Eco-Asset Management: Banking on Nature's Fortune

Electricity Technology Roadmap
Limiting Challenge #12

1009443

Final Report, December 2003

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PREFACE

Ecosystems regulate Earth's atmosphere, supply life's essentials (nutrients, water, and energy), and otherwise nurture modern society. Ecological assets, or *eco-assets*, reflect the economic value assigned to improvements in the ability of natural and managed ecosystems to provide these critical services. Frequently institutionalized in the environmental marketplace as *mitigation credits*, eco-assets are commodities generated by efforts to recover ecosystem service values and replenish the *natural capital* previously lost as economic *externalities* to ever-expanding human enterprise.

Eco-assets are created through voluntary, reward-driven enhancements in ecosystem structure and function. They are sponsored by government agencies, being grounded in policy instruments that promote investments producing measurable, sustainable improvements in air, land, and water quality and biodiversity. They have the same market liquidity as other forms of commercial paper. They offer significant value to society—through both the public sector and the private sector—in terms of improved ecological function, enhanced regulatory compliance, and expanded business opportunity.

Eco-asset management harnesses market forces to preserve, enhance, restore, and create the natural capital life itself depends upon. In this report, eco-asset management is described within the context of the societal objectives defined by the *Electricity Technology Roadmap*, a collaborative exploration of the future of the global electricity enterprise. Eco-asset management is characterized as a market-based approach with promise for maximizing the productivity of natural resources to promote economic vitality, protect environmental and public health, improve the human condition, and accelerate global progress toward a sustainable future.

For companies in the energy, agriculture, mining, timber, real estate, land management, and other resource-based sectors, eco-asset management offers significant opportunities for increasing revenues, reducing compliance costs, eliminating liabilities, and managing risks. Improving environmental quality, protecting public health, and demonstrating corporate citizenship represent additional—and substantial—benefits. For government agencies and other stakeholders, market-based approaches promise solutions for achieving environmental goals more efficiently and at lower cost, as well as for addressing complex challenges such as climate change, water shortages, and biodiversity loss.

Yet for all that is believed about eco-asset management's potential, its widespread acceptability seems hampered by incomplete or disorganized policy-, science-, and business-based support systems. Over the past 5 years, EPRI, working in collaboration with energy and other

companies, government agencies, nongovernmental organizations, and additional stakeholders, has enhanced the knowledge foundation for eco-asset management, developed leading-edge tools and technology, and facilitated landmark business transactions monetizing diverse eco-asset values.

To further advance the case for ecosystem service restoration and the cause of eco-asset management, this report recommends broad, sustained collaborative R&D in diverse areas of policy (scope, depth, consistency, etc.), science and technology (ecological economics, conservation biology, restoration ecology, biotechnology, etc.), and business (market costs, supply vs. demand, pricing and sales, infrastructure, etc.).

In many areas, relevant work is under way but not yet focused on critical knowledge and capability gaps pacing the adoption of eco-asset management policies and practices. The initial R&D planning objectives are to synthesize existing knowledge and define the state of the art in key areas and to interact with potential funding sources and partners in the policy, science and technology, and business communities.

The ideas, plans, and actions described in this report represent a starting point for the development of robust, public-private R&D strategies that engage government agencies, corporations, nongovernmental organizations, academic institutions, and other stakeholders in efforts to account for and maximize the societal value provided by the global ecosphere. This Limiting Challenge is a living document that provides a starting point for further discussion and debate. Comments and suggestions for continued refinement are invited. For more information, contact Michael Miller at 650-855-2455 or micmille@epri.com.

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1 OVERVIEW

Ecological asset (eco-asset) management is identified by the *Electricity Technology Roadmap* as a *limiting challenge* that will help determine the future of the energy enterprise in global society. Addressing the Eco-Asset Management Challenge presents opportunities for maximizing the productivity of energy and other natural resources to promote economic vitality, protect environmental and public health, improve the human condition, and accelerate global progress toward a sustainable future.

Eco-asset management harnesses market forces to preserve, enhance, restore, and create (PERC) the natural capital life itself depends upon. Its foundation lies in institutions, policies, and instruments that wed natural resource management with environmental quality improvement. The intent is to create sound, efficient markets for allocating the goods and services furnished by the natural ecosystems that regulate Earth's atmosphere, supply life's essentials (nutrients, water, and energy), and otherwise nurture a growing global population (Figure 1-1).

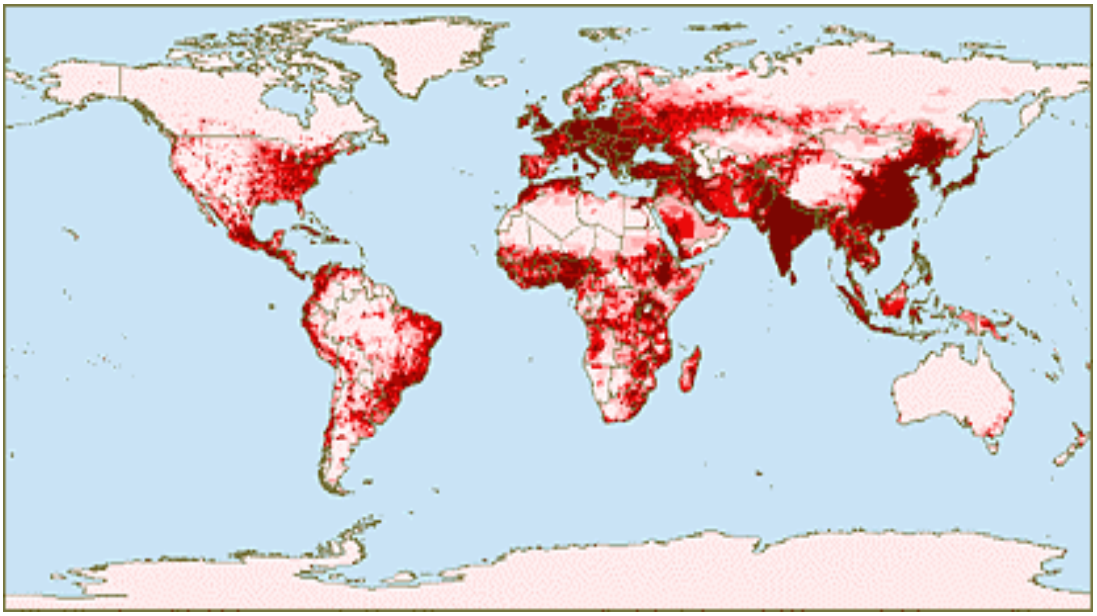

Figure 1-1
Eco-Asset Management's Promise—Using Market Forces to Build Natural Capital, Optimize Resource Allocation, and Meet the Needs of a Growing Global Population[1]

At present, the global economy largely ignores the importance of eco-assets to human survival. Furthermore, conventional technology-based environmental policies and regulations, though

[1] Source: World Resources Institute (WRI), 2002

historically successful in improving air and water quality, institutionalize sub-optimal "end-of-pipe" approaches and constrain innovation. They also offer limited capabilities for resolving complex challenges such as climate change, water shortages, and biodiversity loss.

Market-based management frameworks that account for the economic value of natural capital promise to help address these challenges and achieve environmental goals more efficiently and at lower cost. Experiences to date indicate that such frameworks can spur innovations that maximize resource productivity by stimulating "beyond compliance[2]" investments in the stewardship of natural ecosystems and the goods and services they provide.

This report characterizes the opportunities and challenges associated with ecosystem service enhancements and eco-asset management. By educating and engaging government agencies, the private sector, the research community, nongovernmental organizations, and the public, EPRI seeks to catalyze public-private R&D collaborations that focus society's resources on institutional barriers and knowledge and technology gaps that must be addressed in order to establish a robust scientific foundation for market-based management of natural capital.

Report Content

Section 2 of this report discusses the context for eco-asset management, in terms of ecology, economics, policy, and business.

Section 3 describes how the Eco-Asset Management Challenge relates to the societal objectives defined by the *Electricity Technology Roadmap*.

Section 4 introduces six interdisciplinary and interdependent critical capability gaps that, once addressed, will help resolve this challenge.

Section 5 proposes a collaborative R&D program for developing policy-, science-, and business-based support systems to support expansion of market-based policy frameworks. It identifies both broad disciplines and specific topics for investigation, approximate funding levels, and potential partners.

Section 6 defines connections between the Eco-Asset Management Challenge and other *Roadmap* challenges.

Section 7 identifies key stakeholders and characterizes their roles in helping resolve this challenge. Issues and opportunities associated with specific government agencies, major industrial sectors, and certain other stakeholders are described in some depth.

[2] Regulatory compliance is the bottom-line standard for environmental managers. Standards establish pollution limits that, by definition, protect health and welfare. On the other hand, incentive-based environmental quality programs are meant to improve ecosystem services above and beyond the *de minimus* standards established in laws and regulations.

Section 8 details EPRI's two-pronged strategy for advancing the concepts and practice of ecosystem service valuation and eco-asset commoditization. Both service-based and collaborative R&D components are included, and exemplar projects and activities are described.

Resources consulted by the authors during the development of this report are cited in Section 9.

2 CONTEXT

2.1 Ecology

Ecosystems are communities of species living together and interacting with each other and their physical environment. The natural assets they generate deliver both goods and services critical to human health and welfare (Figure 2-1). Ecosystem goods include life's essentials—water, nutrients, and energy—as well as the minerals, timber, and other resources that human society has harnessed to survive and prosper.

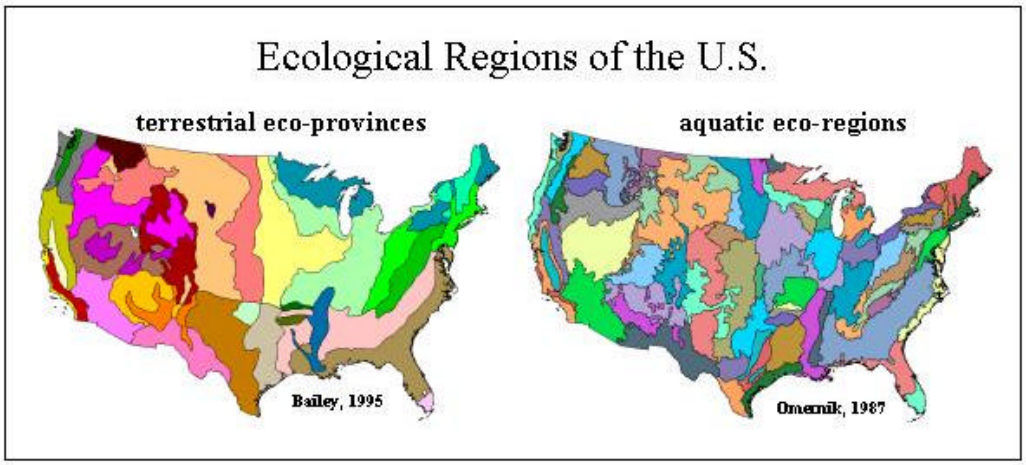

Figure 2-1
Eco-Regions—Placing Human Society in Ecological Context[3]

Ecosystem services are the roles played by biological communities and their physical surroundings in creating a hospitable, productive environment for humanity. At the most basic level, ecosystem services deliver the air society breathes, the water it drinks, and the foodstuffs it consumes. Ecosystems control the atmospheric, aquatic, and terrestrial cycling of nutrients and other chemicals. They absorb and filter waterborne contaminants and detoxify and recirculate other wastes and by-products. They generate and renew productive soil, provide habitat, and pollinate crops. They are primary sources for ecosystem goods such as agricultural, industrial, and pharmaceutical products. They moderate climate, mitigate flooding and erosion, and screen out the sun's ultraviolet rays. And they afford recreational, aesthetic, and spiritual benefits.[4]

[3] Source: Bailey, 1995; Omernik, 1987
[4] Powicki, 1998

2.2 Economics

Traditionally, economic systems have valued only certain ecosystem products, such as minerals, fuels, timber, and food, with prices set according to the principles of supply and demand. Ecosystem services, by contrast, have had little, if any, market value. They have generally been treated as public goods, or common property, both accessible to and provided to all. Moreover, the negative effects of resource extraction and use on the ability of ecosystems to continue providing goods and services have been considered externalities, i.e., costs imposed on society because they are not reflected in the conventional marketplace. The global consequences of these economic incongruities were limited—until recently.

Historically, the Earth's supply of natural capital dwarfed the capacity of the human population to deplete it. The gap began to narrow after the onset of the Industrial Revolution, when humanity harnessed technology to begin "spending down" ecological capital at unprecedented rates. Economic growth and productivity accelerated to improve the human condition in many countries, while the negative impacts of unrestrained resource expenditures were limited mostly to local or regional levels.

As the scale and reach of human enterprise has expanded, the gap between natural capital accounts and society's spending capabilities has narrowed. The failure of economic systems to reflect the true costs of resource extraction and use has encouraged market participants to continue drawing down natural capital. This perverse incentive, "the logic of the commons," was described by Garrett Hardin[5] in the context of herdsmen sharing pasture open to all:

> Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

In some instances, society's withdrawals of natural capital have exceeded the regenerative capacity of ecosystems. For example, major oceanic fisheries have collapsed. Desertification has occurred in once-verdant areas where groundcover was removed for food and fuel. The influx of nutrient-laden sediments from the Mississippi River has exceeded the assimilative capacity of the Gulf of Mexico, producing an hypoxic "dead zone" as shown in Figure 2-2.

[5] Hardin, 1968

Figure 2-2
The "Dead Zone"—Nutrient Loading Exceeds Assimilative Capacity in the Gulf of Mexico[6]

2.3 Policy

It is beyond dispute that punitive, command-and-control environmental policies have improved air and water quality, ecosystem integrity, public health, and other key health and welfare indicators in the United States over the past 30-plus years. Technology-based requirements have compelled point-source dischargers such as industrial facilities to invest hundreds of billions of dollars in "maximally achievable" environmental controls. However, this approach has embedded within it reverse incentives that allow continued releases of regulated chemicals in amounts right up to established permit limits.

The externalities imposed on society by regulated human activities, when added to those created by the diffuse, nonpoint sources of pollution that are difficult to regulate efficiently under command-and-control frameworks, contribute to persistent environmental quality problems such as regional haze, acidic deposition, water quality degradation, climate change, and the loss of biological diversity critical to ecosystem productivity. Thus, even as policies are created to optimize resource management or to reduce waste generation, incomplete markets continue to send conflicting signals regarding society's need for sustainable ecosystem services.

In an era driven by quality-of-life considerations, society's demand for sustainable environmental quality improvements—which would likely require ultra-expensive, politically unpopular technology-based choices—requires more creative policy solutions.

Devising market-based cures that assign the rights to impact ecosystem services—and draw down the ecological capital of the commons—provides a means for internalizing these impacts as costs shared by market participants rather than costs borne by society overall. With proper design, market-based frameworks can focus the efficiency of modern markets on rebuilding ecological capital by reducing impacts *and* improving environmental quality and ecological functions beyond prescribed levels. They can encourage investors, buyers, sellers, permittees, and other market participants to manage and use natural resources in ways that PERC eco-assets,

[6] Source: U.S. Environmental Protection Agency, 2002a

yielding economic value while gradually reestablishing the sustainable productivity of natural ecosystems.

The SO_2 allowance trading program for U.S. power producers represents one of the earliest applications of market-based principles to internalize externalities. It also the most successful, according to both the U.S. Environmental Protection Agency (EPA) and Resources for the Future (RFF).[7] In Phase I of the Acid Rain Program, which began in 1995, EPA set a cap that established the maximum allowable level of total sulfur emissions in 2000 from more than 250 power plants (Figure 2-3). Each plant was given an emission permit (a right to discharge) for a specified quantity of SO_2. Companies were offered flexibility to protect environmental and public health in the most effective, economical way possible.

An efficient market quickly evolved, in which a range of strategies and innovative approaches was developed for reducing emissions and managing risks. Some companies chose to over-comply, creating unneeded permits (emissions credits) that could be banked and then sold to the highest bidder. Various speculative interests entered the market, increasing its liquidity. By 2000, the required reductions in SO_2 emissions had been surpassed throughout the country by about 25%—at about one-tenth the cost originally projected by EPA.[8] Based on the early success of this program, EPA launched the federal NO_X Budget Trading Program[9] aimed at reducing interstate transport of ozone.

[7] U.S. EPA, 2002b, 2002c; RFF, 2002
[8] Dailey & Ellison, 2002
[9] 40 CFR Part 75

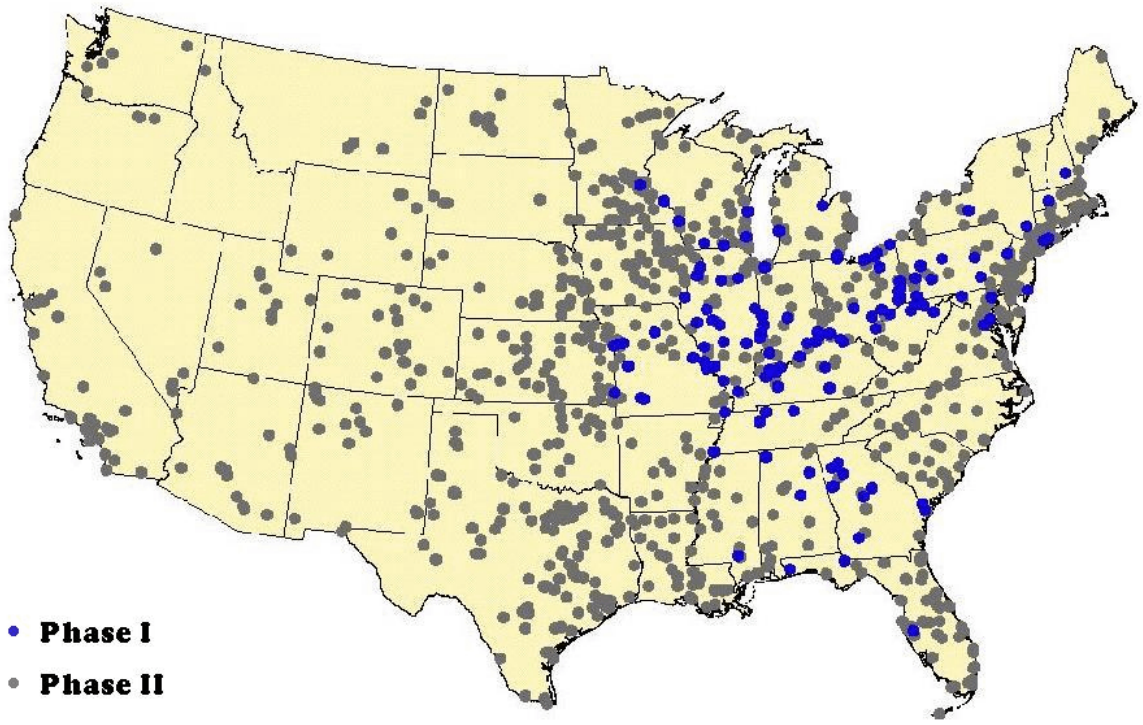

Figure 2-3
U.S. Acid Rain Trading Program—Economic and Environmental Success in Reducing SO_2 Emissions from Affected Sources Expands Use of Market-Based Management Frameworks[10]

2.4 Business

In recent years, environmental markets have begun to emerge, grow, and diversify. These markets essentially assign a dollar value to the services provided by both natural and managed ecosystems. Policymakers and regulators help create these markets by establishing incentive-based environmental management frameworks that reward investments for eco-asset PERC. In addition to SO_2 and NO_X emissions allowances, commodities such as aquifer recharge credits, wasteload allocations for point and nonpoint source pollutants, and mitigation credits for wetlands, biodiversity (critical habitats and listed species), and riparian buffer zones are being bought and sold in U.S. markets. For other commodities—notably, emission offset credits for carbon dioxide and other greenhouse gases—markets are emerging over scales ranging from regional to global.

[10] Source: EPA, 2002b

Companies and property owners are leveraging market-based programs to increase revenues, enhance compliance, and reduce overall liabilities while improving environmental quality and protecting public health. Meanwhile, society benefits as the "invisible hand" of the marketplace first described in 1776 by Adam Smith in *The Wealth of Nations*[11] works its magic to protect ecosystems and the products and services they provide.

In 2002, for example, an energy company sought to maximize the economic *and* ecological value of a property in central North Carolina that was about to be sold at a price (less than $1 million) based on the standard value of neighboring hog farms. An eco-asset valuation directed by EPRI discovered opportunities for PERC of wetlands, stream corridors, and riparian zones to create eco-assets that, together with conventional land management options, represented at least $5 million *net* in prospective value.

In another example, an energy company collaborated with the U.S. Fish and Wildlife Service (FWS) and other stakeholders to preserve 12,000 acres in West Virginia as part of the Canaan Valley National Wildlife Refuge in early 2002.[12] The landmark transaction hinged upon the eco-asset value of this unique property, the ecological importance of which had been assessed by EPRI in prior studies. A comprehensive appraisal, also arranged by EPRI, determined the property's value according to a "highest and best use" plan that blended traditional options, such as residential and recreational development, with eco-asset management options. The then-current market value of the eco-asset base—specifically, mitigation credits associated with protecting and enhancing habitat (such as the wetlands shown in Figure 2-4), preserving open space, and sequestering carbon—essentially doubled the property's appraised value.

Figure 2-4
Accounting for Eco-Assets Enables Preservation of Unique Habitat[13]

FWS purchased the property in 2002 at a price in line with the traditional appraisal value, per agency policy. Based on bargain sale provisions in the federal tax code, the company was able

[11] Smith, 1937
[12] Powicki, 2002
[13] Source: Allegheny Energy, Inc.

to claim a charitable contribution of the additional eco-asset-based value, augmenting quarterly earnings by about $6 million in tax-related savings.

2.5 Challenges

Early applications demonstrate the promise of eco-asset management approaches, but a number of challenges remain to their widespread adoption. They include the following:

- To recognize, quantify, and monitor the economic and social value of local, regional, and global ecosystem services;
- To develop representative, marketable economic instruments commensurate with the location, scale, quality, and productivity of ecosystems;
- To foster the creation, acceptance, and operation of viable environmental markets for eco-asset-based commodities; and
- To begin the arduous process of internalizing externalities, i.e., of fully introducing to economic systems the societal costs that have historically been externalized.

Although knowledge and capability gaps are significant in ecological economics, conservation biology, restoration ecology, biotechnology, and other relevant scientific disciplines, the most daunting barriers are not technical in nature. Society must willingly reconsider modern values, reshape government institutions, and restructure economic systems to properly account for the essential goods and services provided by functional ecosystems. These efforts will require extensive collaboration between—and concerted action by—elected officials, government agencies, the financial community, nongovernmental organizations, industrial sectors, the scientific community, the public, and other stakeholders.

In no small way, the widespread adoption of eco-asset value principles will help change the course of human history by preventing present generations from unknowingly appropriating the natural capital of future ones. Unleashing market forces on nature's account promises to bring ecosystem structures and processes onto an equal footing with other natural resources. This, in turn, will optimize resource allocation, improve public health, enhance quality of life, and steer global development in the direction of a sustainable future.

3 ELECTRICITY TECHNOLOGY ROADMAP CONNECTIONS

In the late 1990s, EPRI spearheaded a collaborative exploration of the future of the electricity enterprise and global society. The end result, published in 1999 as the *Electricity Technology Roadmap*, identifies five principal *destinations* to be pursued through public-private R&D in order to maximize the societal benefits of electrification.[14] Subsequently, a set of 15 *limiting challenges* was defined to provide more detailed R&D planning guidance. The challenges represent critical issues and opportunities facing the electricity enterprise and society. Underlying each challenge is a series of *critical capability gaps* representing the most important needs and barriers in terms of knowledge, technological capability, and other factors.

Progress in resolving the Eco-Asset Management Challenge will help address three of the destinations defined by the *Roadmap*:

- Accelerate Economic Growth and Productivity
- Resolve the Energy/Carbon Conflict
- Meet the Global Sustainability Challenge

The *Roadmap* identifies electricity-based innovation as the catalyst for "a 'long boom' of unprecedented economic expansion." It posits that only growing economies will possess adequate resources to meet the quality-of-life aspirations of both present and future generations while solving global challenges such as climate change, biodiversity loss, and sustainable development.

Historically, economic growth has driven social progress, but at a cost—the depletion of ecological capital. Sustaining economic vitality requires adequate supplies of water, energy, and other finite natural resources. Based on current trends, growing global demand for eco-assets is projected to exceed the capacity of ecosystems to replenish them, perhaps irreversibly in some instances. Already, local and regional deficits of ecological goods and services abound, and global deficits loom. Climate change, for example, is a physical manifestation of ecological disruption—the volume of heat-trapping gases released to the atmosphere by fossil fuel combustion, deforestation, and other sources has surpassed the carbon uptake and storage capabilities of aquatic and terrestrial ecosystems.

Under the traditional economic paradigm, accelerating growth and productivity and *decarbonizing* the energy system appear to be mutually exclusive aims, as shown by the diverging arrows in Figure 3-1. Ecosystem service valuation and eco-asset management promise to transform these objectives from competing to complementary by helping restructure the global

[14] EPRI, 1999

economy and the generation and use of electricity along pathways promoting global sustainability, as shown by the converging arrows in the figure.

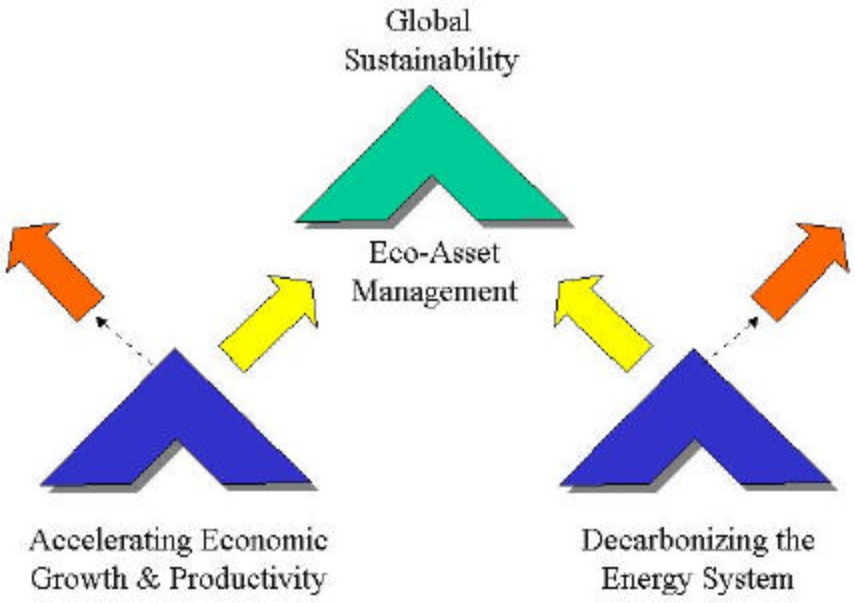

Figure 3-1
Eco-Asset Management—Pointing *Roadmap* Destinations in Sustainable Directions

For example, greenhouse gas emissions trading and other market-based mechanisms assign economic values to the carbon uptake and storage capabilities of natural and managed systems. They enlist market-driven forces to make least-cost emissions reduction opportunities available and to control the total costs of compliance.[15] In addition to minimizing compliance-related constraints on economic growth, these eco-asset-based approaches create new markets and opportunities for investment and innovation in areas that reduce emissions and increase carbon capture and storage.

Incentive-based policies that account for the value of ecological services will complement existing policy frameworks, encouraging and cajoling market participants to internalize externalities. This will impose efficiencies that temper and ultimately reverse the depletion of natural capital. Driven by scientific knowledge and technological innovation, economies will grow within their means as market forces cut global energy intensity, accelerate decarbonization, and maximize resource productivity. The pathway to sustainable development will be guided by incentives that balance present social demands with appropriate, achievable, and emerging goals for present and future society.

[15] Moore, 2000

4 CRITICAL CAPABILITY GAPS

Within the *Roadmap* context, critical capability gaps represent priority areas that, once addressed, will help resolve a limiting challenge. Six multidisciplinary, interconnected, and interdependent gaps have been identified for the Eco-Asset Management Challenge. They are listed in the table and characterized below.

Table 4-1
Critical Capability Gaps for Eco-Asset Management

Critical Capability Gap	Title
Institutions do not consistently or comprehensively account for the value of ecological services.	Institutional Restructuring
Government policies (legal frameworks, regulatory criteria, and related guidelines) need to be standardized and harmonized at all levels of government to enable development of public-private partnerships and design of efficient markets.	Standardized Policy Frameworks & Criteria
The knowledge and technology base must be expanded to support optimal design and implementation of eco-asset management programs.	Scientific Knowledge & Technological Capability
Markets for eco-asset trading are in their infancy, as is the development of valid commodities for specific types of assets.	Market Assessment, Development & Expansion
Tools and strategies are needed for designing and optimizing ecosystem sustainability and eco-asset management programs to maximize value for diverse stakeholders.	Tools & Strategies for Maximizing Eco-Asset Value
Greater public understanding and support are required for market-based approaches to managing eco-assets.	Public Education & Acceptance

4.1 Institutional Restructuring

Institutions do not consistently or comprehensively account for the value of ecological services.

Economic, political, and social institutions must be restructured to account for the value of eco-assets while avoiding widespread disruption and confusion—a daunting challenge.

Market-based economies can offer distinct resource management efficiencies. At present, however, the prices of many essential goods derived from natural capital are distorted by direct subsidies and other externalized costs, while many ecosystem services are priced not at all. As a result, local, regional, national, and global markets operate under false pretense, failing to reflect the true costs and benefits associated with economic activities. This incomplete accounting creates incentives for resource inefficiency, which can result in over-consumption, waste production, environmental degradation, and depletion of natural capital.

Markets are shaped by policies (laws, regulations, and guidelines), which are the instruments most often wielded by government in the public interest. Market transformation to promote eco-asset valuation and management requires government intervention to change market structures, reduce barriers, and influence the behavior of market participants. Such a transformation will unleash market forces for integrating environmental quality improvement within traditional resource extraction, management, and utilization activities. EPRI has a long history of designing and implementing collaborative, coordinated strategies for transforming energy efficiency markets—an experience base that could prove valuable in reshaping eco-asset, energy, and related resource-based markets.

Vested interests in the status quo represent a major barrier to the restructuring of economic and governmental institutions. Rigorous assessments of eco-asset values and the true costs and benefits of resource management alternatives will provide quantitative evidence to bolster the recognition—growing within both the private and public sectors—that restructuring will be necessary to steer and accelerate economic development in sustainable directions.

Research is also needed to explore human ethics within the sustainability context and to express an ethic that balances economic, environmental, and social considerations, both in the present and for the future. Such an ethic will recognize the symbiosis between the Earth's ecosystems and humanity. It may be simply stated as follows: to harbor life as it harbors society.

Work by ethicists, ecologists, economists, and scientists in other disciplines will provide both the emotional and technical underpinnings for this ethic. Outreach and education projects will accelerate its acceptance by the public and other stakeholders. Visionary leaders and government agencies, acting on behalf of an informed citizenry, will apply it as a common ground, a starting point, for restructuring institutions to recognize, protect, and enhance the value of eco-assets. Such an ethic seems both desirable and inevitable if society is to move toward an enlightened and sustainable resource management future.

4.2 Standardized Policy Frameworks & Criteria

Policies (legal frameworks, regulatory criteria, and related guidelines) need to be standardized and harmonized at all levels of government to enable development of public-private partnerships and design of efficient markets.

Eco-asset management enlists the entrepreneurial spirit in pursuit of sustainable health and welfare by providing incentives for environmental quality improvement. Positive incentives promote environmental protection and enhancement, while negative incentives discourage

environmental degradation. The public sector strives to protect society's interests by creating market-based policies and market designs that encourage private sector participation and reward both intelligent investment and innovation. A number of factors must be considered for these public-private partnerships to be successful.

The economic instruments used to design markets and create incentives—whether positive or negative—include permits, direct and indirect subsidies, penalties and fees, punitive taxes, and tax credits. Tradable permits and punitive taxes are currently receiving the most attention as instruments capable of catalyzing new levels of voluntary environmental quality improvement.[16] In general, tradable permits produce markets that promote ecosystem service enhancements beyond the level predetermined by regulations. Environmental taxes are used to reduce a negative impact or encourage a positive impact by stimulating pervasive, long-term change in overall asset management. Although permit-based markets may require the development and administration of complex rules and procedures, regulatory authorities are developing appropriate guidelines at all levels of government. Environmental taxes are conceptually simpler to implement, though barriers may be higher. There is a significant need to assess the present experience base with these instruments and to understand conditions under which they are most effective.

The evolution of wetland mitigation banking programs illustrates several additional challenges associated with the design and operation of eco-asset markets.[17] Section 404 of the U.S. Clean Water Act (CWA) requires developers to provide compensatory mitigation for unavoidable impacts to wetlands. Compensatory mitigation typically entails the restoration or enhancement of diminished wetland functions or the creation of new wetland areas.[18]

On-site compensatory mitigation projects generally involve only small areas dedicated to wetland PERC. Wetland mitigation banks were conceived as a market-based solution for problems constraining the ecological success of on-site mitigation. Banks typically involve large, contiguous areas (Figure 4-1), permanently protected from development, where PERC activities improve wetland ecosystem services to an extent unachievable through discrete, site-by-site mitigation. To reward eco-asset value creation, permitting authorities assign credits to the bank that may be used by developers for compensatory mitigation.

[16] Brown, 2001
[17] U.S. Army Corps of Engineers, 1996; Environmental Law Institute, 2001
[18] Under federal statutes, wetland preservation is allowed under exceptional circumstances; attitudes toward preservation vary at the state level.

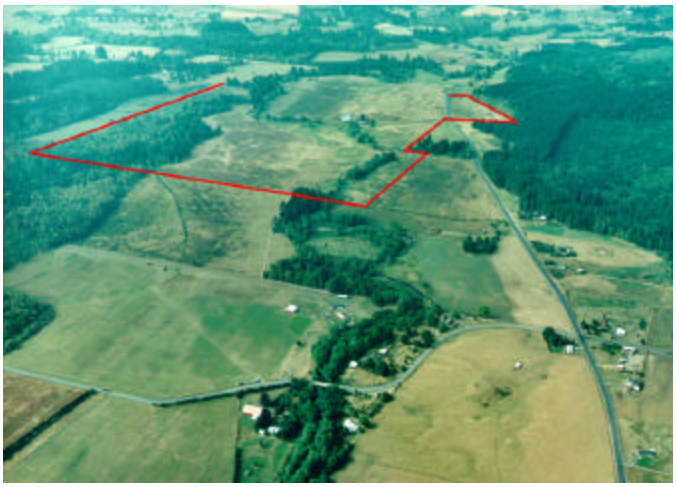

Figure 4-1
Wetland Mitigation Banks—Creation of Large, Contiguous Wetland Areas Enhances Ecological Functions and Builds Eco-Assets[19]

In the early 1990s, most existing wetland mitigation banks had been established by state agencies, primarily highway departments, to generate credits for meeting their own compensatory mitigation requirements. In many cases, the absence of clear federal guidance resulted in improper design and insufficient monitoring, enforcement, and other provisions. Furthermore, because watershed-based management policies had not yet been adopted, centralized mitigation banks were not being created to address the cumulative impacts of discrete wetland losses or to serve regional needs for balancing development with wetlands protection. These conditions created a major obstacle to private sector investment in the development of mitigation banks.

In 1993, the Clinton Administration announced federal support for mitigation banking and initiated an effort to develop federal guidance with input from the U.S. Army Corps of Engineers (Corps), U.S. EPA, U.S. Fish and Wildlife Service, National Rural Conservation Service (NRCS), and National Oceanic and Atmospheric Administration.[20] This guidance clarified at the federal level how wetland mitigation banks can be used under CWA S. 404 and the "Swampbuster" provisions of the U.S. Food Security Act. Subsequently, complementary policies and regulations have been developed at the state, regional, and local levels to govern the creation and use of wetland mitigation banks.

The existence of clear guidelines has enticed market forces to enter the picture, accelerating the creation of wetland mitigation banks during recent years.[21] Largely fueled by the investments of private sector entrepreneurs, these banks are in the business of producing ecosystem service enhancements beyond those required to offset already permitted losses.

[19] Source: Washington Department of Transportation, 2002
[20] "Federal Guidance for the Establishment, Use and Operation of Mitigation Banks," issued in November 1995 (Federal Register, 11/28/95)
[21] Environmental Law Institute, 2001

The number of banks selling credits on the open marketplace to meet regional demand for mitigation requirements has expanded greatly. Moreover, economic and ecological effectiveness of wetland mitigation banking—along with the lessons learned while implementing this market-based approach—have catalyzed the establishment of bank-and-trade programs to account for adverse impacts and encourage ecosystem PERC across all environmental media. These experiences demonstrate the importance of harmony among federal, state, and local agencies for encouraging private sector participation in eco-asset markets, as well as for ensuring their effectiveness.

Market-based approaches must also complement existing frameworks in order to maintain overall regulatory consistency and prevent backsliding from *de minimus* standards. Wetland mitigation banks, for example, are administered by the Corps under CWA S. 404 and the NRCS under "Swampbuster" provisions. As a market-based compliance mechanism, they provide flexibility and promote innovation in directions that lead to environmental quality improvements far greater than would be achieved under existing practices and policies. For more widespread eco-asset management, it is important to identify existing regulatory frameworks at global, international, national, regional, state, and local levels that may be particularly amenable to market-based solutions, as well as to identify situations where existing frameworks, criteria, and guidelines present barriers.

The success of eco-asset markets in achieving environmental goals may also be determined by the *fungibility* or liquidity of assets within the marketplace. In permit-based markets, government agencies authorize the creation of mitigation credits to reward improvements in ecosystem services within a defined region. Credits then become commercial paper that can be bought, traded, or sold anywhere: Because the marketplace knows no borders, buyers, sellers, bankers, and traders may be from any location. The transferability of monetized ecological value beyond its region of origin is real and measurable.

Though credits have unlimited *market* scope, their *geographic* scope is determined by the agency-defined service territory of the ecological enhancement they represent. For example, though they literally may be owned by anyone, anywhere, the credits awarded to most wetland mitigation banks can only be "cashed in" (used) within the watershed or region in which the impacts requiring compensatory mitigation occurred; generally, the service territory of wetland mitigation credits is relatively limited.[22] Service territories may vary widely, however, depending on the type of credit developed. For example, the eco-service territory for greenhouse gas mitigation credits is global in scope. Species credits may be local, regional, or even hemispheric in extent—migratory birds, for example, may range from Canada to Mexico or South America.

Given these complexities, incomplete understanding of how ecosystems and their component parts behave, and difficulties inherent to eco-asset valuation, study is required to assess the transferability of credits within and between agency-defined and ecologically-based regions, as well as to develop mechanisms for trading that preserve ecological restoration value (Figure 4-2).

[22] According to a 2002 study by Environmental Law Institute, trades outside of the defined service area of many wetland mitigation banks may be considered on a case-by-case basis.

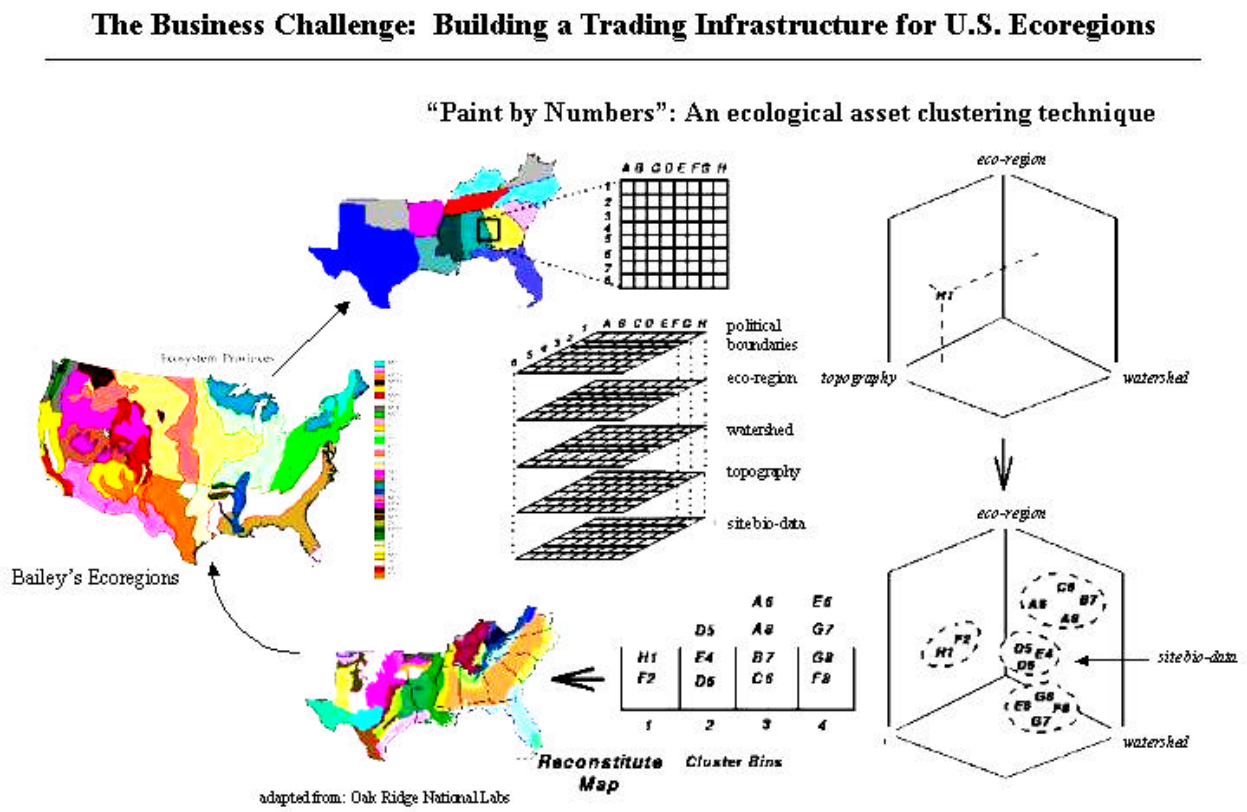

Figure 4-2
An Approach for Building an Eco-Asset Trading Infrastructure [23]

The figure presents a geographical clustering approach that might be applied to support eco-asset development and market expansion beyond agency-defined eco-service territories. At present, eco-assets are generally anchored to specific locales, wherein improvements to ecosystem service quality yield measurable economic value in active markets represented by a combination of compliance requirements and certified, market-based mitigation projects. Spatial clustering techniques could be applied to physical, biological, economic, and other data to identify geographic areas that are similar with respect to ecological, regulatory, and market conditions. These areas, representing either contiguous regions or discrete geographic patches, could be said to delineate broader service territories for eco-assets. Expanding the geographic scope of eco-asset markets could provide permittees with more cost-effective mitigation alternatives, resource management agencies with the ability to improve ecosystem service quality across wider regions, and investors with expanded eco-asset development opportunities.

The interactions between environmental and electricity markets represent another important R&D topic. Connections between electricity markets and markets for NO_X emissions allowances contributed significantly to the costs experienced by ratepayers during the California power crisis. The effects of a global market for carbon credits—or of a carbon tax—on electricity markets cannot be underestimated. EPRI tools developed for power market simulation may be

[23] Source: Adapted from Hargrove & Luxmoore, 1997

used to study interactions between energy and environmental markets. Accounting for these interactions during market design will improve the overall efficiency of resource-based markets.

4.3 Scientific Knowledge & Technological Capability

The knowledge and technology base must be expanded to support optimal design and implementation of eco-asset management programs.

The knowledge foundation for eco-asset management draws on many technical fields, notably diverse areas of economics, ecology, biology, sociology, and the earth sciences. Biotechnology, environmental controls, remote sensing, and other areas represent potential sources for technology-based eco-asset management solutions. The emerging discipline of ecotechnology also shows promise. Ecotechnologies are designed to improve economic performance and environmental quality while minimizing harm to the environment—thanks to a more developed capacity to absorb by-products and control impacts on ecosystems.[24] The drivers for ecotechnology and its three primary research areas are illustrated in Figure 4-3.

In many areas of science and technology, relevant work is under way but not yet focused on specific eco-asset management challenges and opportunities. The initial R&D planning objectives are to synthesize existing knowledge, define the state of the art in key technology areas, assess ongoing work by EPRI and other stakeholders, identify key gaps and priorities, and interact with potential funding sources and R&D partners. This will allow development of collaborative public-private R&D strategies capable of addressing the full range of scientific and technological needs pacing adoption of eco-asset management policies and practices.

[24] International Ecotechnology Research Centre, 2002; National Institute for Resources and Environment, 2002; Asian Ecotechnology Network, 2002

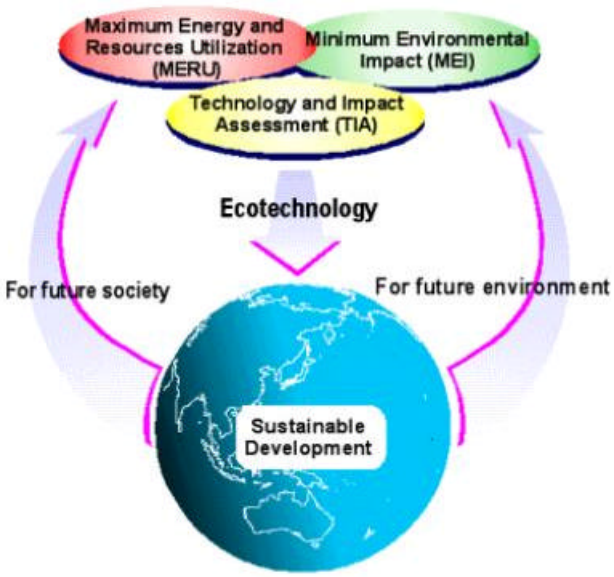

Figure 4-3
Ecotechnology Drivers and R&D Areas[25]

A few overarching needs in diverse areas of science and technology are listed below:

- To determine the true costs of resource extraction, management, and utilization
- To quantify the benefits of integrating economic, environmental, and resource management policy
- To understand, assess, and monitor the multiple ecological functions and services provided by natural and managed ecosystems
- To identify and value eco-assets and establish priorities for their preservation, enhancement, restoration, and creation
- To develop strategies and tools for restoring and managing ecosystem services and monitoring and maximizing eco-asset value
- To characterize the potential opportunities, contributions, and constraints of relevant areas of biotechnology
- To develop and demonstrate ecotechnologies and related environmental control technologies targeted to meet specific eco-asset management needs

4.4 Market Assessment, Development & Expansion

Markets for eco-asset trading are in their infancy, as is the development of valid commodities for specific types of assets.

[25] Source: National Institute for Resources and Environment, 2002

In 1997, the annual, average non-market economic value[26] of the ecosystem services associated with breathable air, potable water, and waste assimilation alone was estimated at $33 trillion in a Nature article.[27] This estimate, deemed "a minimum" by the article's authors, attracted significant media attention, while the methodology used to derive it has proven highly controversial. Perhaps the most important conclusion to be drawn from this work is that ecosystem service value was estimated to be almost twice that of the global gross national product, which the 1997 article gave as $18 trillion. Thus, even the most conservative estimates of the value of natural capital may not undermine a central tenet of this report: Ecosystem services support all economic productivity, and at levels of enormous consequence to the quality and character of human endeavors.

Even if environmental markets capture only a fraction of the annual non-market value delivered to society by ecosystem services, they offer considerable opportunity. U.S. markets for airborne emissions, commoditized as emissions allowances, derive from "atmospheric gas regulation," "air quality," and related ecosystem services. They provide some indication of the growth potential in environmental commodities. EPA transaction records—a conservative estimate of market activity—indicate that the SO_2 allowance trading market exceeded $4 billion in 2001.[28] As shown in Figure 4-4, trading activity has grown in volume as well as value. Reflecting the market's maturity and liquidity, numerous speculative interests have joined regulated sources as participants, and a dizzying array of transactions has emerged to provide participants with options for hedging risks while pursuing economic and environmental objectives.[29]

[26] Non-market values represent the relative worth of ecosystem services not captured by markets. Marketplace values often derive from non-market values. For example, the eco-tourism industry, offering market-based trekking and educational services, has arisen from non-market values attributable to travelers' enjoyment of nature and the outdoors. These values were previously captured by non-market valuation techniques such as "travel cost" or "factor income" methods that indirectly represented willingness to pay for unique outdoor experiences. Now such willingness to pay can be captured via market-based prices established for eco-tourism goods and services.
[27] Costanza, 1997
[28] Evolution Markets LLC, 2002
[29] Natsource, Inc., 2002

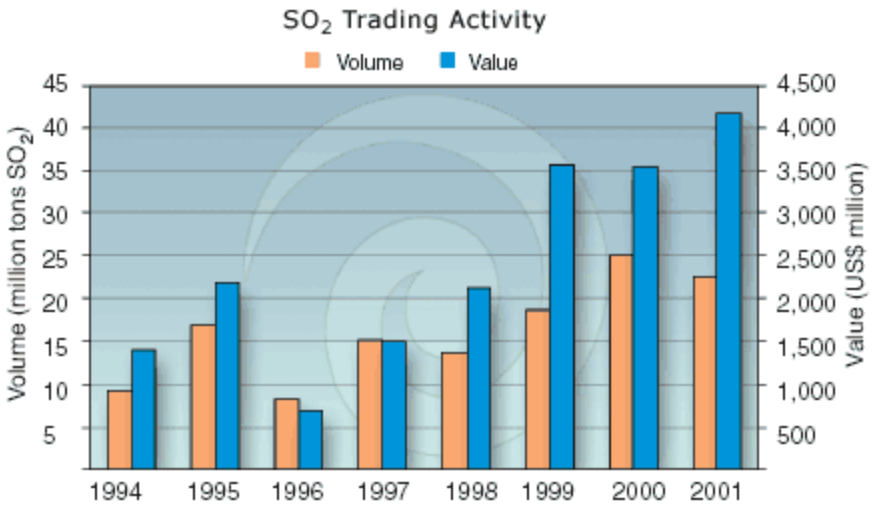

Figure 4-4
Market Expansion—Growing Transaction Volume and Value for the SO_2 Allowance Market[30]

For NO_X emissions, conservative EPA figures indicate that the value of private allowance transfers under the nine-state Ozone Transportation Commission's trading program exceeded $300 million in 2001. The federal NO_X allowance trading market is expected to grow dramatically within the next 2 years as its regional coverage expands. Cities, regions, and states also operate SO_2 and NO_X markets. The "Clear Skies Initiative" proposes new federal trading programs that would establish tighter caps on SO_2 and NO_X emissions and a first-ever national cap on mercury emissions by power plants,[31] possibly fueling additional growth in the U.S. air quality marketplace.

U.S. markets for airborne emissions—though extensive, well publicized, and positioned for substantial expansion—represent only the tip of the iceberg. Eco-asset markets are developing on scales from local to global, spanning all physical media. The list below illustrates the diverse entities for which markets exist, are being planned, or have been proposed under the sponsorship of government agencies:

City, state, and regional markets

- wetlands, streams, riparian zones, and other habitats
- biodiversity: listed species and their habitats
- SO_2, NO_X, and other select airborne emissions
- CO_2 and other greenhouse gas emissions

[30] Source: Evolution Markets LLC, 2002
[31] EPA, 2002c

- multimedia releases into watersheds[32]
- open space, aquifer recharge, carbon sequestration, and flood protection services
- water resource allocations

National **markets**[33]

- SO2 emissions (United States and Slovakia)
- atmospheric mercury emissions (United States)
- CO2 and other greenhouse gas emissions (Denmark, Norway, United Kingdom, etc.)

International

- CO2 and other greenhouse gas emissions (European Union, Atlantic Canada provinces/New England states, etc.)

Global

- CO2 and other greenhouse gas emissions (signatories to the Kyoto Protocol)

Markets for greenhouse gases (especially CO_2) and biodiversity appear to show the most potential. By some estimates, a U.S. carbon market may reach $30 billion annually[34] and the global market many times that total. Biodiversity markets, largely unexplored, could approach these figures, according to one method for estimating eco-asset market values that is based on current known costs of regulatory compliance.[35] This approach reflects experience indicating that during a market's early stages, when competition is low, eco-asset prices are typically value-based and are thus set at or near the avoided cost of traditional compliance requirements. The U.S. federal government has estimated that the ecosystem restoration and management necessary for recovery of endangered species would cost more than $4.6 billion, while another $10.4 billion would be required for consultations with scientists and other stakeholders beforehand. This ~$15 billion estimate appears low because the total estimated cost of protecting the Northern spotted owl alone ranges from $21 billion to $46 billion, depending on the scope of plans implemented by federal agencies in the northwestern United States. If bank-and-trade programs were to arise for the 1500 federally listed and candidate species, overall market value might conservatively range from $15 to $50 billion annually.[36]

[32] The assimilative capacity of individual watersheds is being determined by EPA under its Total Maximum Daily Load (TMDL) regulatory program. The TMDL program, designed to address for the first time nonpoint runoff into watersheds, will likely merge with the 30-year old National Pollutant Discharge Elimination System (NPDES) program for point-source discharges. This may open the door to combined command-and-control/reward-based watershed management systems implemented at the state level.
[33] International Emissions Trading Association, 2002
[34] Moore, 2000
[35] National Center for Policy Analysis (NCPA), 1998
[36] NCPA, 1998; see also Shogren, 1995

Ultimately, the aggregate value of eco-asset markets could total $1 trillion annually. As a benchmark, the total annual value of U.S. real estate, the foundation upon which most eco-asset value rests, is estimated to be $12 trillion.[37]

A number of key considerations must be addressed to accelerate market evolution for all types of eco-assets, as well as to maximize the economic potential of the environmental marketplace. To expand existing markets, a technical foundation and economic case are needed to attract new participants and/or to broaden eco-service regions. Similarly, emerging markets cannot mature unless potential participants have a compelling economic reason for joining the fray.

At present, many commodities produced by market-based regulation are thinly traded and available only from market makers.[38] These markets, which are said to lack liquidity, are characterized by high bid/asked spreads (the difference between the price at which a company can buy or sell a commodity) and difficulties in determining prevailing market conditions. Overcoming these barriers is critical for attracting new participants to fledgling markets. Market creation for certain types of eco-assets may require the design of new types of commodities having both economic and ecological validity.

Studies and demonstration projects focused on existing and emerging markets—such as for ecosystem services associated with wetlands, biodiversity, and carbon—will help define conditions and institutions required for the evolution of open, efficient eco-asset markets. These activities will also help identify lessons learned and support the development of guidance for market creation and expansion.

4.5 Tools & Strategies for Maximizing Eco-Asset Value

Tools and strategies are needed for designing and optimizing ecosystem sustainability and eco-asset management programs to maximize value for diverse stakeholders.

Government agencies, companies, and other stakeholders require new decision aids, resource management approaches, and business strategies for informed, effective design and implementation of eco-asset management frameworks.

Software tools may be used to improve understanding of environmental processes, assess risks, evaluate the impacts of market-based and other management options, weigh tradeoffs, analyze costs and benefits, and build multi-stakeholder consensus around preferred management alternatives. They can also help government agencies and companies integrate eco-asset management with traditional resource management and business processes.

The prototype Strategic Eco-Asset Management (STREAM) framework employs modern finance methods and option value analysis to assess eco-asset-based and traditional land use management options. It may be used to weigh the costs associated with various management options against production schedules reflecting the quantity of eco-assets and traditional assets

[37] Freeman, 2002
[38] EPRI, 2002a

(e.g., timber) that may be provided over time. The framework estimates market values, quantifies uncertainties about future prices, and expresses outputs in terms of the net present value of each option. Additional work is needed to develop a commercial STREAM tool and demonstrate its applicability to the design of resource management and business strategies.

The RAMAS[39] suite of risk assessment tools requires enhancements to support biodiversity risk assessment in support of bank-and-trade programs for habitats and species. Additional commercially available software tools are also potentially applicable, providing insights regarding the management of airsheds, rivers, watersheds, wetlands, soil and groundwater contamination, and brownfields redevelopment. Work is required to demonstrate media-based and application-specific codes for eco-asset management and to integrate them with GIS-based tools already used by government agencies, the scientific community, and other stakeholders. Finally, development of an eco-asset application service provider (ASP) platform is being considered to provide seamless access to multimedia codes and databases.

New resource management strategies are required to integrate eco-asset management with the traditional approaches of government agencies that influence and/or control resource management on both private and federally owned lands. For example, the USDA operates various incentive-based programs in which subsidies are used to encourage environmentally beneficial practices by farming and timber operations on private lands. It may be possible to adjust these programs such that eco-asset markets create the incentives while subsidies are reduced. As another example, consider agencies with substantial property portfolios. These agencies might consider granting concessions to the private sector for the enhancement, restoration, and creation of eco-assets, either alone or in concert with other already approved land uses, such as grazing, recreation, forestry, mining, etc. "Eco-asset developers" could then use, bank, sell, or trade credits to offset resource development and environmental impacts elsewhere, either on public or private lands.

Outreach, education, and demonstration projects provide opportunities for agencies to explore and test innovative strategies. Market-based approaches for accelerating the reclamation of privately owned mined lands are already being pursued through a collaborative project involving EPRI, the U.S. Department of Interior (Office of Surface Mining), and the U.S. Department of Energy (Office of Fossil Energy, National Energy Technology Laboratory).[40]

Business strategies are required to maximize the overall value of corporate assets by integrating eco-asset development and management with conventional land use, property management, facility operations, and environmental compliance plans. These strategies help uncover opportunities to generate collateral eco-asset value while pursuing conventional activities, as well as to develop new, eco-asset-based business lines. They help organizations identify, create, and manage eco-assets that can be sold or traded in the environmental marketplace—or used to reduce costs and enhance compliance by offsetting internal mitigation requirements.

[39] Developed cooperatively by EPRI and Applied Biomathematics, Setauket, NY. Applied Biomathematics subsequently developed a suite of RAMAS products. See http://www.ramas.com/ .
[40] Powicki, 2002

Physical assets that may be particularly suited to eco-asset development and management include the following:

- Industrial facilities
- Active, reclaimed, and abandoned mined lands
- Rights-of-way for fuel pipelines and transmission and distribution corridors
- Surplus or fallow property
- Contaminated or brownfields sites
- Natural or managed forest lands
- Land abutting rivers, lakes, reservoirs, estuaries, etc.

Property size is not a critical determinant for successful eco-asset management: Small properties may harbor high-value eco-assets, such as endangered species habitat. Larger properties may present myriad eco-asset development options; for example, a reclamation plan for mined lands or other disturbed sites could include a mix of wetlands, riparian buffer zones, and forested areas, each holding value in the environmental marketplace (Figure 4-5).

Figure 4-5
Eco-Asset Management Strategies Can Maximize the Overall Value of Property Portfolios[41]

Individual properties may also be managed to maximize returns by *stacking* eco-assets with traditional assets; for example, a holding could be forested to yield carbon sequestration credits and, eventually, marketable timber. In addition, individual properties may provide opportunities to enhance compliance while generating eco-assets; for example, industrial sites bordering streams in watersheds where TMDLs have been implemented could restore vegetation to control surface runoff and sediment loading.

[41] Source: TXU, Inc.

Case study projects involving organizations in the energy, agriculture, timber, mining, and other sectors will help demonstrate the promise of eco-asset management strategies in diverse corporate settings. It will also be useful to analyze the economic and environmental effects of internal schemes for trading carbon credits, such as those adopted by BP and Shell.

4.6 Public Education & Acceptance

Greater public understanding and support are required for market-based approaches to managing eco-assets.

Clear strides in environmental quality improvement have been achieved since the 1960s, when the U.S. government began addressing pronounced public concerns about the impacts of economic development on ecological and public health. As evidenced by many surveys conducted in the United States and abroad, public awareness of environmental challenges and public support for environmental quality improvement remain high.[42] However, even if the public is generally aware of complex challenges such as climate change and worldwide loss of biodiversity, its understanding of both the risks they pose and the promise of market-based solutions is limited.

Beginning with the seminal work[43] of Chauncey Starr, EPRI's founder, it has long been clear that the public does not judge risks in the same way that technical analysts do.[44] There are pressing needs to understand the basis for perception of environmental risks by the public and to develop effective information, tools, and technologies for communicating the risks to society posed by the continued drawdown of ecological capital.

Similarly, proactive outreach and education programs are necessary to improve understanding of the limitations of command-and-control frameworks and to build support for market-based environmental policy. Rapid adoption of eco-asset management frameworks—or even isolated incidences of suboptimal performance—may arouse strong sentiments in an uninformed public, potentially affecting the willingness of government officials and agencies to continue the shift toward market-based policymaking. Similarly, issues that suddenly capture public attention—e.g., widespread concern over large-scale environmental change—may affect government policymaking.

Eco-asset management education and outreach programs need to be carefully planned and implemented. Because the public gets its information from many sources, the full range of stakeholders—including government agencies, nongovernmental organizations, the private sector, the research community, and the media—should be engaged to develop and communicate tailored, credible, objective, clear, and useful information.

[42] Biodiversity Project, 1996; League of Women Voters, 2001; Wirthlin Worldwide, 2000
[43] Starr, 1969
[44] EPRI, 2002b

5 PROPOSED RESEARCH PLANS

Eco-asset management introduces a new perspective to resource management, integrating the use of natural resources with the stewardship of natural capital. Accelerating its widespread adoption requires a robust, coordinated, collaborative program of research, development, application, and communication addressing the many disciplines that influence the resource management philosophies of government officials and agencies, the private sector, and the public.

The critical capability gaps defined for the eco-asset management challenge span social, political, economic, environmental, and other disciplines. A diagram illustrating key issues and milestones in the realms of eco-asset science, policy, and business is shown in Figure 5-1.

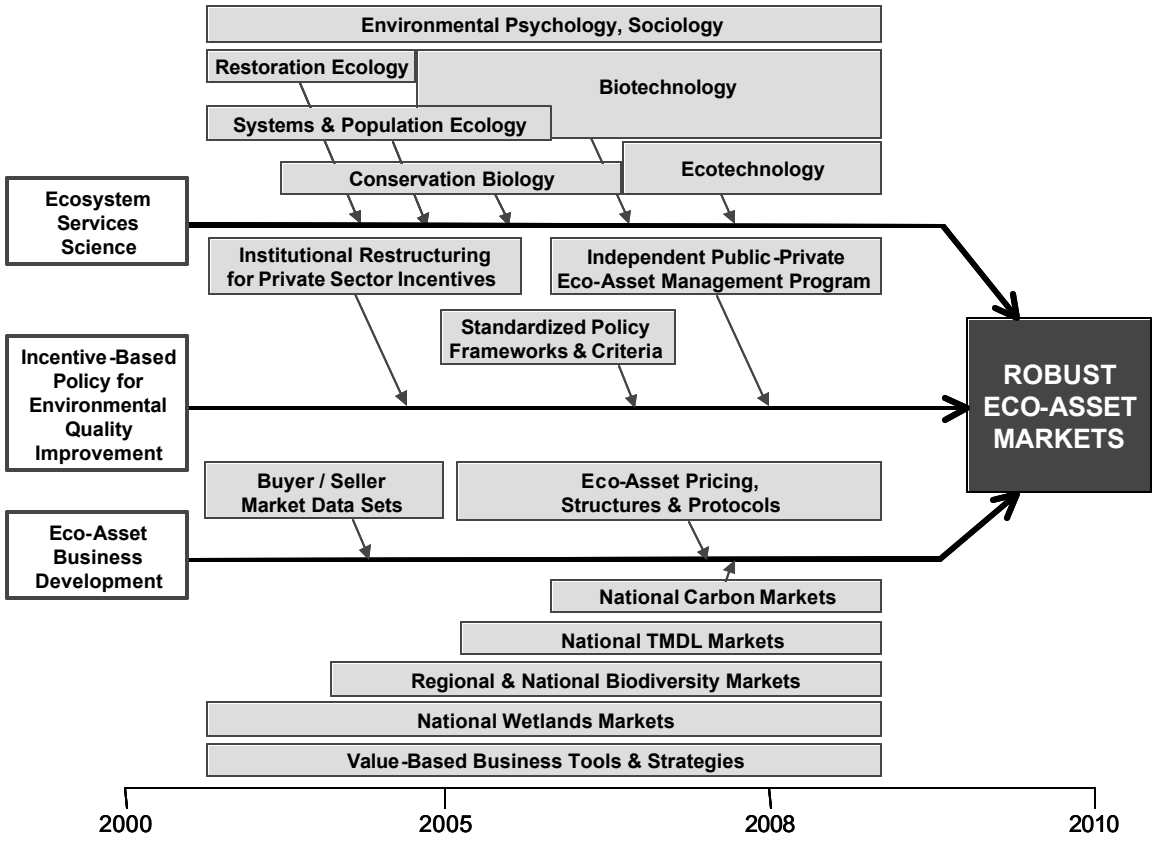

Figure 5-1
Eco-Asset Management Science, Policy, and Business—Issues and Milestones

Any discrepancies between Figure 5-1 and the "fishbone" diagram in the *2003 Roadmap Summary and Synthesis* reflect subsequent changes in how the power industry and the research community perceive the state of ongoing technological development initiatives, market opportunities, and funding efforts. This is to be expected, as both the Limiting Challenges and the Roadmap itself are living documents that will evolve over time and synthesize new data as it becomes available.

As shown in the diagram, science, policy, and business issues are expected to remain active beyond 2008. Additional key points include the following:

- Eco-asset *science* will experience a convergence of ecology, biotechnology, and environmental engineering, especially in areas of bioremediation, genetic ecology, and ecotechnology.
- Contiguous, strategic, incentive-based government *policies* will remain critical to eco-asset market creation and evolution.
- *Markets* will strengthen as buyers develop confidence around the value and liquidity of eco-asset paper. Market solutions will, by design, eventually replace some government subsidy programs.

EPRI's existing science and technology portfolio addresses many issues central to widespread adoption of market-based frameworks for managing the interactions between industry, society, and the environment. Examples include EPRI's climate, air quality, water resource management and protection, land protection and remediation, and environmental control programs, which have served the public and private sectors by informing policy development, improving the scientific basis for agency and corporate decision-making, and enhancing environmental compliance in specific technical areas. These programs—and EPRI work in power market design, market transformation, clean generation, carbon capture and storage, global electrification, and other relevant areas—will provide knowledge, guidance, and tools applicable for encouraging the adoption of eco-asset management across all environmental media and by all business sectors.

However, several individual critical capability gaps and much of the work required to resolve them fall outside EPRI's normal sphere of operation. Accordingly, the gaps presented in Section 4 must be considered preliminary—and any plans to address them similarly tentative. Meetings, workshops, public-private partnerships, outreach and education projects, scoping studies, and demonstrations are perceived as ways to help convey the promise of ecosystem service valuation and eco-asset management to diverse stakeholders. These are also important ways for engaging the research community and other stakeholders in the development of comprehensive, collaborative R&D plans for addressing gaps in knowledge and technological capability.

Given that context, listed below are proposed topics and opportunity areas, funding requirements, and milestones for the critical capability gaps. Each gap is assigned to individual initiatives proposed to address policy, science, business, and crosscutting challenges.

5.1 Policy Challenges

This initiative addresses the *Institutional Restructuring* and *Standardized Policy Frameworks & Criteria* gaps. A funding level of $3–$5 million annually is proposed between 2003 and 2005 for coordinated U.S. and international assessments.

Potential partners include the following: U.S. Department of Commerce; Resources for the Future; the International Society of Business, Economics and Ethics; the International Society for Ecological Economics; the United Nations Environmental Programme; the United Nations Development Program; the Organization for Economic Cooperation and Development; World Resources Institute; Natural Step; the Global Futures Foundation; U.S. Council on Environmental Quality; etc.

5.1.1 Institutional Restructuring

- Assess the Character and Intent of Sustainability Ethics
- Develop the Case for Integrated Economic and Environmental Policymaking
- Develop Concepts and Methods Supporting Transformation of Resource Markets and Expansion of Eco-Asset Markets

5.1.2 Standardized Policy Frameworks & Criteria

- Incentive-Based Policy Instruments—Experience and Application Guidance
- Market-Based Ecosystem Service Enhancements—Opportunities and Obstacles
- Cost-Benefit Analysis of Management Alternatives for Natural Resources and Eco-Assets
- Eco-Asset Market Design
  - Guidance on Eco-Asset Market Conditions and Efficient Market Structures
  - Methods for Integrating Electricity and Eco-Asset Markets

5.2 Science Challenges

This initiative addresses the *Scientific Knowledge & Technological Capability* gap. A funding level of $50 million annually is proposed between 2003 and 2010 for coordinated work by U.S. and international nonprofits, universities, government labs, and other enterprises.

Potential partners include the following: Stanford Center for Conservation Biology; Conservation International; World Wildlife Fund; Defenders of Wildlife; Center for Biodiversity and Conservation Biology (Royal Ontario Museum); International Society for Ecological Economics; Beijer International Institute for Ecological Economics; Ecological Economics, Inc.; Society for Ecological Restoration; Ecological Society of America; International Ecological Engineering Society; American Ecological Engineering Society; Oak Ridge National Lab;

University of Tennessee; Environmental Biotechnology Institute (Cal Polytechnic); British Ecological Society; International Ecotechnology Research Centre; National Institute for Resources and the Environment (Japan); International Union for the Conservation of Nature; etc.

5.2.1 Scientific Knowledge & Technological Capability

- Systems Ecology—Adaptive Context for Eco-Asset Analysis & Management
  - – Understanding the Interdependencies Between Economic and Natural Systems
  - – Studies of the Structures, Processes, and Fluxes of Systems
- Ecological Economics—The True Value (and Costs) of Goods and Services
  - – Concepts, Methods, and Tools for Eco-Asset Valuation
  - – Assessment of Water Allocations and Entitlements
  - – Evaluation of Flood Management and Catchment Planning Benefits vs. Costs
  - – Assessment of Tradable Discharge Permits and Capacity Sharing
  - – Techniques for Measuring Self-Regulating Conditions for the Creation of Sustainable Eco-Economic Systems
- Conservation Biology—Protection and Adaptive Management of Ecosystem Services
  - – Regional Monitoring Techniques for North American Bird and Amphibian Populations
  - – Response of Coastal Ecosystems to Sea Level Rise
  - – Ecological Importance of Riparian PERC
  - – Methods to Estimate Species Richness and Community Dynamics from Species List Data
  - – Effects of Management Activities on Rare Species and Natural Communities
  - – Effects of Patches and Corridors in Managing Native Biodiversity
  - – Development and Application of Remote Sensing Indices for Ecosystem Health and Productivity
  - – Techniques for Monitoring and Assessing the Consequences of Ecosystem Change
- Restoration Ecology—Guidelines, Tools, and Techniques for Ecosystem Services Enhancement, Restoration, and Creation

  - Standard Methods for Measuring and Monitoring Biodiversity
  - Impact of Bottomland Hardwood Restoration on Avian Populations
  - Methods for Change Detection in Patch Dynamics
  - Methods for Recreating Historical Conditions at Extant Ecosystems
  - Methods for Evaluating Restoration and Mitigation Success
- Sociology—Role of Human Behavior in Ecosystem Services PERC
- Biotechnology—Opportunities, Contributions, and Constraints
  - Ecological Biotechnology: Genetics and Applied Ecology
  - Biosequestration of Carbon and Collateral Eco-Asset Development
  - Plant/Microbial Genetics for Ecosystem Services PERC
  - Biomarkers for Ecosystem Performance Monitoring and Measurement
  - Conservation Genetics for Rare Plant and Animal Populations
  - Bioethics, Biosafety, and Emerging Biotechnology Policy
- Ecotechnology—Ecofriendly Design, Engineering, and Construction
  - Ecotechnology Applications for Industrial Cooling and Wastewater Treatment
  - Constructed Wetlands and Passive Treatment for Watershed PERC

5.3 Business Challenges

This initiative addresses the *Market Assessment, Development & Expansion* gap. A funding level of $10-20 million annually is proposed between 2003 and 2007 for coordinated U.S.-led assessments.

Potential partners include the following: International Finance Corporation, Environmental Markets Group; Stanford Energy Forum, Joint Environmental Markets Unit; Environmental Financial Products, Ltd.; World Bank; Emissions Marketing Association; Emissions Trading Education Initiative; International Emissions Trading Association; Environmental Defense; The Nature Conservancy; Conservation Fund; Audubon Society; Resources for the Future; New York and Chicago Mercantile Exchanges; Natsource; Cantor Fitzgerald; Evolution Markets LLC; Environmental Resource Trust; World Resources Institute; MIT Center for Energy & Environmental Policy Research; National Science and Technology Council; National Economic Research Associates; Dow Jones Sustainability Group; etc.

5.3.1 Market Assessment, Development & Expansion

- New Market Dynamics—Concepts, Methods, and Tools for Emerging Markets
- Wetlands Market-Making—Methods and Tools for a National Market
- Biodiversity Market Opportunities—Concepts, Methods, and Tools for Multi-State Habitat and Species Conservation Banks
- Stakeholder Roles in Carbon Markets—Opportunities, Infrastructure Needs, and Outcomes for Domestic vs. International Markets
- Parallel Market Considerations

  – Impacts of Green Certification on Ecological Economics Concepts and Methods

  – Opportunities and Constraints of Eco-Asset Subsidies and Public Assistance Programs

  – The Economics of Gene Conservation

5.4 Crosscutting Challenges

This initiative addresses the *Tools & Strategies for Maximizing Eco-Asset Value* and *Public Education & Acceptance* gaps. A funding level of $3-$5 million annually is proposed between 2003 and 2007 for coordinated U.S.-based activities.

Potential partners include the following: NatureServe; U.S. Geological Survey, Biological Resources Division; Ecological Society of America, Ecological Information Network; Winrock Institute; Environmental Systems Research Institute; Applied Biomathematics, Inc.; University of Idaho GAP Analysis Program; U.S. National Environmental Data Index; Environmental Data Resources, Inc; Resources for the Future; The Nature Conservancy; Environmental Law Institute; Environmental Defense; etc.

5.4.1 Tools & Strategies for Maximizing Eco-Asset Value

Decision Support and Risk Assessment Tools

- Frameworks for Managing Eco-Assets and Conventional Assets (STREAM framework)
- Biodiversity Risk Assessment and Valuation Tools
- Integrated, GIS-Based Management and Application Systems for Eco-Asset Information, Methodologies, and Software

Resource Management Strategies

- Agency Innovations—Demonstrations and Lessons Learned
- Ecosystem Service Improvements for Climate Change Mitigation and Adaptation

- Integrated Watershed-Ecoshed Assessments, TMDL/Wasteload Allocations, and Species Modeling
- Airshed Integrity, Multimedia Air-Ecosystem Assessment, and Intermedia Trading
- Eco-Asset Development for Improving Ecosystem Health and Productivity

Business Strategies

- Corporate Innovations—Demonstrations and Lessons Learned
- Eco-Asset Development at Remediated Sites, Closed Sites, and Brownfields
- Mine Land Reclamation
- Eco-Spatial Solutions for Industrial Corridors and Fragmented Habitats

5.4.2 Public Education & Acceptance

- Risk Perception and Acceptance for Eco-Asset Management—Persuasive Communications
- Public Outreach and Education—Multi-Stakeholder Communications Planning and Facilitation

6 CONNECTIONS TO OTHER LIMITING CHALLENGES

Many of the ethical, institutional, and technical issues that must be addressed to promote widespread implementation of market-based environmental management frameworks are relevant to the resolution of other limiting challenges defined by the *Electricity Technology Roadmap*. Primary points of interaction with other limiting challenges are characterized below, with secondary interfaces also briefly mentioned.

6.1 Improved Scientific Understanding and Advanced Methods for Effectively Communicating and Applying Scientific Knowledge

Complex, distributed environmental problems tax the decision-making capabilities of both policymakers and the public. This creates needs for (1) multidisciplinary research to expand scientific understanding of the interactions between human society and aquatic, terrestrial, and atmospheric environments; and (2) the development of strategies, methods, and tools to present results in ways that communicate explicit links to the larger social, political, and economic context. Contributions to public discourse and government decision-making should help align environmental policy with eco-asset management science, economics, and technology realities.

Progress in addressing the eco-asset management challenge is contingent upon efforts to enhance the scientific basis—specifically, the economic basis—for environmental management and protection. In turn, the success of the U.S. SO2 allowance trading program and the emergence of other effective market-based instruments provide opportunities to inform government agencies, the public, and additional stakeholders on the value of economically efficient environmental policy.

6.2 Accelerating Development of Carbon Capture and Storage Technology

Policy proposals are being considered at international, national, regional, and local levels to mitigate the possible effects on climate of rising atmospheric concentrations of CO2 and other greenhouse gases. Internationally, the focus is on the Kyoto Accord, whose status as of October 2002 is illustrated in Figure 6-1. However, the Accord and its derivative agreements will represent only a first step toward stabilization of greenhouse gas concentrations.[45] A robust portfolio of economical, safe technologies for the capture and long-term storage of carbon is necessary to meet growing global demands for reliable, inexpensive electricity while addressing apparent climate change.

[45] Moore, 2000

While development of carbon capture and storage technology proceeds, emissions trading and other market-based mechanisms included in the Kyoto agreements—but modified to ensure worldwide participation—represent the most promising tools for cost-effective mitigation of greenhouse emissions. Accordingly, progress in market-based policy and regulation seems critical. By assigning economic values to emissions of CO2 and other greenhouse gases, such progress will also help determine the cost-performance potential and influence the deployment of carbon capture and storage approaches. Ultimately, the use of additional market-based instruments, such as carbon taxes, may prove most effective for decarbonizing the global energy supply mix.

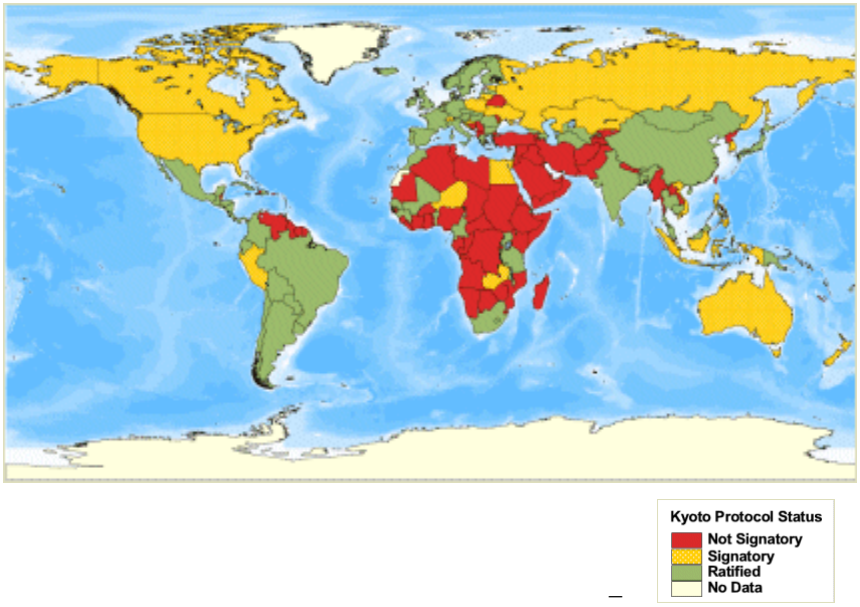

Figure 6-1
Kyoto Protocol Status[46]

6.3 Maintaining and Improving Water Availability and Quality

Water has come to be thought of as the primary limiting resource for global sustainability. In many societies, water quantity and quality strongly influence infant mortality, life expectancy, economic productivity, and other critical quality-of-life indicators. As the global population grows, water's importance can only expand, making all nations increasingly vulnerable to both quantity constraints and quality problems. This creates an urgent need for water management strategies, tools, and technologies to balance economic productivity with environmental realities and social goals.

Market-based solutions have proven effective for efficient allocation of water resources among competing uses, but their use is limited by the complications involved in developing and implementing pricing schemes that accurately reflect water's value and scarcity. Incentive-based strategies are increasingly being applied to improve water quality. For example, EPA's

[46] Source: WRI, 2002

wasteload allocation program, under which TMDLs are planned for 40,000 watersheds nationwide, focuses on controlling nonpoint source pollution—a category that has plagued regulators since the inception of the Clean Water Act in 1972. Progress in eco-asset management will expand the applicability of market-based solutions for equitable, cost-optimized water resource enhancement.

6.4 Transforming Electricity Markets

As electricity industries are restructured to suit modern business realities, dramatic institutional changes are occurring without a firm understanding of the interdependences between economic incentives, dispatch demands, infrastructure requirements, technology advances, and market behavior. Market designs that are based on greater understanding of critical technical and economic issues, sound theoretical principles, and lessons learned from previous restructuring experiences are more likely to produce consistent, complete, and efficient power markets. Data, knowledge, tools, and technologies are required to optimize market design and accelerate the evolution of fully competitive markets.

There is growing recognition that electricity markets should be designed to include incentive mechanisms encouraging infrastructure investment, risk management, operating, compliance, and other decisions that explicitly account for the interrelationships between energy and the environment. Recent experiences in California underline the already strong connections between electricity markets and environmental markets: Weather-related shortages of hydroelectric power led to increased reliance on units fired by natural gas, which in turn led to a shortage of NO_X emissions allowances. During peak periods, allowances traded at prices many times normal levels, producing substantial increases in the market clearing price for electricity.[47] Accounting for the interconnections between eco-asset and electricity markets will help ensure more effective market design and operation.

6.5 Maintaining and Strengthening the Portfolio of Generation Options/Universal Global Electrification

As worldwide population grows in the 21st century, substantial institutional efforts and financial resources will be required to supply sufficient electricity for enhancing quality of life in the developed world and raising living standards for billions of impoverished people. A robust energy supply portfolio is needed in order for both developed and developing countries to meet global challenges, such as climate change, while addressing diverse regional and local factors, such as indigenous fuel resources and economic, environmental, and political conditions.

Environmental policy and regulation already play an important role in shaping the economics of power generation. Market-based frameworks that account for ecosystem service values will influence the kinds of generation facilities that are operated, how these facilities are dispatched, and the character of their "footprint" on the natural world. They will influence the lifetime of existing facilities, technology selection for capacity expansion, and siting of new facilities, as

[47] EPRI, 2003

well as the demand for and the penetration of diverse generation options throughout the world. This includes distributed renewables, clean coal, hydrogen, and other technologies for achieving universal global electrification in sustainable ways.

For example, market-based frameworks could create incentives for tying investments in generating capacity with investments in eco-assets within an eco-service region. Construction permitting/relicensing for generating facilities could be expedited if applications include plans for ecosystem PERC sufficient to offset emissions and other impacts within the region. Development of a sliding scale of impacts versus eco-asset offset requirements might even be used to create incentives that accelerate deployment of certain types of generation.

6.6 Secondary Interfaces

Interactions between eco-asset management and additional limiting challenges are briefly characterized below.

6.6.1 Development of Electricity-Based Transportation Systems

Market-based policies for environmental quality improvement will affect demand for electricity-based transportation systems and could even be devised to accelerate their penetration. For example, California has established a program for rewarding efforts to reduce greenhouse gas emissions from automobiles. The new policy—the first of its kind in the United States—authorizes the California Air Resources Board to introduce regulations providing for the "maximum feasible reduction of greenhouse gases" by passenger cars and trucks by 2005. To the extent that market forces can help satisfy this new requirement, eco-assets will become an important part of the state's transportation enterprise.

6.6.2 Advances in Enabling Technology Platforms

Two enabling technology platforms, recyclability and biotechnology, are of particular relevance to eco-asset management. As shown in Figure 6-2, environmental biotechnology is already projected to see growing use for waste treatment—possibly in applications harboring opportunity for collateral eco-asset development. Similarly, efforts to address the eco-asset management challenge may influence demand for and penetration of recyclable materials and products, industrial ecologies, ecotechnologies, etc.

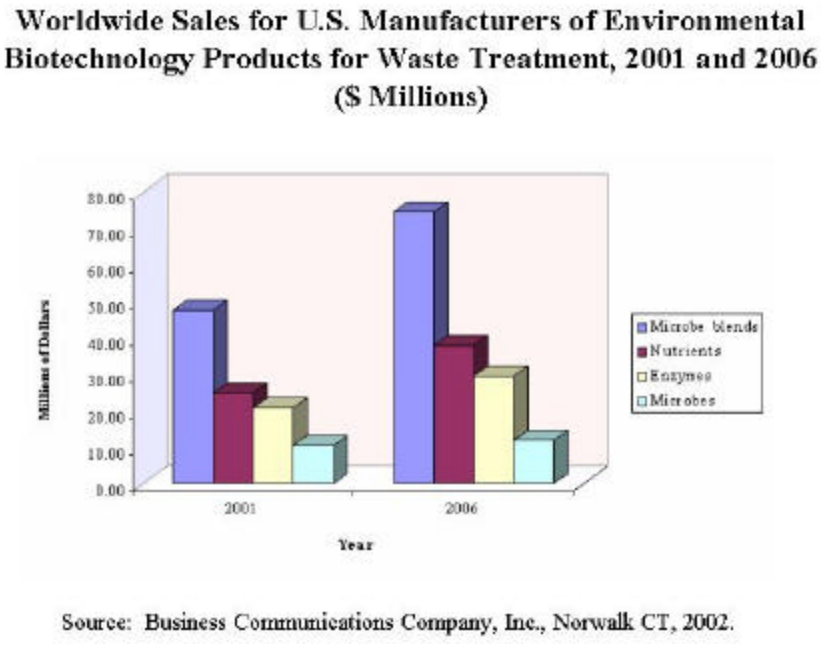

Figure 6-2
Environmental Biotechnology—Waste Treatment *and* Collateral Eco-Asset Development?

6.6.3 High-Efficiency End Uses of Energy

Efforts to address the eco-asset management challenge will affect demand for and penetration of energy- and resource-efficient technologies, particularly industrial ecology. Market-based policies for environmental quality improvement could even be devised to transform specific markets in favor of high-efficiency technologies.

6.6.4 Exploiting the Strategic Value of Bulk Storage Technologies

Resolving the energy storage challenge will influence prospects for environmental dispatch to be used as an eco-asset management strategy.

7 STAKEHOLDERS AND ROLES

Eco-asset management's impact will be determined by the myriad stakeholders that must first contribute to the emergence, acceptance, and operation of market-based frameworks. Four general stakeholder categories are characterized as follows.

Government and the *public* it serves will play the most important roles. As keeper of the public trust, government officials and agencies will be responsible for restructuring fiscal, environmental, and other policies and creating market-based frameworks to protect the public interest in the health and integrity of ecosystems and in the eco-assets they provide. The people, through both individuals and organizations, will communicate their ethics and interests and trust they are well served. The *private sector*, operating within a restructured social, political, and regulatory landscape, will fuel the marketplace with innovation and investment, realizing measurable value while helping markets work their magic to PERC natural capital. The *research community*, with financial support from all stakeholders, will guide and accelerate progress in eco-asset management, delivering the scientific knowledge, tools, and technology required to inform decisions at individual through global levels.

The four general stakeholder categories are further subdivided below. For some individual stakeholders, detailed information is provided on potential roles and opportunities.

7.1 Government

Continued dialogue among representatives from the private sector, the scientific community, and government branches, departments, agencies, and offices is needed to encourage the development of a sound technical foundation for consistent, broad-based eco-asset management guidelines.

EPRI is continuing to meet with key federal agencies to communicate how eco-asset management can protect and enhance natural resources in cost-efficient ways and to discuss eco-asset management within the context of their responsibilities and/or the resources under their purview. These interactions are useful for identifying policies and programs amenable to market-based solutions and for highlighting key issues, concerns, and needs. These meetings also help EPRI, individual agencies, and other stakeholders identify specific opportunities for public-private R&D partnerships, outreach and education projects, and demonstrations.

7.1.1 U.S. Federal Executive Officers and Executive Office of the President

The overall tone for U.S. government policy—both domestic and international—is set by the White House. Prospects for widespread penetration of eco-asset management are strongly

influenced by an administration's level of interest in and support for market-based environmental policy and related issues.

Key stakeholders include the President and Vice President, Executive Staff, the Cabinet, and executive offices such as the Council on Environmental Quality, Office of Science and Technology Policy, Office of Management and Budget, Council of Economic Advisers, and Office of Policy Development. The current administration has advocated market-based solutions to environmental challenges such as air pollution and climate change. An interagency, multi-industry meeting convened by the Council on Environmental Quality could represent an effective mechanism for accelerating the shift to market-based environmental management.

7.1.2 U.S. Federal Cabinet-Level Departments

Cabinet-level departments direct programs, sponsor research, and establish policies, criteria, and guidelines that influence and/or control resource management on both private and federally owned lands. Key departments and associated issues and opportunities are discussed below.

Department of Agriculture (USDA)

Through the National Rural Conservation Service (NRCS) and U.S. Forest Service (USFS), the USDA operates a number of incentive-based programs that encourage environmentally beneficial activities by farming and timber management operations on private lands. These programs are generally subsidized under the Farm Security and Rural Investment Act. Examples include the Wetlands Reserve Program (WRP), Conservation Reserve Program, Environmental Quality Improvement Program, Wildlife Habitat Incentives Program, and the Forestry Incentives Program. On every acre enrolled in the WRP, for example, the NRCS provides technical and financial support to improve wetland functions and optimize wetland habitat (Figure 7-1).

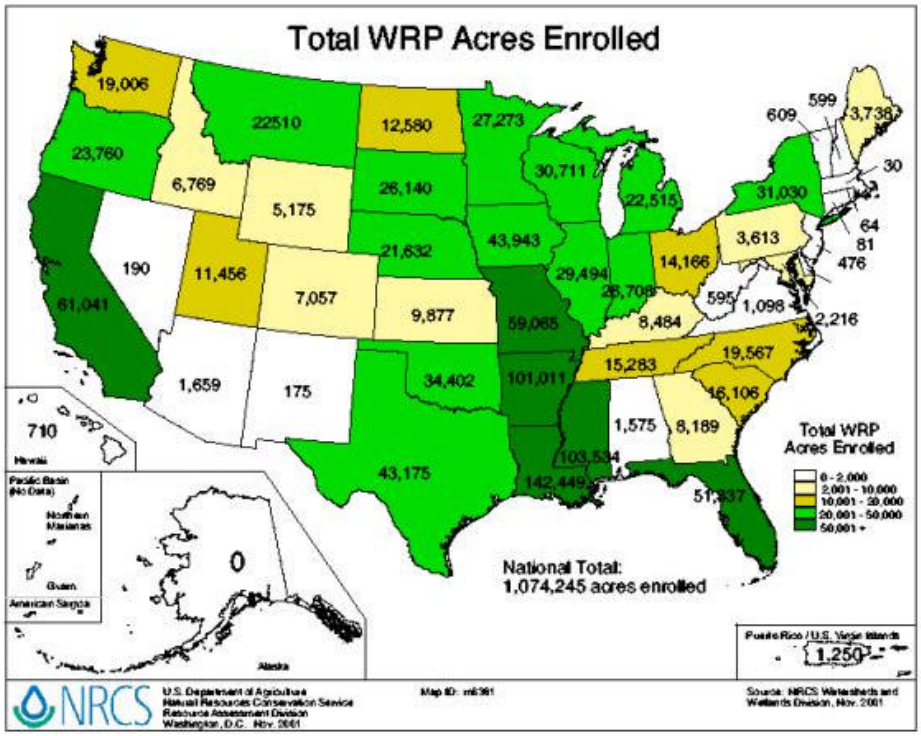

Figure 7-1
The Wetlands Reserve Program (WRP) Builds Eco-Asset Value Not Yet Being Captured in the Environmental Marketplace

These NRCS and USFS programs create measurable non-market eco-asset value on private lands, i.e., this value has not been captured by the marketplace. There may also be ways of generating and building market-based eco-asset value on private lands through informed planning and management of crop, livestock, and timber operations. EPRI has begun a dialogue with senior USDA officials to explore how non-market programs and market-based initiatives can complement one another while preventing "double-dipping," i.e., situations where a private landowner applies government subsidies to create eco-asset value (such as enhanced wetland functions) and then leverages a market-based framework to monetize this value (such as in the form of wetland credits under a mitigation banking program).

The national forests and grasslands managed by USFS also harbor opportunities for eco-asset creation. USFS commonly enters into lease and fee agreements for timber, grazing, mining, recreation, and myriad other uses on these public lands. Similarly, it may be possible for the USFS to grant concessions for the enhancement, restoration, and creation of eco-assets, either alone or in concert with other land uses. "Eco-asset developers" could then use, bank, sell, or trade credits to offset resource development and environmental impacts elsewhere, either on public or private lands.

Integrating consistent, comprehensive, market-based approaches for eco-asset management within USDA policy and regulatory frameworks is expected to increase environmentally beneficial activities, reduce government subsidies, and create new sources of revenue for agricultural, timber, and other operations on both public and private lands.

Department of Commerce

The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries) focuses on rebuilding and maintaining sustainable fisheries, promoting the recovery of protected species, and protecting and maintaining the health of coastal marine environments. Market-based mechanisms, such as tradable fishing permits and allocation quotas, are seeing increasing use in fisheries management. Eco-asset management solutions may prove effective in meeting the regulatory goals and objectives of NOAA Fisheries for protected species.

For example, in the Pacific Northwest, debate continues as to the best ways of implementing fish and wildlife protection in areas typified by competing interests and unclear regulatory responsibilities. Agency-sponsored markets for salmon, spotted owl, marbled murrelet, and other listed species could drive land and water management solutions aimed at restoring ecosystem services both inland and in marine environments, benefiting the region overall in terms of environmental quality and economic productivity. EPRI has initiated dialogue with technical staff in the Office of Habitat Conservation.

Department of the Interior (DOI)

As the nation's principal conservation agency, DOI is responsible for managing, protecting, restoring, and preserving land, water, energy, mining, ecological, and other resources. Policies at the executive level and within individual bureaus will shape the success of eco-asset management frameworks in optimizing use of natural resources.

The U.S. Fish and Wildlife Service (FWS) administers the Endangered Species Act (ESA), under which bank-and-trade programs for several listed species have been launched. Species banks may be created to (1) satisfy mitigation demand under the ESA or (2) to secure certified species credits under FWS "Safe Harbor" guidelines. EPRI has initiated dialogue with FWS staff regarding the creation of new species banks under existing bank-and-trade programs; opportunities to create new species banks have been identified in New York (Long Island), Ohio, South Carolina, Indiana, and California.

The U.S. Geological Survey's Biological Resource Division (BRD) assists others in their efforts to inventory, monitor, and evaluate the character and quality of the nation's ecosystems and to implement strategies for improving ecosystem function. Working closely with governmental organizations and nonprofit groups such as the Ecological Society of America, Society of Restoration Ecology, and the Missouri Botanical Garden, BRD seeks to quantify ecosystem health and integrity and provide DOI resource management bureaus, other federal agencies, state agencies, and additional stakeholders with the scientific information and technology necessary

for sound ecosystem management and conservation. Because its recommendations and findings often set the direction for federal ecological research and natural resource management programs, BRD's technical teams—both nationally and in targeted U.S. regions—may have important influence on the development of eco-asset management frameworks.

The Office of Surface Mining (OSM) is responsible for protecting environmental and public health during coal mining, as well as for ensuring post-mining reclamation and restoration. Collaborative work by OSM, other agencies, and EPRI has focused on reclamation of coal mining sites, but results are expected to be applicable to restoration of surface mining operations for copper or nickel. In 2002, OSM sponsored a conference on incentives for AML reclamation. A cooperatively developed manual providing guidance on market-based reclamation is being published. Efforts are now under way to develop collaborative demonstration projects in states such as Pennsylvania and West Virginia and to promote market-based reclamation by U.S. mining companies.

The Bureau of Indian Affairs is charged with managing, protecting, and improving more than 50 million acres of land held in trust by the U.S. government for Native American tribes and individuals. There is a natural affinity between eco-asset management and Native American cultural norms, especially those dedicated to harmony with natural environments and sustainable, low-impact ecosystem management. Tribes may have opportunities to develop market-based eco-asset value on reservation lands for internal mitigation or external marketing, as well as to lease "mining rights" to private sector clients interested in eco-asset development. BIA could provide tribes with development grants (or equivalent) for support of demonstration projects testing the viability of eco-asset management on reservation properties.

The Bureau of Land Management manages about 262 million acres of federally owned land, overseeing a wide range of both resources and uses. The Bureau of Reclamation (BOR) manages more than 8.6 million acres of federally owned land associated with its water storage, water supply, and hydroelectric power facilities and operations. Like other federal agencies with large property portfolios, it may be possible for BLM and BOR to grant concessions for the enhancement, restoration, and creation of eco-assets, either alone or in concert with other uses such as grazing (Figure 7-2). "Eco-asset developers" could then bank, sell, or trade credits to offset resource development and environmental impacts elsewhere, either on public or private lands.

Figure 7-2
Eco-Asset Development Concessions—A New Revenue Source for Federally Managed Lands?[48]

Department of Energy (DOE)

Extensive historical collaboration among DOE, EPRI, energy companies, and other stakeholders provides a foundation for partnerships focused on development of market-based solutions for environmental challenges facing the energy industry.

The National Energy Technology Laboratory (NETL) and Office of Fossil Energy have collaborated with EPRI and OSM to characterize the benefits of market-based AML reclamation through the development of carbon sequestration, water quality and supply, species banking, or related eco-asset values. As noted previously, funding is being pursued for public-private demonstration projects for market-based AML reclamation.

Market-based solutions for water quality enhancement are already being demonstrated in a collaborative project in West Virginia involving EPRI, Allegheny Power, and NETL. Investments in watershed improvements that reduce nonpoint source pollution are being used to earn wasteload allocations under EPA's TMDL program. Once certified, such allocations will provide a cost-effective alternative to the installation of expensive technology-based controls, helping improve water quality while offsetting discharges from power plants or other facilities within the watershed. In cooperation with other energy companies, EPRI plans additional public-private projects to demonstrate use of eco-asset management strategies to enhance compliance by energy and other facilities in diverse U.S. eco-regions.

The Federal Energy Regulatory Commission (FERC) oversees several key areas for eco-asset management, notably the licensing of hydroelectric generating facilities and the regulation of interstate markets for electricity and natural gas. FERC's Office of Energy Projects manages the

[48] Source: TXU, Inc.

hydro licensing program to protect the public interest, balancing facility operations with consideration for fish and wildlife, recreational uses, and other water resource management concerns. Licensing applications may include the dedication of hydro project lands and water resources to the public interest, including preservation and enhancement of ecosystem services. As market-based policies gain traction, it is likely that FERC will approve ecosystem service enhancements that provide the public with non-market eco-asset value and the licensee with market-based eco-asset value.

Department of Defense (DOD)

Like other federal agencies with large property portfolios, it may be possible for DOD to grant concessions on certain properties to "eco-asset developers" who could then bank, sell, or trade credits to offset resource development and environmental impacts elsewhere, either on public or private lands.

The U.S. Army Corps of Engineers already plays a critical role in the development of wetland mitigation banks under CWA S. 404. The Corps is likely to have opportunities to address broader ecosystem service needs during the planning and implementation of its own projects, as well as to encourage additional ecosystem service enhancements by third parties who must mitigate for wetlands impacts under CWA S. 404.

Department of State

The Bureau of Oceans and International Environmental and Scientific Affairs helps formulate U.S. government positions and leads negotiations with foreign governments and international organizations in a number of areas where eco-asset management may play an important role, including climate change, sustainable development, transboundary pollutants, biodiversity, endangered species, etc.

7.1.3 U.S. Federal Independent Agencies

Independent agencies have been established to address both domestic and international concerns. A couple key agencies with significant influence on eco-asset management are identified below.

Environmental Protection Agency (EPA)

EPA manages a complex set of regulations under multiple statutes driven by the National Environmental Policy Act. Over the past decade, EPA has been gradually working to supplement command-and-control regulations with incentive-based guidelines designed to achieve new levels of politically acceptable environmental quality improvement. EPA-managed or -approved incentive programs now exist in all environmental media, as well as for biodiversity. EPRI has been actively engaged with EPA in developing a knowledge foundation to support scientifically sound, ecologically relevant, and economically efficient alternatives to technology-based environmental controls.

Federal Emergency Management Agency (FEMA)

FEMA oversees taxpayer-funded recovery programs associated with natural disasters and other national emergencies. Storm-caused flooding represents an increasingly large liability that FEMA has been attempting to minimize through a variety of means, including incentive-based relocation programs for residents living on high-risk floodplains. Development of multimedia eco-asset management solutions for floodplain protection may reduce taxpayer burdens while at the same time restoring or enhancing the productivity of wetlands and river systems.

U.S. Agency for International Development (USAID)

USAID works to advance U.S. foreign policy while helping other countries address economic challenges and quality-of-life considerations. USAID's field offices and its partnerships with domestic and international agencies, organizations, and corporations offer opportunities to promote the benefits of market-based environmental policymaking in developing nations.

7.1.4 U.S. Federal Legislative Branch

The Senate and House of Representatives make the laws that are interpreted and enforced by federal and other government agencies. Accordingly, individual Senators and Representatives, Congressional Committees with influence over resource management policies, and agencies such as the Congressional Budget Office and General Accounting Office represent important stakeholders in advancing eco-asset management.

7.1.5 U.S. State, Regional, and Local Governments and Agencies

In many instances, policy innovation at lower levels of government provides the impetus for action at the federal level. Government officials and agencies at the state, regional, and local levels may establish or enforce policy frameworks, regulatory criteria, and related guidelines that promote market-based management and use of natural resources. For example, wetland mitigation banks exist at the county level, trading programs for wasteload allocations are managed at the watershed level, and greenhouse gas mitigation programs are under way at the city and state levels.

As is the case for federal officials and agencies, interaction and outreach are necessary to improve understanding and acceptance of market-based management frameworks, to promote their implementation in appropriate situations, and to publicize success stories. Key stakeholders include state, regional, and local agencies and officials involved in the management of water (water supply, wastewater treatment, flood control, etc.), transportation, energy, air, agriculture, wildlife, fisheries, and other resources. These stakeholders may also represent partners in and funding sources for R&D and demonstration projects.

7.1.6 Non-U.S. Governments and Agencies

Government officials and agencies in other countries are increasingly turning to market-based environmental policy frameworks, building on U.S. experiences, and extending the approach in new directions. For example, many countries are planning or beginning to implement national trading programs for greenhouse gas emissions. These programs are being designed for compatibility with those having larger geographic scope, including the cap-and-trade systems proposed by the European Commission and developed under the Kyoto Protocol.

Interaction and outreach are necessary to assess international experiences with carbon trading and other market-based approaches and to improve worldwide understanding and acceptance of eco-asset management. Non-U.S. governments and agencies may also represent partners in and funding sources for R&D and demonstration projects.

7.1.7 Bilateral, Multilateral, and International Institutions

Because complex challenges such as climate change, water resource management, biodiversity loss, and fisheries management know no borders, international cooperation is essential to their resolution. Bilateral, multilateral, and international institutions already involved in addressing environmental and resource management problems may provide effective mechanisms for cooperative action to expand eco-asset management.

Examples include the United Nations Environment Programme, Conference on Trade and Development, and Commission on Sustainable Development; the World Bank; the International Joint Commission; the International Boundary and Water Commission; and the North American Commission for Environmental Cooperation.

7.2 Public Interest Groups

As noted previously, increasing public understanding and acceptance are critical to the widespread adoption of market-based environmental management frameworks. As entities that endeavor to serve the public interest, both nongovernmental organizations (NGOs) and the media can play important roles in informing the public and fostering support for eco-asset management.

Some NGOs enthusiastically advocate market-based environmental management approaches, others support their use under limited circumstances, and still others view them as harmful. NGOs can be very effective in capturing public attention, forging partnerships and alliances, and spurring action by both government and the private sector.[49] Similarly, the media can influence public opinion and catalyze collective action.

Engaging NGOs in collaborative outreach, education, and R&D will enhance both the scientific basis for eco-asset management and its communication to the public through the media. Potential partners include Environmental Defense, Environmental Law Institute, The Nature Conservancy, Audubon, and others.

[49] Brown, 2001

7.3 The Private Sector

Eco-asset management offers enormous opportunity to many major sectors of the global economy. Within each of these sectors, there is a need to engage individual companies, as well as industry professional associations, in outreach, education, and demonstration projects to build their appreciation of and participation in the environmental marketplace.

Key sectors include the following:

- ***Energy*:** Many U.S. energy companies already participate in SO_2 and NO_X emission allowance markets, and they may be affected by market-based frameworks for multimedia emissions and water resource allocations. Energy companies worldwide are planning for market-based climate policy. In addition, as large landowners, energy companies have opportunities for eco-asset development through ecosystem PERC. Working in partnership with EPRI and other stakeholders, several companies have identified, quantified, and realized substantial market-based eco-asset value. In addition to generating shareholder value, these activities may begin to attract investment from the growing number of ecologically minded investors.
- ***Agriculture*:** As large landowners, agricultural enterprises may have opportunities for eco-asset development through ecosystem PERC; non-market eco-asset value is already being generated under various USDA programs. Agricultural companies may also be subject to market-based policies for controlling nonpoint source pollution and allocating water resources. Public-private partnerships that involve state and federal agencies, agribusinesses, and other stakeholders may be used to demonstrate the potential benefits of market-based eco-asset development and management to the agricultural sector.
- ***Timber*:** Companies in the timber industry are expected to become increasingly active players in carbon markets. In addition to their carbon sequestration potential, the landholdings of timber companies also harbor opportunities to develop other eco-assets. For example, International Paper, the largest private landowner in the United States, operates a mitigation banking program for the red-cockaded woodpecker (Figure 7-3) on forest properties in the southeastern United States. This pioneering program demonstrates that forests can be managed for both ecological values, such as endangered species habitat, and economic values, such as timber production.[50]

[50] International Paper, 2002

Figure 7-3
Mitigation Banking for the Red-Cockaded Woodpecker—An Example of Eco-Asset Management Potential for Large Landowners[51]

- ***Mining***: Like other land-intensive sectors, the mining industry has opportunities to develop eco-assets on its property base. EPRI, OSM, NETL, and the Office of Fossil Energy are collaborating to promote market-based reclamation of abandoned coal mining sites; the experience, tools, and techniques developed in this work are expected to be applicable to other sectors of the mining industry.
- ***Finance***: Brokerage services, banks, venture capital funds, institutional investors, and other participants in the financial sector are beginning to see significant business and investment opportunities in the environmental marketplace. The growing number of entities focused on this marketplace is expected to attract new entrants—both existing and new companies.

7.4 The Research Community

Government, public interest groups, and the private sector combine to support the international research community, which must deliver the scientific knowledge, tools, and technology required to guide and accelerate progress in eco-asset management. As noted previously, relevant work is under way in numerous disciplines, but much of it is not focused on specific eco-asset management challenges and opportunities. Concerted effort is necessary to synthesize existing knowledge, define key gaps, and develop public-private R&D partnerships that leverage resources while focusing on critical technical areas.

Key stakeholder categories include the *U.S. federal and state agency research offices*; *U.S. federal research agencies* such as the *National Science Foundation* and the *national laboratories*; *non-U.S. government research agencies*; *universities; foundations; think tanks;*

[51] Source: Carolina Biological Supply Company, 2002

industry research organizations; *corporate research departments*; and the *research offices of bilateral, multilateral, and international institutions* and *NGOs*.

The *Millennium Ecosystem Assessment* (MA) merits special mention.[52] The MA, initiated in April 2001 and modeled after the Intergovernmental Panel on Climate Change, is engaging worldwide experts in the natural and social sciences in a collaborative 4-year process designed to synthesize existing research focused on the ability of global ecosystems to sustain biodiversity and produce the goods and services essential to human welfare. It involves integrated assessments of the productivity of the Earth's natural and managed ecosystems over diverse temporal and geographic scales. These assessments are designed to produce the peer-reviewed scientific information required by policymakers and other stakeholders to balance tradeoffs and manage natural capital in ways that maximize resource productivity.

[52] Source: Millennium Ecosystem Assessment, 2002

8 RECOMMENDED ACTIONS

The most daunting barriers to the widespread adoption of eco-asset management principles are not technical in nature. Society must willingly reconsider modern values, reshape government institutions, and restructure economic systems to properly account for the essential goods and services provided by functional ecosystems.

According to the *2003 Roadmap Summary and Synthesis,* building the foundation for robust eco-asset markets will require about $50 million/year over the next 10 years. Table 8-1 shows nearer-term funding needs for bridging the critical capability gaps discussed in this report. These estimates, however, are not intended to be exhaustive; additional investment beyond the figures named in the table below will almost certainly be needed.

Table 8-1
Critical Capability Gaps and Estimated Funding Requirements

Critical Capability Gap	Realm	Estimated Funding Requirements
Institutional Restructuring Institutions do not consistently or comprehensively account for the value of ecological services. **Standardized Policy Frameworks & Criteria** Government policies (legal frameworks, regulatory criteria, and related guidelines) need to be standardized and harmonized at all levels of government to enable development of public-private partnerships and design of efficient markets.	Policy	$3-$5 million annually, 2004–2005
Scientific Knowledge & Technological Capability The knowledge and technology base must be expanded to support optimal design and implementation of eco-asset management programs.	Science	$50 million annually, 2004–2010
Market Assessment, Development & Expansion Markets for eco-asset trading are in their infancy, as is the development of valid commodities for specific types of assets.	Business	$10-$20 million annually, 2004–2007

Critical Capability Gap	Realm	Estimated Funding Requirements
Tools & Strategies for Maximizing Eco-Asset Value Tools and strategies are needed for designing and optimizing ecosystem sustainability and eco-asset management programs to maximize value for diverse stakeholders. **Public Education & Acceptance** Greater public understanding and support are required for market-based approaches to managing eco-assets.	Crosscutting	$3-$5 million annually, 2004–2007

It is important to note that much of the recommended work in the policy, science, and business realms is already under way or planned, but it is not designed specifically to enable the widespread adoption of eco-asset management principles and practices. Moreover, a growing number of stakeholder groups are separately advocating increased use of market-based solutions for environmental quality improvement. Recommended below are several near-term actions to engage the full range of stakeholder groups in exploring the opportunities associated with eco-asset management and in catalyzing comprehensive, collaborative efforts to realize them.

8.1 Near-Term Actions

1. Sponsor high-level meetings to focus agency, industry, and public attention on the importance of eco-assets and on the promise of market-based environmental policymaking.

   A series of high-profile events, perhaps convened by the White House Council on Environmental Quality, could represent a particularly effective mechanism for introducing the principles of eco-asset management to a broad audience. Such meetings would also send strong signals to elected officials and federal agencies. In the near term, these signals could accelerate the shift to market-based environmental policymaking; over the longer term, they could seed efforts to restructure economic, political, and social institutions in ways that account for the value of eco-assets.

2. Convene working groups/task forces that bring together representatives from the policy, science, and business realms to exchange perspectives and brainstorm collaborative approaches for addressing the barriers pacing adoption of eco-asset management policies and practices.

   A "Market-Based Environmental Policy" group, for example, would include high-level officials from government agencies and other stakeholders with influence on resource management and fiscal and environmental policymaking. It could explore the use of eco-asset management within the context of the responsibilities of individual agencies and/or the resources under their purview. This group could also identify policies and programs amenable to market-based solutions while highlighting the key issues, concerns, and needs of both agency officials and regulated industries, leading to public-private R&D partnerships in specific areas.

Similarly, an "Eco-Asset Management Science & Technology" group would bring together leading researchers and practitioners from myriad technical disciplines. It could synthesize existing knowledge, identify relevant ongoing work directed by diverse stakeholders, define the state of the art in key areas, and highlight key gaps in the worldwide R&D portfolio. This group could also identify potential funding sources for collaborative, highly leveraged work in critical technical areas.

Finally, an "Eco-Asset Business Strategy" group would include high-level officials responsible for natural resource management, asset management, environmental compliance, investor relations, community relations, corporate strategy, risk management, etc., for companies in the energy, agriculture, mining, timber, real estate, land management, and other sectors. It could promote knowledge exchange between industries, as well as collaborative R&D, outreach, education, and advocacy in areas of common interest.

3. Initiate focused, collaborative demonstration programs in eco-asset management "enterprise zones."

   Eco-asset management demonstration programs can promote learning and experience within government and industry, as well as inform the public regarding the benefits of market-based environmental management.

   For example, EPRI, DOI (OSM), and DOE (Office of Fossil Energy, NETL) are cosponsoring a program to accelerate reclamation of mined lands by demonstrating that market-based solutions yield multiple economic, environmental, and social benefits. Guidance and tools are being developed to help site owners and other investors discover and exploit opportunities to extract financial value via eco-asset PERC. In complementary work, EPRI's STREAM framework is being applied to evaluate alternative management and reclamation strategies for two mining sites owned by TXU Corp. This innovative tool has been used to assess various post-mining land-use options, including conventional options such as pastureland as well as eco-asset development opportunities such as creation of wetland mitigation and carbon sequestration credits. This comprehensive approach is helping TXU develop integrated resource management strategies that maximize the economic and environmental value derived from its mined land portfolio.

   In addition to mined land reclamation, *enterprise zones* for advancing eco-asset management science, technology, and practice through demonstration projects include the following:

   - Eco-asset development at remediated sites and brownfields,
   - Use of constructed wetlands and other passive treatment methods as ecotechnologies for watershed PERC,
   - Biosequestration for carbon storage and collateral eco-asset development,
   - Aquatic ecotechnology for industrial cooling and wastewater treatment applications, and
   - Eco-spatial solutions for expanding the ecological value of industrial corridors (such as rights-of-way for electricity, fuel, water, and other infrastructure) and other developed areas and for mitigating habitat fragmentation.

8.2 Anticipated Outcomes

For companies in the energy, agriculture, mining, timber, real estate, land management, and other resource-based sectors, eco-asset management offers significant opportunities to increase revenues, enhance compliance, eliminate liabilities, and manage risks. Improving environmental quality, protecting public health, and demonstrating corporate citizenship represent additional—and substantial—ancillary benefits. For the public sector and the citizens it serves, market-based environmental management approaches promise solutions for achieving goals more efficiently and at lower cost, as well as for addressing complex challenges such as climate change, water shortages, and biodiversity loss.

Realizing these benefits will require extensive collaboration among, and concerted action by, the full range of stakeholders—elected officials, government agencies, the private sector, nongovernmental organizations, the research community, the public, etc. The action items listed above are expected to help bring the promise of eco-asset management into clearer focus. This will enable the development of comprehensive R&D plans focused on addressing the critical gaps in knowledge and technological capability required to account for and maximize the societal value provided by both local and global ecosystems.

Unleashing market forces on nature's behalf will impose efficiencies that temper and ultimately reverse the drawdown of natural capital. Driven by scientific knowledge and technological innovation, economies will grow within their means by banking on nature's fortune—and by making investments for future generations to appreciate.

9 REFERENCES

Asian Ecotechnology Network(AEN), 2002. "AEN Action Plan and Programme Priorities." United Nations Educational, Scientific and Cultural Organization (UNESCO)—Man and Biosphere, Cousteau Ecotechnie Programme. At www.unesco.org/mab/capacity/ucep/aen-plam.htm.

Ayley, Catherine, 1996. *Molecular Systematics and Conservation Genetics*. Centre for Biodiversity and Conservation Biology, Royal Ontario Museum, Ontario Canada.

Bailey, Robert G., 1995. *Description of the Ecoregions of the United States (2nd edition)*. Misc. Pub. No. 1391, Map scale 1:7,500,000. USDA Forest Service. 108 pp. At http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html.

Beijer International Institute of Ecological Economics, 2002. *Research*. The Royal Swedish Academy of Sciences, Stockholm, January. At www.beijer.kva.se/research/research.html.

Biodiversity Project, 1996. "Current Trends in Public Opinion and the Environment." Prepared by Belden & Russonello Research and Communications. At http://www.biodiversityproject.org/resourcespublicopiniontrends.pdf

Brown, Lester, 2001. *Eco-Economy: Building an Economy for the Earth.* W.W. Norton & Company: New York

Carolina Biological Supply Company, 2002. "Wildlife of the Alligator River: Red Cockaded Woodpecker." At http://www.carolina.com/redwolf/animals/birds/woodpecker.asp.

Center for Applied Biodiversity Science, 2000. "Conservation Research, Conservation Economics, Reptile and Amphibian Conservation." Conservation International, Washington D.C. At www.biodiversityscience.org/xp/CABS/research/biology/bioloby.xml.

Center for Conservation Biology, 2002. "Themes on Ecosystem Services and Biodiversity Conservation." At www.stanford.edu/group/CCB/themes.htm.

Clewell, Andre, John Reiger, and John Munro, 2000. "Guidelines for Developing and Managing Ecological Restoration Projects." Society for Ecological Economics, June. At http://ser.org/reading.php?pg=guidelines.

Costanza, R., *et al*., 1997. "The Value of the World's Ecosystem Services and Natural Capital." *Nature*, 387, 253-260.

Dailey, Gretchen, and Ellison, Katherine, 2002. *The New Economy of Nature: The Quest to Make Conservation Profitable*. Island Press: Washington.

Environmental Law Institute, 2001. "Preliminary Findings of The Environmental Law Institute's Wetland Mitigation Banking Study." At http://www.eli.org/.

Environmental Law Institute, 2002. *Banks and Fees: The Status of Off-Site Wetland Mitigation in the United States*. Summary results available at http://www.eli.org/.

EPRI, 1999. *Electricity Technology Roadmap: Powering Progress—1999 Summary and Synthesis*. Palo Alto, CA. CI-112677-V1.

EPRI, 2002a. *Interim Report on Methods for Systematic Evaluation of Emission Reduction Options: Managing Risks from Climate Policies.* Palo Alto, CA. 1005247.

EPRI, 2002b. *Human Performance Management and Optimization: Strategic R&D Directions for Human-Centered Technologies, Tools, and Methods*. Palo Alto, CA. 1004665.

EPRI, 2003. *Transforming Electricity Markets: Limiting Challenge Report*. At http://www.epri.com/.

Evolution Markets LLC, 2002. "The Evolution of the Environmental Markets." At http://www.evomarkets.com/assets/articles/evoenvima.html.

Farber, Stephen and Dennis Bradley, 2002. "Ecological Economics." University of Pittsburgh, Pittsburgh PA and USDA Forest Service, North Central Forest Experiment Station, St. Paul MN. At www.fs.fed.us/eco/s21pre.htm.

Freeman, Richard, 2002. "Fannie and Freddie Were Lenders: U.S. Real Estate Bubble Nears Its End." *Executive Intelligence Review*, June 22.

Gill, Roderick, 1995. "Workshop Report: Research Priorities in Environmental Management." Sponsored by the Land and Water Research and Development Corporation, in conjunction with the inaugural Australia and New Zealand Society for Ecological Economics (ANZSEE) Ecological Economics Conference, Coffs Harbor NSW, Australia, November 19-23.

Gill, Roderick, and Wolfenden, John, 2002. "Projects." Centre for Ecological Economics and Water Policy Research, University of New England, Armidale, NSW, Australia.

Green, Carol, and Richards, Louise, 1998. "A Guide to Restoration Ecology." University of Washington, July. At www.washington.edu/machung/restoration.html.

Hardin, Garrett, 1968. "The Tragedy of the Commons," *Science*, 162, 1243-1248.

Hargrove, W.H. and R.J. Luxmoore, 1997. "A Spatial Clustering Technique for Identification of Customizable Ecoregions." GIS and Spatial Technology Group, Oak Ridge National Laboratory, Oak Ridge, TN. At http://research.esd.ornl.gov/~hnw/esri/.

International Ecotechnology Research Centre, 2002. At www.cranfield.ac.uk/sims/ecotech.

International Emissions Trading Association, 2002. At http://www.ieta.org/.

International Paper, 2002. "Sustainable Forestry Initiative: Enhancing Wildlife Habitat." At http://www.internationalpaper.com/our_world/sfi_brochure/enhance.html.

Jackson, L., 1995. "Commentary on Ecological Restoration: A Definition and Comments." *Restoration Ecology*, 9/28.

League of Women Voters, 2001. "American Voters Place a High Priority on Environmental Protections, Despite Concerns About Energy and the Economy." Prepared by Greenberg-Quinlan Research, Inc., and the Tarrance Group. At http://www.voteenvironment.org/pdf/EnergyPoll.pdf.

Leopold, Aldo, 1948. *Sand County Almanac, And Sketches Here and There*.

Millennium Ecosystem Assessment, 2002. At http://www.millenniumassessment.org/.

Moore, Taylor, 2000. "The Value of Greenhouse Gas Emissions Trading." *EPRI Journal*, Summer issue, pp. 17-25.

National Center for Policy Analysis, 1998. "The Endangered Species Act: First Step toward Fixing a Costly Failure." Brief Analysis No. 276. At http://www.ncpa.org/ba/ba276.html.

National Institute for Resources and Environment (NIRE), 2002. "The Basic Concept of Ecotechnology." Tsukuba, Ibaraki, Japan. At www.aist.go.jp/NIRE/eco_tec_e/yakuwari_e.htm.

Natsource, Inc., 2002. "Types of SO_2 Transactions." At http://natsource.com/markets/index.asp?s=30.

Olson, David M., *et al*. "Terrestrial Ecoregions of the World: A New Map of Life on Earth." *BioScience,* 933, November, Vol. 51, No. 11.

Omernik, J.M., 1987. "Aquatic ecoregions of the conterminous United States." At http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/ecoregions.htm.

Patuxent Wildlife Research Center, 2002. "List of Active Research/Science Projects with Links to Project Descriptions." U.S. Department of Interior, U.S. Geological Service, Laurel, MD. At www.pwrc.nbs.gov/research/sis2002/sislist.htm.

Powicki, Christopher R., 1998. "The Value of Ecological Resources." *EPRI Journal*, July/August, pp. 8-17.

Powicki, Christopher R., 2001. "Market-Based Reclamation Strategies for Mined Lands." *EPRI Journal online*. At http://www.epri.com/journal/details.asp?id=316&doctype=features.

Powicki, Christopher R., 2002. "Eco-Solutions Plays Key Role in Landmark Conservation Deal." *EPRI Journal online*. At http://www.epri.com/journal/details.asp?id=306&doctype=features.

Resources for the Future, 2002. "Does the Clean Air Act Measure Up?" *Resources*, Issue 147, pp. 2-3.

Shogren, Jason F., 1995. "Economics and the Endangered Species Act." President's Council of Economic Advisors, Washington D.C. At http://www.crowley-offroad.com/economics_and_the_esa.htm.

Smith, Adam, 1937. *The Wealth of Nations*. Modern Library: New York.

Starr, Chauncey, 1969. "Social benefit versus technological risk." *Science,* 165, 1232-1238.

U.S. Agency for International Development, 2002. At http://www.usaid.gov/.

U.S. Army Corps of Engineers, 1995. "Wetland Mitigation Banking: Entering a New Era?" *Wetlands Research Program Bulletin*, Vol. 5, No. 3/4. At http://www.wes.army.mil/el/wrtc/wrp/bulletins/v5n3/brum.html.

U.S. Department of Agriculture, 2002. At http://www.usda.gov/.

U.S. Department of Commerce, 2002. At http://www.doc.gov/

U.S. Department of Defense, 2002. At http://www.dod.gov/

U.S. Department of Energy, 2002. At http://www.doe.gov/

U.S. Department of Interior, 2002. At http://www.doi.gov/

U.S. Department of State, 2002. At http://www.state.gov/

U.S. Environmental Protection Agency, 2002a. "Mississippi River Basin: Gulf of Mexico." At http://www.epa.gov/msbasin/images/hypoxia-map.gif

U.S. Environmental Protection Agency, 2002b. *The EPA Acid Rain Program 2001 Progress Report*. At http://www.epa.gov/airmarkets/cmprpt/arp01/index.html.

U.S. Environmental Protection Agency, 2002c. "Clear Skies Legislation Introduced in Congress Proposal Will Improve Air Quality, Prevent Premature Deaths, Illnesses." At http://www.epa.gov/clearskies.

Washington State Department of Transportation, 2002. "Wetland Mitigation Banking Program: Teitzel Wetland Mitigation Bank Site." At http://www.wsdot.wa.gov/eesc/environmental/programs/biology/bio_teitzel.htm.

Wilson, Edward O., 2002. *The Future of Life*. Alfred A. Knopf: New York.

Wirthlin Worldwide, 2000. "Current Trends in Public Opinion: Environmental Update." *The Wirthlin Report*, Vol. 10, No. 8. At http://209.204.197.52/publicns/Twr1100.pdf.

World Resources Institute, 2002. "Earth Trends: The Environmental Information Portal." At http://earthtrends.wri.org/index.cfm.

Zoological Institute, University of Bern, 2002. "Key topics in ecological research: Behavioral Ecology, Community Ecology, Conservation Biology, Evolutionary Ecology, Population Ecology." At www.zoology.unibe.ch/nat/index_e.htm.