Incorporating Resilience and Innovation into Law and Policy: A Case for Preserving a Natural Resource Legacy and Promoting a Sustainable Future

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Incorporating Resilience and Innovation into Law and Policy

A Case for Preserving a Natural Resource Legacy and Promoting a Sustainable Future

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The concept of sustainability has been widely embraced by society and in environmental law and policy as a measure to ensure a heritage of economic viability, social equity, and environmental stewardship. In a large number of statutes, Congress and many state legislatures have begun to adopt the goals of protecting a natural resource legacy and promoting sustainable use of the nation's valuable natural resources. However, many of the statutes enacted have been virtually unenforceable due to lack of standards and guidance on reconciling complex and often competing priorities. Moreover, reports continue to surface regarding such problems as diminishing natural resources, freshwater supplies, and biodiversity (World Wildlife Fund 2008). These undesirable impacts illustrate that contrary to the stated goals of existing law, the way we do business and consume resources remains unsustainable (Flourney and Driesen 2010). Hence, while it is clear that the ideals of sustainability are widely supported, the shift toward this paradigm is essentially unrealized.

One key aspect of sustainability is ensuring that the resources and ecosystems on which we depend continue to support human existence from generation to generation; thus, it inherently is a dynamic concept. However, this ideal is in conflict with contemporary environmental law and policy, which have traditionally assumed that systems are predictable and that change is linear, incremental, and generally slow.
For the past several decades, ecologists have noted the dynamic nature of ecosystems and sought to account for this reality. In turn, legal scholars have begun to grapple with the challenge of developing policy for systems that change and evolve through time (Bosselman and Tarlock 1994; Wiener 1996). The importance of these efforts is highlighted by such irreversible ecological impacts as may occur due to climate change. Therefore, it is critical that laws and policy be developed and adapted to ensure the patterns of human interactions with the ecosystems on which we depend are sustainable. Because many of the present natural resource management laws still embody the goal of preserving ecosystems in some ideal or "natural" state, it is a goal that demonstrates tension with the dynamic reality of these systems. As such, the question is: How do we bridge the gap between the goals we espouse, the nature of what we want to protect, and current practice?

Resilience has particular promise as a concept that can help us to design laws that account for ecosystem dynamics. Resilience refers to the ability of a system to withstand perturbation and continue to function, thus acknowledging the variable nature of ecosystems over time. In the context of sustainability, Mayer et al. (2004) stated that resilience "focuses on the degree to which human activities increase or decrease the [persistence] of a particular dynamic regime that provides desirable goods or services" (420). This concept embodies pertinent aspects of sustainability and helps define a path toward sustainability. Further, it highlights the fact that preserving a resource legacy requires the protection of the ecosystems that provide it.

Complementing the focus on using resilience to achieve better stewardship of public natural resources, this paper also explores efforts to harness technological innovation and competitive pressures of the market to encourage industry to innovate in ways that promote sustainability, thus reducing risks to human health and the environment. Just as static measures are inadequate to ensure sustainability of natural resources, static regulatory approaches are also inadequate to engage industry's innovative power in the quest for operational, human health, and environmental benefits. The question this raises is how to create an economic incentive for those creating and selling goods and services to improve the environment, when the improvement benefits society as a whole rather than their consumers.
In response to the questions posed, this chapter articulates two strategies. One applies to decision making affecting management of publicly owned natural resources and the second to decision making in the private sector. The implementation of these strategies is illustrated by drawing on two proposals for new legislation and a recent public–private initiative. The first strategy is to incorporate resilience into policy and laws that govern the management of public natural resources to help reach the broader goals of sustainability—protecting ecosystems and natural processes, as well as the goods and services they provide. To date, few if any laws take direct, explicit account of resilience, although managers in many cases have discretion to, and already may, consider resilience in implementing decisions under these laws. To illustrate the potential embodied in the concept of resilience, we explore the implementation of a piece of model legislation: the National Environmental Legacy Act (Legacy Act) proposed by Flournoy et al. (2010), which is designed to promote sustainable resource use and decision making for public natural resources. Further, we investigate how the incorporation of metrics and indicators of resilience and sustainability into the Legacy Act framework may aid in target setting.

The second strategy is to harness technological innovation and competition to promote sustainable outcomes in private sector decision making. To illustrate the untapped potential of these forces, we explore how the Environmental Competition Statute (ECS) proposed by Driesen (2009) could advance sustainability if applied within the chemical sector of the economy. This second strategy is designed to overcome regulators’ timidity and to create a market for innovation that benefits the environment. We then also draw on the example of a recent public–private cluster initiative that the U.S. Environmental Protection Agency (EPA) has embraced as a tool for maximizing economic development and environmental protection.

The Legacy Act

The concept underlying the Legacy Act is to give meaning to the often invoked goal of sustainable use of publicly owned natural resources and, therefore, to effectuate our desire to protect a stock of these resources
for future generations. This requires a proactive, adaptive management strategy with associated monitoring tools and metrics that can react in something close to real time. Adoption of the Legacy Act would first require us to confront a key question: What resource legacy do we wish to leave our children and grandchildren?

Despite the stated goals, and in some cases mandates, of existing laws to achieve sustainable resource use, it is clear that they have not achieved their aspirations (Flournoy et al. 2007). Many public natural resources are currently managed under statutes with notoriously open-ended standards that require federal agencies to "balance" a variety of often- incompatible uses, many of which degrade or deplete relevant resources. Many of these statutes contain no enforceable standard mandating protection of any particular quality or quantity of a resource (Flournoy et al. 2007). The on-the-ground results of implementation of statutes such as the Federal Land Policy Management Act of 1976, the Multiple-Use Sustained Yield Act, and the Magnuson-Stevens Fishery Conservation and Management Act demonstrate failure to accomplish even laudable stated mandates of sustainable use of publicly managed rangeland and fishery resources. The Legacy Act seeks to address the problem of death by a thousand cuts, the ongoing incremental loss of resources that leads to a shifting baseline and public acceptance of degradation of resources as inevitable (Ankersen and Regan 2010).

Building on the goals already expressed in numerous laws, the Legacy Act incorporates some key concepts. First is the demand that legislators articulate the legacy of resources that we seek to leave the next generation, covering a broad and diverse array of publicly owned and managed resources. Second, the law must define what type of degradation of the resources' quality or quantity is compatible with preserving that legacy. Therefore, if the legacy is to leave forest resources of the same quality and quantity as we currently have, then the permissible standard of uses of forests would be to prevent any degradation. Rather than authorizing use as long as it is sustainable, a Legacy Act shifts the burden and mandates that the stewardship agency not permit activity that would cause degradation in quality or quantity of the relevant resource. Further, actions inconsistent with this enforceable mandate would be expressly prohibited (Flournoy and Driesen 2010).
Thus, the Legacy Act would require management of public resources to conserve some defined stock of resources for future generations. Embracing the Legacy Act concept would demand that we identify our long-term goals, which would then help us chart and maintain a course to achieve our shared goals. It would also improve our decisions over the long term by generating the information base needed to support adaptive learning. This type of clearly defined limitation and prohibition on degradation beyond statutorily defined limits has proven successful in several statutory schemes. The Endangered Species Act’s prohibition on taking of endangered species and the Clean Air Act’s prevention of significant deterioration mechanism have both provided mandates that are specific and amenable to monitoring and that have been successfully enforced. The Legacy Act would seek to bring similarly effective management to a broad array of public resources.

A key issue to be resolved by Congress, through its democratic legislative process, would be to specify the contours of the legacy we commit to preserve. We could decide to commit to preserving a quantity and quality of all renewable resources equivalent to those we have today. Alternatively, we might decide to permit a specified degree of depletion or degradation. For nonrenewable resources, such as fossil fuels, we would very likely want to allow some specified pace of depletion or degradation, but for the first time we would actually consider what pace is a responsible one in consideration of future generations. The choices made in a Legacy Act would be intentional, and there would be greater accountability and transparency about the choices—both of which are frequently lacking under current law.

Under a Legacy Act, agencies already charged with the responsibility as trustees for federal lands and natural resources would now have a new mandate: to manage these lands and resources to ensure no impairment of the designated legacy, whatever that legacy may entail. This would require that the agencies translate the general standard of permissible degradation and depletion (if any) into operational terms. Design and implementation of such a statute poses two key challenges that resilience and sustainability metrics could help to meet. These related challenges are the dynamic and interdependent nature of ecosystems and the need to avoid creating excessively costly or impractical data demands.
The dynamic nature of ecosystems means that we cannot preserve ecosystems in a static state—whether this is the current state or some ideal state. Thus, to operationalize the Legacy Act, resource-specific goals (e.g., a prohibition of any degradation of water quality) are supplemented with the goal of retaining the resilience of overall ecosystems. This allows a more holistic and flexible approach, complementing the resource-specific mandates that serve as a backstop. It also addresses the reality that it is not feasible to monitor and set enforceable mandates for every specific resource. The overall mandate to maintain resilience provides broader protection and, as described below, there are analytic tools and data available that make this a feasible goal.

Implementation of a Legacy Act also depends upon identification of metrics that allow us to track degradation of publicly owned natural resources without imposing an unrealistic data demand. The concept of resilience and recent developments in sustainability metrics could have tremendous power and facilitate our efforts to achieve our stated goals. Adopting such methods into a Legacy Act could provide managers of federal public natural resources with a workable tool that would ensure federal public natural resources are managed to facilitate continuous progress toward sustainability.

Managing Ecosystems for Sustainability and Resilience

Experts have amassed an abundance of evidence on important properties of ecosystems, enabling the delineation of key features of ecosystem function and structure. For example, many ecosystems are characterized by gradual accumulation of biomass and nutrients. These processes typically cycle and change along usual patterns driven by the daily and yearly cycles of light, tides, and seasons, along with longer-term decadal, centurial, and other temporal and spatial variations. Although complex, these processes often follow orderly patterns and are sufficiently consistent to be studied and understood (Odum 1971; Maurice and Phillips 1992).

If managed systems are resilient, they can withstand periodic fluctuations and still maintain self-organization and function through time (Eason and Cabezas 2012). However, it is possible for a dynamic system
to reach a threshold and abruptly shift from one set of system conditions (i.e., regime) to another. When any system undergoes a change from one characteristic pattern or set of behaviors to another, the change is generally termed a \textit{regime shift}. Regime shifts have been demonstrated for a multitude of ecological and social systems and often have significant ecological and economic consequences. For example, a lake may shift from oligotrophic to eutrophic due to the inflow of phosphorus, resulting in algae overgrowth, lack of oxygen needed for fish species survival, and consequently, a reduction in biodiversity and water quality. Hence, ecosystem change typically tends to be episodic rather than constantly erratic. Further, unlike engineered systems, ecosystems have multiple equilibria (i.e., multiple stable regimes) and may transition from one set of conditions to another with different underlying structure and behavior. Management of such systems must be flexible and adaptive, because it is often very difficult to predict exactly how or to what regime a system may transition. Because no two regimes have the same observable patterns, the characteristics of these regimes may be measured using metrics and indicators of underlying system behavior.

\textit{Demystifying Sustainability and Resilience}

The practical application of the concepts of sustainability and resilience require a new perspective. From a systems point of view, a system may be characterized by the parameters critical to its survival. For example, a regional system that supports human populations can be described by its economic, technical, ecological, social, and legal dimensions. The behavior of a dynamic system may be depicted as a trajectory through time in a space where the dimensions are its critical parameters (dotted line labeled "system trajectory" in Figure 10.1). In this context, sustainability relates to finding a set of system conditions that can support the social and economic development of human and ecological systems without major, irreversible environmental consequences (Karunanithi et al. 2008). Although optimizing based upon one aspect alone may result in localized benefits, managing systems myopically may result in burden shifting or lead to adverse or even catastrophic events for the entire system. Hence, a system is sustainable only if it meets key criteria
for all pertinent aspects. Accordingly, its trajectory must remain within a region of acceptable variability (tubular shape in Figure 10.1) for all of its critical dimensions. Resilience, then, is the ability of the system to remain within this region over time while under pressure from external forces and its own internal dynamics.

One important fact that must be kept in mind is that there is no explicit way to measure sustainability (U.S. EPA 2010). However, it is possible to assess whether the patterns of system behavior imply movement toward or away from sustainable conditions. Moreover, there are two principles to consider: (1) while an unsustainable system moving toward sustainability is trending in a desirable direction, a sustainable system moving away from sustainability will eventually become unsustainable; and (2) systems that are sustainable or that are moving toward
sustainability must have sufficient resilience to remain on the path in the face of perturbations. Hence, sustainability is impossible to maintain or to achieve without system resilience. Metrics and indicators are a means of assessing these patterns. An indicator is a measure that provides information on specific system attributes (e.g., carbon dioxide emissions). Multiple indicators may be aggregated to form an index or metric, which may be used to assess integrated attributes of systems (e.g., the burden of human demand on land is evaluated using Ecological Footprint Analysis, as outlined below in the section on metrics and indicators). Both types of measures are used to provide understanding of human and natural systems, their corresponding linkages, and the burden of human activity on the systems that support them.

**Metrics and Indicators**

Metrics and indicators tracked over time afford the ability to evaluate the observable behavior of systems and assess dynamic trends with respect to associated criteria. Although most widely used metrics and indicators focus on tracking specific and important concerns (e.g., the concentration of ozone or the estimated reserve in a fishery), the quantities needed for resilience and sustainability are broader concepts that represent the ability of ecosystems and societies to meet human needs. For example, assessing human burden on resources and ecosystems is pertinent for evaluating whether the burden is increasing or decreasing with time and, ultimately, whether that burden is within the capacity of the earth's system. While there is no consensus on specifically how to measure sustainability or resilience, there is a great deal of activity in this area.

**Sustainability Indicators**

The National Environmental Policy Act of 1969 (NEPA), a precursor to the establishment of the U.S. EPA, formalized a growing understanding of the importance of the relationship between humans and the environment, foreshadowing ideals soon to be of great importance on a global stage. Nearly two decades later, the World Commission on Environment
and Development (WCED) coined the term “sustainable development” as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations 1987). Years after the WCED definition was accepted, researchers have continued to struggle with reaching a consensus on exactly how sustainability should be measured. One key development and widely accepted convention was to establish what are termed the “three pillars of sustainability”: environment, economy, and society. Each of these pillars denotes particular aspects of the product, process, or system that may be assessed via observable and measurable criteria.

Using the “triple bottom line” as a working principle for sustainability, there is a plethora of activity related to sustainability indicators throughout the world. From individual researchers to large international task groups (e.g., World Bank, Eurostat, Organization for Economic Co-operation and Development), researchers have produced a multitude of measures for assessing aspects of sustainability for various scales and topics. The International Institute of Sustainable Development (IISD) lists 895 sustainable development initiatives worldwide, which include nearly 150 indicator development activities (IISD 2011). One of the key challenges of assessing sustainability is determining indicators based on sound science and pertinent to the system under study.

The protection of natural resource inventories and ecosystems is core to the mission of the National Environmental Legacy Act. Hence, indicators such as resource consumption rate, resource availability, land use and type, freshwater availability, deforestation, and biodiversity are critically important, as these indicators may be tracked over time and used to determine suitable targets for management. However, as mentioned previously, the true question is whether the trends in these indicators are sustainable. Accordingly, not only should systems be assessed by trends in sustainability indicators, but the resilience of the system should also be measured to evaluate its propensity to experience undesirable shifts.

MEASURES OF RESILIENCE

As previously noted, resilience relates to the ability of a system to withstand perturbation and continue to function. Even under extreme
external pressure, many natural systems will adapt and shift into alternative regimes without human intervention. However, like the case of a clear, thriving oligotrophic lake that shifts to a turbid, eutrophic regime, the new regime may be undesirable and unproductive from a human perspective. One reason is that the costs of remediation and potential for unalterable consequences can be substantial. Consequently, the resilience community has been focused on identifying catastrophic shifts before they occur.

Using variance-based measures, Carpenter and Brock (2006) indicate that increases in variability signal impending regime shifts. Van Nes and Scheffer (2007), Dakos et al. (2008), and Chisholm and Filotas (2009) propose rate of recovery from perturbation (i.e., “critical slowing down”) as a measure of system resilience. Biggs et al. (2009) suggested increasing variability, skewness, kurtosis, autocorrelation, and slow rates of recovery from perturbations (i.e., critical slowing down) as leading indicators of impending regime shifts. However, they noted that increases in these indicators typically occur once the regime shift is underway, which is too late to implement effective management actions (Biggs et al. 2009). Moreover, Scheffer et al. (2009) state that while these indicators show great promise in detecting regime shifts in simple and model systems, work is still needed to determine whether these indicators provide warning of imminent shifts in real complex systems. In response to this research question, Eason et al. (2013) used various model and complex real systems to compare the performance of traditional indicators to that of Fisher Information, an information theory approach. Fisher Information affords the ability to characterize the dynamic behavior of systems and to include its regimes and regime shifts. Results of this work offer great promise for resilience science and sustainability.

USE OF METRICS AND INDICATORS FOR ENVIRONMENTAL MANAGEMENT

Arguably, the measures needed for environmental management should be those representing the most important, fundamental processes and services essential to human existence. Fortunately, the number of such critical processes is likely to be modest. For example, human existence depends on the ability of ecosystems and the environment to: (1) cycle
nutrients, including carbon, nitrogen, phosphorus, and oxygen; (2) capture and distribute energy from the sun throughout the planetary ecosystem; (3) support an economy that can help to provide for human welfare over the long term; and (4) maintain the system's integrity and self-organization, which is the basis of life and societal existence. Naturally, this listing is not complete; however, it does provide a reasonable sense of the matter. In this context then, assessing resilience and sustainability is related to finding appropriate scientifically grounded measures that can be used to track and assess these various system properties, subsystems, and functions.

Researchers have recently undertaken a study to assess whether a seven-county region in south-central Colorado is moving toward or away from sustainability over time (U.S. EPA 2010). By using four metrics based on publicly available data, it was demonstrated that it is possible to assess sustainability through time as a function of basic properties of the system. These properties are the ecological impacts of human activity through Ecological Footprint Analysis (EFA); economic well-being with Green Net Regional Product (GNRP); flow of available energy through the system using Emergy Analysis (EmA); and system order and stability with Fisher Information (FI). Brief information on each metric is provided below; however, more details may be found in the work by U.S. EPA (2010).

Time-series data of variables characterizing pertinent features (e.g., demographic, production, consumption, land use) of the San Luis Basin region in Colorado were compiled and used to calculate the aforementioned sustainability metrics, each of which captures distinct aspects of the system. Ecological Footprint Analysis is a measure of the impact of a population on environmental resources and involves identifying the amount of biologically productive land (biocapacity) and determining the demand (ecological footprint) placed on the land to support the human consumption, production, and waste-generation activities. Emergy Analysis assesses energy flow through a system and is a means of estimating the value (in terms of captured solar energy) that the environment contributes to society. Roughly stated, emergy is the amount of solar energy invested by the environment into the creation of something (e.g., a living thing, a resource, a product) or in maintaining a natural process. This may include emergy created over geologic time, as is the case for fossil fuels (petroleum, coal, etc.), which are considered nonrenewable over human
timescales. Green Net Regional Product is a macroeconomic measure that captures the economic well-being of a system and is equal to the difference between aggregate consumption and the depreciation of human and natural capital, i.e., \((\text{value of all market transactions}) - (\text{depreciation of human} + \text{natural capital})\). Fisher Information assesses dynamic order by capturing the patterns in the observable behavior in a system. Because order relates to the ability of a system to maintain a desirable steady state (i.e., regime), Fisher Information is used to characterize self-organization, regimes, and regime shifts (Karunanithi et al. 2008).

Criteria were established to interpret each metric and determine whether the system shows signs of moving toward or away from sustainability. The criteria did not seek to preserve any particular state of the system (e.g., pristine or ideal), rather they ensured the maintenance and preservation of the basic properties, products, and processes necessary for continued function and livelihood. Further, an unsustainable path was defined as one whereby human welfare, ecological balance, emergy flows into the system, or system organization (as defined by GNRP, EFA, EmA, and FI, respectively) is compromised. Accordingly, as illustrated in Figure 10.1, a violation of the criteria for any metric indicated an unsustainable path and undesirable trajectory.

The regional sustainability project described above provides key insights on evaluating the dynamic changes in a region largely comprised of publicly owned land. Although it was a pilot project, it offers a model that enables resource management agencies to track trends, which delineate movement toward or away from sustainability, and provides a scientifically credible set of measures suitable for assessment and management (U.S. Department of Housing and Human Development 2011). With increasing recognition of the need for such strategies and the ongoing interest in finding ways to assess and achieve sustainability, the study offers a practicable path for policy development in land and resource management.

**Linking Metrics and Indicators to a Legacy Act**

Embedding the concept of resilience more deeply into the framework of the Legacy Act and incorporating measures like those used in the
San Luis Basin study offer potential strategies for improving on the model Legacy Act described by Flournoy et al. (2010). The core of the act is a standard that precludes impermissible degradation of the quantity or quality of all public natural resources and charges the agencies managing them to document that no such degradation is occurring over a long time horizon. As originally described, the Act would require agencies to collect data on all individual resources and monitor the change in relevant parameters over time, a potentially monumental task. For some subset of nonrenewable or threatened resources, this level of monitoring of individual resources to ensure no impermissible degradation or depletion would be appropriate. But for the broader array of resources in public ownership (and particularly for assessing impacts to ecosystems and renewable resources), a modification in the approach under the Legacy Act could streamline implementation and take better account of both the dynamic nature of ecosystems and the key role of resilience. We therefore propose a modification to the proposal for the Legacy Act. For the majority of renewable resources under public management, the statute could direct agencies to ensure that the ecosystems remain on a sustainable path and that their resilience is not impaired.

Thus, rather than requiring agencies to identify the current quantity and quality of all individual natural resources under public management and to monitor these on an ongoing basis, the Legacy Act would require agencies to focus on a key subset of resource parameters. This would involve collecting the data needed to assess the sustainability and resilience of the relevant ecosystems, thereby affording the ability to monitor trends and ensure that the system is on a sustainable path. Such an approach would not only ensure that the services and value of the ecosystems are preserved, but would also allow the agencies to use publicly available data in many cases, thus avoiding unrealistic or impractical data and monitoring demands. The resource-specific measures would remain an important backstop, ensuring that key resources are preserved according to whatever standards are set forth in the statute. This information would enable near real-time adaptive management by public resource managers and provide the same transparency, accountability, and long-term protection that the Legacy Act seeks.
As detailed in the previous sections, the roles that environmental law and science play to safeguard and protect human health and environment for not only our current generation but also for future generations are extremely important. In addition to their importance, the ability for each to complement the other has been established, and society is continuing to learn of new opportunities to expand these complementary efforts. The science of sustainability is one that is transdisciplinary in nature and operation and is continuing to evolve. Thus, there exist opportunities to bridge concepts, theories, and methodologies to understand, advance, and operationalize this new approach to environmental preservation. One concept that has been introduced demonstrates the merging of new approaches to make environmental law a mechanism for generating change for a more sustainable environmental future. This concept, the ECS (Driesen 2009), provides a mechanism that embraces dynamic and constructive change. The ECS incorporates a “triple bottom-line” concept into an environmental regulatory regime. This triple bottom line embraces economics, environment, and society rather than solely addressing environmental protection.

In the case of the ECS, this triple bottom-line approach to sustainability uses economic incentives to stimulate innovation in environmental technology. While the role of innovation and technology in environmental protection will be discussed in more depth in the next section, it is important to point out that technology has long played an important role in the remediation of environmental degradation but is now also widely employed as a means of preventing pollution. By introducing the use of competition into the mix, the ECS opens the door to advancing the development and application of novel and innovative technologies for environmental protection and overcomes the inherent limitations of traditional regulatory approaches in stimulating innovation. As with any next-generation environmental law or statute, the stimulating of movement toward a more sustainable future is the goal.

The ECS responds to a number of flaws that Driesen (2010) identifies as characteristic of first- and second-generation environmental laws. First, regulation under most pollution control laws is hampered
by regulators' timidity in setting ambitious standards. Driesen describes why and how agencies are overly concerned with impacts on the most antiquated actors in an industry and too little concerned with the positive benefits of incorporating new technology. Even under statutes designed to force technology, agencies tend to demand "relatively modest improvement based on well-understood technology" (Driesen 2010, 175). He describes how this occurs not just with command-and-control regulation but can also affect the design of emissions-trading regimes and pollution taxes, limiting their efficacy to spur innovation and implementation of the best technology.

So what is the goal of an ECS? While it can be seen as advancing the role of law in environmental protection, it is also a mechanism for introducing the inclusion of competition and innovation to improve the environmental quality of a system—to create a race to the top in the development of environmentally superior technology. This is analogous to creating the dynamics of a market in a business sector. In industry, competitors vie for greater market shares within their sector by introducing new, better, or less costly products to meet consumer demand and desires. In return, they are typically rewarded by increased sales, greater profits, and an increased market share. If this type of atmosphere can be created in the environmental technology and protection market, the development of novel and innovative technologies would be promoted and nurtured. The ECS creates this type of competitive environment by providing a premium or reward (i.e., incentive) to businesses for introducing new technologies that exceed regulatory baselines. This "market" provides the ability for technology developers (innovators) to have free rein in improving environmental quality while advancing their firms' economic interests, making it possible to reduce pollution, preserve natural resources, and generate a profit from doing so.

The following scenario highlights the possible implementation of ECS. Five manufacturers of a plastic polymer product are subject to the same environmental regulations, utilize similar technologies in the manufacture of their products, and have similar emission profiles. Additionally, they comply with the relevant environmental regulations. One manufacturer, Company D, has recently been purchased and the new CEO wants to introduce a greener technology for producing the polymer. While this new process has higher operating costs, which the company is willing to
absorb, it will allow Company D to lower its emissions in one category below the regulated level. Because the company is already in compliance with the environmental regulation, there may be no market incentive to reduce the emissions. As noted above, these emissions are externalities—costs borne by the public at large. Thus, the market will not inherently create incentives to minimize or eliminate the emissions. The inevitable timidity characteristic of regulators operating under a traditional regulatory regime similarly will prevent regulators from setting an ambitious regulatory standard, even though it may be within the industry’s economic and technological reach. Therefore, society misses the benefit of applying an existing technology to reduce pollution even further. Under this scenario, if an ECS were in place, the other four companies would be required to pay a fee to Company D (i.e., a reward) for exceeding compliance that would cover the cost of using and developing the environmentally superior approach and provide a premium to Company D. The other companies, therefore, have an incentive to implement a new (or a similar) technology not only to avoid paying the reward to Company D but also to have the opportunity to be paid a fee for implementing a compliance-exceeding technology themselves by the remaining companies who have not exceeded regulatory requirements. From this scenario, we can see that a competition strategy could create a “domino effect” through its market and incentive approach, resulting in companies developing and implementing cleaner technologies and creating a less polluted environment.

Although this is a fictional example, it illustrates the ability to create the incentives to exceed the norm, a major facet of the proposed ECS. This “surpassing of the norm” also presents an opportunity to incorporate the concepts and practices of sustainability and innovation through environmental protection.

Harnessing Technology and Innovation for Sustainability

As touched on briefly above, technology has played a pivotal role in the area of environmental protection. However, this role has largely been limited and relegated to the remediation of environmental degradation and to implementing strategies to allow for remaining within regulatory limits. These actions are typically associated with a reactive mindset.
Since the groundwork laid over four decades ago with the NEPA of 1969 and the definition formally introduced over twenty years ago (United Nations 1987), the concept of sustainability has begun to play a critical role in environmental protection. True adoption of such an ideal requires a paradigm shift from a reactive to a proactive approach in business, science, and society at large. This preemptive approach avoids creating an environmental challenge, which would later require a corrective action and can be demonstrated by such examples as developing a technology that no longer uses toxic chemicals (or creates a toxic product) or one that releases minimal to zero fugitive emissions. Although this green chemistry approach (discussed further in the section on green chemistry) is still relatively new, there are numerous reports and examples of successes (U.S. EPA 2011).

It is imperative that society become as proactive in considering resource needs and environmental challenges as we are reactive in handling environmental consequences. Many of the environmental challenges that our national and international partners face are the result of human activities and human-generated products, including chemicals. Chemicals, in particular, have the potential to generate environmental and human health impacts throughout their entire life cycle. With this potential for impact, it is evident that a sustainable and holistic approach to chemical design, synthesis, management, and reuse can contribute significantly to addressing current and future environmental and human health impacts created by these manufactured chemicals. By applying a proactive and holistic approach, we can begin to minimize or eliminate these impacts across the entire chemical life cycle and increase protection of the environment.

The goal of sustainability is being employed in the chemical sector to reduce negative effects on the environment and human health. To achieve sustainability across the life cycle of a chemical, we must have the ability to not only minimize or eliminate this risk across the life cycle, but we must also be able to assess and quantify any remaining risk and ensure a more sustainable path is being achieved. As the life cycle of a chemical or technology is mapped out, many opportunities exist for improvement to current technologies, as do research areas for development of novel and innovative processes. This is where a proactive approach coupled with a holistic view provides the best opportunity
to increase the sustainability of a system. The ECS illustrates a novel regulatory approach that achieves this.

Green Chemistry and Green Engineering

To further build on this point, examples of this proactive approach that have received tremendous support since their introduction are the areas of green chemistry and green engineering. These are not new disciplines for chemistry and engineering; they are new approaches to performing chemistry and engineering. Introducing concepts based on pollution prevention, sustainability, and industrial ecology into the disciplines of chemistry and engineering encourages the development of new technologies and methods that have environmental protection at their foundation.

The twelve principles of green chemistry described by Anastas and Warner (1998) offer a philosophical basis to identify potential areas in which the level of greenness in designing or implementing chemical technology and reactions can be increased. With these efforts in mind, the number of opportunities increases significantly upon the introduction of chemical engineering and the twelve principles of green engineering articulated by Anastas and Zimmerman (2003). These principles introduce concepts for process design, scaling up, and the use of alternative reactor configurations and geometries for influencing reaction conditions and product and emission profiles. Collectively, these twenty-four principles provide a significant foundation for utilizing technology to protect the environment and advance society along the path of sustainability. Regulatory models like the ECS offer the opportunity to build on and engage these promising foundations in the sciences by providing companies an economic incentive to implement these new opportunities for greener industrial practices.

Innovation

Technology generally is central to minimizing any potential for impact to the environment and human health, but there are other contributors to the goal of increasing the sustainability of a system. One such
contributor is innovation. Innovation can be described using a multitude of definitions; common in those definitions is the desire to capitalize on new ideas or technologies. This is usually driven by economic considerations, yet typically also affects societal and environmental conditions. The impact of innovation is manifest in advances ranging from the use of a cell phone and its technical capabilities to increase access to medical information in a remote region, to the development of a new technological product that creates a completely new market sector. From an environmental perspective, the value of innovation depends on how we capture a technology to satisfy a need and advance society's other interests while preserving the environment.

In recent years, the ability to incorporate innovation into our daily and professional lives has seen a dramatic increase. Within the environmental research and business communities, innovations have included the use of: (1) technology applications to make access to environmental information easier; (2) social networking and media to bring "up to the minute" information to users; (3) innovation as a means of increasing entrepreneurship and intrapreneurship; (4) the use of transdisciplinary teams for technology development; and (5) environmental protection as a means of spurring economic development. The ECS would help to promote innovation that enhances environmental performance by providing an economic incentive for such innovation in lieu of existing economic disincentives.

**Maximizing Economic Development and Environmental Protection in the Administration of Environmental Law and Policy**

Beyond the regulatory approach embodied in the ECS, government can also play a role in promoting environmentally beneficial economic development through participation in creative public–private initiatives. Recent developments by the U.S. EPA provide an example of utilizing environmental protection to spur economic development. U.S. EPA is using the agency’s research and development mission to transform some aspects of the function of the agency. In a 2010 speech to the National Press Club (http://yosemite.epa.gov/opa/admpress.nsf/a883dc3da7094f97852572a00065d7d8/70ba33a218b8f22f852576e00
06b2a53!OpenDocument), the administrator stated "that it is not the economy or the environment, but it is the economy and the environment." In other words, EPA policy and actions will be structured to stimulate economic development in the United States while preserving and improving our environment. Although the agency will continue its role in environmental remediation, it will also become much more proactive in increasing the incorporation of sustainability. To achieve this, it will work more closely with the private sector and local governments to identify practices that increase sustainability and provide alternatives derived from the development and application of innovative policies and technologies.

One example of this new approach to environmental protection is the formation of clusters. A cluster is a unified group that brings together all the expertise needed to take technologies from conceptualization into end use, while maintaining a sustainability focus. From research to demonstration and marketing to deployment, a cluster calls upon the skills of key sectors, including universities and colleges; large corporations; emerging companies; federal, state, and local government; and support groups. The cluster will identify the needs of the industries and communities they serve to produce products that help to protect human health and the environment.

An example cluster is the Confluence—Water Technology Innovation Cluster located in the Cincinnati, Ohio, metropolitan area. This regional activity encompasses southwestern Ohio, northern Kentucky and southeastern Indiana and is based on an EPA and Small Business Administration initiative that recognizes the importance of harnessing regional expertise in public utilities, research partners, and innovative business to encourage economic development and environmental and human health protection. While the concept is not new, the bringing together of partners and groups from the onset to advance the technology continuum is a novel contribution of this concept. Additionally, the cluster concept also recognizes the need to include policy makers into the discussion and executable actions to ensure newly designed and commercialized technologies take into account their environmental and human health impacts.

While this is only a subset of recent activities and successes that demonstrate the use of innovation and technologies for increasing
environmental preservation and protection of a system, it is very evident that society can no longer approach problems and challenges as in the past if a sustainable future is truly desired. Further, the role of technology is more than a means of providing an innovative solution in isolation from legal, societal, and economic considerations. The ECS and the cluster initiative involving U.S. EPA and other entities show two complementary ways in which government can play a critical role in ensuring that economic activity also advances society’s environmental objectives.

Conclusion

The preservation of natural resources and ecosystems is directly tied to the ability to promote a long-term vision and to secure a commitment to implement proactive strategies for meeting human needs from generation to generation. Hence, it is critical that approaches are developed that consider the dynamic nature of systems and avoid static policies that are insufficient in this context. Further, the approaches developed must be bounded by resource supply horizons, environmental regulations, technological capabilities, and the capacity of critical supporting ecosystems to absorb human burdens while continuing to thrive. While there is still much effort needed to further develop the practical means of moving toward sustainability, this work provides key insights on the type of legal and policy instruments, market practices, and technological innovation that are critical to the success of this endeavor. As articulated in this chapter, the following mechanisms provide three possible strategies to support this effort. Model legislation such as the Legacy Act provides a foundation that is flexible and adaptive when coupled with scientifically sound measures of sustainability and resilience. The ECS offers a way to harness economic incentives to promote environmentally beneficial technological innovation. Lastly, the U.S. EPA’s participation in the cluster initiative provides an example of how public and private sectors working together can advance economic and environmental goals. We therefore propose a multi-pronged approach to preserving a resource legacy, promoting intergenerational equity, and moving toward a more sustainable future.
References


