

## EPA at 40: Bringing Environmental Protection into the 21st Century

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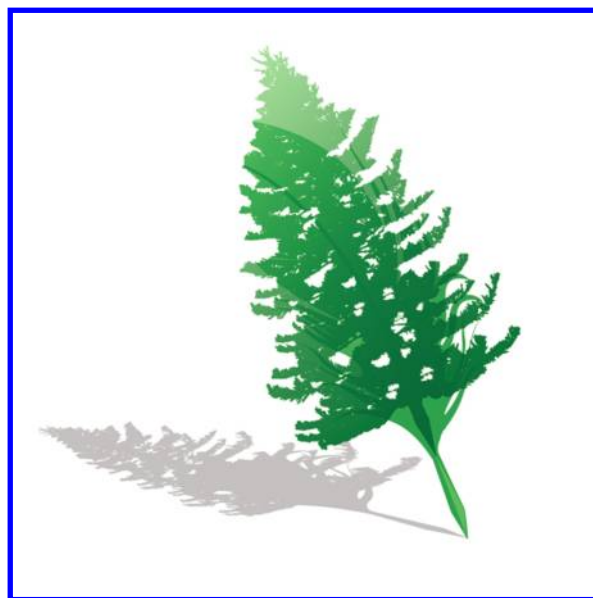
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Sustainability science suggests that effective environmental protection requires an integrated systems approach.

It has been 40 years since the passage of the National Environmental Policy Act (NEPA; signed into law January 1, 1970), which established a broad environmental policy for the United States, and the formation of the Environmental Protection Agency (EPA). Anticipating the agency's 40th birthday on December 2, 2010 provides an opportunity to take stock of its past successes and future challenges.

Since 1970, important advances in environmental protection, product design, and occupational safety have been prompted by problem-, media-, and chemical-specific legislation. Our air and water are now cleaner, less pollution is being produced, and many waste sites are being restored. Yet despite such significant progress, it has become clear that the new century's problems are more complex and involve multiple environmental media and stressors: they therefore require new kinds of interdisciplinary thinking and systems solutions.

Today, the resilience of both human society and the natural environment are being tested on a global level by pressures of population and economic growth, which have



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in turn led to increasing greenhouse gas emissions, declining biodiversity, and other threats to such vital natural resources as fresh water, soil, forests, and wetlands. The threats were clearly delineated in the 2005 Millennium Ecosystem Assessment, which determined that 15 of 24 global ecosystem services are being degraded or used unsustainably (1).

It is also becoming clear that the forces influencing human and ecological health are systemic and interdependent. The scientific and regulatory communities are struggling to deal with impacts of changes in climate, land use, and ecosystems; faster technological change and emergence of biotechnology and nanotechnology; cumulative and possibly synergistic effects from exposure to multiple compounds; and concerns about bioaccumulative toxicants and nonpoint pollution sources.

All of these stressors suggest that it is time to launch a new dialogue on science and the environment. How can science best address these problems, and what critical next steps are needed to move environmental science into the 21st century? History shows an early recognition of multiple stressors acting on the environment and the need to address them in an integrated manner. It is urgent today to investigate and determine how best to address this need.

### Evolution of Environmental Science and Policy

At the beginning of the 20th century, the first environmental movement in the U.S. was led by a diverse coalition of conservationists and business leaders seeking to preserve and manage land resources for their most valuable uses. Both groups saw the need for the government to intervene in the market with new laws and regulations, especially on government-owned lands. The legislation that set aside land for the first national park at Yellowstone called for the Department of

Interior to preserve in their natural conditions the park's timber, mineral deposits, and natural wonders (2).

The early environmental movement was also advanced by scientific research on health, occupational hazards, and air pollution. The research in turn generated attention and political debate on the respective roles of government and the private sector. Subsequent events highlighted the linkage of economic activities to health and safety. For example, in 1948, a temperature inversion trapped toxic gases from zinc and steel plants in Donora, Pennsylvania; 20 people died and approximately half of the town's 14,000 residents became ill (3). In 1969 the Cuyahoga River oil-slick fire drew national attention to environmental problems in the Great Lakes region and elsewhere in the U.S.

Events like these prompted the launch of a second environmental movement that focused less on conservation and more on short-term risks faced by humans in their everyday lives. U.S. environmental policy advanced the concept of risk management as a basis for policy actions. Social and urban justice movements concerned with public health played a critical role in shaping the 20th century environmental movement and subsequent passage of federal and state environmental laws (4). At the same time, environmental stressors such as population growth, urban development, and industrial pollution motivated the enactment of NEPA, the creation of EPA, and the first international environmental conference in Stockholm in 1972.

### National Environmental Policy Act (NEPA) and the Ash Council

NEPA's enactment in 1970 formally established as a national goal the creation and maintenance of "conditions under which [humans] and nature can exist in productive harmony, and fulfill the social, economic and other requirements of present and future generations of Americans [emphasis added]" (5)—language remarkably similar to the UN-sponsored Brundtland Report's definition of "sustainable development" 17 years later (6).

NEPA required the federal government to act in four specific areas:

- Long-term Planning: "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations"
- Equity: "assure for all Americans safe, healthful, productive, and esthetically and culturally pleasing surroundings"
- Widespread Prosperity: "achieve a balance between population and resource use that will permit high standards of living and a wide sharing of life's amenities"
- Resource Management: "enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources."

How NEPA's vision could be implemented was addressed by the President's Advisory Council on Executive Organization chaired by Roy L. Ash (the Ash Council). Recognizing that the "national Government (*sic*) is neither structured nor oriented to sustain a well-articulated attack on the practices which debase the air we breathe, the water we drink, and the land that grows our food," the Council proposed and outlined the structure of a new administrative agency that would carry out national environmental policy (7). It recommended that antipollution programs from five federal departments be combined in a new Environmental Protection Agency (EPA) that would "recognize the interrelated nature of pollution problems" and be the principal instrument for meeting this challenge (7).

Unfortunately, in the decades that followed, a lack of coherence in federal environmental legislation made it increasingly difficult to pursue an integrated approach to environmental management. Unlike NEPA and the Pollution

Prevention Act of 1990, the media- or subject-specific environmental laws have been described as so "fragmented and unrelated as to defy overall description" (8).

The U.S. is now facing many of the same stresses that confronted the Ash Council in 1970, but society today needs to recognize these stresses' more complex and interrelated nature. Continued focus on media-specific problems will not solve pollution problems, but simply shift them from one medium to another (e.g., from air to water). The experience of many states demonstrates that a media-based approach misses about half of the emissions of a typical facility compared to the findings of integrated permitting. Research in the Great Lakes and other major bodies of water shows that toxic pollution comes from many sources: air deposition, sediment, groundwater, and land runoff (9).

Despite the Ash Council's recognition of the need to address environmental problems in an integrated manner, the initial EPA structure organized by separate media has persisted until today. This structure needs to be enhanced to address new challenges of the 21st century. The National Research Council observed in 2000 that the nation's environmental problems "can only be addressed through an understanding of the complex interrelationships among environmental media (air, water, land, and biota), human health, ecology and economic sectors" (10).

Today many observers are arguing that it is imperative to revisit the goals of NEPA and the recommendations of the Ash Council to consider what further transformations of science and environmental management are required. For example, a distinguished group of environmental lawyers has argued, "The opportunity is now at hand to adopt fundamental reforms in outdated 1970s environmental statutes, not only to deal with new problems such as climate change, but also to fix structural problems in the statutes to address many older problems that have gone unresolved" (11). Terry Davies, who was among senior EPA officials charged with implementing the Ash memo, has recently called for sweeping restructuring of federal environmental research and management functions and creation of a new Department of Environmental and Consumer Protection (12). Also, several former federal officials have advocated a new Earth Systems Science Agency to address interrelated environmental challenges on a global scale (13).

Tackling the new global and national environmental challenges demands a new dialogue on science and the environment, extending beyond EPA to all federal and state agencies. For example, EPA's activities concerning water issues depend heavily on the work of the U.S. Geological Survey (USGS) and state agencies; the success of endangered species protection programs relies upon collaboration among the Fish and Wildlife Service, EPA, the states, and nonprofit organizations; and the effectiveness of climate change programs depends on cooperation among EPA, the National Oceanic and Atmospheric Administration (NOAA), and state agencies.

Within this collaborative space, there is opportunity for EPA's science programs to go beyond media-specific needs and provide the interdisciplinary physical, biological, and social science analysis needed to address complex policy issues and define new strategies promoting a sustainable environment. EPA needs to be one of the leading federal agencies working to establish an integrated, comprehensive science and management approach that can address the complex and urgent environmental problems of today and the future. How can this be done?

### Organizational and Systems Thinking

The Ash Council wisely recognized the crucial role of organizational and systems thinking in mobilizing "people, ideas, and things in ways best calculated to achieve clearly

articulated goals.” One of us (Senge and colleagues) expressed a similar insight nearly 40 years later: “If we see each problem—be it water shortages, climate change, or poverty—as separate, and approach each separately, the solutions we come up with will be short-term, often opportunistic quick fixes that do nothing to address deeper imbalances” (14).

Traditional approaches to economic and environmental management are based on static, compartmentalized models. But the ecosystems and industrial systems that we try to manage are themselves tightly coupled and dynamic systems which often operate far from equilibrium and exhibit nonlinear and sometimes chaotic behavior. To better understand these phenomena, scientists have been pursuing research in the field of biocomplexity, which seeks to characterize interdependencies and feedback loops among networks of human and biophysical systems. This research investigates the flows of information, materials, energy, financial capital, and labor among economic systems (including resource extraction, agriculture, and industry), societal systems (including urban centers, education, communication, and human interactions), and natural systems (including atmospheric, aquatic, biological, and geological).

Biocomplex systems challenge naïve notions of sustainability as steady-state equilibrium. Such systems require understanding of economic, societal, and environmental forces of change that can disrupt cycles of material and energy flows. Few people foresaw key connections that may have significant consequences: U.S. ethanol production based on corn may drive up food prices in Mexico; Mississippi River floods may lead to fuel shortages; global population growth may exacerbate imbalances in the world’s nitrogen cycle.

Twenty-first century environmental protection will depend upon shared public understanding of the deep interdependence among global systems for the production and distribution of food, energy, and industrial goods. Implementing this perspective should be a core function of government and educational institutions, encouraging the study of sustainable systems to prepare citizens for a globalizing world.

Rather than treating environmental management as a subject for static optimization, we need to apply advanced modeling and decision support approaches for dynamic, adaptive management (15). This means that federal agencies will need to find new ways of collecting, analyzing, and communicating data and engaging diverse stakeholders. Alternative, market-based approaches to environmental protection, such as cap-and-trade systems, can only succeed with scientific insights as to the underlying drivers of environmental outcomes. In the long run, a balance between economic growth and environmental protection can only be achieved through advancing sustainable systems as a policy and management objective.

## **Sustainability Science and Technology in the 21st Century**

From the perspectives of global and U.S. science, policy, and regulation, the time has come to evaluate how agencies can deploy a more integrated approach to research and policy-making. For example, in response to growing trends in waste management and toxic chemicals, the European Union (EU) has enacted several directives with important global environmental implications: Restriction of Hazardous Substances (RoHS), Waste Electrical and Electronic Equipment (WEEE), and Registration, Evaluation and Authorization of Chemicals (REACH), among others.

Rather than just managing wastes, these directives call for managing material flows over product life cycles and applying green engineering and green chemistry principles to product manufacturing processes. Similarly, the 2007 U.S.

Energy Independence and Security Act (EISA) mandates life cycle analysis of greenhouse gas emissions for biofuel feedstocks and recognizes the need for assessment of key environmental variables to fully understand the impacts of biofuel production and use. Such initiatives must be widely adopted to achieve a broad systems approach to dealing with emerging and newly recognized environmental problems.

Responding to these new challenges is sustainability science and technology (SS&T), an emerging field of study with origins in social and natural sciences, as well as engineering. Drawing upon many perspectives, SS&T seeks to forge a multidisciplinary and systems approach toward environmental management and technological transformation. As Charles Perrings has argued, “Although the development of discipline-based science has been the source of almost all scientific advances of the last century, it has also limited the capacity of science to address problems that span multiple disciplines” (16).

SS&T examines new questions, such as: Why aim merely to treat toxic waste when we can limit its creation through the use of more benign materials, more holistically designed and better engineered processes, and the establishment of a regulatory system favoring recycling and reuse?

SS&T also requires a deep understanding of human behavior and patterns of knowledge dissemination to inform decision-makers and the public. A recent study suggested how global attitudes could support sustainable development, concluding that “... sustainability science will play a critical role, at multiple scales and using multiple methodologies, as it works to identify and explain the key relationships between sustainability values, attitudes, and behaviors—and to apply this knowledge in support of sustainable development” (17). To reshape our economic and social foundations so as to ensure sustainable environmental protection in the 21st century, we need improved environmental measurement and accounting as well as more effective public reporting.

## **Enriching Environmental Data, Communicating Results**

Although national economic accounts provide extensive data on stocks and flows of natural and manufactured capital, the U.S. is currently lacking a parallel national accounting of physical information on the environment. Such data are collected at national and regional levels but are often incomplete, incomparable, and uneven in quality. These limitations lead to inadequate support for environmental indicators essential for assessing and understanding the state of the environment and its changes over time. Without an effective physical accounting system, a more sustainable environment will be difficult to realize (18).

Computer simulations and other tools can present data in interactive decision-support environments that help to make the data more meaningful for decision makers. For example: simulators were at the core of the EU’s approach to regulating acid rain (19); new sets of climate simulators, such as the C-ROADS interactive climate model (20), are being used to prepare negotiating teams for the December 2009 United Nations Climate Change “Conference of the Parties 15” in Copenhagen. The simulators allow negotiators to test their propositions against the best understanding of reductions in greenhouse gas emissions, deforestation, and land use; they also allow nonscientists to test the effects of national positions and improve the accuracy of their own conceptual models.

A comprehensive system of environmental data generation, management, communication, and continuous learning is vital to addressing the challenge of managing complex environmental and economic systems—especially in this age of turbulent change and uncertainty. Many developed nations have established accounting systems that better track physical flows of raw materials, manu-

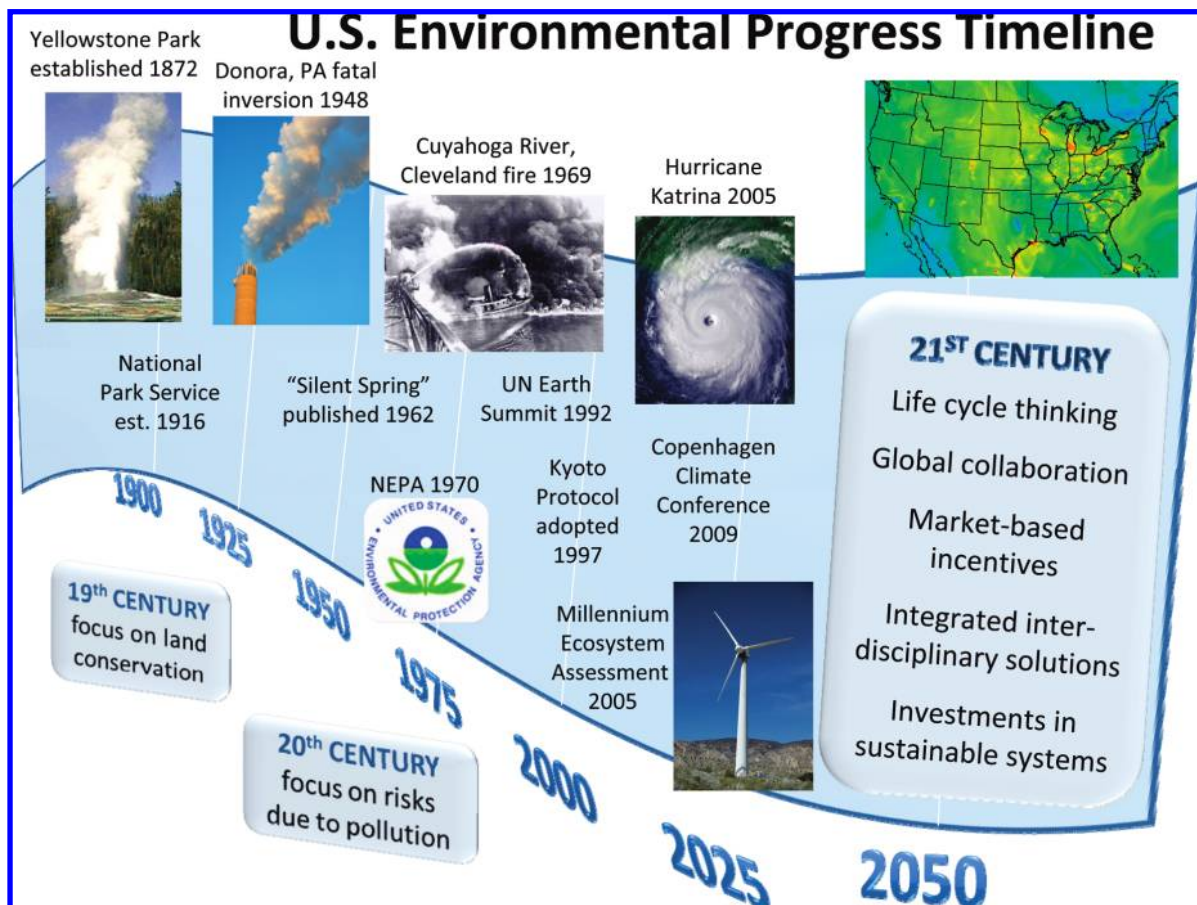
**TABLE 1. Two Centuries of Evolving U.S. Environmental Policy**

	19 <sup>th</sup> Century	20 <sup>th</sup> Century	21 <sup>st</sup> Century
<b>Focus</b>	Land conservation	Human health risk; media/site/ problem-specific	Complex regional/global problems
<b>Outcome</b>	Land preservation	Pollution control; management of anthropocentric ecological risk	Global sustainable development
<b>Principal Activity</b>	Land/water regulation/simple contaminant controls	Compliance/remediation/ technological emphasis on problem solving	Integration of social, economic, and technological information for holistic problem solving
<b>Economic Focus</b>	Value of land use and industrial development	Cost minimization	Strategic investments/long-term societal well-being
<b>Regulatory Activity</b>	Low	Heavy	Flexible, including market-based incentives
<b>Conceptual Model</b>	Expansion vs. preservation	Command-and-control	Systems/life cycle approach
<b>Disciplinary Approach</b>	Disciplinary/insular	Multidisciplinary	Interdisciplinary/ integrative

factured goods, and other commodities. Without an approach incorporating the perspectives of “industrial ecology,” the U.S. will be seriously hampered in evaluating sustainability strategies and in collaborating and competing with other nations.

To promote public understanding of the ecological footprint of product development and to better influence the priorities of decision-makers, environmental data and

information must also be available and meaningful to the public. Citizens and consumers cannot be expected to delve into the complexities of sustainability science, but policy-makers have an obligation to inform the public about the risks and trade-offs that are implicit in decision making. How to move beyond the oversimplification of indicator schemes such as “carbon labels” remains an open question.



**FIGURE 1. Timeline of environmental progress in the U.S.**

## A Call to Action

Table 1, adapted from Allenby and Graedel (21), summarizes U.S. environmental policy in past centuries and how it must evolve in the 21st century. This evolution will help meet the challenge, voiced in 1989 by the House Committee on Science, of science helping society to make good decisions about the environment (22). Figure 1 summarizes some of the major events that have punctuated the transition from land conservation to pollution control to systems thinking.

To support this essential evolution in environmental policy, EPA must continue to use science to fulfill its mandate to develop and enforce regulations that protect human health and the environment. It must also use sustainability science to move beyond the current regulatory framework and develop and implement a more integrated, systems-based, and cross-media approach to address the challenges of this new century. This will require that the agency's efforts be expanded to collect, develop, synthesize, and disseminate integrated scientific and technical information; to develop metrics for determining progress toward national sustainability goals; to develop cost-effective and innovative solutions consistent with smart economic growth; and to attract a new generation of exceptional minds by making the search for talent a strategic priority (23). Working with other agencies, businesses, and civil society organizations toward these ends, EPA will thus earn wide recognition as the nation's proactive environmental leader and facilitator.

As EPA approaches its 40th anniversary, the time is right for public deliberation on the next level of environmental protection and the role of sustainability science and technology in reaching sound environmental social and economic decisions.

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## Acknowledgments

Views expressed in this article do not necessarily represent official positions of EPA, its advisory committees, or the Senior Environmental Employment (SEE) program. We gratefully acknowledge Edward B. Fallon, Ph.D., a Social Science Analyst in the SEE program (sponsored by the EPA and the National Caucus and Center on Black Aged, Inc.) for his work to strengthen the analysis, structure, and language of this Viewpoint. We also acknowledge the assistance of Terry Davies in clarifying the history of EPA's formation.

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ES901653F