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COMMUNITY ESSAY

Working toward a sustainable future

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Authors' Personal Statement:

How can our society address the complex interaction of environmental, social, and economic problems in the 21st century? We propose that federal agencies in the United States complement their existing regulatory framework with new initiatives based on the "innovation cycle" for sustainability. This approach includes engaging stakeholders, advancing sustainability science and systems thinking, encouraging public-private partnerships, and developing decision-support capabilities to enable sustainable and resilient solutions. The United States Environmental Protection Agency (USEPA) is moving in this direction through new actions defined in the agency's Strategic Plan for 2014–2018. In this Community Essay, we highlight examples of how the innovation cycle enables progress on critical issues facing USEPA and other agencies, and we argue for increased government-business collaboration, federal agency coordination, and public involvement.

Introduction

How can contemporary society address the complex interaction of environmental, social, and economic forces? What factors are currently limiting the sustainability of business enterprises? How can federal and state agencies break down silos and work together to pursue sustainability? What is the preferred model for business-government collaboration and engagement with civil society and nongovernmental organizations (NGOs)? We raise these questions because in the 21st century all sectors of society must confront the challenge of sustaining economic development while protecting critical environmental resources.

In 1970, when the modern environmental movement was coalescing and the United States Environmental Protection Agency (USEPA) was created, environmental protection focused mainly on addressing issues related to industrial emissions and occupational health and safety. Most environmental challenges were highly visible and easy for the public to understand. For instance, on June 22, 1969, an oil slick and debris in the Cuyahoga River in Cleveland caught fire, drawing national attention to environmental problems in Ohio and elsewhere in the United States. *Time* magazine wrote on August 1, 1970, "Some River! Chocolate-brown, oily, bubbling with subsurface gases, it oozes rather than flows."

Congress addressed the obvious problems of air, water, and land pollution in the United States through media-specific environmental legislation. In the late 1960s and early 1970s, there was significant bipartisan popular demand for federal leadership in ameliorating pollution problems (Andrews, 2011). The Clean Air Act of 1970, the Clean Water Act of 1972, the Safe Drinking Water Act of 1974, the Resource Conservation and Recovery Act of 1976, and the Comprehensive Environmental Response, Cleanup, and Liability (Superfund) Act of 1980 yielded great progress in improving the quality of the environment. These initiatives relied on federal regulations that set maximum pollutant limits and heavily fined businesses that did not comply. The success of these laws and subsequent regulations is evident today: our air and water are cleaner, less hazardous waste is produced, and contaminated sites are being remediated. Existing regulations provide a strong "safety net" against the domestic impacts of pollution, although the potential remains for environmental problems to be "exported" across global supply chains.

Table 1 Evolving environmental problems and policy approaches in the United States.

	19th Century	20th Century	21st Century
Problem focus	Land use	Safety & health risks; Media/site/problem-specific	Complex regional/global problems
Outcome	Land preservation	Pollution control; Management of human-caused ecological risk	Sustainable development; Resilient society
Principal Activity	Land/water regulation; Contaminant controls	Compliance/remediation with technological emphasis on problem solving	Integration of social, economic, and technological information for holistic problem- solving
Economic Approach	Assure value of land use and development	Cost/benefit analysis; Emphasis on efficiency	Investments in natural capital; Concern for long-term societal well-being
Regulatory Approach	Narrow scope	Intensive, broad scope; Media-centric risk assessment	Flexible, including market-based incentives and community engagement
Conceptual Model	Expansion vs. preservation	Command-and-control	Systems/life cycle approach; Innovation and adaptation
Research Methods	Disciplinary; Insular	Multidisciplinary	Integrative; Transdisciplinary

Source: Adapted from Fiksel et al. (2009).

Despite these significant accomplishments, newly emerging pressures are threatening the well-being and resilience of human society and the natural environment, thus jeopardizing economic prosperity. The urgency of dealing with today's problems is evident. Worldwide population growth and urban development, as well as globalization of industrial production, have driven increased consumption of energy, water, materials, and land. The consequences include increased greenhouse-gas emissions, decreased biodiversity, and threats to vital natural resources including water bodies, soils, forests, wetlands, and coral reefs. The Millennium Ecosystem Assessment found that fifteen of 24 global ecosystem services are being degraded or exhausted (Hassan et al. 2005). A study by the Stockholm Center for Resilience suggests that on a planetary scale we have exceeded our "safe operating boundaries" in terms of greenhouse-gas emissions, nitrogen flows, and biodiversity (Rockström et al. 2009). The Global Footprint Network has estimated that if current trends continue, by the 2030s, we will need the equivalent of two Earths to support the world's population.[1] Planetary ecosystems will experience even greater pressures by 2050, when global population could reach 9 billion, some 30% more than the 2000 level (UNDESA, 2012), while rapid economic growth and urbanization in developing nations will exacerbate resource demands.

Table 1 provides an overview of the evolving nature of environmental problems and policy responses in the United States. The focus has shifted from land conservation in the 19th century to risk management in the 20th century to broader sustainability concerns (requiring a systems approach) in the 21st century. By anticipating future challenges, we can embark on a new era of cooperation, coordination, and public support for achieving sustainable development (Hecht et al. 2012). We need to think ahead, and this Community Essay outlines positive steps toward a resilient and sustainable future.

Strategies for a Sustainable Future

Addressing the problems of the 21st century will require a combination of strategies, including creative use of existing environmental policies and regulations, innovative application of science and technology, and collaboration among stakeholders. These are not easy challenges given the rigid nature of government operations, the tensions between business and government, and the potential conflicts between local and national interests.

Fortunately, major institutions are beginning to respond positively to these challenges. As Figure 1 shows, the confluence of economic and environmental risks, regulations, financial investment and public reporting, and international forces have propelled business and government leaders toward adoption of more sustainable practices (Hecht, 2012). There is clear evidence of this transition in the business community—in one recent survey of nearly 3,000 company officials, two-thirds confirmed that "sustainability was critically important to being competitive in today's marketplace" (Kiron et al. 2013).

In June 2012, the "Rio+20" United Nations Conference on Sustainable Development emphasized the importance of strong public-private partnerships to assure that the economy provides social benefits such as job creation, poverty alleviation, and improved environmental conditions. The conference resulted in

[1] See http://www.footprintnetwork.org/en/index.php.

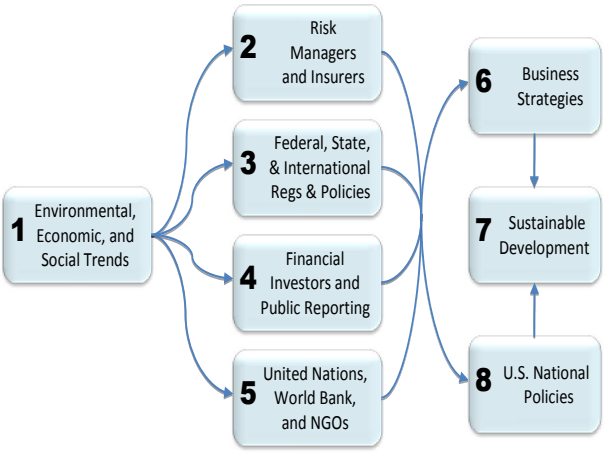

Figure 1 Business-government convergence on sustainability (Hecht, 2012).

the commitment of over US$513 billion by businesses and governments to address critical sustainability issues, including energy and food security, access to drinking water, and management of the oceans.[2] For example, the United States government announced US$2 billion in grants and loans to advance clean-energy technology. The following are examples of commitments from private enterprises:

- Microsoft committed to achieve carbon neutrality in its operations in more than 100 countries by 2030.
- Bank of America set the goal of allocating US$50 billion for low-carbon energy financing over the next ten years.
- DuPont committed US$10 billion by 2020 to research and development, and plans to launch 4,000 new products by the end of 2020 to produce more food, to enhance nutrition, and to improve farming sustainability worldwide.
- The Consumer Goods Forum, a partnership of more than 600 companies, agreed to "zero net deforestation" in their supply chains by 2020.

Despite these positive signals, the United States and the world as a whole face daunting challenges that will not be resolved by the actions of a few progressive organizations or changes in some practices of even major corporations. Collective action will be needed on a broad scale to reverse current unsustainable trends and to prevent a global "tragedy of the commons."

[2] See Rio+20 Voluntary Commitments (http://www.uncsd2012.org/voluntarycommitments.html) and Action and Accountability at the Rio+20 Earth Summit and Beyond (http://www.cloudofcommitments.org).

The Innovation Cycle, Systems Thinking, and Resilience

A classic definition of a sustainable society is "one that can persist over generations, one that is far-seeing enough, flexible enough and wise enough not to undermine either its physical or its social system of support" (Meadows et al. 1992). Today more than ever, the creative power of innovation is necessary to meet the challenges of reducing humanity's global footprint and balancing economic growth with social and environmental concerns. Technological innovation must be accompanied by innovative business models and governance approaches.

For a start, we need to embrace new approaches that apply systems thinking and transdisciplinary research to capture the full scope of environmental, social, and economic problems and to identify potential solutions. In particular, we need to apply advanced decision-support tools, such as life-cycle assessment, to help decision makers evaluate alternative responses. Second, we need to promote effective engagement and collaboration among federal agencies, businesses, local communities, NGOs, and other stakeholders to understand and address their respective goals.

All of these activities contribute to what we call the "Innovation Cycle for Sustainability," which draws upon well-established principles of innovation. The following are key elements of this cycle:

- Engaging stakeholders to understand their needs, constraints, and priorities.
- Using sustainability science and systems thinking to enable integrated problem solving.
- Encouraging transdisciplinary collaboration among government, business, academia, and NGOs to design innovative technologies and practices.
- Developing comprehensive decision-support tools to help policy makers and decision makers implement sustainable and resilient solutions.

The innovation cycle relies heavily on collaboration in defining and responding to stakeholder needs, as well as integrating across research disciplines. It builds on the concept of "sustainability science," which aims to link many scientific disciplines to create an integrated systems approach to problem assessment and management (Kates & Parris, 2003). As John Sterman (2002) notes, "overcoming policy resistance and building a sustainable world requires meaningful systems thinking coupled with community engagement in promoting common good."

Systems thinking leads to a better understanding of resilience, defined as "the capacity to survive,

adapt, and flourish in the face of turbulent change and uncertainty" (Fiksel, 2007). Over the past several years, attention to resilience and sustainability has increased significantly as a consequence of natural disasters such as Superstorm Sandy, which ravaged large portions of the New York metropolitan area in October 2012. According to the insurance company Munich Re, North America has seen the world's sharpest increase in the cost of natural catastrophes during the past 32 years, a trend that appears to correlate with climate change. While climate adaptation is an important aspect of resilience, equally important is anticipation of future disruptions such as infrastructure breakdown.

The concepts of sustainability and resilience are interrelated (National Research Council, 2012a). Sustainability tends to focus on long-term goals and strategies, while resilience is oriented to preparing for unexpected disruptions that may destabilize an otherwise sustainable system. Generally, approaches taken to address one concept would also be supportive of the other, although there may be tradeoffs. The more sustainable we are, the less we expose ourselves to unpredictable disruptions; the more resilient we are, the less we risk compromising our future well-being (Fiksel et al. 2014).

A recent National Academies report, *Disaster Resilience: A National Imperative* (National Research Council, 2012b), recommends that "Federal government agencies should incorporate national resilience as a guiding principle to inform the mission and actions of the federal government and the programs it supports at all levels." As noted above, resilience strategies are needed not only for coping with disasters but also for addressing slower-moving threats, such as sea-level rise, that can make us more vulnerable to disruptive events.

Further evidence of the growing importance of resilience is the creation of ResilientCity, a network of urban planners, architects, designers, engineers, and landscape architects that seeks to develop creative and practical planning and design strategies to increase the resilience of cities and communities.[3] The group aims to deal with the potential impacts associated with climate change, environmental degradation, and resource shortages. Similarly, the Rockefeller Foundation has launched a worldwide grant program called "100 Resilient Cities," helping cities to better address the increasing shocks and stresses of the 21st century.[4]

Decision-Support Tools

A key element of the innovation cycle is the use of decision-support tools and indicators to help decision makers assess the combined social, economic, and environmental impacts of alternative policies, technologies, and practices. The USEPA and other agencies have a long history of applying such tools (e.g., cost-benefit analysis). Today, using modern technologies such as geographic information systems, new applications and indicators are being developed to integrate diverse data sources and models, enabling a systems approach. As a result, decision makers at all levels—federal, state, and community—will be better equipped to understand the overall consequences of proposed actions in terms of sustainability and resilience.

Currently, USEPA is taking a systems approach to address serious water-quality problems in the Narragansett Bay watershed.[5] The health of the bay is jeopardized by excessive releases of nutrients—primarily nitrogen and phosphorus—from agriculture, wastewater treatment, and stormwater runoff, among other sources. Excessive nutrient overloads cause algae blooms that can degrade or destroy aquatic ecosystems and interfere with fishing, recreation, and tourism. The USEPA is collaborating with many regional stakeholders to consider a portfolio of possible solutions, such as septic and sewage-treatment technologies, low-impact development, and green infrastructure, as well as to assess the long-term outcomes of these measures.

To support this effort, USEPA has developed a policy analysis and decision-support tool based on a systems framework called the Triple Value Model (Fiksel, 2012). A user-friendly, dashboard-style visualization interface enables users to construct alternative intervention scenarios aimed at reducing adverse nutrient impacts to the watershed, and to project over a 40-year time horizon the expected changes in a variety of environmental, economic, and social indicators such as water clarity, tourism revenue, and property values (Fiksel et al. 2013). The underlying model uses system dynamics to integrate relevant data and scientific relationships across the economic, social, and environmental spheres (see Figure 2).

The above example illustrates how the innovation cycle can extend beyond the "safety net" of current legislative mandates and address a complex set of problems that requires integrated thinking. For instance, why aim merely to treat toxic waste when we can limit its creation through the use of more benign materials, the design of innovative conversion

[3] See http://www.resilientcity.org.

[4] See http://100resilientcities.rockefellerfoundation.org.

[5] See http://www.epa.gov/research/docs/3vs-tool-nutrient-mgt-narr-bay.pdf.

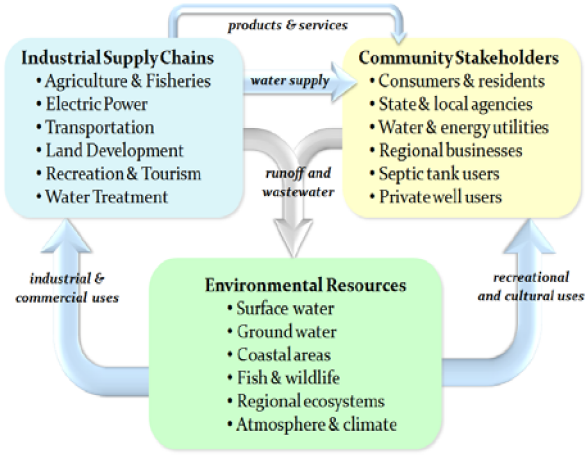

Figure 2 Systems modeling for nutrient impairment in New England.

processes, and the establishment of a regulatory system favoring recycling and reuse? As Michael Weinstein et al. (2013) and others have pointed out, the global sustainability transition is "more than changing light bulbs"; it involves changing our approach to decision making.

Government Linkages

Effective implementation of the innovation cycle requires collaboration among federal and state agencies, transcending regulatory boundaries and coordinating existing sustainability programs. Statutes, budgets, and government culture often encourage federal agencies in the United States to focus on a single area (e.g., energy, water, occupational safety) with little attention to how these areas affect one another. It is essential to overcome this "stovepipe" or "silo" effect to address sustainability issues that cut across agency boundaries.

One successful example of effective interagency collaboration is the partnership between USEPA, the Department of Housing and Urban Development (HUD), and the Department of Transportation (DOT) (USEPA, 2009). In 2009, the three agencies agreed to work together to support sustainable community development by applying federal transportation, water infrastructure, housing, and other investments in a coordinated manner. The agencies are also working collaboratively on tools and metrics to benchmark existing conditions, measure progress toward achieving community visions, and increase accountability. For example, the HUD-EPA-DOT partnership has launched a project in Gary, Indiana to revitalize four decaying neighborhoods, including clean-up of contaminated brownfield sites and development of green infrastructure.[6]

Building on this kind of multi-agency engagement, seven federal agencies, two private entities, and two foundations asked the National Research Council (NRC) to study how agencies could better consider complex and cross-cutting sustainability challenges. The NRC established an expert committee to review the literature, hold public fact-finding meetings, and explore examples in three landscapes: urban, suburban, and rural. The study's basic premise was that sustainability is a systems problem, and rather than separately optimizing its pieces one must understand the "nexus" where domains intersect but existing institutions and disciplines do not. The final study report, *Sustainability for the Nation: Resource Connections and Governance Linkages,* produced a number of important recommendations (Committee on Sustainability Linkages in the Federal Government et al. 2013):

- Adopt a decision framework that emphasizes preparing and planning, designing and implementing, evaluating and adapting, and assessing long-term outcomes.
- Support innovative efforts to address sustainability issues by identifying key administrative, programmatic, funding, and other barriers and by developing ways to reduce these barriers.
- Legitimize and reward the activities of individuals who engage in initiatives that "cross silos" in the interest of sustainability, both at the staff and leadership level.
- Support long-term, interdisciplinary research underpinning sustainability.
- Support scientific incentives to collaborate on sustained, cross-agency research.
- Adopt a National Sustainability Policy to provide clear guidance to executive agencies on addressing governance linkages related to complex sustainability problems.

The last recommendation is a formidable but achievable challenge. The objectives of a National Sustainability Policy would be to encourage coordination among agencies, reduce "silos," and improve integration of research and operations. Furthermore, the policy would enhance communication among agencies and between the federal government and stakeholders, while reducing duplication and improving cost effectiveness. One example of such an initiative is the United States Global Change Research Program (USGCRP), mandated by Congress

[6] See http://www.garycommunity.com.

in 1990 to coordinate research across thirteen agencies.[7]

Making sustainability an explicit policy goal at all levels of government, as well as the private sector, can send a clear message about the need for innovative practices and creative regulatory approaches that serve the collective interests of the public, business, and government. Jordan & Benson (2013) note that sustainability is more than a vision, but an *organizing principle* for the future of policies and governance. Their focus is on the Gulf of Mexico where the population has nearly doubled between 1970 and 2000, placing significant pressures on natural resources. In the Gulf Coast region, federal policies, regulations, and management programs apply to a complex suite of issues, including human health, water and air quality, waste management, marine fisheries, endangered species, fossil-fuel extraction, oil pollution, ocean dumping, ports and waterways, and public access to beaches. In some cases, federal policies are administered by the states, in others (e.g., air quality) by national mandates, and in yet others (e.g., marine fisheries) by multi-state entities.

These authors describe the experience of Tampa Bay, which by 1970 was experiencing deteriorating water quality and loss of sea grasses due to increased nutrient concentrations. Without intervention, these trends could have altered the estuarine ecosystem irreversibly. Combined action by citizens groups and the federal government led to advanced wastewater treatment, greatly reducing nitrogen discharges into the bay. Subsequent accomplishments included major reductions in nutrient loads from other sources, along with preserving and restoring mangrove and tidal marsh habitats. Thus, stakeholders working together had significantly addressed critical environmental needs.

The successes of Tampa Bay highlight the importance of anticipatory and proactive strategies. Future challenges, including climate change, sea-level rise, and population growth, are now being addressed comprehensively by a diverse regional network of stakeholders and authorities. In contrast, serious problems exist along the Louisiana coast, where there have been persistent failures to address the complexities of environmental change in the context of competing economic and social interests. For example, while fisheries policies strive explicitly for sustainability, critical habitats are being lost because of failures to account for cumulative impacts over space and time. To prevent further deterioration of the coastal zone, the state of Louisiana recently updated its coastal master plan to emphasize comprehensive, sustainable approaches. While many stakeholders were engaged in development of this master plan, an effective governance network comparable to Tampa Bay has not yet been instituted; this remains a clear challenge for the future.

More recently, following the Deepwater Horizon oil spill in 2012, the Restore Act established a Gulf Coast Ecosystem Restoration Council to coordinate funding of restoration actions. The Act mandates that 80% of recovery funding be allocated to activities contributing to the environmental and economic well-being of the Gulf Coast and its residents. The council, chaired by the United States Secretary of Commerce, includes the five Gulf-state governors and the leaders of relevant federal agencies. Continued stakeholder collaboration will be crucial for dealing with ongoing problems throughout the region.

Stakeholder Collaboration

The examples in Narragansett Bay and the Gulf of Mexico illustrate the need for broad engagement of government agencies with NGOs, academic institutions, the business community, and civil society. Common to all stakeholders is the recognition that energy, water, land use, and material consumption are interrelated, and that these linkages must be understood to enable effective policy formation. Many in the business and financial communities view sustainability as a means to reduce long-term risk, enhance economic competitiveness, and promote social well-being. Many consumers are also becoming more aware of sustainability issues and expect manufacturers to develop greener and/or safer products. The goal of sustainability can be pursued most effectively when business, government, and other stakeholders collaborate to identify critical issues and common goals, adopting a systems approach to innovative resource management.

As noted earlier, contrary to the traditional view that environmental responsibility is a burden on industry, leading companies are now embracing sustainability as a core strategy for long-term success. The World Business Council for Sustainable Development (WBCSD) has formulated an ambitious agenda to assist global industries in moving toward sustainable growth. The Council's *Vision 2050* report coined the phrase "green race" and outlines a "pathway that will require fundamental changes in governance structures, economic frameworks, business and human behavior." The report argues that these changes are "necessary, feasible and offer tremendous business opportunities for companies that turn sustainability into strategy" (WBCSD, 2010).

Business and government have identified a number of common objectives, one example being waste

[7] See http://www.globalchange.gov.

reduction. The WBCSD report cited above set forth a vision for 2030: "not a particle of waste." Many prominent companies, including Disney, General Motors, and Unilever, have established zero-waste goals. For example, Unilever recycles 97% of its waste through its waste contractor Veolia Environment. At the same time, federal, state, and local governments are grappling with approaches for limiting both the volume and toxicity of waste. The fact that business and government share common themes—such as zero waste—creates an opportunity for collaboration on 1) developing the needed science and innovation to design products with minimal waste and 2) removing regulatory barriers that impede the effective recycling or reuse of materials.

Innovation can emerge in surprising ways. One inspiring example involves Veronika Scott, a 23-year-old Detroit resident who had the radical idea of making coats out of scrap material and delivering them to the homeless. She envisioned no ordinary garment—and her material came from no ordinary source. She created a coat that converts in seconds into a sleeping bag, and much of the material comes from waste products of General Motors, which donated 2,000 yards of scrap material from the doors and dashboards of newly manufactured vehicles. This was enough to make 400 coats produced by homeless women in Detroit. The USEPA's Tom Murray wrote a blog about this, linking sustainability's three dimensions: "John Bradburn (from GM) and Veronika's efforts are a classic example of sustainability. Scrap material is diverted from the landfill (environment) and is being used instead to help a fledgling non-profit enterprise grow (economy) while offering a helping hand to the homeless (social)."[8] Veronika's efforts have not gone unnoticed by those outside of Detroit. She became the youngest person ever to receive the New Frontier Award from the John F. Kennedy Library Foundation.

An example of USEPA efforts at collaboration is the creation of "technology clusters," which engage businesses, federal agencies, local governments, universities, investors, and others to promote environmentally sustainable economic development and technological innovation. This initiative has led to formation of a water-technology cluster linking Ohio, Kentucky, and Indiana (USEPA, 2011). Likewise, many companies and industry associations are encouraging collaboration among business, government, and NGOs. For example, IBM and the World Environment Center established the Innovations for Environmental Sustainability Council, involving some of the world's leading companies, to identify next-generation technologies and best practices, addressing critical sustainability challenges (Silicon Republic, 2012). Dow Chemical is collaborating with the Nature Conservancy to advance the science and practice of valuing ecosystem services (Walsh, 2011). Industrial consortia such as the Sustainable Apparel Coalition, the Outdoor Industry Association, and the Sustainability Consortium are actively engaged with academia, NGOs, and government to establish voluntary sustainability standards for commercial products (Golden et al. 2011).

USEPA: Evolving from Regulator to Innovative Problem Solver

While existing laws and regulations are crucial for protecting human health and the environment, they alone cannot ensure a sustainable future. To achieve beneficial changes, regulatory agencies must adopt a broader and more systems-oriented approach. The above examples from Narragansett Bay and the Gulf of Mexico illustrate the evolving role of USEPA from environmental regulator to innovative problem-solver. It is important that the agency gain understanding and support from both the public and the business community for this continuing evolution.

When USEPA was created in 1970, it was characterized as "the federal government's watchdog, police officer, and chief weapon against all forms of pollution" (Shabecoff, 1993). While at first the agency had bipartisan support, it "quickly became the lightning rod for the nation's hopes of cleaning up pollution and its fears about intrusive federal regulations" (Andrews, 2011). By the mid-1980s, USEPA had expanded its regulatory role based on the practice of risk assessment. In 1983, the National Academies published a landmark report, *Risk Assessment in the Federal Government: Managing the Process* commonly known as the *Red Book* (National Research Council, 1983). Today, the challenge for USEPA, as well as other federal agencies, is to augment the risk-based paradigm by adopting a new role as an innovative problem solver focused on environmental stewardship. Richard Andrews (2011) notes that the future challenge for USEPA is "not simply to regulate individual pollutants and facilities, but to lead in transforming existing government policies into more effective incentives to create a greener, economically efficient, and environmentally sustainable economy."

Former Administrator Lisa Jackson (2008–2013), like many of her predecessors, was sensitive to the complex problems of the 21st century. She reached out to the National Academy of Sciences for guidance at the time of USEPA's 40th anniversary. "As we celebrate 40 years of incredible accomplishments, we find ourselves at a critical juncture," she

[8] See http://blog.epa.gov/blog/2012/12/veronika-scott-and-her-amazing-dream-coat.

stated. "We have a new awareness of environmental complexity and, at the same time, we have new tools, insights, and experiences to guide our mission." The resulting Academy report affirmed that a "sustainability approach can strengthen USEPA as an organization and a leader in the nation's progress toward sustainability. Adopting a vision for sustainability as a goal will provide a unifying and forward looking stimulus to the Agency" (Committee on Incorporating Sustainability in the United States Environmental Protection Agency et al. 2011). The NRC report specifically called for USEPA to develop a sustainability framework for decision-making. This study was carefully reviewed by other federal agencies, many of which have begun incorporating sustainability practices into their own operations. For instance, the United States Army has established a "net zero" program to manage water, energy, and waste at all of its facilities. The Department of Agriculture is advancing sustainability objectives in food and agricultural practices as well as in forest management. The National Oceanic and Atmospheric Administration (a unit of the Department of Commerce) is working with stakeholders to better manage the nation's fish stocks.

The title of this Community Essay reflects a theme emphasized by USEPA Administrator Gina McCarthy, explicitly included in the agency's Strategic Plan for the period 2014–2018. In describing the goal of "working toward a sustainable future," McCarthy notes that "our traditional approaches to risk reduction and pollution control can only go so far to deliver the long term and broad environmental quality we seek."

Enhancing Public Understanding of Sustainability

A key role of government and NGOs is to better inform decision makers and the public of existing trends, stressors, and threats to health and the environment. The public, in turn, must recognize the value of proposed actions without fearing loss of jobs or other adverse social impacts. A key step in this direction is the development of indicators and metrics that help to justify policy changes. The USEPA, along with other agencies of the federal government, has been actively engaged in developing such tools. For example, the agency's *Report on the Environment* (ROE) regularly describes the current state of the environment and observes national trends (USEPA, 2008). The latest version of ROE (to be published online in 2014) will be the first to include a set of sustainability indicators that quantifies the changing *intensity* of energy, water, and waste relative to economic and population growth. Another example is *EnviroAtlas*, a web-based mapping tool that will provide an easy-to-use, visual way to explore and better understand the benefits of natural ecosystems and how they can be protected to assure a sustainable future (USEPA, 2013).

The wealth of available indicators from federal and state agencies is overwhelming. The challenge ahead is not further development of such measures but their application and use. Such metrics are most effective when they serve as drivers of change. One example of an overarching strategic indicator is the ecological footprint of the United States, which reveals that certain regions of the country are already stressed with respect to the "biocapacity" of their ecosystem assets (see Figure 3). This indicator provides a method for understanding current burdens, projecting future stressors, and determining how decision makers can best anticipate and respond to these challenges (Wackernagel, 2013).

Similarly, regional studies are assessing the "water footprint" of society; for example, California's total water footprint is estimated to be 64 million acre-feet per year (Pacific Institute, 2012). This is more than double the annual volume of water that flows down the state's two largest rivers, the Sacramento and San Joaquin. An estimated 38 million acre-feet of water is used to produce goods and services within California, about half of which is exported and consumed outside the state. An additional 44 million acre-feet is required to produce goods and services imported into California, so that the state is a net importer of "virtual" water. Collaborative actions by industry, agriculture, government, consumers, and other sectors can potentially help California to achieve a sustainable balance between the availability, allocation, and use of natural resources.

The value of these studies is both to assess the current state of the environment and to stimulate a discussion about potential actions in anticipation of future changes. Society must take a longer-term view to consider emerging pressures on ecosystems at different scales of resolution and how the built environment and ecosystems can be managed in a synergistic way. For industrial innovators, the long view involves thinking about how business models can be transformed so that materials and energy are used more effectively in product and process life cycles and wastes and hazardous residuals are reduced or eliminated. A key challenge for all states is to engage federal, state, and local agencies, as well as academic and business leaders, to analyze future stresses on ecosystems and water resources and to identify science and technology needs and appropriate partnerships to best deal with these challenges.

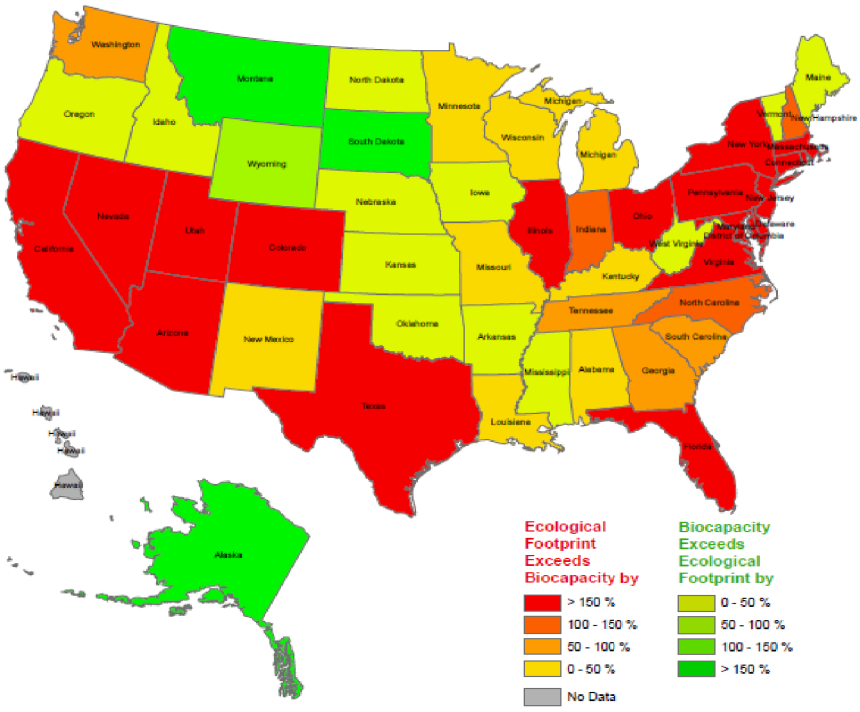

Figure 3 National Comparison of Ecological Footprint to Biocapacity (Source: Global Footprint Network).

Summary: The Path Forward

Returning to the questions posed at the beginning of this Community Essay, we again ask: How can today's society address the complex interaction of environmental, social, and economic forces? In other words, how can we ensure a balance among economic development, social well-being, and environmental protection?

We believe that sustainable development is a crucial objective for all levels of government in both developed and developing countries. Population growth, economic development, and globalization of industry have led to greater consumption of energy and materials and wide-ranging changes in land use. These pressures not only increase greenhouse-gas emissions, but also threaten biodiversity, natural resource integrity, human health, and social well-being. The increasing stresses on natural resources have resulted in damage to natural capital, including water resources, soils, forests, wetlands, and coral reefs, which will create serious challenges in the decades ahead.

Quality of life in the United States will likely decline unless we adopt innovative approaches to transform our production and consumption patterns. We are fortunate that both government and business leaders view sustainability as the appropriate lens for envisioning enhanced competitiveness and social well-being. For the business world, sustainability has become the "mother lode" of organizational and technological innovations. Firms increasingly realize today that "there is no alternative to sustainable development" (Nidumolu et al. 2009). For federal agencies, regulatory policy and research must augment media-specific risk assessments by adopting a systems approach to address these sustainability problems. While fulfilling their core mandates to minimize risks to human health and the environment, government bodies must also evolve to develop science-based, integrated approaches that address the complex challenges of the new century. This evolution can be facilitated by what we call the "innovation cycle for sustainability."

The path forward can build on strategic business imperatives and strong recommendations from the National Research Council. A new model for sustainability in the 21st century requires a convergence of 1) advances in science, technology, and innovation; 2) business practices that promote sustainable solutions; 3) greater coordination across federal agencies; 4) effective business and government collaboration; and 5) public support, understanding, and behavior change. All sectors of society will need to work together to pursue this model and assure continued American prosperity and competitiveness. The public must come to understand that sustainability provides both the vision and approach to achieve outcomes

that enhance the economy and protect health and the environment. By anticipating and responding proactively to future challenges, we can disprove Benjamin Franklin's adage, "It is not until the well runs dry that we know the worth of water."

Authors' Note

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