone starts talking about cutting down rain forest. However, some respondents were uncertain whether there could be a need to fell rain forests to make space to grow biocrops.

Female, 44 years: The way the destruction of the rain forest is being handled is not in accordance with...how they should do it, right? At least in the countries I’ve heard of where they do it completely uncritically and without thought for the costs it inflicts on nature there. So...you have to set up some high standards for how to proceed, if you...have to do it. I don’t know if there are other possibilities [than using rainforest].

On one hand, this respondent wants to preserve the rain forest, but, on the other hand, she has an eye on the necessity to provide fuel for transportation. As such, she is conscious that there is a connection between the desire for high mobility and the need for fuel. At the same time, she wishes to preserve nature and rain forests and to avoid climate change. In the quote, she expresses the paradox of most people who want to solve environmental problems, but simultaneously do not want to curtail travel or consumption in general.

Other respondents worried about the preservation of landscape and biodiversity in Denmark and more generally:

Male, 37 years: I believe that still more forest will be cut down...so that we can cultivate fields [for production of biofuels]. And it seems to be at the expense of living organisms like little animals and small game and big game and...it’s the fauna in nature that’ll pay the price.

Thus, if it is necessary to cut down forests, especially rain forests, the attitude among the respondents was that this is highly problematic. This does not necessarily mean, however, that cultivation of new land was categorically unacceptable for them, at least not in faraway places. Some proposed, for example, to search for areas for the production of biofuel crops where nature and the environment will not be endangered. A few suggested reclaiming Danish fallow land for cultivation, but more often the respondents suggested that uncultivated land in Eastern Europe, Russia, and Siberia could be used for the purpose—yet without pointing to any specific area.

Economic Interests

Circumscribing the respondents’ concerns and skepticism about the social and environmental consequences of biofuels is considerable suspicion about the economic interests involved in their development. Respondents argued that they found the relationship between economic interests and decisions on implementing biofuel production (as well as the conditions for doing so) very problematic. If a company with economic interests in developing biofuels introduced experts who recommended their promotion, one had to take it with a grain of salt, and, if possible, find other, more independent experts to assess the case. Several respondents were concerned about how money is driving the development.

Male, 37 years: It should not be individuals, and it must not be private companies who are going to decide on it. Because then things go wrong.

Female, 61 years: And then it shouldn’t be private interests, but then I am somewhat naïve: I don’t think it should be private interests that are controlling it. But as I see it...that’s just the way it is.

Male, 61 years: I think one ought to be a little careful, I mean if they have an economic interest in what they say...then I would like to have a second opinion...to express their views too; someone who was not employed in the same company.

The quotations highlight the skepticism of respondents toward recommendations from companies or individuals with economic interests in developing the technology behind biofuels. If, for example, a firm can make a profit on generating the enzymes to be used in second generation biofuels, or constructing plants that can refine organic waste into biofuels, then they did not believe that the firm’s assessment of the necessary technology should stand unchallenged. Several respondents argued that the development should primarily benefit the common interests of society—in this case the climate. There was general agreement among respondents that “money” should not determine whether to develop biofuels. At the same time, the interviews showed that the uncertainty surrounding the general topic also appeared in relation to the question of whom else to trust if one wants an “objective” or “neutral” assessment of the advantages and disadvantages of introducing biofuels
for transport. This question could not be easily answered in the interviews.

**Problem Solving and Responsibility**

As we have seen, concerns about climate change were prominent among respondents in this study, and they generally found it important to “do something” about the transportation sector’s large contribution to climate change. At the same time, the uncertainties and risks surrounding biofuels and other potential solutions make problem solving in this area a very complex matter. In this section, we look at respondents’ views on the issue of responsibility for “doing something”—both for making the complex choices among potential solutions and for putting solutions into practice. For respondents, the latter task in particular was underpinned by a dilemma between a demand for climate-change solutions and a desire for continued mobility and prosperity. This dilemma, and respondents’ views on how to handle it, is discussed further in the last part of this section.

**Knowledge-Based Decisions**

As already noted, respondents found that decisions about biofuels need to be made on the basis of factual knowledge. This is true for other potential climate-change solutions as well. However, a typical answer was that respondents had neither the knowledge nor the influence to determine what should be done about climate change, not least when it comes to choosing between complex and uncertain technological solutions. As two respondents put it:

*Female, 49 years:* I think, as an ordinary person, to sit here and assess all that: That’s a hard one!

*Female, 37 years:* As a private person you might have an opinion about it, but fundamentally you know that you’re not the one who’s going to decide. It isn’t Mr. and Mrs. Jones and…people here in our small town. You know, no matter how hard we thump our feet or yell our heads off we won’t be the ones to decide.

We might say that by declaring themselves incompetent or outside of influence in this way, respondents resigned from direct individual responsibility for choosing among potential solutions. This does not mean that they were content to leave decision making to just anyone, or that they resigned from more indirect responsibility for taking part in the broader democratic decision-making process. As we have seen, they almost unanimously agreed that economic interests should drive neither technological development nor decision making. Instead, they pointed to a broadly defined group of “politicians” to take primary responsibility for making choices, based on overall assessments of a wide range of preferably independent expert knowledge. Several respondents singled out a key role for politicians at an international level, to respond to the global character of both the issues involved and the market forces that tend to take control. Some added that the public needs to be heard as well, though still assuming that “politicians” should take charge of collecting and openly displaying all relevant expert and lay views and steering through a democratic process of decision making.

*Female, 32 years:* Once you’ve found…the side effects and all, then at least you can set up an equation, or several equations…Once the clever fellows in Parliament can set up these equations next to each other, then first of all they can put it up for referendum, with big debates and all. And then it must be up to the people to say: It’s a good thing, or it’s a bad thing.

The overall message here is that to be regarded as legitimate, decision making needs to be carried out through an open, democratic procedure based on political assessments of a broad range of knowledge from reliable and preferably disinterested sources. In this process, respondents positioned themselves as democratic citizens with responsibility, at least in principle, for putting pressure on politicians, participating in the formation of opinions, in referendums, and so forth, but with politicians as more powerful actors located at the center of decision making.

Some respondents also pointed to problems with making democratic decisions in relation to biofuels, or other similar socially and environmentally complex technologies for that matter.

*Male, 61 years:* When we live in a democratic society, then it is the politicians...And this means that basically it is all of us who have to take a stand. And of course this is also one of the strengths of democracy. But it is not always particularly easy to handle. Sometimes it would be easier if there were only one [person] that could dictate things.

While emphasizing the role of politicians, and in the end all citizens, in democratic decision-making process...
processes, this respondent also pointed out the democratic system’s weakness—the difficulty of coming to an agreement and being able to act on it. He concluded that it might be easier for only one authority to solve energy and climate-change problems. Another respondent touched upon the same issue, but was somewhat more radical in his conclusions.

**Male, 46 years:** Democracy...well this is too complicated to leave to each and every one to choose...I can’t stand all that...one has to choose, and one has to get involved...There are many of these things that I actually think you will find to be pseudo discussions when you bring people into it. And it makes it difficult to assign responsibility...And then you just have to make the decisions for people.

These two respondents had similar views on the problems of making decisions about complex issues in a democratic society, but they drew different conclusions. While the former felt that, at the end of the day, it was a strength to involve “all of us,” the other respondent was convinced that engaging the public would prevent the decisions necessary to solve the problems.

**The Problem of Bringing Solutions into Practice**

Deciding which kind of solutions to pursue is a first step. The next is to implement them. On this point, respondents assumed more of a dual perspective. They were not only democratic citizens, but also consumers of fuel, transportation, and mobility. While a growing body of literature discusses the problem-solving potential of citizen-consumers, or of political consumerism, to unite collective and private interests and responsibilities (e.g., Micheletti et al. 2004; Soper & Trentmann, 2008), the response here pointed to a somewhat uneasy relationship between the collective and the private.

For some respondents, their role as consumers of transportation and energy presented an opportunity to make a difference as individuals, and they expressed willingness, some even eagerness, to actively take responsibility for putting solutions to climate change into practice. As expressed by one respondent, a devoted member of an environmental organization:

**Female, 68 years:** I think it is possible to imagine [transportation reductions] if you were to make a great many efforts in everyday life. You know, I can tell from myself, because I’ve tried to say: “Is it really necessary to drive just now? No, you’ll do it to-morrow and then plan a route,” and things like that. And I think you can do that.

Generally, however, there was some hesitation among respondents as to the degree of responsibility they were ready to assume as individual consumers of transportation if it would seriously affect their ability to maintain their accustomed lifestyles. Most respondents said, for example, that there were limits to how much of a premium they would be willing to pay for biofuels, even if biofuels were to turn out to be an acceptable solution to climate-change problems.

**Male, 33 years:** I don’t mind paying more for it, it just depends how much. I’m willing to compromise about comfort as well, but again: how much? All is relative…I think that if something like this is to be a success, well then it has to be that people don’t have to compromise.

For most respondents, the same kind of hesitation applied to the idea of reducing transportation and travelling if that was what it would take to prevent further climate change. Typical responses to whether this was an option included:

**Male, 51 years:** And the way you decide where to produce goods now, that’s who can do it...if not better, then cheaper, right? And that’s nearly all over the world. Then we will have all that transportation cutting across. You know, if we want to be able to get the goods we can get today, plus the ones coming, well, then we will have that transportation.

**Female, 32 years:** I don’t think we can make people restrain themselves. You know, it’s…I like travelling a lot myself. Only right now, I don’t happen to have the “time” for it [laughs, indicating she really means “money”]. No, why is it wrong to get out there and see the world? It’s just that now more people have saved enough so that they can go see the world too.

Comments such as these pointed to the difficulty of giving up the dream of “the good life,” with a spacious and comfortable family home, an ability to acquire all of the material goods imaginable, an opportunity to enjoy luxury travel, and so forth. Moreover, the uncertainties surrounding climate change and the costs and benefits of potential solutions did not make it easier to act as environmentally responsible con-
sumers. Thus, even those respondents who seemed most inclined to believe in the willingness and ability of individual consumers to compromise personal interests in favor of the collective, and who most stressed the civic responsibility of consumers, found “green” living difficult. As the earlier mentioned devoted member of an environmental organization put it:

Female, 68 years: I wrote an article for our latest newsletter about being “the green consumer.” From when you get up in the morning there are…[laughs] it’s really, really difficult to act responsibly and ethically and in an environmentally correct manner and so on, because there will always be something. You know, is this the one I should pick or is it that one and…and how? Or should I stay at home or should I…?

This respondent furthermore confided that she was planning a trip to the Galapagos Islands, even if she did not like to think of the CO₂ emissions associated with her travel. She apologized for the trip by explaining that for many years she and her husband had wished to visit the Islands. Like several other respondents, she illustrated the dilemma that many affluent individuals often confront. They want to be environmentally friendly/save energy and to travel, but they feel it is difficult or impossible to do both at the same time. When they have to choose, the choice often favors the trip—one of the reasons being that it is crucial to modern identity to travel (Jensen, 2011).

In short, while expressing serious concerns about climate change and stressing the need for solutions, our respondents still realized that taking personal responsibility will never be easy, especially if it means sacrificing one’s everyday comforts and freedoms, or the promise of future prosperity.

Similarly, several respondents argued, if not for legislation and control, then for other measures of political regulation meant to motivate more climate-friendly behaviors. Examples mentioned were tax reductions on lower CO₂-intensive fuels and more CO₂-efficient cars, better and cheaper public transportation, and so forth. However, as some respondents pointed out, this would not necessarily resolve the overall dilemma of putting solutions into practice—it may only divert it to a political level. One of the respondents put it like this:

Female, 68 years: I think you could do a lot of things [with regulation], but it’s just that it takes political interference in people’s freedom. And that’s difficult, you know. Who will stand up as a politician and say: “Now, this is necessary!” That doesn’t get you many votes, does it?

In other words, our respondents pointed at personal interests impeding collective solutions to climate change, not only when it came to private companies with vested interests in the development of technological solutions, but also with respect to politicians and even to themselves as citizens and consumers.

Skepticism and Hope

Despite their skepticism and awareness of the dilemmas involved in trying to alleviate climate change, many respondents remained hopeful, or even confident, that solutions would be found and implemented after all. For example, one respondent expressed optimism about the possibility of reducing transportation and travelling via taxes and continued:

Male, 47 years: I don’t think you’re interested in changing your consumption habits, but I simply believe there will be a pressure on politicians to the effect that now something has to happen. Whether that also means stepping in from the public sector to support those areas of research that might develop new things…at least we get some new technologies that will make everything more efficient and less polluting.

The idea expressed here is that general awareness of the problems of climate change will eventu-
ally drive political decision making to find solutions and put them into practice. Part of this optimism hinges on hopes for an ultimate solution in the shape of new technologies that will resolve the climate-change dilemma once and for all. Nevertheless, the overall argument is that problem awareness can open a window, even for difficult political decisions, for unpopular regulation.

This is exactly the more recent point made by Ulrich Beck (2009). He argues that so-called world risk society is faced with the problem, whether recognized or not, of having to make decisions on the basis of not knowing—as in the case of climate change, what can be done about it, and what will be the unintended consequences of our solutions. This means that the boundary between rationality and hysteria becomes blurred. Risk awareness should not be seen as hysteria, however, but as the anticipation of catastrophe. Because of this expectancy, world risk society is also a latently revolutionary society: The belief that the grave risks facing humanity can be averted by political action becomes an unprecedented resource for consensus and legitimacy, nationally and internationally.

We can say that Beck’s optimism is reflected in the hopes of respondents that politicians, locally and globally, will take problem-solving responsibility to find acceptable solutions to climate change. At the same time, however, this is contrasted by their skepticism about whether politicians—or for that matter private companies and people in general—are able and willing to assume this kind of accountability.

Conclusion

Our study found that public awareness of the risk of climate change was high, but that the question of what to do about it was surrounded by uncertainty. The immediate and rather positive reactions of respondents to the idea of using biomass for fuel production were contrasted by their more complex reflections on the risks and benefits of biofuels in relation to the main contested issues in the debate: the social and environmental consequences of large-scale introduction of biofuels.

In general, our respondents looked to politicians to take up primary problem-solving responsibility and not to leave decision making on matters pertaining to biofuels to private companies. The obligation of individuals was regarded with ambivalence and characterized by, on one hand, a demand for solutions to the problem of climate change and, on the other hand, a desire for mobility and prosperity.

The issue of developing biofuels must be understood as part of an overall demand for solutions to major international environmental and climate problems, which, as Beck and others (e.g., Giddens, 2009) point out, have in recent years become important items on the agenda both locally and globally. And this demand was also clearly present among the respondents in our study. Overall, they found it important to search for sustainable solutions that could be implemented and come to fruition in practice. They had different starting points, assumptions, wishes, proposals, and so forth but they all considered the problems to be real and serious—and felt that someone ought to address them. In the following discussion, we describe the major conclusions of our study.

Terms of Solutions

Our respondents agreed that for solutions to be acceptable, the needs and desires of people to travel and be mobile should not be neglected. Several of them, however, saw a paradox of both wanting to continue to travel in the ways to which they are accustomed and to solving environmental and climate problems. Those who considered lifestyle changes necessary particularly pointed to this conflict. One of the respondents expressed her concerns in the following terms:

Female, 61 years: Our earth is our common earth. And it must be in everyone’s interest that we make some changes in our way of living...so that we can respond to the warming that is now extra. It’s not just us humans. There are animals, and there are...gee it’s so intertwined.

Although she did not say it directly, it was probably implicit in the formulation of this observation that a reduction in consumption is needed to mitigate climate change. Her answer could indicate that she was aware of the problem’s complexity but was reluctant to express herself sharply, perhaps because she was not herself able to predict the consequences of the changes she felt were needed, or because she thought it would be extremely difficult or impossible to make the necessary decisions to implement restrictions on consumption.

Another issue concerning reduction in consumption was about equality. A female respondent expressed her opposition to abandoning either travel or anything else in favor of climate or environment if all did not sacrifice equitably. She would not be the only one who did “the right thing,” and even if she were convinced that a reduction in consumption was necessary to address climate-change problems, she underlined that in her opinion any restrictions to mobility (or other consumption goods) must be equal to be regarded as fair and acceptable.
Others argued that technological solutions had to be developed and that this could solve or at least reduce the problems.

**Male, 62 years:** But we have to produce another kind of energy, right?...In the transportation sector one can try to produce either an alternative fuel...or perhaps produce engines that use fuel much more efficiently...Technological development should encourage the type of engine that promotes energy efficiency because it’s quite clear that transport is using...I mean it’s incredible how much people are driving, right?

And here, biofuels could be part of a technological solution, although even technologically optimistic respondents stressed that such interventions had clear limitations because biofuels in their view would hardly be of any significance given the scale of the overall challenge. They agreed that biofuels could only make a limited contribution to mitigating the huge and complex problem of climate change, and the quantitative restriction on biofuels alone challenges the value of greater reliance on the technology. Other respondents emphasized the need for alternatives to the development of biofuels. In the following, one respondent points to other technologies relying on renewable energy:

**Female, 32 years:** Now, I also think that now we have bioethanol, but there’s also wind and water mills and...Well, it’s a better way to create energy, so it is perhaps in that direction we must [turn] instead, but we don’t know as long as we don’t know the impact of biofuels.

Although this respondent initially was sympathetic toward biofuels, she emphasized several times during the interview that there are different alternatives. She expressed an indirect skepticism toward investing in a development with so many conflicting and complex issues built in, as in the case of biofuels.

Our study of public perceptions of biofuels illustrates the complexity of understanding and managing environmental and climate-change issues in the contemporary world. People are convinced of the need for solutions, but they have no clear insight into how to address the problems in practice. Some of our respondents remained hopeful that social and environmental problems could be resolved, but an overall message was that more knowledge is needed to determine whether and how to introduce biofuels and subsequent monitoring is required to avoid the unintended and unintended consequences of doing so. In short, biofuels were deemed acceptable only to the extent that the presumed benefits prove substantial and that they are not outweighed by inadvertent social and environmental costs.

**The Implication for Mobility**

One can argue that to be mobile and to travel have essential connotations in the current age. Both are seen as part of “the good life,” and are often perceived as a necessity, a commitment, a prerequisite to “get everyday life to hang together.” Mobility is crucial to the identity of modern individuals and to their self-understanding (see Urry, 2007; Jensen, 2011). The mere idea of reducing the extent of mobility will often prompt people to cling to the idea that technology can enable sustainable transportation. Similarly, several respondents in our study felt that technology would probably be able to resolve the problems of climate change as well as the environmental issues due to energy consumption in general and the challenges associated with the consumption of fossil fuels for transportation in particular. At the same time, most respondents expressed skepticism regarding the side effects of technological development, including the development of biofuels. They acknowledged the paradoxes inherent in these different approaches—and even if they accepted living with it, they still considered it a contradiction or a dilemma and wanted the problem of climate change to be solved.

**Overall Implications**

We have discussed issues concerning the use of biofuels for the purpose of addressing (some of) the environmental and climate-change problems associated with contemporary modes of transportation. Often the notion of complexity is used in social science literature to characterize the relationship between the public and solutions to environmental problems (e.g., Cohen, 2000). In our study, we have pointed to this complexity as well, but have also sought to understand and explain the driving forces behind the complex issue of how and why people perceive and interpret environmental and climate-change problems and their reflections regarding potential solutions. We consider the understanding of this complexity to be an important finding of our study.

More tangibly, we have described how the general public weighs the advantages and disadvantages of possible interventions to transportation-related environmental and climate-change problems and how they reflect on the notion of developing biofuels for this purpose. In that context, we have focused on a number of conflicting aims: human vs. environment, hope vs. skepticism, mitigating climate change vs. maintaining current mobility practices, and techno-
logical fix vs. technological risk. Together, these dualisms lead to a general sense of public ambivalence and this dissonance was in evidence throughout our study, irrespective of the specific issue on the agenda. Our respondents pointed to uncertainty about how to handle and address problems in both their own (everyday) lives and the wider world around them. And they considered environmental as well as climate-change issues as core dilemmas with no easy solutions.

An important conclusion of this work is that there is ambivalent and conditional acceptance among the Danish public about developing biofuel technologies for transportation, and the contingencies have a number of different components. This means that there is no simple answer to the question of whether the public (or individual members) are “for” or “against” the development of biofuels. It depends on the context in general and how this development is executed in practice. Even if the focus of our article has not asserted a specific view on the emergent political and economic decisions in this field, we hope that our findings provide useful background insights for an informed debate, both about the efficacy of continued development of biofuels and about how to make and implement decisions in this complex area within a democratic framework.

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ARTICLE

“In the morning I just need a long, hot shower:” a sociological exploration of energy sensibilities in Norwegian bathrooms

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This article proposes a new area of research centered on the study of how energy sensibilities—in terms of esthesia which is understood as responsiveness and awareness—are distributed and redistributed. Energy is approached as a polyphonic concept with many meanings, of which none enjoys privileged status. Given this polyphony, the common observation that end-users have no idea (or wrong ideas) about their energy consumption loses importance. Instead, unevenly distributed ways of sensing and making sense of energy become the object of study. Drawing on the work of French philosopher Jacques Rancière, the article discusses contemporary distributions of energy sensibilities in domestic settings and how they have been redistributed during the previous two decades. Analysis of visual representations of bathrooms in the largest Norwegian interior lifestyle magazine and 600 real estate advertisements shows how a specific, resource-intensive energy sensibility has become dominant through a politics of refurbishing.

KEYWORDS: energy consumption, attitude measures, social organization, resource utilization, households

Introduction

Changing current ways of producing, distributing, and using energy is prominent on the sustainability agenda. However, like other resources such as water or air, energy is a highly abstract concept (Shove, 1997). For instance, the basic physical fact that energy cannot be created or destroyed, but can only be transformed, seems to contradict frequent discussions about its production and consumption. There is no contradiction, obviously, since some transformations of energy are more easily reversed than others. But these principles of thermodynamics, fundamental as they may appear to the scientist, are generally inaccessible to the vast majority of people using energy.

Heightening the challenge of understanding energy in everyday contexts, energy consumption within sustainability discourses is generally discussed on a highly aggregated level. Taken alone, individual use of fossil energy for purposes of mobility, for instance, is unproblematic. It is the pervasive ubiquity of individual cars that constitutes one of our current and most intractable dilemmas. However, the billions of cars in the global fleet today are an abstract aggregation, one that is “invisible” to someone who has no immediate access to mobility statistics.

I argue here that despite this invisibility and pervasiveness, end-users have clear notions of energy. Energy users experience energy on a daily basis immediately as heat, light, velocity, and physical resistance. These sensations coexist with more abstract notions, for instance, in energy bills. I propose a research agenda that explores the manifold ways of how energy is made “sensible,” that is, how people make sense of energy, which sensations are connected to their understanding, and vice versa.

The first part of this article lays out the theoretical foundation of this agenda. I start with the common sociological insight that different ways of (not) sensing energy exist, and form patterns distributed unequally across social groups involved in different kinds of daily activities. These distributions are not arbitrary, but at the same time are not determined by social or economic structures. Rather, following the French philosopher Jacques Rancière’s (2006) critique of Pierre Bourdieu, I assume that collectively enacted gaps exist between individuals’ social positions and practices on the one side and how they perceive the world on the other. According to Rancière (2004; 2006), these cleavages are political in the sense that they contain opportunities for change.

In the second part of this article, I explore energy sensibilities as they are present in two fields: representations of bathrooms in a Norwegian lifestyle magazine and advertisements for Norwegian homes. In these representations, energy is invisible in the scientific, quantified, and aggregated form directly relevant for sustainability. However, widening the scope to include sensual aspects, the analysis reveals a specific way of presenting energy consumption as being at the core of a good life. I argue that this con-
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The history of the past two hundred years is a story of unprecedented explosion in energy use. In the 1960s, a large car in normal operation used as much energy as a sizeable American factory during the early nineteenth century (Nye, 1999) and this was seen by most people as a desirable sign of progress. It was not until the first oil crisis of the 1970s that “too much” energy consumption became a widely acknowledged societal problem. However, by that point in time virtually every daily activity in industrialized countries had become dependent on the consumption of copious amounts of energy, most of it derived from fossil fuels.

It is this outsized use of energy that is at the heart of everyday life in developed countries and is the main reason that it is necessary to turn to cultural and social research on everyday-life activities to understand changes in energy consumption. Already in the 1980s, scholars such as Richard Wilk & Harold Wilhite (1985) and Loren Lutzenhiser (1988) introduced alternatives to the kind of simplistic models of human behavior that disregarded this embeddedness of energy consumption in everyday life. Following these early examples, today a growing body of work is turning toward the study of practices (for an overview of the practice turn in consumption studies see Røpke, 2009). Energy consumption as part of practices, as Reckwitz (2002) defines it, is a routinized type of behavior which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, “things” and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge.

Based on this definition, research on the energy dimensions of daily activities has explored showering (Hand et al. 2005), hygiene, laundering, and air conditioning (Shove, 2003), freezers (Hand & Shove, 2007), mobility (Shove, 2002), and heating (Kuijer & De Jong, 2011), among others. These contributions all describe practices in their genesis, evolution, and diffusion. By contrasting practices that are taken for granted and appear without alternative today with practices that once were equally common, deeply routinized activities can potentially become the subject of change again. Further, these contributions reveal how practices are embedded in a background consisting of other practices, discourses, and material infrastructures that would have to change in concert to enable other practices to take hold.

The research agenda proposed and tested here complements these explorations of practices by adding a focus on how subjects sense energy practices in everyday life, how these sensations are distributed among subjects, and how they change. This approach is based on the assumption that a broad range of possible ways of sensing and making sense of energy exists, both in everyday life and in terms of energy’s physics: as heat, as speed, as kilowatts per hour, and so forth. In both scientific and nonscientific discourse, energy, just as any other word, has a range of meanings. This is not a problem as long as the person experiencing a “lack of energy” in the morning does not confuse this situation with other uses, say, with respect to the fact that “domestic energy use is responsible for roughly one third of Norway’s energy consumption.” However, it becomes problematic, or rather, interesting, when the perceived lack of vital energy in the morning nonetheless leads people to take daily, hot, and extended showers, which then may contribute to a shortage of energy on a societal scale. In this instance, the two meanings of energy interfere with one other. People may not understand the first thing about the kind of energy that is quantified and aggregated on the societal scale, but nevertheless have “folk theories” about energy (Kempton & Montgomery, 1982; Kempton, 1986) that may be informed by the sensation of hot water on a cold winter morning.

How this relationship between the two meanings of energy is conceived depends on whether energy is understood in a monologic or a polyphonic way. According to Bakhtin’s (1984) use of musicological terminology, a text is polyphonic when a story is told by many equally valid voices instead of one privileged narrator. Polyphony thus challenges the hierarchy of one denotation (intended by a single narrator) and many connotations (Barthes, 1975). If we, for instance, decide on the meaning of energy as something managed on a societal level (which could be called a technoeconomic sensibility, see Guy & Shove, 2000), we are likely to think that the use of the word “energy” to describe a bodily experience in a hot shower is mistaken. Thus, in a monologic approach, we already have taken sides in favor of a certain (desired) distribution of energy’s sensibilities before we even have tried to understand which sensibilities exist in the first place.

The polyphonic approach that is used here is further inspired by Rancière’s (2004; 2006) conception of how distributions of the sensible are changed within aesthetic practices. For him, uneven distributions of the sensible are a political question. He starts with the common sociological insight that what peo-
ple sense together, as well as what they cannot sense, is always related to their position in an organized system of roles. Bourdieu (1984), for instance, has described this system of tastes and preferences extensively and his notions of field and habitus is well-known in contemporary social science. Rephrased in practice-theoretical terms, an agenda for studying energy’s sensibilities based on this first premise would inquire about the distribution of different perceptions of energy and how they are connected to patterns of energy-related practices. In other words, the focus would be on how energy is made sensible (or insensible) for and by specific groups. This process would then produce a map of different “folk theories” (or “practices”), or, as Reckwitz (2002) articulates it, an overview of “routinized ways of understanding, knowing how and desiring” related to energy.

But Rancière does not mean to reduce sensibility to an effect that is singularly determined by social position and practice. Instead, he is interested in the possibility of politics, which he locates within the gaps between sensibility and social position. He quotes the description of a nineteenth century French worker who dreams of possessing the aristocrat’s house in which he is laying the floor. The worker’s changed sensibility, which in other aspects will still be restricted by his social position and practices, is making space for political actions, which in turn may, or may not, change his social position. Rancière (2006) impugns sociologists like Bourdieu for not being able to describe this “effective disjunction between the arms and the gaze” of the worker appropriately. The kind of politics that takes shape, based on the gap between his social position/practice (“the arm”) and his sensibility (“the gaze”), is open. Neither are certain social patterns meant to be determined by specific sensibilities, or vice versa. However, a society in which sensibility is always identical with social position and practice, according to Rancière, would be a society without political change, because people could not even imagine themselves to inhabit a different position in society.

In the research agenda on energy’s sensibilities proposed here, this theoretical twist introduced by Rancière leads beyond the still important precondition of mapping different sensibilities. However, one would have to focus on the gaps between social position/practices and sensibilities of energy—as they may materialize in a collectively enacted longing gaze, a dream of change, but also fears and idiosyncrasies—to explain change and changeability of energy consumption.

This approach reintroduces the notion of a subject who is sensing and makes sense of her or his actions in the empirical study of practices. But this is neither an atomized individual behaving according to external stimuli nor a sovereign actor. Instead, she or he makes sense of the world through practices that consist as much of practical arrangements, material affordances, and mundane routines as they are brimming with sensual and emotional immediacy.

**Energy Sensibilities in the Bathroom**

To test the potential of a polyphonic perspective on energy sensibilities and the interest in gaps between social position/practice and sensibility, I analyze the changes that have taken place in Norwegian stationary household-energy consumption since the 1990s.¹ This energy use in Norway has been more or less stable since 1996. This is bad news for several reasons. Stabilization has occurred in the case of one of the largest (in per capita terms) electricity-consuming countries in the world. This development consequently means that considerable gains in energy efficiency have been offset by more energy intensive daily lives (for a similar observations regarding British households, see Simon, 2008). Even though there are no data on the level of the different rooms with different functions, certain aspects of domestic energy consumption are more likely to have contributed to this trend than others. One locale of domestic energy consumption that in a qualitative Danish case study was identified as contributing to rising energy consumption is the bathroom (Quitzau & Røpke, 2008).

A special methodological problem arises from the fact that domestic sensibilities are often performed hidden well within the household. The following empirical exploration is based on two notable exceptions. First, a public exhibition of domestic sensibilities happens when homes are bought and sold. And second, sensual qualities of domesticity are extensively discussed in lifestyle magazines. The following discussion analyzes the energy sensibilities present in Norwegian bathrooms from these two angles. Accordingly, a content analysis was carried out of all issues of the largest Norwegian interior design and lifestyle magazine, Bønitt, published between 1990 and 2008. The magazine addresses private homeowners and claims to have more than 300,000 readers (quite commendable given that Norway’s population is only 4.7 million people). The qualitative analysis focused on visual representations of bathrooms, including image captions, and selected editorials that explicitly address bathrooms. The ma-

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¹ The research presented here has been conducted together with Helen Jøsok Gansmo as part of the project Paradoxes of Design funded by the Norwegian Research Council within its Fri prosjekstøtte (FRIMUF) program [Independent Projects].
terial was first coded openly (adding categories as they were found), then axially (establishing relations between these categories), and then selectively (around the previously identified core categories). In addition, I analyzed 600 real estate advertisements published during October 2007 on FINN, a website geared to Norwegian consumers. Here, the analysis was conducted by counting word frequencies and word co-occurrences found in the complete text corpus extracted from the advertisements (Callon et al. 1983).

It is reasonable to assume that lifestyle magazines and advertisements, at least to a certain degree, aim at reproducing existing sensibilities because they want to communicate meaningfully with their readers. However, it would be naïve to approach them as simple depictions of users’ ways of sensing energy in their bathroom. Both are carefully edited products that serve a variety of motivations, of which selling things is the most obvious one. Thus, when the magazine displays photographs of, for instance, the bathroom of a particular architect, it always conveys a double message. On one hand, the aim is to communicate how the bathroom of the featured architect is designed and, on the other hand, to convey how readers’ bathrooms could look if they were to purchase a specific set of highlighted products. The same applies to the advertisements, which typically consist of sober descriptions of the object in question (“Two bedrooms,” “kitchen from 2006,” “balcony,” “located 20 minutes from the city center,” and so forth), but which also frequently use normative and evocative images (“very attractive,” “located at popular Øya,” “nice, new kitchen”). Again, the message is doubly loaded: “This is how the flat for sale looks” and “This could/should be your flat!”

In terms of energy sensibilities, this ambivalence of the source material opens a second layer of analysis, one in which the question is no longer just which kinds of energy sensibility are dominant, but what indications exist of gaps between these representations and the users’ energy-sensing practices. Exploring the latter intention can provide useful insights about an ongoing politics of energy sensibilities.

**Mapping Bathroom Energy Sensibilities**

If energy is mentioned explicitly, it is most often connected to “consumption” (energiforbruk, only nine mentions in 600 advertisements). Analyzed for words used frequently in close proximity, energy consumption is often related to “economy” (økonomi), the qualifier “modest” (beskjeden), and the abbreviations “ca.” (circa) and “kWh” (kilowatt hours). The lifestyle magazine similarly had few references to energy, with two descriptions of toilets that conserve and recycle water as the only mention of resource use at all. Thus, in terms of energy sensibility, it can be stated that “energy” as a word is mostly absent. If it is used in the advertisements at all, it is clearly connected to an economic and quantitative understanding.

According to the extension of energy into the realm of senses, however, this does not mean that energy is absent in all its manifestations. The energy-related qualities of the technologies and spaces that are represented in the material include hot water, large heated spaces, and warm floor tiles as the most relevant elements.

Visual representations of large volumes of hot water especially dominate the bathrooms pictured in the magazine. The images have changed over the course of the several decades studied here, moving slowly from whirlpools to large showerheads (“jungle showers”), but the underlying aestheticization of (a lot of) hot water that covers the body remains stable. In addition, almost all bathrooms featured in the magazine have ceramic floor tiles, which, given the Norwegian climate, are only feasible in conjunction with underfloor heating. These observations are supported by analysis of the advertisements that express a very positive connotation of warm floor tiles. Viewing all of the advertisements as a group, the energetic quality “warmth/heat” (varme) appears frequently, together with “completely covered with tiles” (helfliset), “bathroom floor” (badegulv)—only matched in frequency by “summer days” (sommerdager), “heating” (oppvarming), “radiator” (radiator), and the positive qualities “nice” (hygge) and “good” (god).

Both the magazine and the advertisements present large bathrooms as an asset. Behind other more generic qualities (like “good” and “new”), “large” is actually the most frequent qualifier used in the advertisements (593 instances). Analyzed for co-words, the advertisements relate the quality of being “large” (stor) to all kinds of rooms, including the bathroom. The dominance of images depicting free flows of hot water, heated ceramic floor tiles, and spaciousness produces a compelling picture of a specific collective energy sensibility connected to Norwegian bathrooms, which is particularly powerful because of its mutually reinforcing character. The sensation of walking into a large room barefoot on warm tiles and splashing great quantities of hot water on a naked body produces a strong image of indulgent hedonism based on high energy consumption in the bathroom.

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2 See http://www.finn.no.
3 The analysis was carried out using the software package AutoMap developed by CASOS at Carnegie Mellon University. Assembly of the text corpus was conducted using the PERL modules Lingua::Stem::No and Lingua::StopWords.
Gaps and Imminent Changes

The longitudinal study shows that Norwegian bathrooms have only gradually become objects of collective sensibility. In the 1990s, bathrooms were still significantly underrepresented in visual portrayals of interior designs. As was also observed in the Danish study (Quitau & Røpke, 2008), after around 2000 they became publicly exposed and sensibilities connected to these spaces have become discussed frequently.

For instance, in a special issue on bathrooms published in 2005, the editor of Bonytt expounded,

I have many ideas for the bathroom of my dreams...The bathroom can be everything from a room for teeth brushing to a room for relaxation. Or both. Definitively it is a room where many want to realize their interior dreams (Kolberg, 2005; author’s own translation).

A reading of these sentences inspired by Rancière would focus on the tension they construct between teeth brushing and relaxation. In this juxtaposition, the brushing of one’s teeth is easily recognizable as a representation of a mundane daily task, while relaxation describes a positively connoted regenerative activity. In this tension, the editor claims, everything goes, and dreams can come true.

But how exactly has the bathroom become the place where dreams can come true? Two years earlier, the editor wrote:

The kitchen is still the room which best reflects people’s daily lifestyle, but if you want to measure the spirit of the times you have to look to the bathroom. That is where the new things happen, with a completely different weight than before being placed on furnishing and design (Holte, 2003; author’s own translation).

This observation makes the claim that the bathroom is the locale where change is happening. Complementing this sense of change, during the second half of the 1990s and the early 2000s, the magazine regularly published articles that focused on how to refurbish outdated bathrooms in a do-it-yourself fashion, featuring all the elements described above: ceramic floor tiles, floor heating, and large bathtubs.

In the editor’s quotes and the articles on do-it-yourself refurbishing, a gap between existing and represented bathrooms is implicit: that bathrooms have to become like the ones represented implies that they are not like that, yet. If we reflect on Rancière’s worker discussed above, it is easy to picture the readers of the magazine dreaming of splashing hot water on warmed floor tiles in a large bathroom, while sitting in their old-fashioned and frugal existing bathroom. Consistent with Rancière, the question may now be asked, what kind of politics resides in the gap between the glossy bathrooms, the sensations they promise, and the real bathroom. The magazine’s answer is simple: it is a politics of refurbishing.

Looking for a complementary gap in the energy sensibilities identified in the real estate advertisements, this refurbishing aspect was particularly present. In 2011, in a short-lived feature, advertisements on the FINN website were represented as random pictures from advertisements offering “inspiration.”

Watch inspiring rooms from the dwellings that are sold at FINN real estate right now! Are you dreaming of a new bathroom or kitchen, but not sure where to start? Now you can see thousands of inspiring images and use them as a starting point for your own refurbishing or new furnishing.4

The similarities to the rhetoric used in the magazine are obvious. Again, dreams can come true and a change to the better is imminent—through refurbishing.

The core business of the website, however, is selling new homes. As the previous section showed, the advertisements describe rooms as “large”—without regard for the real size of the object the advertisements want to sell. If we again are looking for a gap in Rancière’s sense, and given the site’s purpose of persuading its users to leave their old home behind, “large” can be translated to “larger than the current home.” Here, the politics, in Rancière’s term (which may include changes in social identities), residing in the gap between existing home and the one presented in the advertisement is the acquisition of a larger home.

Conclusion: Toward a Research Agenda on Energy Sensibilities

To say that energy is invisible in the material studied here is only meaningful if one adheres to a monologic understanding of energy. In fact, energy consumption is very present, especially in the form of representations of thermal energy. But the results also show that there is not just arbitrary polyphony in this material. Instead, a dominant energy sensibility is present in which energy features as a complementary combination of hot water, large heated spaces, and

4 See http://www.finn.no/finn/inspirasjon (author’s own translation).
warm ceramic floor tiles. This is no doubt a powerful contender to any alternative sensibility and should be taken seriously as a legitimate way of representing energy.

As a next step, this analysis could be developed further to a proper mapping of energy sensibilities and how they are distributed according to different practices in society. To achieve this objective, variations within the material would have to be studied, for instance whether there are differences according to the size (and, thus, potential buyers) of the objects represented in the real estate advertisements, or between different lifestyle magazines with different target groups. Extending the study even further, a broader range of arenas in which bathroom-energy sensibilities are enacted publicly could be explored (e.g., energy-saving guides or public-policy documents).

Given the specific character of the sources studied here, I have argued that a significant gap exists between the bathrooms depicted in the material and real Norwegian bathrooms, addressed explicitly as a division between the existing and the “bathroom of your dreams.” The politics residing within this gap is one of upgrading the existing bathroom to resemble the dominant image described above. Although the average Norwegian household had 2.9 members in 1970 and 2.3 in 2001, in the same period, the average area available to Norwegian households increased from 88 square meters (m²) (1973) to 115 m² (2001) (Boeng, 2005). At the same time, Norwegians are “the world champions of refurbishment” according to an annual market survey conducted by the marketing research institute Prognosesenteret which estimated that about 50 billion NOK (€6.4 billion or US$8.6 billion) were spent in 2010 by private Norwegian households to upgrade existing homes.5 Additionally, and not surprisingly, given the nature of the material, parallel to the refurbishment theme is one of buying a larger home. These results resonate well with overarching trends toward larger living areas and ever more frequent refurbishments in Norwegian homes.

The study presented here has demonstrated that a research agenda based on a polyphonic approach to energy is not only able to map distributions of energy sensibilities, but also to shed light on secular changes and trends that are important determinants for energy consumption in Norwegian bathrooms (and homes in general).

The objects of the study of sensibilities, such as routines of pleasure (the sensation of an abundant hot water shower in the morning) and habitual dreams of change (reading the lifestyle magazine every month), may sound like a contradiction. But in terms of practice theory they make sense: they represent a subset of practices in which bodily sensations and mental processes (sensing/making sense of) are connected to changes in practices that—in our case—unfortunately point toward less sustainable states. The group of practices that is enacted in consumer sensations and dreams is clearly relevant for the study of energy. For a majority of people, many highly aggregated sustainability indicators will be just as “invisible” as energy. A study of the distribution and redistribution of carbon-dioxide (CO₂) sensibilities, for instance, would look at how different social groups collectively sense and make sense of CO₂ emissions and which politics resides in which gaps between their social position and their sensibilities.

Following and complementing Wilk’s (2010) invitation to take “folk models” more seriously, the approach introduced here acknowledges that these models contain important knowledge. How people sense and make sense of sustainability related indicators, and how these sensibilities are distributed and redistributed, deserves to be taken seriously within the field of sustainability. Dismissing these sensibilities simply as misconceptions makes for naïve research, policy, and action—to say the least.

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ARTICLE

How not what: teaching sustainability as process

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Ever since the word “sustainability” entered public discourse, the concept has escaped definition. The United Nations has christened the years 2005–2014 “The UN Decade of Education for Sustainable Development” and has called upon universities “to make education for sustainability a central focus of higher education curricula, research, physical operations, student life, and outreach to local, regional, and global communities.” Nevertheless, the indeterminacy of sustainability as a concept has challenged those designing university sustainability efforts, in terms of both campus planning and curricula. Some instructors and campus sustainability planners have chosen to stabilize sustainability concepts into a technical and ethical “greenprint” based on some agreement concerning shared (or imposed) concepts and values. Yet others have realized that this is not a problem to be “solved” but instead presents an opportunity to advance and implement alternative approaches to teaching and learning “post-normal” or “Mode 2” science. This article describes a curricular design that attempts to maintain both canonical disciplinary learning about the techniques of sustainability and training in the reflexive skills necessary to explore sustainable change through post-normal learning processes, which we delineate as three “modes of knowing.” By training students to practice these ways of knowing sustainability, they come to understand the “how” of sustainable practice, process, and design, while allowing the “what” of sustainability to emerge from group interaction in a collaborative context.

KEYWORDS: education, learning, colleges and universities, design, environmental engineering, sustainability

The Challenge of Teaching Sustainability in the University Context

The United Nations declared 2005–2014 to be the Decade of Education for Sustainable Development, calling on universities to help create a more sustainable world (UNESCO, 2005). Yet, higher education may not be well prepared to fulfill this goal. Historically, the university has created knowledge with individual experts in siloed disciplines who research and transfer codified knowledge using didactic pedagogies (Jonassen, 1991; Sharp, 2002). Yet, many observers have argued that working toward a sustainable future requires educational models that go beyond teaching codified “what” facts to models that emphasize “how”: that train students in the transdisciplinary, collaborative ways of knowing-how that have been recently characterized as “new knowledge production” (Hessels & van Lente, 2008), “post-normal,” or “Mode 2” science (Functowitz & Ravetz, 1993; Gibbons et al. 1994; Wiek et al. 2011).

In this article, we describe the problems with defining sustainability as codified, stable “whats.” We then look at new characterizations of sustainable knowing and learning as a more collaborative, “dialogic” process (Gibbons et al. 1994). These new conceptualizations of knowledge production separate out codified didactic knowledge—what we call here “know what”—from the more contextual, tacit, and relational knowledge production we emphasize here and refer to as “know how.” We then ask, can universities, as centers of codified, disciplinary knowledge, teach students how to practice this new way of knowing? Then, we use one example of an interactive learning activity we have designed to train students to be competent, reflexive producers of sustainable knowledge in collaborative group processes. Through our own collaborative process of designing this learning activity, we found that students practiced three post-normal “modes” of knowing. We describe each of these modes and show how the learning activity evolved to explicitly teach both disciplinary technical learning about sustainability along with these other three transdisciplinary, reflexive process-based “how” modes of knowing. Finally, we briefly show how we are developing ways to assess student acquisition of these process “how” knowledge competencies.

Our example comes from a learning activity we have designed and conducted as part of the University of California (UC) Santa Cruz Sustainable Engineering and Ecological Design (SEED) consortium, a
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Sustainability as What

A focus on sustainable knowledge and practice as simply gathering and imparting to students the right codified information has led to confusion in the classroom. Sustainability knowledge continually slips out from under these codified, standardized, canonical definitions. This situation has led to a frustrating indeterminacy in which “[s]ustainability appears to be about ‘everything’ and ‘nothing’ all at once,” (Sherren, 2006) so that “[a]t times, the plurality of angles, concerns, and interests embodied in sustainability debates devolve into a confusing cacophony” (Brand & Karvonen, 2007). The slipperiness of sustainable knowledge means that those attempting to prepare students to make informed contributions are often puzzled “in stipulating what is core to educate in something so amorphous as sustainability” (Sherren, 2006) leaving universities to become caught up in the question (to paraphrase Dave Eggers (2006): “What is the What?” of sustainability.

Universities have so far emphasized answers to “what” questions, fulfilling the United Nations sustainability mandate by creating campus “greenprint” plans that lay out sustainability “best practices” (Heinz Family Foundation, 1995; Bulkeley, 2006), a set of advisable technology adoptions to make campuses more “ecoefficient” (Bartlett & Chase, 2004; El-Mogazi, 2005). In addition, campuses often combine these technological recommendations with new “sustainability learning” initiatives that include inculcating “values and motivations that bring about environmentally responsible behavior” (Hansmann, 2010). In other words, universities teach notions of what technologies are sustainable along with what norms and behaviors lead to “good,” sustainable lifestyles (Sherren, 2006). In these greenprint processes, a group of interested stakeholders on campus define sustainable technologies and behaviors and then hope that business decisions and instruction will follow suit. These processes of sustainable knowledge creation tend to be reductionist, that is, to reduce sustainability to a simple list of technologies and behaviors, both in terms of the sustainability plans for the campus itself and a set of codified facts and values that should be taught (Bulkeley, 2006). Pedagogy also tends to be didactic, relying primarily on the lecture-test “banking” model, an approach that treats students as passive recipients receiving codified information transmitted to them from “the sage on the stage” (Friere, 1970; Sharp, 2002; Gao et al. 2007). This “codify and convince” strategy of creating sustainable change is not confined to the classroom. It is evident in a broader range of campus sustainable planning operations. Organizations such as the Association for the Advancement of Sustainability in Higher Education (AASHE) standardize sustainability into a set of “best practices”—technologies and behaviors—and then certify an institution’s progress in meeting these standards through the “Sustainability Tracking Assessment and Rating System” at levels from bronze to platinum (AASHE, 2012).

Sustainability as How

In contrast to these “codify and convince” university planning and teaching initiatives, new approaches define this sustainable knowledge as “post-normal science” comprising “a multiplicity of knowledge as well as a multiplicity of forms of knowledge” (Brand & Karvonen, 2007) requiring new, multidisciplinary, “reflexive” research and pedagogies (Functowitz & Ravetz, 1993). These scholars describe sustainable knowledge production as “a vibrant arena that is bringing together scholarship and practice, global and local perspectives from north and south” (Clark & Dickson, 2003).

Weik et al. (2011) recognize that training students in the post-normal science of sustainability “does not imply that ‘regular’ competencies, such as critical thinking and basic communication skills, are not important for sustainability professions and academic programs (they are!).” However, they argue that there are several other key competencies “critically important for sustainability efforts” (Weik et al. 2011). To teach these post-normal key competencies requires “an alternative model of policy learning [that] points to processes of argumentative struggle between competing frames or discourses as a means through which new understandings of policy problems arise, and policy change takes place” (Bulkeley, 2006). Teaching the “how” of sustainability requires us to “replace pedagogical approaches based on (relatively ‘authoritarian’) transfers of information with more interactive and collaborative learning processes: citizen participation can start with the creation of a community of learners” (Simon, 2002). In addition, a growing body of research in the learning sciences has shown that courses that rely only on didactic pedagogic strategies are less successful in attracting, retaining, or preparing students for STEM efforts. See, for example, the University of Colorado’s Blueprint for a Green Campus at http://ecenter.colorado.edu/greening-cu/blueprint-for-a-green-campus, and the University of California Santa Cruz’s Campus Sustainability Plan at http://sustainability.ucsc.edu/actions-planning.
(science, technology, engineering, and mathematics) disciplines (Seymour, 2002; Smith et al. 2009). For these reasons and others, this article explores research on post-normal forms of knowledge and on socioconstructive pedagogies to teach noncodified or “reflexive” ways of knowing.

UC Santa Cruz’s SEED curricular design team has been experimenting with pedagogy that embraces the reflexive nature of sustainability as a field or a concept. Defining sustainability is not taken as a problem that needs to be “solved,” but an opportunity to raise new ways of thinking about the world. This approach recognizes sustainability as an intrinsically unstable concept, a dynamic idea that can never be pinned down to a particular technology, set of behaviors, or even worldview and set of values. Under this scenario, the challenge becomes to design a curriculum around an unfixed concept and engage students with multiple modes of knowing without creating an unfocused strategy, agenda, and pedagogy.

Faced with this challenge, SEED curriculum designers have to date focused on training students in understanding multiple frames, problem-based and transformational learning, critical thinking, and dialogic exchange in group learning (Wells, 1999; Thomas, 2009). These emphases shift the focus away from codified knowledge toward various processes—“modes”—used to create new understanding (Barad, 2007). Our approach follows sociocultural theories of learning and teaching that focus on alternative options for participation in “joint activity” (Lave, 1991; 1996; Lave & Wenger, 1991; Rogoff et al. 2003). These efforts reflect broader transformations in the conceptualization of knowledge and understanding toward an embrace of what Silvio Funtowicz & Jerome Ravetz (1993) characterize as “post-normal” knowledge, what Gibbons et al. (1994) call “Mode 2” forms of knowledge, and revive ideas about those kinds of knowledge that escape codification, or what Karl Polanyi called “tacit” knowledge (Nonaka & Takeuchi, 1995). We characterize all of these understandings as “know how” modes of knowing. According to this perspective, leaving the definition of sustainability open, interdisciplinary, and emergent enables a focus on the “how” of technical and social processes informing sustainable designs (Brand & Karvonen, 2007).

Curriculum design that enables the “what” of sustainability to continually emerge and be redefined through group interaction around intersubjective knowledge-production practices prepares students for the kind of experimental creativity, reflexivity, and collaboration that will be required to produce new sustainable ways of knowing and living. Gibbons et al. (1994) describe this kind of knowing as always in the making. It is experiential, discursive, processual, social, tacit, contextual, transdisciplinary, open to different worldviews, collaborative, practice-based, and informal (Martens, 2006; Brand & Karvonen, 2007; Luks & Siebenhüner, 2007). In this kind of “new knowledge production” (Hessels & van Lente, 2008), discursive processes are not seen as separate from scientific research but rather as integral to it. This leads to a more dynamic and decentered view of knowledge-creation as emergent and historically “contextualized,” based in practices and distributed across agents and artifacts (Cole & Engestrom, 1993; Gibbons et al. 1994; Shove & Ingram, 2008). Such a counterview is based on acceptance of coexisting multiple ontologies, in which codified knowledge exists with other marginalized knowledge processes that are contingent on context and exist only so far as they are “in use”—that is, applied through interpretation, experience, and practice.

**Ways of Knowing How**

The increasing acceptance of multiple ways of knowing does not lead automatically to new forms of pedagogy. To achieve collaborative learning, students need to work through their multiple and competing ways of knowing and commit to a process of collaboration despite tacit and/or explicit commitments to different frames/worldviews: ways of understanding and of acting in the world. To teach these skills we relied on the work of educational theorists John Dewey, Paulo Friere, and others working in the Dewey tradition, such as Jerome Bruner (1990). These education thinkers have attempted to create socioconstructivist pedagogies around active, experiential, service, and practice-based learning that require not only training across fields but also in the application of collaboration skills that can span disciplinary divides/boundaries. We ultimately categorized our pedagogy into four separate modes, including the didactic strategy of teaching normal science as “facts”—knowledge that is delivered from experts to non-experts—and three collaborative, post-normal modes of knowing (Table 1).

**Know How 1: Subjective Knowing**

Each person learns important information through personal experience, history, and their own social situatedness. Subjective knowledge is the embodied knowledge we carry within ourselves through our histories and connections. A number of scholars have been seeking recognition for this kind of “situated” (Haraway, 1988), “local” (Geertz, 1983), and “standpoint” (Collins, 2000) or “witness” knowledge (contextually based and “true” in particular places, with particular people in particular times and contingent to particular situations). Postcolonial and critical
race theories especially emphasize witness testimony based in particular histories, memories, identities, subjectivities, and embodied knowledges (Ahmed & Stacey, 2001). These are also the knowledges tied to a particular culture’s ecologies (Cronon, 1983) or agroecologies (Altieri, 1995).

Those who take the subjective-knowledge perspective see Kuhn’s (1962) notion of paradigm as restrictive. Different ways of knowing can coexist even if one form has dominance. Sustainable agriculture provides an excellent illustration of this point; because it depends on a more agroecological, and therefore place-based context, it tends to be more tacit and situated and therefore harder to teach. Industrial agriculture, on the other hand, is dominant not only because industrial economic interests heavily influence agricultural education but also because industrial agriculture knowledge is more codified and universalizable, a form of knowledge more open to didactic university pedagogies (Goodman et al. 2011).

**Know How 2: Discursive Knowing**

Discursive knowing is produced through social interaction and respectful deliberation among collaborators who work jointly to complete complex tasks that require coordinated action. As Tomasello and his colleagues have explained (Tomasello, 1999; Tomasello et al. 2005), coordinated action requires establishing a common purpose and a “joint focus of attention.” Since complex tasks require a division of labor, individual participants who come with different histories, worldviews, and frames of understanding must learn “intersubjectivity”: to communicate their individual subjective understandings through language (verbal and written), gesture, physical movement, facial expression, demonstrations, symbolic inscriptions, and so forth in ways that articulate and respect subjective framings, yet accomplish common goals.

Like personal subjective knowledge, discursive knowledge is often a combination of rational, tacit, and emotional knowledge. Rather than seeking universals, it involves how we, in society, cope with various predicaments, contradictions, and dilemmas that are intrinsically irresolvable, “wicked” problems (Rittel & Weber, 1973). Yet, despite this unresolvable

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**Table 1 Modes of knowing and pedagogical strategies.**

| Lab Steps     | Modes of Knowing | Competencies | Processes | Ontology | Pedagogy (example) |
|---------------|------------------|--------------|-----------|----------|--------------------|
| Rank Individual | Subjective       | Reflexivity  | Empowerment | Interpretive | Journaling         |
| Rank Group    | Intersubjective  | Deliberation | Understanding | Relational   | Discussion         |
| Analyze       | Scientific       | Research     | Analysis   | Positivist | Lecture            |
| Redesign      | Practice         | Innovation   | Creativity | Design     | Project            |

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not by moving toward one worldview but by working through particular kinds of group processes that enabled them to synchronize their differences as they made decisions about the design of the product.

**Know How 3: Practice-based Knowing**

New theories of social behavior have stressed various kinds of practice-based “know how” (see, e.g., Hargreaves, 2011). In a related way, Cultural Historical Activity Theory (Cole, 1985; Cole & Engestrom, 1993), Communities of Practice Theory (Lave, 1991; 1996; Lave & Wenger, 1991) and Actor Network Theory (Latour, 2005) emphasize the inter-relations that organize decentered networks of activity, including physical and social actions, shifting the focus from individuals to a dynamic “supra-individual” unit of analysis (Cole, 1985). Work in strategic management also emphasizes processes of trial and error in innovation and competent “know how” practice (Von Hippel, 1994; Nonaka & Takeuchi, 1995). Science studies scholars look at scientific knowledge production as more than the creation of codified knowledge through experiment and hypothesis testing, but as a form of situated activity—or practice—that is distributed across the tools-in-use, users, and material and social context in the field of discovery (Latour, 1987; Rheinberger, 1997). These scholars show how particular combinations of all of these elements are intrinsic to any performance and not merely variables among others. From this perspective, what we know (and how we come to know it) is not separate or distinct from what we do, and furthermore the particular ways we set about doing things will shape and orient what we know and understand at any point in time (Shove & Ingram, 2008). Since what we do, and the ways we go about doing the things we do, are constantly changing as we encounter new situations with different people, different materials, different social norms, and so forth, we must also assume that our knowledge base is continually being modified and adapted with each new performance.

Hargreaves (2011) explains the advantages of using practice-based theories to understand and promote proenvironmental behavior and sustainable social change. Practice-based perspectives abandon deficit models that focus on particular behaviors as “maladaptive,” “irrational,” or “ungrounded” and shift attention to the tensions and interplay among social conventions (e.g., patterns of consumption), immediate needs (e.g., staying warm) and the attributes of the material world that constrain and/or afford different possible actions (e.g., opening a shade in a south-facing window vs. turning up the heat) (Shove & Ingram, 2008). And unlike theories that focus on individual decision making as constrained by various contextual and/or conceptual barriers that need to be identified and removed, practiced-based theories of knowing emphasize how it is only through robust and continuing engagement that individuals build a coherent understanding of the complex relations that define the world around them.

**SEED Lab Activities as Scaffolds for Reflexive Learning**

The SEED curriculum trains students in reflexive thinking through peer support and collaborative pedagogies, often using Internet applications and other computer-based information technologies. The curriculum includes didactic learning of codified knowledge through lectures and readings as well as collaborative, active, group- and problem-based interactive exercises—which we call “labs”—and service-learning components. A lab series generally covers such technical concepts as life-cycle analysis, carbon-footprint calculation, and sustainable supply-chain analysis and examines topics ranging from raw materials and technology used in solar photovoltaic systems, to biofuels such as ethanol, to the marketing of commodities as consumer goods.

Individual labs are used in several classes, including general lower-division engineering courses on renewable energy and sustainable design; an upper-division sociology course entitled “Sustainable Design as Social Change”; and a senior capstone course open to all majors called “Impact Designs: Engineering and Sustainability through Student Service” that supports interdisciplinary teams of undergraduates in completing community-based sustainable design projects. Readings focused on technical content are paired with readings on communication strategies, sociological analyses of technical change, business-management theories of innovation, and histories of design. Lectures, readings, and prologues to the labs introduce students to codified information on different topics in sustainability. For instance, students learn about the technical concept of life-cycle analysis in assigned readings, through lectures, and with a lab activity on ethanol formulated to teach the role of reflexive analysis in understanding various ways to design life-cycle studies.

Each lab in the series is structured around the notion of scaffolding (Wood et al. 1976), a concept in education theory that explains how individuals meet new challenges, appropriate new skills, and develop new understandings during interaction. Scaffolding has been broadly defined as the process by which a teacher or more knowledgeable peer provides assistance that enables learners to accomplish tasks or succeed in problem situations that would otherwise be too difficult to resolve on their own (Wood et al.
students and collaborating community partners, pragmatic and authentic problem-solving (Bringle & Hatcher, 2007). Service learning can provide a powerful way to build a sense of student investment, motivation, and ownership. Through the application of academic content to tangible situations, service learning can support student appropriation of challenging technical skills and the understanding of complex ideas (Kezar & Rhoads, 2001). However, without a shared understanding of project goals, service learning can also be distressingly unproductive, wasting the time and “spinning the wheels” of both students and collaborating community partners, leading to an unwillingness to partner. The labs are designed to function as practice sessions, to prepare undergraduates to participate fully in collaborations with community partners to solve real-world challenges. It is important that they first practice key skills in a controlled setting and then are supported through the process of translating these skills into the applied context.

Example: The Packaging Lab

To demonstrate how a collaborative, active-learning curriculum design can support multiple modes of knowing, we will describe the first activity in the SEED series of interactive activities. Commonly known as “The Packaging Lab,” this initiative was originally developed as an opening activity in 2009 for Sociology 115: Sustainable Design as Social Change, an upper-division seminar that included an emphasis on student-led service-learning projects. The activity has since undergone several revisions and has been adapted to at least four other courses. Altogether, the activity has now been completed by approximately 500 undergraduates. In each case, The Packaging Lab was one of the first instructional activities presented to students.

This activity requires students to rank a set of consumer packages provided by the instructor, then reflect on and discuss their initial ranking before providing a “group” ranking, and then revisit their initial individual ranking to decide if they want to add changes to an individual “reranking.” After viewing the selection of consumer packages, students are asked to rank the way they were packaged. In some of these classes, students are simply asked to rank packages from “best” to “worst.” In some other versions, students are asked to rank packages specifically in terms of their sustainability: from “most” to “least” sustainable. Students are also asked to state reasons for each ranking, and then to boil down each reason into criteria they used to make their ranking (e.g., plastics can be recycled, plastics recycling reduces dependencies on petroleum, vs. plastics have been shown to disrupt ocean ecology). Students next defend their criteria to a small group of their peers and finally are given the opportunity to rerank the items, integrating any new considerations resulting from the small-group discussions.

The sequencing of successive “steps” within the activity is designed to help students work gradually, adding layers to complicate a working definition of sustainability as applied to different exercises in the lab. The idea is that students will learn the criteria they considered important in the definition of sustainability and, by discovering that other students have different criteria, learn that sustainability is a discursive concept not open to a single definition. The activity concludes with an instructor-facilitated whole-class discussion and some questions, typically assigned as homework, to give students further opportunity for reflexive practice.

Step 1: Subjective Knowing

We assume that most students will come to the lab with some notion of sustainability, such as ideas about recycling or conservation of energy and resources. We also imagine that a few students with more sophisticated ideas will include criteria related to more comprehensive views of sustainability such as the “triple bottom line” (economy, environment, equity). We expect that students will also bring their own priorities to their decision criteria—including economic feasibility, convenience, efficiency, aesthetics, social justice, and, of course, ecology—representing their different backgrounds and training.

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2 The SEED Curriculum includes a number of different service courses that involve students in problem solving of sustainability issues in the Santa Cruz community, including both lower division and upper division SEED courses.
Accordingly, the first step in The Packaging Lab is designed to help students reveal and then think reflexively about their pre-existing frames of understanding (both tacit and explicit). Students begin by individually ranking the packaging of selected consumer goods from “best” to “worst” or in terms of their degree of “sustainability” (with these concepts left undefined in the lab) relative to the others. Students invariably ask us to define these terms but are consistently reminded that it is part of their job to do so. After ranking each commodity, students are instructed to provide a reason for the ranking assigned. From this set of reasons, students are asked to identify and articulate the more general criteria they use to define sustainability (such as aesthetics, economics, reusability, recyclability, dematerialization). Students are able to see how different criteria, including some based on tacit assumptions or framing understandings, lead to very different rankings. For example, some students ranked a metal tin as sustainable because it could be reused while others questioned the assumption that it would be reused and gave it a lower ranking.

Student subjective knowledge includes the assumptions, expectations, and even the emotional or visceral reactions that each individual accumulates over time through different lived experiences. The lab prompts each student to understand (and thereby be prepared to articulate in Step 2) her or his criteria for sustainability. Rather than imposing a singular definition, the first step in this lab is intended to help students to realize their own working definitions of sustainability and to compare with others by asking them to make and articulate concrete choices, and then reveal and reflect on their criteria. The goal is not only to awaken and expose students’ subjective knowing but also to prepare students to gain reflexive awareness about their own frames of understanding. Reflexivity—understanding how one’s own ways of knowing are based on who one is and that collaboration requires that we respect others who see the world differently—takes practice. This step is designed to give students some initial experience along these lines.

**Step 2: Discursive Knowing**

This step is designed to help students learn more reflexive knowledge practices, by compelling them to engage with the multiple subjective frames that different participants bring to a problem. Reflexivity as a practice is greatly enhanced by interaction with others who have different ideas about the world, in this case as expressed through focused discussion of the different criteria students individually assign to their rankings to support their working definitions of sustainability. In Step 2 of The Packaging Lab, students work in small groups and therefore must come up with consensual rankings despite different individual criteria. In the process of deciding on a final group ranking to present and defend to the rest of the class, the individuals in each small group consider and deliberate over the different rationales and criteria offered by other team members to decide which criteria justify their collective ranking. It should be emphasized that, during this activity, students were not encouraged to strive for absolute consensus or to agree on a singular vision but to bring their different worlds together through deliberation. Step 2 therefore compels students to go beyond merely articulating explicit criteria and to build intersubjective understanding through debate and argumentation with group members, even as they also come to understand how others might have different frames.

These small-group discussions are therefore a process by which students, through their reflexive understandings of their own “situatedness,” learn to make emergent decisions with others through a group process that does not try to come up with one “ideal” definition. Students further understand sustainability as a discursive concept and expand their own comprehension by adding new transdisciplinary, transframe layers to their prior definitions of the term.

Yet, this kind of discursive knowledge building can lead to problems in multidisciplinary design teams as people talk past each other, confuse one another, and disbelieve each other because each participant has a different frame. Therefore, to support discursive modes of knowing, our pedagogical approach includes not only scaffolds for students to reflect individually upon a more expansive definition of sustainability but also scaffolds for them to articulate their individual perspectives and to listen carefully to others’ articulations. To promote receptive/reflexive exchanges and deliberation, professors instruct students to read sources and to use careful listening techniques taken from nonviolent communication, a process skill designed to help groups resolve conflicts through increasing abilities to listen to others, to articulate one’s own frame, and to look for the common interests behind what look like intransigent positions. This training helps students to learn collaborative practices that are an intrinsic part of interdisciplinary teamwork.

**Step 3: Codified Knowing**

For subjective and discursive modes of knowing to become productive they must be infused with technical, codified knowledge production and practice. Throughout the course, all four modes of knowing, including the codified information produced by specialists, were recognized as important learning processes. However, instead of didactic
methods of teaching knowledge from “the sage on the stage,” the lab prompted students to seek out this knowledge on their own through joint research. While it may seem incongruous to plan for gaining technical knowledge as a third step in this largely diagnostic and reflexive activity, we found that, typically, it was indeed at this very point in their learning process that students began to ask technical questions to ascertain whether or not particular packages in fact met their subjective criteria (“Is this plastic recyclable?”, “Is less packaging that is less recyclable really better than more but recyclable packaging?”). Realizing the importance of the technical questions they were beginning to ask, students were then self-motivated to do their own research to support their arguments for or against the features of particular packages as representing the more sustainable choice. In the earlier versions of this lab, we found students spontaneously turning to the Internet and library searches, beginning a kind of investigatory research despite the absence of this step as a required feature of the exercise. As it seemed to be an activity worth encouraging, we have now formally added this new step, with some scaffolding to help students hone and apply research skills in ways appropriate for training in key technical research competencies that enable them to take part in cogent sustainability planning and practice.

Step 4: Practice-based Knowing

Knowledge gained through practical action is fundamental to human understanding: we come to understand concepts by putting them to use in the world. Students participate in practice-based meaning-making from the start of the lab activity. The subjective knowledge they offer and technical information they query and gather becomes more meaningful because they are actually using it to do something—in this case to make decisions (i.e., establish a ranking) and later to defend those decisions to an audience of their peers.

Like the learning activity itself, our design of this lab was a collaborative experience, using student evaluations and our observations to better design the activity. As noted above, we added a technical research component to the exercise because we found that students were turning to this activity on their own. In a future version of this lab, we plan to add a new step that asks students to design a new object based on the criteria that they have been exploring, thereby putting to work the process skills they have just learned. This step will further train students to apply this process knowledge to plan and justify design components of their service-learning projects. Our expectation is that students will gain a deeper knowledge of the subjective and discursive criteria they are using to distinguish “sustainable” from “unsustainable” materials and/or practices to perform the practical work involved in completing their larger service-learning projects.

What We Learned from the Packaging Lab

We examined the results from students completing this lab in two courses, Sustainability and Social Change (Sociology 115) and Sustainability Engineering and Ecological Design (EE80s). In both courses, we found that the activity generally accomplished what it was designed to do, namely: 1) expose students to multiple frames of understanding when it comes to distinguishing unsustainable from sustainable practice, 2) thereby increasing the number and broadening the scope of the kinds of criteria that any one student might apply (or at least consider), and 3) challenge and engage students through problem-based dialogue to work effectively with people who hold different sustainability worldviews, in order to 4) present sustainability as a complex rather than reductive concept and one that is fundamentally discursive in nature.

We found that initially, it was common for students to rely on one or two reductive characteristics in their first attempt to justify a rank order. For example, in the version of the lab that asks students to rank packages “from best to worst,” multiple students used a simple binary heuristic: was the package recyclable or not? Other students remained narrowly focused on the recyclability of a package, but went a bit further to consider the amount of and types of materials used. However, working within small groups to agree on a collective group ranking in Step 2, students exposed each other to other possible decision criteria. For instance, one student, an environmental studies major, reported that when she joined her group, she was surprised to find that other students described “best” in terms of convenience and safety. Conversely, another student in a lab that asked students simply to rank packages from “best” to “worst” and who evaluated her packages by how easy they were to open noted that “I didn’t think of sustainability and most of the group had this option.” In the version of the lab in which we asked students specifically to rank packages according to their “sustainability” (rather than a more general idea of “best”), students also found themselves thinking more broadly about the meaning of this term after com-

3 Sociology 115 was carried out both at UC Santa Cruz and as a version of the academic program at the University of California Washington Center (with DuPuis as instructor). In both cases, the students were involved in service learning internships and represented many majors, including science, engineering, social science, and humanities.
completing the exercises. For example, one student initially focused on whether or not a spray bottle was recyclable and/or “reusable,” but after completing the group discussion and reranking exercises the same student introduced her own notion of a “waste to functionality ratio” to justify her ranking, arguing that the increased amount of material made the bottle more reusable.

Irrespective of the initial prompt (“rank packages from most to least sustainable” versus “rank packages from best to worst”), it was less common for students to integrate multiple types of decision criteria into their first set of rankings. The number of students showing that they integrated multiple characteristics into their reasoning increased after students discussed their individual rankings with a group of their peers and then completed the group and individual reranking phases of the activity.

In some versions of the UC Santa Cruz electrical engineering course (EE80s, Sustainable Engineering and Ecological Design), we also used the lab as a pre- and post-assessment to evaluate what students learned in the class. Students completed the entire lab on the first day of class and again at the end of the course on the final exam. In this case, the same students were asked to rank and justify their rankings for a different set of packages and each of them wrote multiple statements (“entries”) to justify the rank order of each packaged item. Table 2 compares our assessment of a sample (n = 59 students) of student entries on the first day of class to their entries on the final exam. Student entries were characterized as being low-level, mid-level or high-level responses depending on their overall complexity and scored accordingly. Unsophisticated responses showed awareness of only one or two reductive characteristics without including specifics or qualifying statements, or noting any contingencies. Sophisticated responses 1) were characterized by multiple types of considerations, 2) showed more specificity within a theme (e.g., “mineral extraction” vs. “manufacturing”), 3) included more qualifying statements (e.g., the idea that waste should be measured against functionality), 4) showed awareness of contingencies (e.g., an item is reusable but only if well-preserved by the consumer) and 5) did not treat the package as a unified whole but rather as a composite of different materials. As Table 1 indicates, we found that from pre- to post-instruction in the electrical engineering course the proportion of high-level responses increased dramatically while the proportions of low- and mid-level responses slightly decreased.

We also analyzed whether the net differences shown in Table 1 could be attributed to the gradual improvement of many students rather than the dramatic improvement of just a few and found the former to be the case. Specifically, we found that on the final exam, the number of students in our sample (n = 59) that included one or more high-level entries in their response increased by 21 as compared to their performance on the earlier individual ranking exercise. We also found that, while only three out of 59 students (5%) produced responses that included more than three high-level entries prior to instruction, 11 out of 59 (19%) included more than three high-level entries on the final exam. It is also encouraging that the number of students giving responses characterized by a majority of low-level entries (5 > entries) decreased by 15% from pre- to post-instruction.

While these results are evidence of student learning in only one particular course, they reflect the kind of improvement different instructors reported seeing across all courses using this lab.

After completing the ranking exercises and in-class discussions, students answered a series of reflective questions to compile a post-lab report. The work on these lab reports served to further improve their learning about sustainability as a complex concept, and also allowed us to better assess whether students were engaging in the multiple modes of knowing described in Table 1. Indeed, in reflecting on the lab, many students noted the discursive nature of sustainability. For example, one student wrote:

Since there are so many different definitions of sustainability it makes it difficult for society to agree on one specific one. I think a sustainable society has to come from baby steps. I believe that more likely than not, similar priorities of sustainability exist and it’s at these overlaps that we need to promote change. If someone were to just generalize all of sustainability into one giant definition, people would most likely be upset at

| Total entries in sample | Low-level responses | Mid-level responses | High-level responses |
|-------------------------|--------------------|--------------------|---------------------|
| Preliminary individual ranking exercise | 633 | 54% | 37% | 8% |
| Final exam | 788 | 48% | 31% | 20% |

Table 2 Low-, mid-, and high-level student entries.
the statement made. That’s why we need to find the common ground between the definitions and work from there.

Other students were able to comment on the subjectivity of their own position and how they learned reflexively through exchanges with others. One student explained that “through discussion and compromise, I learned about a product’s benefits/negative elements that allowed me to reflect and change my ranking.” Another student found that she shared many of the criteria with others in her group, “but recyclability weighed more in the group than it did for me individually.”

Taken together, these results show that after instruction students considered a broader range of criteria and did so with greater sophistication. We are aware, however, that the activity, as well as our scoring criteria for student performance, is more suited to capturing changes in the “breadth” of students’ thinking than in its depth or sophistication about any one topic. For that reason, it is important to mix an activity like this one with others that focus in more detail on the specific skills and knowledge tied to particular facets of the larger sustainability question.

For the SEED team, the development of the lab was itself an interactive and reflexive design process that required understanding the outcomes of successive changes. To solicit student feedback on the activity as a learning experience, we administered exit surveys, which also changed as the labs developed. When asked about their general experience with the SEED pedagogy, all of the students (n = 39) participating in one iteration of this lab indicated that they either agreed (47%) or strongly agreed (53%) with the following statement: “Through collaboration within my lab and design teams, I learned things I cannot learn in a lecture-based class.” When asked to rate the effectiveness of The Packaging Lab specifically for advancing their learning and skill development, 75% of these respondents rated their experience with this activity as “strong” (rating 4 or higher on a five-point scale). In a comment section, several students reported that this activity in particular helped them to “weigh both sides” of a problem, understand how different people might “think/see things,” and helpful for “putting problems in another perspective.”

However, fewer students saw the connection between their learning and their service-learning activities; only two of 39 students responding to our survey rated their experience with The Packaging Lab as “highly effective” (rating 3) in preparing them for their out-of-class responsibilities, while 38% of the students indicated that it was moderately helpful at best (rating 3 or less). Overall, students did not view the central idea that design can emerge from collaboration in groups with different criteria and different worldviews about sustainability as critical to the success of their action-research projects or internships. Those who did not grasp this point judged the activity as unnecessary but “fun.” With our addition of Step 3, the practice step where students design their own package, we hope to help students connect their learning in class to their service-learning activities.

Overall, we learned that reflexive learning requires substantial class time, although with less lecture time. When students are struggling to find effective ways to collaborate, the professor needs to have some way not to rush the process, to let things go. At other times, the instructor needs to know when to intervene to move things along so that students see the value of the class-time work. When students do productive classroom work, it is also important to devote class time to recognize what has been learned.

We also learned that evaluating the acquisition of uncodified, reflexive knowledge is difficult within standard codified assessment systems. Our multimodal pedagogy requires a different approach to understanding and evaluating student learning. In The Packaging Lab, no one rank order was considered correct. Indeed, we were less concerned with the actual rankings than with how students arrived at different conclusions based on their stated criteria. These challenges compound the difficulties of assessing reflexive, noncodified student learning. It is by definition challenging to codify process learning. Also, if students feel that they have learned something on their own, they do not necessarily credit the pedagogical scaffolding tool that got them there. In addition, in professional assessment (and in articles like this one) researchers must show that the tool (and the professor) has been effective. These difficulties make it tempting to move back to didactic mode, where the professor “gives” the information to the students and is therefore clearly the source of the information.

In other words, collaborative learning requires that the instructor take on a significantly different role in the course, one that is sometimes difficult when one is used to the traditional role of being the authority. In classrooms where the professor is coaching collaborative learning processes, he or she may appear superfluous. In institutions where instructor merit is based on ratings by students, collaborative learning processes put the instructor’s reputation at risk.

Making the world more sustainable presents a formidable challenge for the future. As this study has shown, the challenge is more than just designing the right campus greenprint. Universities that seek to
provide sustainability education must face up to the challenge of training students to become dynamic, reflexive, and collaborative in how they arrive at new understandings and how they participate in multimodal knowledge-production processes. As we have suggested above, this has strong implications for teaching practice as well as for the overall organization of learning within a university setting.

These challenges will not be easily met. In order for a university to research and teach sustainability through an interdisciplinary, dispersed, multimodal learning pedagogy, curriculum designers will need to overcome a long and entrenched history of presenting knowledge as "what": as immutable information held by experts and segregated into siloed disciplinary tracts. Universities that succeed in supporting faculty to create and implement these new types of curricula will better prepare students for the sustainability challenges ahead. UC Santa Cruz’s SEED program designers will continue to design—and redesign—learning activities to meet this goal. New collaborative and reflexive pedagogies to train students in post-normal modes of knowing will hopefully not just impact learning about sustainability, but also transform the university into a learning institution that gives students the competencies to meet the broader challenges of an increasingly complex world.

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COMMUNITY ESSAY

Sustainable approach to automobile society in Japan

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What is the difference between electric vehicles (EVs) in society and an EV society? “EVs in society” means simply the replacement of gasoline-powered cars with EVs without taking into consideration pervasive social issues. By contrast, an “EV society” is a concept whereby EVs are more fundamentally woven into the fabric of society with the aim of solving a range of social problems, while at the same time questioning the meaning of what an automobile “is” and “can be.” It is this “game-changing” principle of integration that drives our research.

Introduction

The number of private cars in Japan grew from approximately 2.3 million in 1966 to 58.1 million (including 17.3 million mini-cars) in 2009. This huge increase has led to a car society in which cars have a dramatic impact on socioeconomic systems such as housing, industrial activity, and health services. The annual volume of carbon-dioxide (CO2) emissions from the transportation sector is 236 million tons and accounts for about 20% of total releases in Japan (1.2 billion tons in 2008). About half of the CO2 emissions from the transportation sector comes from private cars, amounting to some 10% of the country’s total volume.

Against this backdrop, Japan has had considerable interest in electric vehicles (EVs) for some time now. Besides an improvement in battery performance, EV developments in Japan include the provision of grants and subsidies for purchasing EVs and an increase in the number of battery chargers. However, these activities are based on the conventional idea that EVs should simply replace current gasoline-powered vehicles. This approach will be inadequate given the existence of more penetrating social problems such as an ageing society and excessive energy consumption. “Game changing” is therefore essential when thinking about developing a sustainable automobile society in Japan.

What is “Game Changing”?

Figure 1 highlights the concept of game changing in this context. The current approach to EV diffusion is based on continuation of contemporary automobile society and calls for EVs with performance and convenience characteristics similar to current gasoline-powered cars. However, a different view is needed, one that no longer favors the personal car, which is likely to gradually fade out with future social changes. If this happens, a different kind of vehicle will spread. We argue that this new mode of mobility will be produced and integrated into society in response to radical changes such as an aging society, oil depletion, and altered purchasing behavior of young people. The traditional “current approach” outlined in Figure 1 to “energy scarcity” includes simply replacing cars powered by combustion engines with EVs. However, the new, game-changing approach integrates the features of EVs with social issues. Therefore, “EVs in society” and an “EV society” are radically different approaches, changing the meaning of what an automobile “is” and “can be.”

This interweaving of social issues with technological innovations is discussed extensively in the literature on sociotechnical transitions. Basically, a “transition” refers to a long-term change in an encompassing system that serves a basic societal function, a change that dramatically alters both the technical and the sociocultural dimensions of such a system (Elzen & Wieczorek, 2005). Much work has been conducted on the conceptual refinement of transition pathways, and it may therefore be helpful to view this “game-changing” attitude within the context of such research. The so-called multi-level perspective (MLP) outlined by Geels & Schot (2007) is especially helpful. The key feature of the MLP is that system innovations occur through the interplay of the dynamics between multiple levels.
First, the meso-level describes a specific socio-technical regime, which in the case of this essay would be characterized by the current gasoline-powered automobile and its associated social and infrastructural system. Second, the macro-level is the socio-technical landscape, which describes factors that influence a variety of regimes: for example, social demographics, public concern about climate change, and so forth. Indeed, as Geels & Schot (2007) state, “changes at the landscape level create pressure on the regime.” Finally, the micro-level of the MLP refers to technological niches in which radical innovations—for instance related to EVs—are incubated.

According to this multilevel perspective, transitions occur through interactions among processes at these three levels. It could therefore be argued that this interplay between societal issues such as an aging society and technological innovations related to EVs can lead to instability of the current automotive regime. As Geels & Schot (2007) point out, “[d]e-stabilization of the regime creates windows of opportunity for niche innovations.” The imminent radical social changes building in Japan, coupled with the accumulating “side-effects” of automobile society, could potentially undermine the current regime and drive the game-changing approach toward the establishment of a new EV society. We now look at these two areas more closely.

Social Changes in Japan

Japan is confronting several radical social changes related to automobile society, as outlined below.

The World’s Fastest Aging Society

There is no precedent for a process of societal aging comparable to what Japan is presently experiencing. Figure 2 shows the elderly population (>65 years old) as a percentage of the population. According to the Japanese Cabinet Office (2009), the number of people over 65 is projected to reach 30% in 2025 and 40% in 2055. Furthermore, the percentage of people over 75 is increasing at a similar rate.

Over the Peak of Population

Japan passed its demographic peak in 2006 and, due to the low birth rate, the population has been contracting. Indeed, the percentage of children under fifteen-years old has been decreasing since 1982 (MIC, 2010). The ratio of productive age people (from 15 to 64 years old) to aged people (over 65) was 4.8 in 1995, 3.3 in 2005, and is estimated to be 2.0 in 2025 and 1.3 in 2055 (Figure 3).

These trends raise three essential issues with respect to transportation practices in Japan. First, traffic accidents caused by elderly drivers have increased markedly, from 28.4% in 2001 to 31.3% in 2011 (65–74 years old), and from 12.3% in 2001 to 19.0% in 2011 (over 75 years old). Furthermore, Japan has a system whereby elderly people get special services from the public transportation system if they return their driver’s license. The number of elderly people participating in this practice increased from under 500,000 in 2000 to over six million in 2010 (MLIT, 2011). This suggests that even if they have a driver’s license, aging Japanese lose their desire to drive a car. Second, as the average age of the population increases, the total number of drivers in Japan will decrease steadily. Finally, parts of the country—mostly outlying rural areas—are becoming depopulated and senior citizens are living alone. These circumstances demand the design and implementation of new public systems of transportation.
Decrease in Oil Demand

According to the National Institute for Environmental Studies, it is essential to achieve a low-carbon society in Japan (NIES, 2012). However, there are some indications that the country will naturally move toward lower energy consumption without radical measures. The demand for gasoline in Japan has been decreasing, moving from 61.4 million kiloliters (kl) in 2005 to 57.5 million kl in 2008. The Ministry of Economy, Trade, and Industry (2009) estimates that gasoline consumption will be 49 million liters in 2013, down nearly 20% from its 2008 level and this general trend is expected to continue.

Consumption by Youth

Figure 4 shows the number of cars sold in the Japanese market, which peaked in 1996, increased again from 1998 to 2006, then has been in uninterrupted decline since 2006. For nearly two decades, the number of “light cars” (vehicles with total engine exhaust under 0.66 liters and weighing under 1,000 kilograms) has gradually become a large part (about 33% in 2009) of the national fleet. Paralleling this development, the annual growth rate of the country’s gross domestic product (GDP) was 0% in 1997 and -1.5% in 1998 (Cabinet Office Japan, 2011). During the period 2003 to 2007, car sales continued to decline despite an annual GDP growth rate of approximately 2%, suggesting that the decrease in car purchases has not been simply due to deterioration in economic conditions.

According to industry analysts, one factor responsible for this drop in demand for cars is declining purchasing activity by young people. A report issued by the Japanese Automobile Manufacturers Association (2009) noted that car sales have been adversely affected by increased use of videogames, personal computers, cellular phones, smart phones, and other handheld communication devices. At the same time, the “burdens” associated with car ownership, for example parking fees and maintenance and operating costs, increased as economic conditions worsened (JAMA, 2009). In short, Japanese youth are not buying cars with the same enthusiasm as previous generations, a phenomenon that suggests evolving attitudes toward the internal combustion-engine automobile. Such circumstances are an indication that young people may be open to the creation of an EV society.

Side-effects of the Current Automobile Society

Japan is a country with a heavy debt burden. Because of cost increases in medical service for elderly people, the financial burden will increase as Japanese society continues to age. The Japanese currently take air pollution and noise pollution caused by gasoline-powered cars for granted. However, as John Talberth and his colleagues (2007) observe, “[we] reap the benefit of freedom gained by transportation at great cost.” For example, the exhaust fumes from internal combustion can trigger medical conditions, such as respiratory disease, while the noise from these vehicles has been linked to mental stress. At great social cost, the government spends vast sums treating such disorders. How much money do we waste on such side-effects? Although precise data are scarce, regarding traffic accidents the estimated cost would be over 10 trillion yen (US$115 billion). The Japanese public also pays for measuring and mitigating the multitude of social and environmental problems caused by cars.

The issues outlined above suggest that the current automobile society is unlikely to continue. If this is the scenario that will unfold, how can we design for a future where EVs can naturally spread widely? We have already suggested that the “conventional style” of automobile or EVs would decrease in the future. However, both the elderly and the young would embrace an EV society because the new func-
tions that are integrated into the urban infrastructure would address a number of prescient issues, such as a lack of mobility and a short working life for elderly people and the economic burden caused by an aging society for young people. For example, an EV society based on the following scenarios would enable older workers to extend their active lives, which will have an impact on a range of economic issues. Their increased mobility will contribute to economic growth by helping them continue a consumer lifestyle. In addition, because an EV society will allow the elderly to extend their working lives, their pension-age threshold can be increased. These measures will reduce the economic and social burden as well as the anxiety young Japanese feel about problems linked to an aging population.

The Future EV Society

As noted above, many of the preconditions for a transition favoring EVs have begun to diffuse in Japan. However, these activities are based on the simplistic notion that EVs will replace current gasoline vehicles and have not considered the more expansive social and demographic changes taking place in Japan.

Depicting Future EV Society

We used scenario-planning and brainstorming methods to depict an “extreme” (100%) EV society. These methods were carried out during a one-year project. Experts from oil companies, magnet-parts companies, and EV researchers were interviewed. In addition, ten engineers, including four university professors, participated in an intensive two-day discussion on the development of an “extreme” scenario. Extreme thinking was encouraged to avoid “conventional” solutions, for instance that existing technologies would simply be replaced by nominally low-carbon ones to directly decrease CO₂ emissions. While many social factors will have a large impact on future society, we chose two uncertain issues that are likely to have a sizeable effect on future social shaping: distance travelled by a car (no change or shortened) and functional value such as using an EV as a private room (no change or having new value). (This method is similar to scenario-planning methods such as those used by Sharpe & van der Heijden, 2007). The former factor is closely related to urban structure in an aging society while the latter is associated with young people’s interest in cars. These two uncertain issues were expressed by two axes and four quadrants. The future society scenarios below were then placed in each quadrant (Figure 5).

Continuation of Current “Automotive” Society

Japan had 41.8 million ordinary cars and 15.7 million light cars in 2007 (MLIT, 2008). This scenario depicts a continuation of more or less the same situation, but with all gasoline cars being replaced by EVs. Battery chargers would be set up in all public places due to the low capacity of onboard electric storage. Furthermore, non-contact type battery chargers, the method of transmitting energy using electromagnetic waves, would be used on the highway. People could recharge their EVs in much the

Figure 5 Features of EV society scenarios.
same way that they refuel their gasoline cars. This is comparable to the usual scenarios considered by planning exercises to achieve a low-carbon society, meaning a lack of consideration for social changes, such as how to transport aged people (see Table 1 for more details).

**Clean Compact City**

In this scenario, EVs would not need to achieve high mileage and speed performance. Rather, they would be designed for “low speed” and would not harm people in a collision. Advanced controls would make auto-piloting and auto-parking readily and widely available. This future scenario, as with the first scenario, would be free from the negative social costs of traffic accidents and environmental impacts associated with vehicle exhaust and noise pollution.

Senior citizens could utilize a car and walk around safely in a “silent” town due to the EVs’ functional performance. Furthermore, an auto-parking system would make “park & ride” more convenient, reducing the time necessary to search for a parking space as well as simplifying the difficult procedure of parking a car. If this society is realized, it will solve issues of transportation for aged people. Moreover, even if the number of senior citizens using cars increases, overall environmental impact would be lower, as shown in Table 1. However, clear vision and governmental leadership would be essential to construct new “compact cities.” In this society, cars would be mere tools to enable people to travel short distances, used in much the same way as bicycles and scooters.

**Versatile Car Society**

Under this third scenario, the car changes from a “transportation device” to “my room with a vehicle.” By using the unique characteristics of being “clean” and having a battery, EVs could be usefully integrated into different niches. Some people could even bring an EV into a house and use it as a room. Furthermore, EV’s could be docked with a “public station,” a place with facilities that could be used by the public, such as a bathroom and kitchen. This concept is familiar to Japanese citizens. People could dock an EV with such a “public station” and share these utilities.

Because EVs have an automatic low-speed running mode, they could be a means of transportation for physically disabled senior citizens. Moreover, it would be possible to come home in the automatic running mode after alcohol consumption. Thus, accidents related to drunk driving would become obsolete.

This society could be moderately achieved by using innovative ideas from the private sector, for example, a robot that could change its form to fit the situation in which it is used. The government also has a role to assist this activity. Aged people could move freely, and young people could recover their interest in “cars” via a new style that combines ideas from growth industries such as information technology and robotics. This could help stimulate Japan’s economy while reducing environmental emissions.

**“Barrier-Free” Car Society**

In this final scenario, the distance travelled by a car is similar to the “continuation of current automotive society” scenario. However, there is the difference in how the cars are used. In this case, the frequency of short trips increases because of the barrier-free concept. “Everyone” can use EVs “always” and “anywhere.” “Everyone” means elderly people can use EVs while “anywhere” encompasses department stores, train stations, and so forth. “Always” means an EV can be integrated into any situation, whether in...
such as “clean compact city,” could be manufactured in the car industry. By contrast, EVs in the other scenarios, where new firms that blend information technologies, robotics, materials, and interior design. The current automobile companies have supplied different types of gasoline-powered cars, for instance, “high-speed,” “long-distance travelled,” and “safe/comfortable” cars in several countries. Accordingly, when we consider Japan’s “car society” in the future, we cannot ignore the effect of globalization on manufacturers themselves. Regarding resource/energy consumption and CO₂ emissions, we assumed no large differences in the various scenarios.

What is sustainability in Japan? One definition of a sustainable Japan entails maintaining the country’s current affluent society. However, a number of barriers need to be overcome, such as the decreasing “productive-age” population, increasing aging population, and social costs related to environmental issues.

The decreasing “productive age” population will depress Japan’s economy because such individuals currently constitute the highest percentage of consumers and workers. The country’s aging population will increase social costs related to welfare. Furthermore, growing environmental stress, such as air pollution and climate change, will increase social costs. As economic stagnation means a shortfall in tax revenue, an increase in social costs will have a serious impact on Japan’s sustainability. We believe the following scenarios could help solve such problems:

1. **Negative social cost reduction**: Continuation of current “automobile society” will lead to the reduction of negative costs related to air pollution.

2. **New lifestyle provided for young people**: “Versatile car society” will help stimulate young people’s consumption with social cost reduction.

3. **Recover motivation for extending the working lives of an aging population**: “Clean compact city” will reduce the social costs related to air pollution and traffic accidents. Moreover, providing low speed and autopilot cars may support daily life activities and extend the working lives of elderly people.

4. **Recover the consumer mind in aged people by increasing their daily life activities**: “Barrier-free car society” will help recover motivation for extending the working life and consumer mindset of elderly people, leading to reductions in social costs. The size of the Japanese population is decreasing. This means even if we do not take any measures, environmental impacts will tend to decline. It is necessary to maintain a balance between social activities and environment impact.

Figure 6 highlights differences between current approaches of substituting gasoline-powered cars for EVs and a game-changing approach toward a sustainable car society. By considering a range of social factors, we can depict various social scenarios that contribute to such a vision.

**Conclusion**

As outlined in the introduction, in the same way that the authors had to undergo a radical change with regard to their method of study from pure engineering to a more “open” strategy, the scenarios show that the Japanese approach to societal planning must also experience a radical change in the way it utilizes and integrates technology. The current method of substituting gasoline-powered cars for EVs is misguided if we consider future social changes in Japan. This is the conventional approach informed only by technological innovation.
If we employ a more radical strategy where technology is integrated with social issues, EV technology provides us with an opportunity to profoundly transform societal organization. A new kind of society can be created, which will attenuate many of the social problems we face in our current automobile society. These include issues related to an unprecedented aging population with a low birth rate and increasing social costs with respect to transportation and medical care. It will be more effective to start investigating game-changing approaches that broaden our horizons. We have to possess a holistic view of social issues that spans climate change, poverty, global population growth, and economic security and understands the causality among them. The integration of social science perspectives related to human behavior and culture with technology is inevitable.

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