

TECHNOLOGY FOR A SUSTAINABLE FUTURE: A FRAMEWORK FOR ACTION

PHOTOCOPY
PRESERVATION

THE WHITE HOUSE
OFFICE OF DOMESTIC POLICY

CAROL H. RASCO
Assistant to the President for Domestic Policy

To: Brian

Draft response for POTUS
and forward to CHR by: _____

Draft response for CHR by: _____

Please reply directly to the writer
(copy to CHR) by: _____

Please advise by: _____

Let's discuss: _____

For your information: _____

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Designee to attend: _____

Remarks: _____

Advice by E-Mail
by 10am. Wed.
please

MAY 23 1994

THE WHITE HOUSE
WASHINGTON

May 20, 1994

Dear Carol - we hope this effort will be not only interesting but also helpful in knitting a more coherent strategy. Any comments?

J. Gale

Memorandum for Carol Rasco

From: JHG John H. Gibbons, Assistant to the President for Science and Technology

Subject: Approval to Publish NSTC Report on Environmental Technology

As you know, promoting the development and diffusion of environmental technologies is a high Clinton Administration priority. The attached document, *Technology for a Sustainable Future: A Framework for Action*, examines ways to improve federal programs and forge public-private partnerships to advance these important technologies. The report was prepared over the past nine months by an ad hoc working group of the National Science and Technology Council. I am seeking your concurrence to prepare this draft for publication and release.

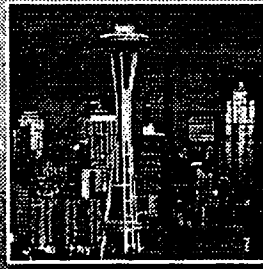
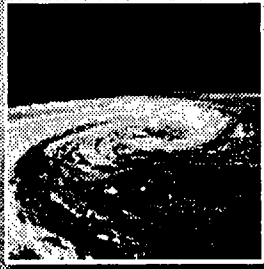
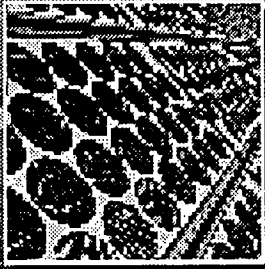
Publication of *Technology for a Sustainable Future* is an important step in a process that will result in an integrated federal environmental technology strategy. It highlights and builds on the initiatives already underway throughout the federal government. Following the release of this report in mid- to late June, a series of workshops will be held throughout the nation to discuss and expand on the ideas presented in it. The workshops will include individuals from industry, academia, nongovernmental organizations, and state and federal government. As requested by the Vice President, a White House conference will be held in the Fall at which we plan to make announcements regarding public-private partnerships and other initiatives. Following the conference, an environmental technology strategy document will be developed.

We are currently developing plans to release the document as part of a White House event. If Hill action on pending environmental technology legislation proceeds quickly, we may be able to release the document in conjunction with a Presidential bill-signing ceremony. We will keep your staff informed as our plans develop. Please treat this as a close hold draft, and do not photocopy or distribute it.

If you have any questions regarding the document or its upcoming release, please contact me (456-7116), or Mark Schaefer (456-6202) or Mike Nelson (456-6039) of my office.

Please let me know no later than 3:00 PM on Wednesday, May 25, if you approve of the release of this report. If you wish to fax a response, it should be sent to 456-6021.

TECHNOLOGY FOR A SUSTAINABLE FUTURE



A Framework for Action

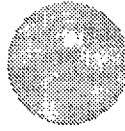
Inside Front Cover

TECHNOLOGY FOR A SUSTAINABLE FUTURE

A Framework for Action

The National Science and Technology Council is actively seeking suggestions for improving federal policies related to advancing environmental technologies. We encourage you to send your ideas to this address:

Environmental Technology Strategy Staff
Office of Science and Technology Policy
Room 443, Old Executive Office Building
Washington, DC 20500



Today we are asking the National Science and Technology Council to initiate a public-private sector dialogue that will culminate in the development of an Environmental Technology Strategy to be released on Earth Day 1995. We envision a strategy that will clearly articulate the role of all sectors of our society in developing and diffusing the environmental technologies that will set us on the path to sustainable development.

Over the coming year, the U.S. government will also seek the views of other nations on ways that we can work together to advance policies that will help us achieve our common goals of global economic prosperity and mutually beneficial environmental protection.

A White House Conference on Environmental Technologies will be convened in the fall of 1994. At that time, we will seek to reach consensus on the key elements of the Environmental Technology Strategy and identify some of the actions that will be necessary to implement that strategy. In some cases, policy changes within the existing statutory framework will be sufficient. In others, however, changes in laws may be required. We will explore new ways, for example, to encourage the development of prevention technologies and the adoption of the low-waste, no-waste tenets of industrial ecology. We will forge stronger public-private partnerships to help shorten the time needed to go from research to diffusion of environmental technologies. Finally, we will endeavor to do everything possible to encourage the use of environmentally sound and socially appropriate technologies throughout the world.

The citizens of all nations have much to gain by forward-looking, clearly articulated policies to guide the development of environmental technologies. These technologies are critical to responding to the environmental challenges we face today and could allow us to avoid similar or worse problems in the future.

We invite you to work with us during the coming months to develop a credible, economically sound Environmental Technology Strategy that will benefit the citizens of the United States and our neighbors throughout the world.

For consideration for signature by President and/or Vice President

Technology for a Sustainable Future

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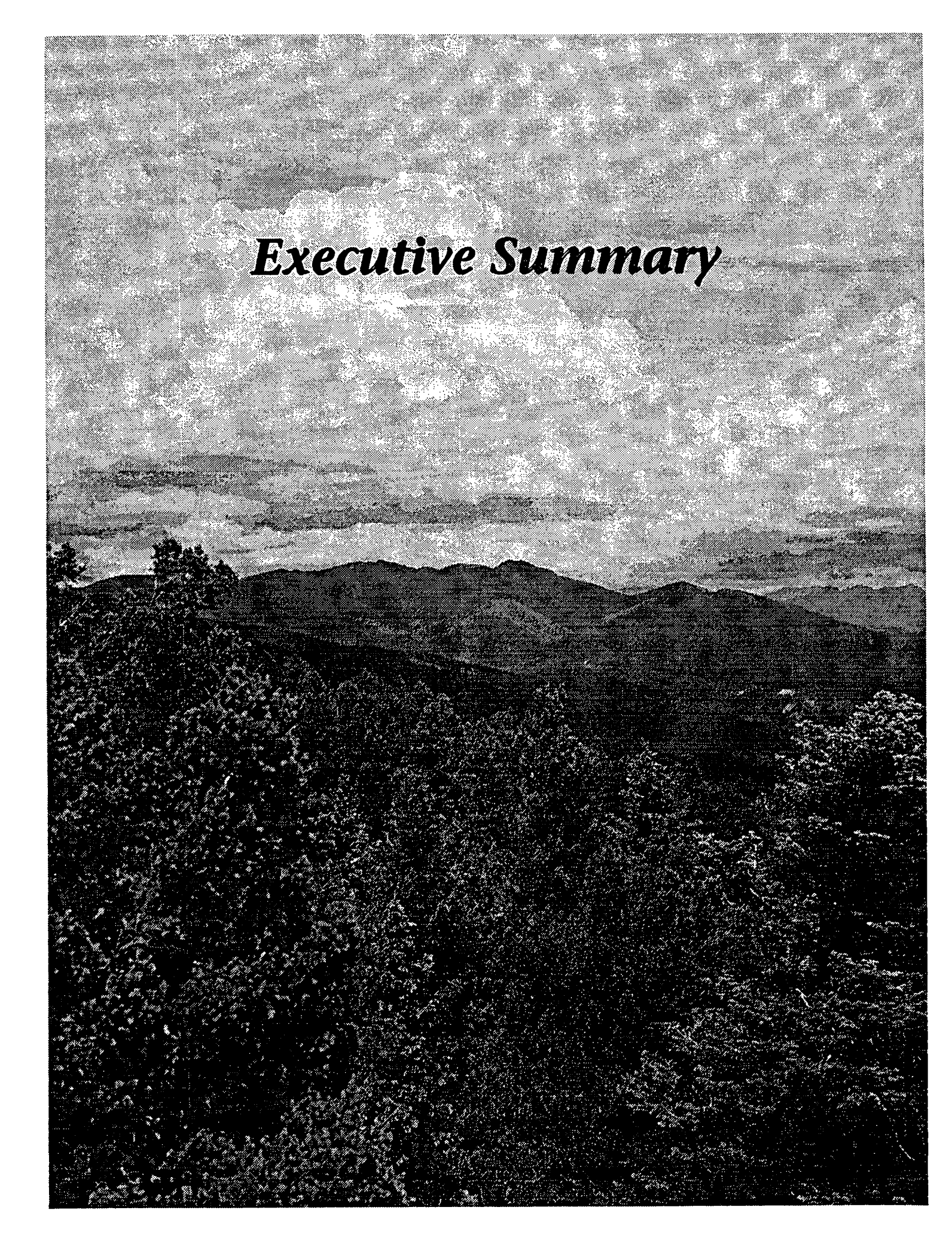
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Executive Summary

LOOKING TO THE FUTURE



Environmental technologies are the bridge to a sustainable future, a bridge that, if well engineered, will facilitate the achievement of our long-term environmental, energy, and economic goals. As the engine of economic growth, technology has been responsible for as much of two-thirds of the increase in our nation's productivity since the Depression. Today, environmental technology offers a win-win opportunity for our nation and the world as a whole: economic growth through the development and diffusion of environmental technology will result in more jobs, and a clean environment will mean a higher standard of living for ourselves and the generations that follow.

We are now at a critical point in environmental and economic policy making, and the decisions we make today can dramatically alter the world of tomorrow. A carefully crafted, for-

Our vision is of long-term economic growth that creates jobs while improving and sustaining the environment. Reconciling these goals requires an environmental technology strategy that helps industry shift from waste management to pollution prevention, efficient resource use, and industrial ecology. A forward-looking approach will help companies become more competitive by lowering their energy and resource needs while reducing or eliminating their waste cleanup and disposal costs. Nationally, it will create economic growth by capturing the rapidly growing market for clean technologies and shifting money from consumption of resources to investment in new plants and equipment. Globally, it will help developing countries leap frog directly into sustainable technologies in many industrial and service sectors.

Being the world leader in clean technologies and processes will make our companies more competitive, increase our exports, and help us lead the world toward sustainable development. Developing and successfully implementing an environmental technology strategy is a key step toward achieving these goals.

Our vision is of an integrated system of social, economic, and environmental values that reinforce each other. *Technology for a Sustainable Future* is intended to catalyze a dialogue on the federal government's role in facilitating innovation and stimulating a shift from incrementalism to technological transformation, from managing waste to sustaining and restoring ecosystems, from reacting to environmental and public health threats to anticipating and preventing them.

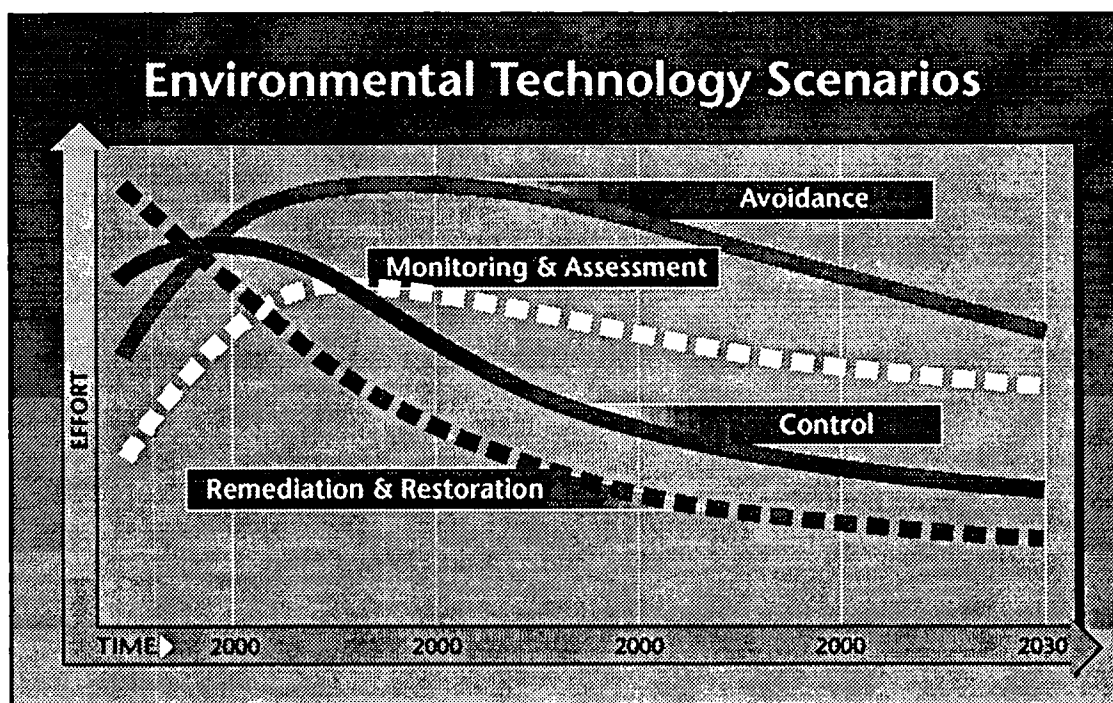


ward-looking environmental technology strategy, along with a strong societal commitment to environmental protection, will allow us to move deliberately toward sustainable development.

This document is intended to lay the groundwork for a dialogue with Congress, state governments, industry, nongovernmental organizations, academia, and interested members of the public to forge a public-private partnership to advance the development and diffusion of environmental technologies. The key to an effective partnership is clearly defining the proper role of each sector of our society in advancing environmental technologies and assuring that federal policies enable each component to interact and contribute effectively. In short, this document is intended to be a starting point for a national dialogue that will result in a clearly articulated strategy to foster the technologies that will help society achieve sustainable development.

"Technology is a powerful tool for making government more efficient and responsive, harmonizing our economic growth and environmental objectives, and making more efficient use of our energy resources."

—President Bill Clinton



Expenditures on environmental technologies will change as we move into the future. The best way to explore these changes is by taking an imaginary trip to the year 2040. During the early part of the new century, investments in remediation will have cleaned up a large proportion of existing hazardous waste sites. Intensified expenditures in technologies to avoid environmental harm will have paid off significantly. Manufacturing processes will be more efficient in the use of resources, consumer products will be designed with the environment in mind, and the infrastructures that supply energy, transportation services, water, and food will be more resource efficient and environmentally benign. By 2040 most industries will be approaching a zero-discharge goal, but some control technologies may still be required to deal with residual discharges into the environment. Investments in large macroscale monitoring systems and new microsensors will permit continual assessment of the state of the environment at multiple scales. At some future date, we will have moved from an environmental paradigm based on cleanup and control to one based on anticipation, avoidance, and assessment.

Initiating a Dialogue

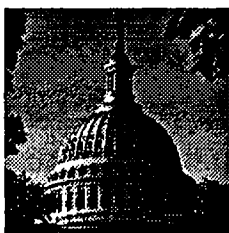
The path from research and development to commercialization and diffusion of a technology is complex and challenging. Traveling the length of what some call the “technology pipeline” may take years or decades, and along the way a variety of engineering, financial, and legal obstacles must be negotiated. In the months ahead, we will examine carefully each section of the pipeline. We will then identify and evaluate the federal policies that influence the process of developing and diffusing environmental technologies, pinpoint the ways that those policies either facilitate or impede private sector efforts to advance these technologies, and then work to reshape federal policies to remove the obstacles and allow innovation to move forward as rapidly as possible.

The main body of this document focuses on four major dimensions of the development and diffusion of technology. Each is further subdivided, resulting in a multidimensional analysis of the life cycle of environmental technologies:



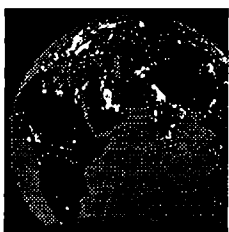
FACILITATING INNOVATION: *Research and Development, Demonstration*

At each of the initial stages of the technological life cycle—research, development, and demonstration—as well as during the later commercialization and diffusion phases, the federal government will facilitate the shift from control technologies and waste management to avoidance approaches and resource conservation.



ENCOURAGING NEW APPROACHES: *Regulatory Policy, Market Stimulation, Fiscal Policy*

Through a variety of innovative regulatory and fiscal policies, the federal government will stimulate the development of environmental technologies and work to expand their diffusion.



ENGAGING THE WORLD: *International Commerce, Foreign Aid and Development Assistance*

By implementing policies that promote export of U.S. environmental technologies and by providing development assistance, the federal government will help increase our nation's share of a dramatically expanding global market.



LEARNING AND WORKING TOGETHER: *Partnerships and Collaboration, Education and Training, Information Dissemination*

In the past, regulatory policies have shaped the markets for environmental technologies. In the future, regulatory policies will continue to drive the development of these technologies, but our policies will be strengthened by public-private partnerships, education that fosters environmental consciousness and ensures an adequately prepared workforce, and improved dissemination of information on clean technologies.

These major dimensions and subsections offer a framework for evaluating federal policies and programs. In each subsection, a set of broad strategic directions to guide federal policies and programs is proposed. We then discuss some of the initiatives already underway that are consistent with these directions. Finally, a number of ideas are offered as potential next steps, which are intended to help stimulate debate on ways to improve current federal policies and programs. These ideas are for discussion purposes only and do not represent policy initiatives.

Fundamental Principles

The strategic directions that are proposed to guide the development of an environmental technology strategy are derived from the following over-arching principles. An environmental technology strategy should:

- *Assure that the federal regulatory and policy-making apparatus is directed toward facilitating the development of prevention and monitoring technologies critical to achieving sustainable development over the long term and balanced with control and remediation technologies needed in the near term.*
- *Increase the resource efficiencies of our technological infrastructure by adopting a systems approach that employs the tenets of industrial ecology.*
- *Forge public-private and federal-state partnerships directed to advancing the development, commercialization, and diffusion of environmental technologies.*
- *Shorten the cycle time from research and development to commercialization and export of environmental technologies.*
- *Promote the use of environmentally sound and socially appropriate technologies in developing nations throughout the world.*

The dialogue during the months ahead will help us refine these principles and the resulting strategic directions, modify and expand the list of next steps, and build a consensus around the best ideas for improving federal policies and procedures.

Developing a Strategy

To facilitate a dialogue over the coming months, we plan to hold a series of workshops throughout the nation. These discussions will culminate in a White House Conference on Environmental Technologies, which will be held in the fall of 1994. In the months following the conference, the strategy will be written under the guidance of the National Science and Technology Council, an interagency cabinet-level council representing federal departments and agencies with major research and development responsibilities.

The environmental technology strategy will define policy and programmatic initiatives that can be taken within the existing statutory framework and identify initiatives that will require legislative action.

Technology and Environmental Protection

Technologies can have profound impacts on the environment, both positive and negative. For example, technology helped bring about the Green Revolution, which resulted in increased agricultural productivity in the developing world. But at the same time poorly designed irrigation systems led to soil degradation in some areas. In the decades ahead, technology will be called upon to feed

"The scientific and technological revolution has almost completely changed the physical realities of our relationship to the earth. With a dizzying array of new tools, technologies, and processes, we have extended our senses and magnified our ability to work our will on the world around us."

—Vice President Albert Gore, Jr.

a growing world population. The challenge is to use technology in such a way that it does not lead simply to short-term advances in productivity at the expense of long-term resource viability. The purpose of this document is to encourage the development of technologies that are environmen-

tally beneficial and benign, recognizing at the same time that it is not technology alone that will lead to a sustainable future. Ultimately, progressive environmental and economic policies, as well as human behavior, will determine whether the world achieves sustainable development.

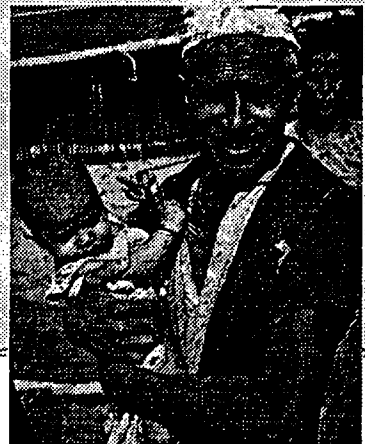
Sustainable Development

The most commonly used definition of the term "sustainable development" is one that originated with the 1987 report, *Our Common Future*, by the World Commission on Environment and Development (commonly known as the Brundtland Commission). By that formulation, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Since the release of the Brundtland Commission report, the phrase has been broadened and modified. The term "sustainable" has gained usage because of increasing concern over exploitation of natural resources and economic development at the expense of environmental quality. Although disagreement exists as to the precise meaning of the term beyond respect for the quality of life of future generations, most definitions refer to the viability of natural resources and ecosystems over time, and to maintenance of human living standards and economic growth. The popularity of the term stems from the melding of the dual objectives of environmental protection and economic growth. A sustainable agricultural system, for example, can be defined as one that can indefinitely meet the demands for food and fiber at socially acceptable economic costs and environmental impacts.

Finally, as pointed out by Tan Sri Razali, chairman of the United Nation's Commission on Sustainable Development, the transfer of modern, environmentally sound technology to developing nations is the "key global action to sustainable development."

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Central to the concept of sustainability is the pursuit of intergenerational equity—assuring that decisions made by the present generation take into account impacts on future generations. The concept of equity was a key objective of the National Environmental Policy Act of 1970, which articulated the general environmental policy framework that we operate within today:

The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances and recognizing further the critical importance of restoring and maintaining environmental quality to the overall welfare and development of man, declares that it is the continuing policy of the federal government, in cooperation with state and local governments, and other concerned public and private organizations, to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.

This statement implicitly points to the long-term goal of sustainable development and to technology's role in enabling or impeding it. Whether technology is used to protect or merely exploit the natural environment will be one of the most challenging policy choices of the 21st century. The decision of which path to pursue rests in the hands of no one government or sector of society. Rather, the decision lies in the collective actions of individuals throughout the world. Recognizing this distinction is the key to the appropriate development and application of technology.

Present Federal Programs

The administration has already moved expeditiously to advance environmental technology policy through a variety of initiatives. In the early weeks of the administration, the broad elements of a new technology policy were defined in *Technology for America's Economic Growth: A New Direction to Build Economic Strength*. The administration also undertook a major interagency effort to develop a forward-looking strategy to enhance the export of U.S. environmental technologies. In addition, funds have been infused into a new interagency Environmental Technology Initiative coordinated by the Environmental Protection Agency. The President has also issued several executive orders that will have a positive impact on the development of environmental technologies. Finally, the administration has worked closely with Congress to advance environmental technology legislation.

In this report we point to many specific initiatives to advance federal activities in all stages of the environmental technology development pipeline. The federal government is spending more than \$4 billion to advance environmental technologies; the bulk of this money is dedicated to research and development. This document is a first step in examining the nature of current federal programs and expenditures, building on the initiatives taken to date, and engaging in a broader dialogue on potential public-private interactions.

Administration Initiatives

Technology for America's Economic Growth: A New Direction to Build Economic Strength, (February 1993), outlines the key elements of the administration's technology policy, including initiatives designed to promote long-term economic growth that creates jobs and protects the environment.

Technology for Economic Growth: President's Progress Report, (November 1993), summarizes actions taken by the administration in the nine months since the February 1993 unveiling of its technology policy, including incentives for private-sector R&D and new business formation, development of a new export strategy, aggressive pursuit of bilateral and multilateral trade agreements, investment in workers' skills, and forging of industry partnerships.

Environmental Technologies Exports: Strategic Framework for U.S. Leadership, (November 1993), proposes an administration strategy to enhance exports of U.S. environmental technologies. This document responds to President Clinton's Earth Day 1993 request that federal agencies assess the domestic and international competitiveness of the U.S. environmental technologies industry and formulate a strategy to expand it.

Draft Technology Innovation Strategy, (January 1994), describes the broad strategies that will guide the new interagency Environmental Technology Initiative, coordinated by the Environmental Protection Agency. The initiative is intended to spur the development of advanced environmental systems and treatment techniques.

DEFINING ENVIRONMENTAL TECHNOLOGY

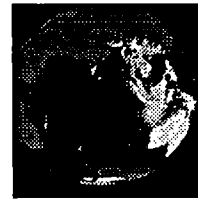
An environmental technology is a technology that advances sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating products and processes that are environmentally beneficial or benign. The word "technology" is intended to include: hardware, software, systems, and services.

Environmental Technology Categories

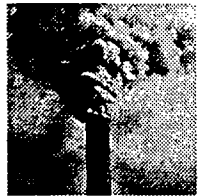
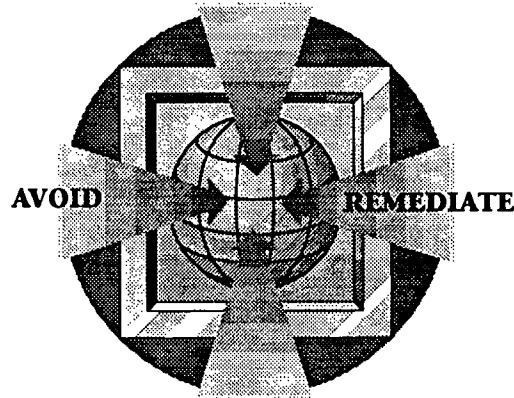
Environmental technologies can be divided into four major categories: avoidance, monitoring and assessment, control, and remediation

and restoration. Avoidance activities involve technologies that avoid the production of environmentally hazardous substances or alter human activities in ways that minimize damage to the environment. The phrase "avoidance activities" is used rather than "pollution avoidance" to indicate that other forms of environmental degradation are intended in addition to pollution. Avoidance activities usually encompass product substitution or the redesign of an entire production process, rather than simply the use of new pieces of equipment. Monitoring and assessment technologies are used to establish and monitor the condition of the environment, including releases of pollutants and other natural or anthropogenic materials of a harmful nature. Control technologies render hazardous substances harmless before they enter the environment. Remediation technologies render harmful or hazardous substances harmless after they enter the environment. Restoration technologies embody methods designed to improve ecosystems that have declined due to naturally induced or anthropogenic effects.

In coming years, two key trends are likely to reshape the U.S. environmental technology industry. One major change will be in the nature of environmental technology itself. Today, the focus is largely on controlling releases and cleaning up pollution that is already in existence: building scrubbers that remove sulfur dioxide from a smokestack, for example, or cleaning up waste sites that are already contaminated. Increasingly, environmental technology will be designed and deployed to avoid pollution altogether. Energy systems will shift toward cleaner fuels, such as natural gas or renewables. Manufacturing firms will increasingly adopt products and processes designed from the outset to minimize the use of raw materials and the output of pollutants.



MONITOR



CONTROL



The other trend relates to the markets for environmental technologies. Today, these technologies are mostly directed to domestic customers, and the largest export markets are in Canada and Western Europe. In coming years, markets in Asia and Latin America will grow rapidly.

A Global Industry

The global market for environmental technologies (including the domestic U.S. market) amounted to nearly \$300 billion in 1992, according to a widely cited estimate, and could grow to roughly \$425 billion annually by the year 1997. The United States has the largest segment of the industry, with \$134 billion in total estimated domestic and international revenues. Revenues for the remainder of the global environmental industry are \$161 billion, most of which is concentrated in Japan and Germany. According to the Organization for Economic Cooperation and Development, production by the United States, Germany, and Japan accounts for approximately two-thirds of total world output of environmental technologies.

Starting at Home

Throughout the executive branch, the federal government is being reinvented to work better and cost less. The environmental field is no exception. A number of executive orders are demonstrating that what makes good environmental sense "at home" in government also makes good business sense.

These executive orders require federal agencies to procure recycled goods; improve energy efficiency in buildings; accelerate the phase-out of ozone-depleting chemicals; prevent pollution; comply with community right-to-know laws; improve landscaping practices; and "green" the White House through energy conservation. These initiatives demonstrate practical actions that all Americans can take to protect the environment, save money, and improve the quality of their surroundings.

In recent months, federal agencies have made much progress in implementing the order to purchase recycled goods. For example, the Department of Energy recycles nearly 15 tons of paper per week at its headquarters in Washington, DC. The Environment Protection Agency has issued recycled-content guidelines for federal purchases of 21 products such as carpet, floor tile, office recycling containers, office waste receptacles, remanufactured toner cartridges, binders, and plastic trash bags.

Another executive order requires that toxic emissions from federal facilities be reduced by 50 percent by the year 1999. The initiative also directs federal facilities that manufacture, process, or use toxic chemicals to report any releases to the public. To implement the order, the Department of Defense is completing prevention plans for every military base in the United States, reducing hazardous waste disposal.

The administration is working to identify other ways to ensure that federal policies and procedures are designed with both economic and environmental concerns in mind.

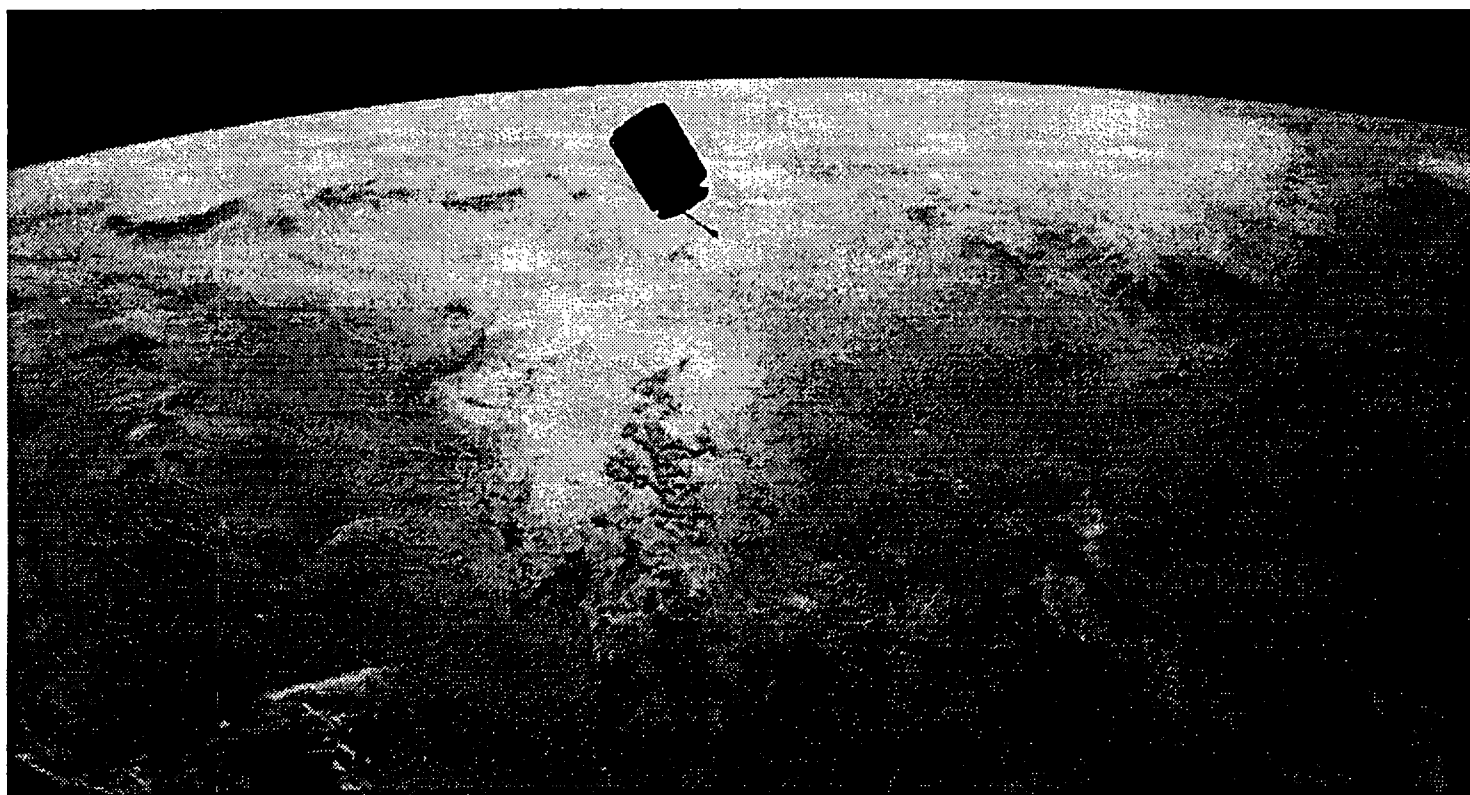
Most U.S. environmental technology exports go to modern industrialized countries. Different segments of the industry export in varying degrees. For instance, firms in the environmental energy sources and environmental instrument businesses derive more than half of their revenues from exports. In contrast, U.S. water utility firms report no revenues from outside the United States.

The United States spends a higher percentage of its gross domestic product on environmental concerns than does any other country. American demand for environmental quality, as partly expressed through environmental regulations, has played a central role in shaping U.S. industry and environmental technology. For example, the air pollution control industry soared after the 1970 Clean Air Act and its 1977 Amendments and fell during the 1980s when the focus of U.S. regulations shifted toward hazardous waste management. The air pollution control sector is projected to grow again during the coming decade due to the Clean Air Act Amendments of 1990. Similarly, the Superfund hazardous waste cleanup program and the large and growing federal expenditures to clean up facilities such as military bases and federal laboratories have given a boost to the U.S. remediation sector.

Key Policy Areas

In Part II of the main document, we discuss strategic directions, current initiatives, and possible next steps in the 10 key policy areas listed below. Here in the executive summary, we present only the broad strategic directions and a brief summary of current initiatives and possible next steps. For information on current federal initiatives and a full discussion of the next steps, the reader should refer to the main document.

- Research and Development
- Demonstration
- Regulatory Policy
- Market Stimulation
- Fiscal Policy
- International Commerce
- Foreign Aid and Development Assistance
- Partnerships and Collaboration
- Education and Training
- Information Dissemination



Facilitating Innovation

Successful technological innovation is dependent on an interconnected system of institutional structures, including research and development (R&D) activities, demonstration, regulatory policies, the industrial infrastructure and tax policies. Every component is critical to the commercialization of innovative technologies.

Research and Development

Historically, the need for new technologies to solve environmental problems has been inadequately recognized, and the government's role in encouraging environmental technologies has been underdeveloped. Traditionally the federal government has chosen to support basic and mission-driven research and to leave the development and application processes largely to industry. Today, diverse policy measures are required, as well as a more active federal government role in promoting technological advance in partnership with private industry.

The vision of tomorrow's environmental technology needs is very different from that of today's. As the shift from cleanup to prevention takes place and the goal of environmental sustainability guides our use of natural resources, policy changes will follow. The opportunity presented to us now is to provide a forward-looking strategy that anticipates the future and positions the United States for a leadership role in the global environmental industry. This anticipatory policy must foster the R&D that will lead to the technologies of the future and allow products to be commercialized rapidly and diffused globally.



Research and Development: Strategic Directions

The administration's technology strategy, which defined for the first time a post-Cold War technology policy, articulated the following broad goals: support R&D to stimulate long-term economic growth, create jobs, and protect the environment; support research and technologies that make government more productive and responsive to the needs of citizens and industry; and maintain world leadership in basic science, mathematics, and engineering.

With these overarching objectives as the starting point, federal agencies will pursue three strategic directions for fostering R&D to advance environmental technologies.

- Appropriately balance avoidance, monitoring, control, and remediation technologies, stressing the need for a shift toward technologies that emphasize sustainable use of natural resources and prevention of environmental harm while still maintaining our commitment to remediate past environmental damages.
- Focus federal R&D support on viable technologies that require support to attract private-sector investment because of high technical risk, long payback horizons, or cases where the anticipated returns are not evident to individual firms or distinct industrial sectors.
- Foster international cooperation on understanding, monitoring, and assessing environmental changes and impacts on a global or multinational scale.

The administration is currently fostering research and development for environmental technologies through programs that leverage private sector funding for innovative technologies; spur industry's development of high-risk, high-payoff technologies; fund technology development projects that have the potential for commercialization within five years; strengthen collaborative efforts with state environmental agencies; and facilitate interagency collaboration on R&D activities related to environmental technologies.

Possible next steps could focus on developing ways to integrate federal agency R&D efforts and promote greater cooperation with the private sector. The emphasis could be on joint activities at the precommercial stage to foster prevention technologies. Potential strategies include developing new environmental criteria for awarding R&D grants; improving environmental technology transfer from federal laboratories; and integrating industry-driven expressions of environmental technology needs with government support of high-risk demonstrations.

Demonstration



The necessary link between R&D and commercialization of a new technology is demonstration, or the testing and evaluation of a technology to show that it can meet necessary standards and perform adequately for the purpose for which it was designed. Testing and demonstrations are essential for determining the useful range of performance of innovative technologies and their potential to solve environmental problems.

Demonstration: Strategic Directions

In order to assist developers of innovative technologies, federal agencies will pursue three broad objectives for facilitating the testing and demonstration process:

- Standardize approaches to evaluating innovative technologies to ensure the acceptability, quality, comparability, and transferability of performance data. Use these approaches to establish a verification program for environmental technologies.
- Increase the availability of specialized government facilities so that private industry can take advantage of controlled settings where tests can be conducted safely over a wide range of operating conditions.
- Increase the accessibility of human resources within federal laboratories and establish new procedures and criteria for the use of national facilities and personnel.

Current demonstration initiatives include a federal-state five-year partnership to address barriers to the development of innovative technologies; programs to demonstrate U.S. avoidance, control, and remediation technologies and renewable energy products overseas; a program to demonstrate innovative environmental technologies at military bases; a test site program to allow new technologies to be compared side by side using standardized data collection and analysis techniques; and a market-driven initiative to promote the use of alternative fuels.

Next steps could involve identifying appropriate federal facilities for testing and demonstrating environmental technologies, encouraging industry demonstration activity by means of cost-shared grant programs, and organizing systems-level demonstrations of technologies.

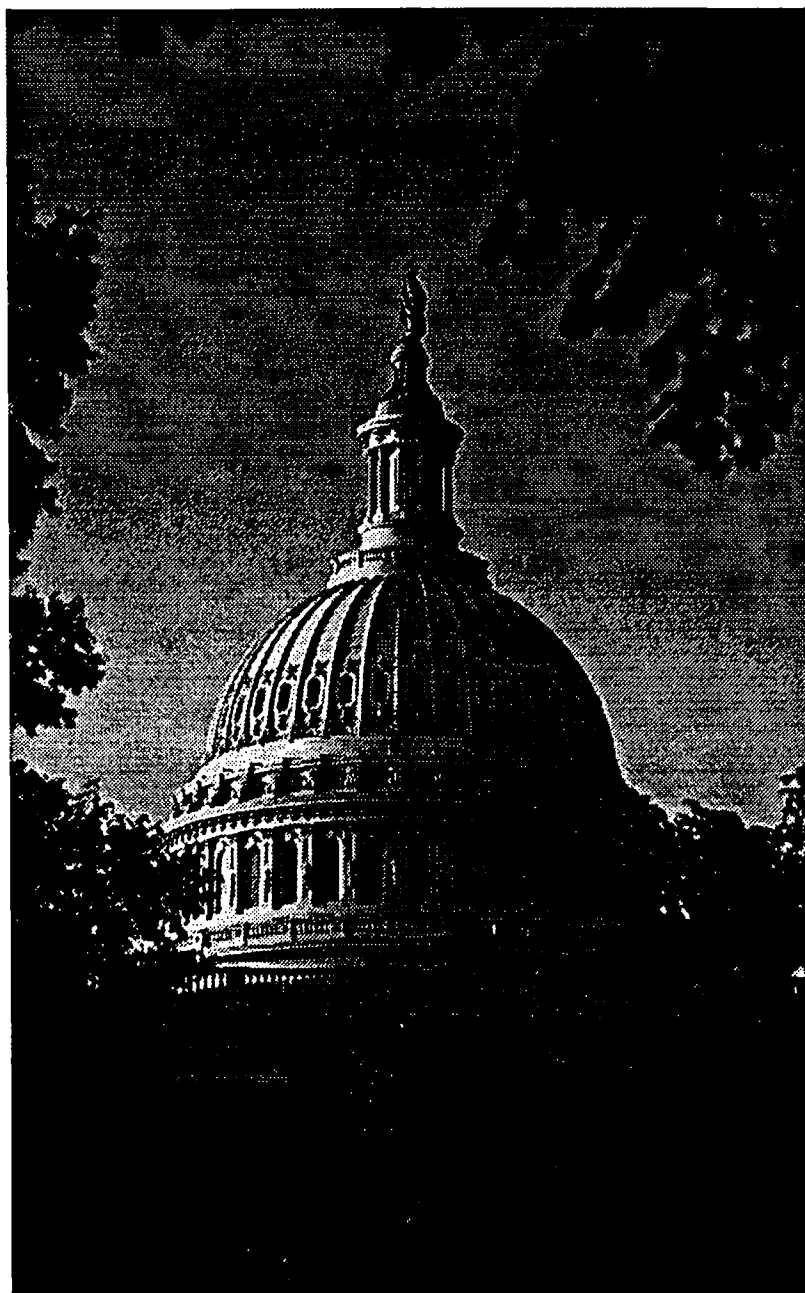
Encouraging New Approaches

A number of avenues are available to the federal government for encouraging markets for environmental technologies. Historically, environmental regulations have had the strongest impact, but consumer labeling, government procurement, and fiscal policy are among other important mechanisms. Stimulating a dialogue on policies in each of these areas is one of the most important steps in advancing environmental technologies.

Regulatory Policy

Markets for environmental technologies are shaped, stimulated, and at times inhibited by environmental regulations. The United States has the most stringent regulatory and compliance framework in the world, which has resulted in strong, comprehensive environmental protection programs. As we look to the future, however, we must find ways to increase the flexibility of our regulatory structure so that it functions to encourage greater innovation.

One aim of this document is to suggest strategic directions that will help overcome unintentional regulatory constraints to innovation, commercialization, and diffusion. As we move from point sources to systemic solutions, our current regulatory structure will need to become more flexible, more resilient, and less focused on single media (air, water, etc.) solutions.



Regulatory Policy: Strategic Directions

The challenge over the coming years will be to fashion regulations that meet aggressive environmental performance goals, while allowing and encouraging innovative approaches to meet those goals. Federal agencies will:

- Continue to review environmental policies and procedures in order to identify specific steps to reduce government-imposed barriers to the development and commercialization of environmental technology.
- Explore existing opportunities to take a sectoral and whole-facility approach to regulations.
- Increase the use of market-based approaches in environmental regulations that will provide tangible rewards to developers of innovative technologies.

Current initiatives include an executive order requiring agencies to identify and assess alternatives to regulation and specify performance objectives; a federal agency review of environmental policies to identify specific steps needed to reduce barriers and stimulate innovation; proposing of revisions to environmental laws that are being reauthorized to allow for greater use of innovative environmental technology; and streamlining of permit policies and procedures for R&D.

Future regulatory policy initiatives might include establishing a public-private regulatory review committee to enhance incentives to develop and deploy innovative environmental technologies; broadening participation in the promulgation of regulations through negotiated rule making; developing a verification process for control, remediation, and avoidance technologies to reduce risk for early adapters of these technologies; and practicing greater flexibility in enforcement.

Market Stimulation



The environmental policy framework shapes the markets for many environmental technologies. Other public policies also have the potential to stimulate or inhibit these markets. A national dialogue should include discussion of how these policy instruments can be thoughtfully and effectively deployed. Consumer labeling and government procurement are two of the areas that deserve examination.

Market Stimulation: Strategic Directions

A number of market failures, particularly lack of information, can inhibit the demand for environmental technologies and their products. Government can stimulate this demand by ameliorating those barriers and by considering environmental criteria in its own procurement decisions. The federal government will:

- Examine market barriers that may inhibit demand for environmental technologies and their products.
- Continue to integrate environmental criteria into government procurement decisions.
- Support the dissemination of environmental information to consumers to allow them to make informed decisions when purchasing products.

Current initiatives to stimulate markets include an executive order requiring federal agencies to increase the market for environmentally preferred products through government purchases; a program to accelerate the commercialization of advanced, energy-efficient technologies; pilot programs to encourage investments by U.S. firms in prevention technologies and reduction of greenhouse gases; and a plan to convert the federal automotive fleet to alternative fuels.

Possible future initiatives to stimulate markets for environmental technologies could focus on encouraging improved regulatory policy in developing countries, increased use of environmental criteria in federal and state procurement decisions, and adoption of green labeling programs to provide consumers with environmental information.

Fiscal Policy



The administration is also committed to advancing federal fiscal policies and encouraging public-private cooperation in order to improve productivity, standards of living, and competitiveness. Among the goals is greater investment in all stages of the technology pipeline, civilian R&D, workforce training, and modern production processes. For environmental technology, these commitments could increase rates of innovation, speed product development, and facilitate the integration of environmental technology into the nation's infrastructure.

Fiscal Policy: Strategic Directions

In order to remain a leader in the research, development, commercialization, and deployment of innovative environmental technologies and high value-added products, federal agencies will:

- Develop and implement fiscal and tax policies that encourage and facilitate private-sector investments in R&D and the manufacture and deployment of innovative environmental technologies.
- Work to increase the rate of civilian investments in R&D, equipment, and plant infrastructures for environmental technologies.

The administration's current fiscal policy initiatives include developing incentives for private-sector research and development and new business formation through extension of the R&D tax credit and reduction of the capital gains tax for investments in small businesses.

Next steps to stimulate investment in innovative environmental technologies could focus on the use of policy instruments such as improved tax credits, accelerated depreciation schedules, and expedited licensing.



Engaging the World

Coordination of the administration's export promotion and foreign assistance policies

is critical to achieving global environmental stewardship and a strong domestic economy. U.S. industry must capture a larger share of the global market for environmental technologies—more than 60 percent of which lies outside the United States—in order to remain competi-

tive. Markets in countries that do not belong to the Organization for Economic Cooperation and Development are expected to experience the fastest growth, particularly in the Pacific Rim and Latin America. U.S. foreign assistance programs indirectly stimulate these markets by creating the awareness and capacity in these countries to address environmental problems.

International Commerce

Exporting environmental technologies presents special challenges that create unique needs for information and support. The needs of companies seeking to export environmental technologies include:

- knowledge of the environmental challenges in the target country and the technologies needed to meet those challenges;
- understanding the legal, political, and regulatory structures in the target country;
- contact with the key decision makers in the target country; and
- access to export financing.

International Commerce: Strategic Directions

On Earth Day 1993, President Clinton directed key agencies of the federal government to "assess the competitiveness of current environmental technologies and to develop a strategy



to give U.S. companies the trade development, promotional efforts, and technical assistance they need to increase exports and create U.S. jobs, as well as to promote a better environment."

In response to this directive, a six-agency Environmental Technologies Export Working Group chaired by Secretary of Commerce Ronald H. Brown authored *Environmental Technologies Exports: Strategic Framework for U.S. Leadership*. This report, released in November 1993, calls for streamlining U.S. export promotion efforts and improving export financing mechanisms. Consistent with the recommendations of this report, federal agencies will:

- Strengthen the technology development and commercialization abilities of the domestic industry.
- Help U.S. businesses succeed in the most important markets today, while developing tomorrow's potentially most valuable markets.
- Coordinate and better focus U.S. government export programs and resources.

The administration is currently developing a strategic plan for promoting U.S. environmental technology exports to Latin America; establishing one-stop shops to foster ties with state and local environmental technology business groups and help firms navigate federal export facilitation programs; training specialists to assist U.S. firms in identifying market opportunities; and establishing regional export councils to work with exporters of environmental technologies.

Possible future initiatives include devising comprehensive strategies for promoting exports to the most promising immediate and long-term markets. Strategies for gaining access to near-term markets should include collecting vital data, facilitating meetings between U.S. firms and potential clients, and providing information on financing support programs. Strategies to enhance long-term market access involve increasing the expertise of foreign service officers; utilizing interagency assignments to build knowledge; and facilitating joint research projects, training programs, and technology demonstrations.

Foreign Aid and Development Assistance



Promoting environmental stewardship is a central goal of U.S. foreign aid in the post-Cold War era. The carrying capacity of the earth itself is being challenged as never before by unsustainable population growth, endemic poverty, and natural resource degradation. By the year 2000, four out of five people in the world will live in developing countries—a trend that is likely to continue well into the 21st century. America's interests and markets will increasingly be shaped by events in developing countries.

Accordingly, the administration has identified sustainable development as a key element of its foreign policy and a cornerstone of its international development assistance program. Sustainable development acknowledges the legitimate economic aspirations of developing nations, as well as their responsibility to preserve and protect the environment for future generations. Environmental degradation is often the result of underlying pressures of poverty and rapid population growth—pressures that must be addressed in any comprehensive effort to promote sustainable development.

Major reforms are underway within the U.S. government to assure that America's post-Cold War foreign assistance program effectively addresses sustain-

able development objectives. The administration has submitted to Congress a major revision of the Foreign Assistance Act, entitled the Peace, Prosperity, and Democracy Act of 1994, to reflect new post-Cold War priorities.

Foreign Aid and Development Assistance: Strategic Directions

Federal programs with respect to foreign aid and development assistance will:

- Foster technology cooperation that incorporates assessment of needs, information exchange, training and technical assistance, capacity building, and technology development.
- Expand efforts to encourage and assist developing nations in identifying and diffusing appropriate environmental technologies.
- Encourage strengthening of environmental, regulatory, and other policies to promote sustainable development while stimulating markets in less-developed countries.

Current administration initiatives include a partnership to promote sustainable development in Asia by mobilizing U.S. expertise and resources; cost-sharing for studies of site-specific applications of renewable energy and programs to promote energy-efficient technologies; financial support of the Global Environment Facility to address climate change and biodiversity loss/preservation; promoting industrial pollution prevention and waste minimization; and the application of U.S. technologies to solving international environmental problems through technical assistance, training, and other capacity-building programs.

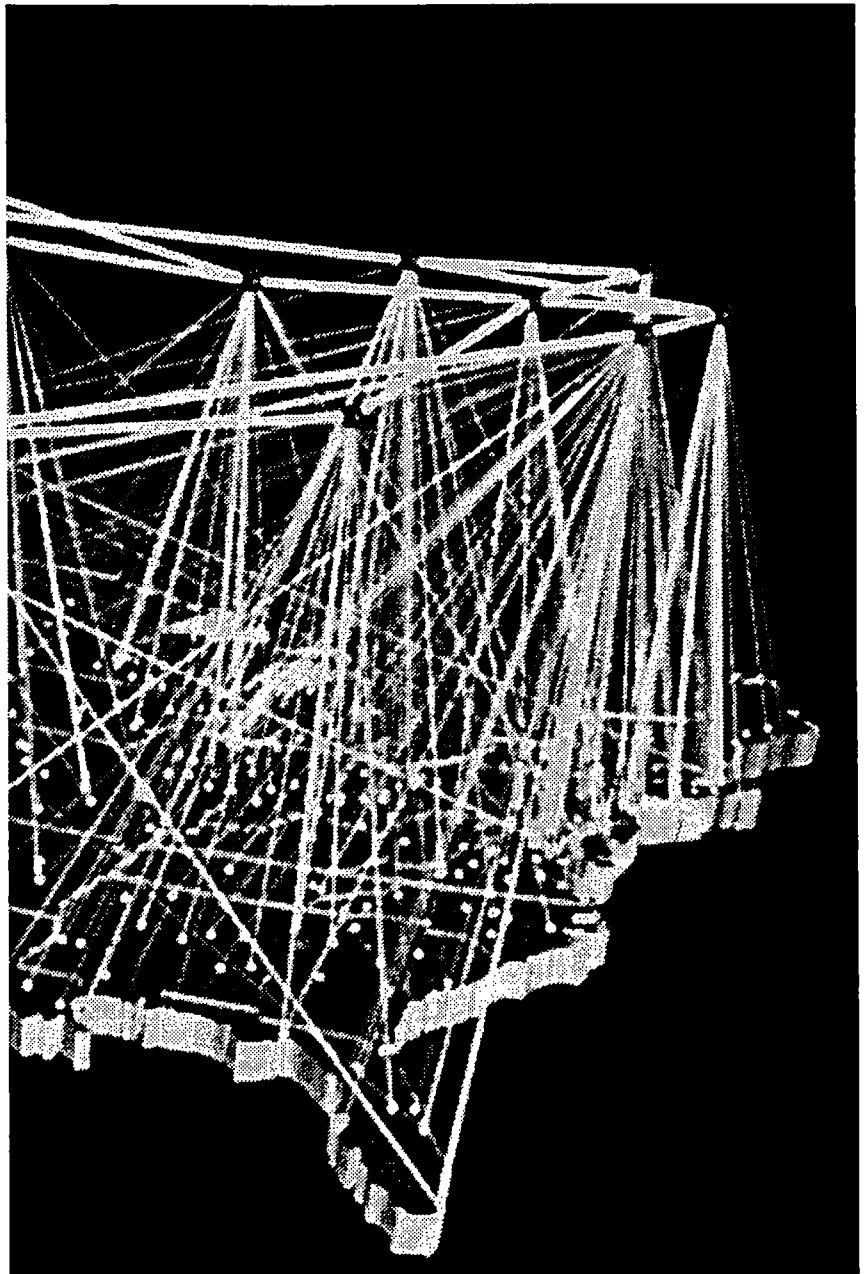
Next steps could focus on fostering technological cooperation with developing countries by articulating a clear technology cooperation policy; establishing an interagency working group on environmental development assistance; publicizing the benefits of environmental technology assistance efforts; and expanding existing assistance programs, especially those emphasizing prevention technologies.

Learning and Working Together

Innovative working relationships will help ensure that public investments in science and technology are guided toward national goals such as sustainable development. In addition to public-private partnerships, the nation's educational infrastructure will advance public awareness and support of environmental objectives and the role of technologies in achieving them. Furthermore, dissemination of information on environmental technologies will facilitate the adoption of the principles of industrial ecology.

Partnerships

The administration is working to advance environmental technologies by strengthening ties with the private sector. Partnerships between the public and private sectors are one of the keys to leadership in the global marketplace. The private sector plays a vital role in identifying, developing, and applying technology for commercial products and processes. Throughout the development process, the federal government best serves as a catalyst to ensure that the value of America's investment in science and technology, especially in times of fiscal restraint, is maximized. Innovative working relationships will help ensure that public investments in science and technology are guided toward national goals such as sustainable development.



Partnerships: Strategic Directions

Government institutions can play a supportive role in the advance of technological capability and the realization of economic opportunities in the environmental area. Many partnerships with state and local agencies, schools and universities, and the private sector, may effectively support this mission. The federal government will:

- Foster collaborations, where appropriate, at each step in the process of developing and diffusing environmental technologies.
- Work to simplify and streamline the procedures required to establish a public-private partnership.
- Establish both domestic and international frameworks and mechanisms by which partnerships will occur.

The National Science and Technology Council is encouraging close collaborations with the private environmental technology sector, such as a partnership to develop a new generation of vehicles that are safer and more fuel efficient than today's cars; a national clearinghouse to link U.S. firms seeking specific scientific or technical capabilities with federal agencies and laboratory facilities; a program to help industry evaluate the relative performance of innovative technologies and their environmental risks; programs to encourage acceptance of new technologies that limit pesticide use; and research partnerships to develop advanced batteries for electric vehicles and innovative cost-effective treatment systems to address contamination problems and alternatives to incineration.

Future initiatives could focus on increasing participation by the private sector in developing environmental technology policy, legislation, regulation, and programs; promoting alliances among industry, nongovernmental organizations, research institutions, and government agencies through regional organizations and an Industrial Ecology Partnership that would include research consortia and jointly agreed-upon performance milestones; initiating an extension outreach program; and reducing impediments and disincentives to partnerships.

Education and Training



The U.S. educational system, broadly defined, includes K-12, college, and graduate education; informal education at museums of science and industry; and life-long continuing education through businesses, community colleges, and television/telecommunications. These varied delivery mechanisms allow access to numerous audiences to foster increased awareness, technical and problem-solving skills, and creative invention in the field of environmental technology. Primary audiences for infusion of new knowledge fall into four groups: student populations from elementary school through advanced graduate level, individuals who work for environmental technology firms, engineers and managers who work for the broad array of companies that use environmental technologies, and the general public.

Education and Training: Strategic Directions

The cultivation of environmental awareness and expertise in the nation's workforce will facilitate the integration of environmental criteria into engineering and business decisions and support the diffusion of environmental technologies. The federal government will:

- Support efforts to develop an appreciation among all citizens for the importance of the environment to their lives through inclusion of environmental concerns and the concept of sustainable development in K-12 curricula.
- Facilitate the training of a cadre of skilled technical workers to help develop, maintain, and operate the increasingly complex environmental technologies.
- Support the development of holistic, multidisciplinary curricula in universities, emphasizing pollution prevention and efficiency in the use of resources.

The administration is currently providing environmental technology-related training for officials in developing countries; supporting the linkage of community colleges with federal laboratories and encouraging other programs to promote environmental education and training for engineers and other professionals, both domestically and internationally; and fostering a student and scientist exchange program to build a basis for future cooperation on environmental cleanup and prevention technologies.

Future directions could involve promoting training in environmental technology in the curricula of engineering schools, community colleges, technical schools, training programs, business schools, and, when necessary, newly created centers of excellence. More generally, new ways could be devised to encourage universities, colleges, and secondary and elementary schools to integrate environmental awareness into their curricula.

Information Dissemination

Information flows are central to innovation. Only rarely in today's world does a single individual or institution possess all the information needed to bring a new product or service to market. Increasingly, U.S. firms rely on external sources to augment their own research and development activities. These external sources can include other firms (both foreign and domestic), universities, or public sector laboratories. The channels of communication can range from informal discussions among researchers to more formal strategic alliances and partnerships. The most innovative sectors of the U.S. economy are often characterized by vigorous exchange of information among individuals and institutions.

The federal government can play an important role in enhancing such information flows. For instance, programs such as the National Institute of Standards and Technology's Advanced Technology Program help fund collaborations between firms and researchers in universities. Programs such as the Manufacturing Extension Partnerships help disseminate information about best practice technologies to numerous small- and medium-sized firms as well as catalyze the formation of regional networks of firms that can enhance innovation in an industry. As a new product moves toward the commercialization phase, the necessary investments become more expensive and firms generally require proprietary interest in information specific to its design. Anti-trust policies and the laws governing the protection of intellectual property thus help set the balance between the free flow of information and private sector investment in new technologies.

Federal government policies can also encourage more vigorous flows of information from government-funded institutions to the private sector. The government uses three primary techniques to disseminate information on technology: publications, databases and associated clearinghouses, and public outreach. The first two are passive techniques, depending on users to access information. The third, outreach, is generally targeted at identified user communities, such as consumers, a specific industry sector, or academia.

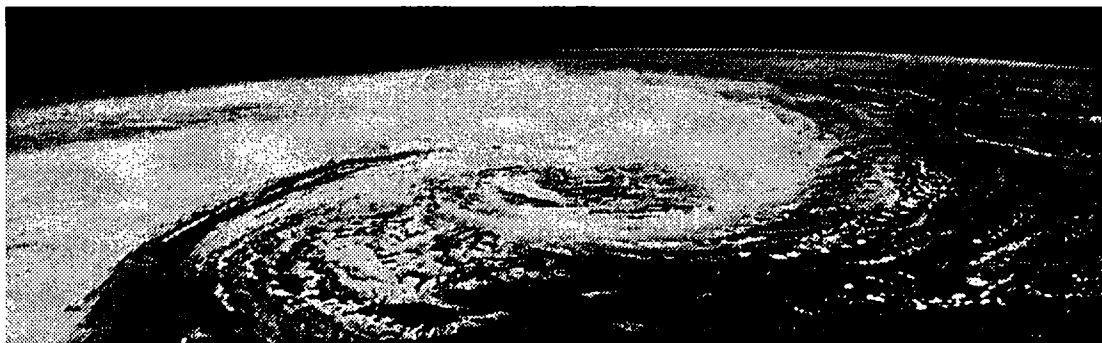
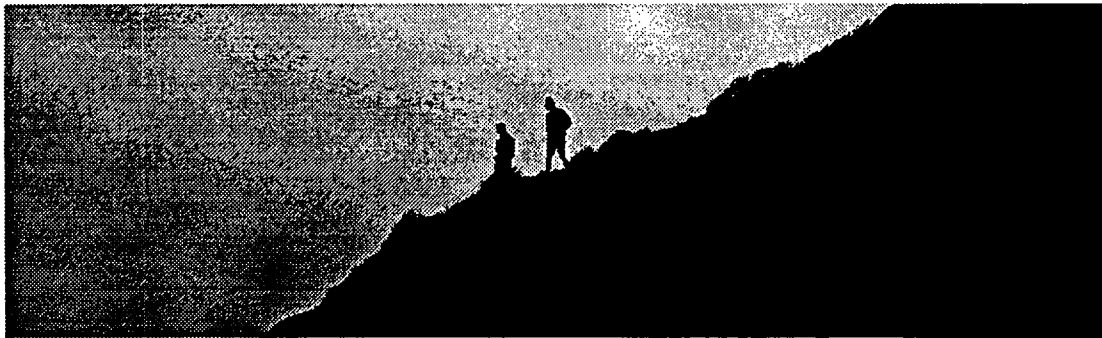
Information Dissemination: Strategic Directions

Broader and more effective dissemination of information will enable individuals and organizations to better satisfy environmental needs, to advance the state of knowledge, and to realize economic opportunities. The federal government can play a constructive role in that process, particularly through collaboration with the private and academic sectors. The federal government will:

- Facilitate the flow of information on environmental technologies among government, industry, nongovernmental organizations, and academia.
- Encourage partnerships, consortia, joint ventures, and personnel exchanges to foster the transfer of information on environmental technologies.
- Provide access to databases supporting global change research and to analyses linking environmental problems with technology needs worldwide.

Current administration initiatives include development of measures of the economic value of environmental assets such as renewable and nonrenewable resources; a listing of manufacturers and service providers by industry sector for use by potential clients; audits of small businesses to identify opportunities for energy-efficiency improvements and waste minimization; and a data collection and dissemination system for global change research.

Possible next steps to improve public access to information on environmental technologies include establishing procedures to transfer information from federally funded research and development activities, regional training programs, a database of certified technologies, and an information clearinghouse. Other steps could include disseminating information to industry and the public on life-cycle costs of technologies, export and domestic markets, the state of the environment, environmental performance of products, and advances in environmental technologies.



Challenges and Technology Needs

Technology is applied in countless ways to integrate environmental quality with high standards of living. At the end of the main document we discuss examples of technological challenges that convey the breadth, potential, and creativity of the environmental technology enterprise. The development and diffusion of solutions to these challenges is likely to yield major environmental dividends.

The examples presented are not comprehensive. Nor do they reflect a government assessment of technological “winners” that merit special support. We put them forward as a starting point for the national dialogue on environmental technology and as concrete examples of the kinds of advances that policy reform can facilitate.

Directions

Some of the technologies that are needed will require new basic research to improve our understanding of natural systems. Understanding the social, political, and economic needs of potential users and varying environmental circumstances is also essential during the initial stages of any technological development or implementation decisions. Technologies appropriate to address an environmental problem in one location or region may not be the most efficient and cost effective at another site.

In today’s highly selective and rapidly expanding environmental markets, new technologies must be competitive. As an administrator of the Global Environmental Fund recently stated, competitive means “better, faster, cleaner, and cheaper.” Technologies that meet these criteria, while also meeting social and political goals, will contribute to achieving a sustainable economy that produces challenging, well-paid jobs in industries that add value to products and services while benefiting the environment.

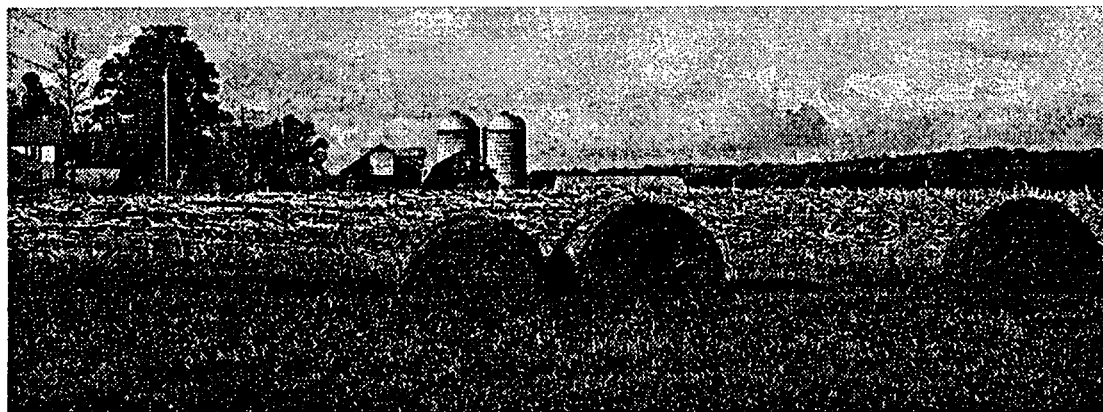
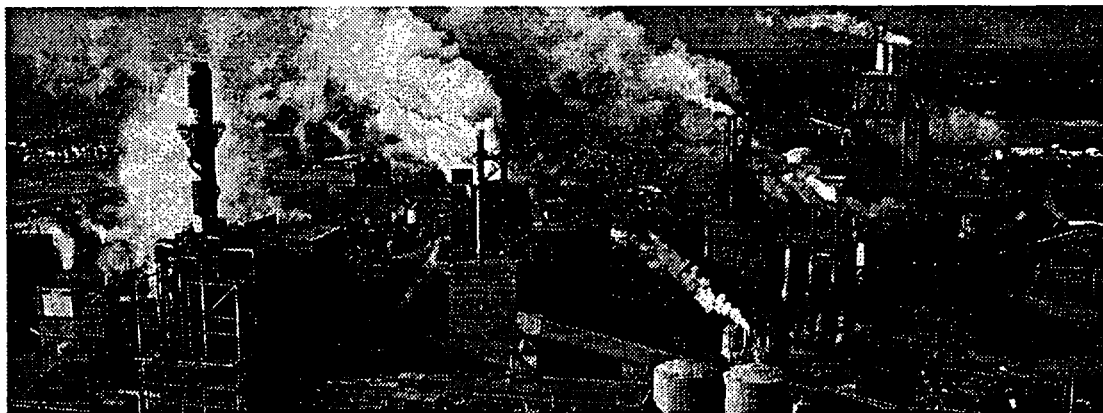
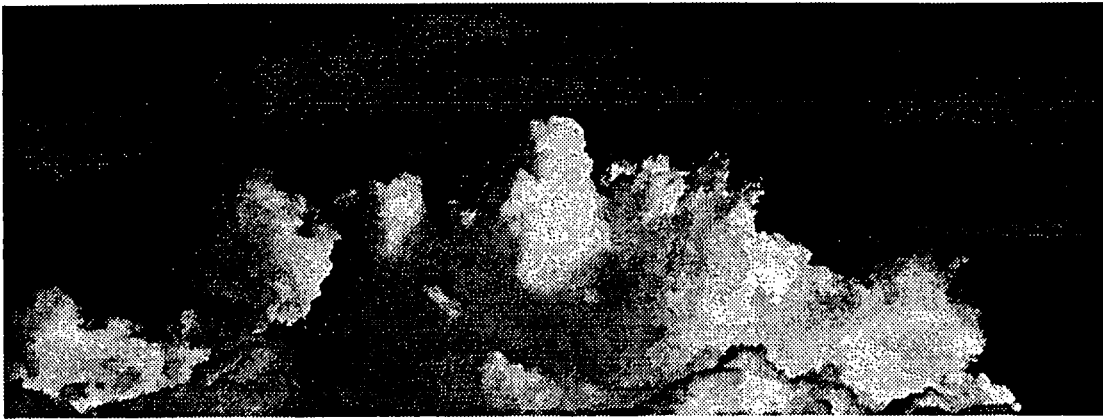
The New Paradigm: Industrial Ecology

Industrial systems can be compared with natural ecosystems in which plants consume minerals, water, and sunlight, and in turn are consumed by other organisms in interdependent processes that include production of wastes. The industrial ecosystem operates much the same way, consuming resources and producing wastes.

As with natural ecosystems, when industrial systems are small, resources and waste sinks are often considered infinite (and free). But as the relative size increases, resources become more limited (and therefore more valuable). Industrial ecology recognizes this shift and accordingly adopts a no-waste or low-waste approach. In-stream recovery and reuse of materials are crucial tenets of industrial ecology and of the new paradigm of environmental technology. In this new paradigm, environmental considerations are incorporated into all aspects of product and process design, and technology plays a more active and positive role in achieving sustainable development.

Life Cycle Analysis

Life cycle analysis can help us understand the full cost, potential, and impact of new products and their associated technologies. As a systems approach, life cycle analysis begins with questioning the need for a new product. In order to minimize waste and the use of natural resources, life cycle analysis then requires integration and modeling of the complex relationships among industrial processes. Shifting to an approach that considers all resources, products, and waste as an interdependent system will take time, but government can facilitate the shift by encouraging the transition to a systems approach.



The Next Steps



The long-term competitiveness of U.S. industry in the environmental technology area will not be achieved simply by competing on a “technology-by-technology” basis with other countries. We must fundamentally change the way we think about technology, processes, and products and rapidly increase the environmental and resource efficiencies of our entire industrial infrastructure. We must also institute far-reaching changes in the policy framework that fosters technology. We will then be in a better position to deliver advanced environmental technologies to the domestic and global markets of the 21st century.

The scientific infrastructure in the United States has been highly successful as an engine of creativity and innovation. It has even supplied other nations that lack strong R&D capabilities with a reservoir of new ideas that they have used to their competitive advantage. A major challenge before us is to turn this flow of new ideas into economic advantage in association with environmental benefits. If we are to create long-term wealth and job opportunities, technological advances must consistently be transformed into economic success.

Our framework for thinking about environmental technologies must have an upstream focus aimed at the earliest stages of technological development. We must seek to understand the entire development process and integrate this view with policies designed to impact the process at critical points. The first crucial step will be expanding our time perspective to make sure we consider all phases of the process and the linkages. If this is not accomplished, we may ultimately run the risk of sacrificing our long-term competitiveness for short-term gains.

A long-term perspective is the precondition for developing technologies that place us ahead of environmental problems and enable the United States to lead the way toward a sustainable global future. Anticipating demographic trends and changes in economic growth, consumption patterns, and technological processes will help us better understand tomorrow’s environmental problems and the implications for technology. We must balance the urgent need to address today’s environmental issues with the longer-term need to anticipate and avoid future problems.

An effective policy framework must look across technologies, across organizations, and across budgets. A narrow focus often misses synergies within our government and between the private and public sectors. The need to bridge institutions is urgent. We need strategies to link scientific, technological, and policy-making communities and to join national and international efforts. Ultimately, the development of green technology must become an integral part of all technology policies and programs.

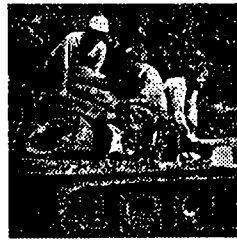
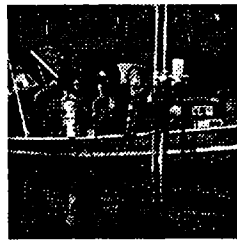
The administration has made a commitment to use technology to “make a difference in the lives of the American people.” We look forward to a dialogue that will lead to a long-term strategy that will ensure that future technological progress is consistent with societal needs and values.

We hope the issues and impediments addressed in this report will serve as a starting point for creative discussion. Over the coming year, we will develop an environmental technology strategy that fosters the integration of federal, state, and private efforts. Our overarching goal is to develop federal policies that will enable the private sector to advance the environmental technologies that will function as a bridge to a sustainable future.

“We will work with Congress to create tax, regulatory, procurement, and trade policies that encourage technological innovation and favor efforts that link environmental and economic goals.”

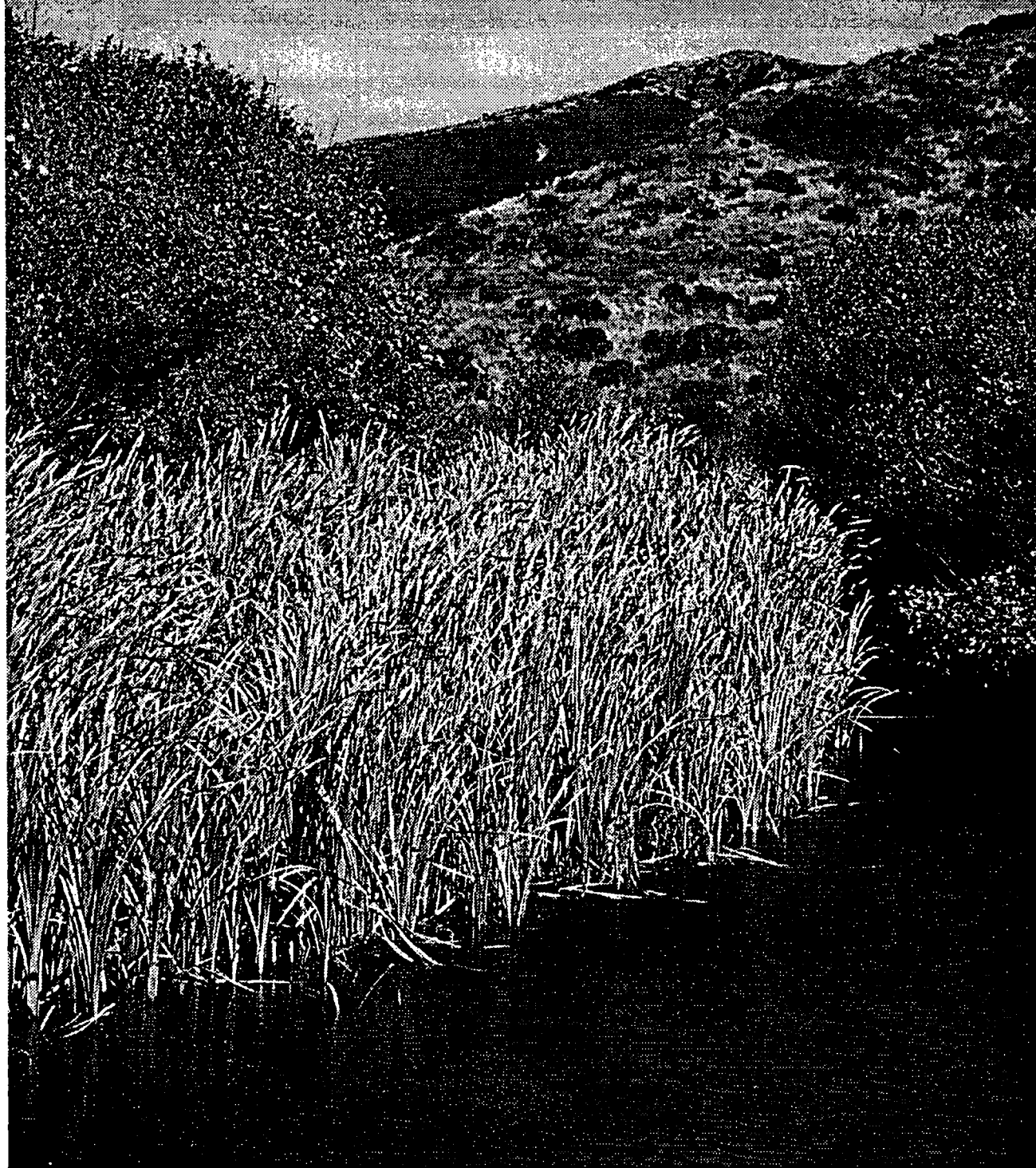
—John H. Gibbons
Assistant to the President for
Science and Technology

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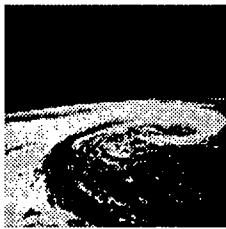


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Part I
Opportunities and Challenges



THE NATIONAL AND GLOBAL CONTEXT



Human activities began to have major impacts on the environment at least as early as the great civilizations of antiquity and have accelerated in modern times. By the 16th century, most of Europe's ancient forests were cut, and by the end of the 19th century, air pollution plagued many of the cities of the newly industrialized world. But after the Second World War, the impacts increased dramatically in scale, rate, and form, as the world entered a period of unprecedented economic and population growth.¹

Today we are facing environmental problems on local, regional, national, and global scales. For example:

- More than 50 percent of the wetlands of the contiguous United States had been lost by 1990.²
- Between 1980 and 1990, the average annual rate of deforestation worldwide was approximately equivalent to an area the size of the state of Georgia.³
- The United States put almost 5 billion metric tons of carbon dioxide in the atmosphere in 1991, almost entirely from the use of fossil fuels.⁴
- In 1988, 1.25 billion people worldwide breathed air containing unhealthy concentrations of particulate matter.⁵
- In the past 45 years, almost 11 percent of the earth's vegetated surface has suffered significant soil degradation caused mainly by deforestation, agricultural activities, and overgrazing.⁶

Many of these pressing problems are cumulative in nature and may cause irreversible damage to the future health of our people and planet.

Environmental policy, social factors, individual behavior, and environmental technologies will determine whether these and other environmental stresses worsen or improve. The deterioration is not inevitable, but it will depend on the choices that we make. Continuing present trends in energy consumption, for example, would greatly intensify environmental degradation.

If current trends in population growth continue in the decades ahead, the world's economy will need to expand even faster in order to permit the citizens of all nations to achieve a desirable quality of life. This is especially true in the developing and post-communist countries, which currently account for 80 percent of the total global population. Such trends could cause intolerable environmental damage unless a fundamental transformation occurs in our environmental and technology policies.

Until recently, the usual response to the need to protect the environment was to approach problems through piecemeal efforts. If a factory polluted the air, control measures were initiated to capture the emissions. If a copper mine contaminated a river, settlement ponds were used to divert the runoff. This type of response is no longer adequate. A more anticipatory, holistic systems approach to environmental protection must be initiated if the goal of sustainable development is to be attained.

The failure to change course will lead to continued resource depletion, higher costs for basic necessities, lower living standards, and possibly to confrontation and conflict. The degradation of renewable resources, such as arable land, forests, freshwater supplies, and fish-

eries, has already contributed to conflicts throughout the world.⁷ The resulting resource scarcities can lead to destabilizing social effects such as mass population migrations, which in turn can result in civil strife. These conflicts may be small and localized at first, but, if unchecked, could spread to regional conflicts that have global implications.

The cumulative impact of increasing scarcities may ultimately reach a critical threshold beyond which recovery of the system becomes very difficult or impossible. Avoiding such a future requires a more forward-looking approach to environmental policy making. Because changes in complex systems often evolve over a period of decades, recognizing the long-term effects of environmental impacts and initiating corrective action are imperative. The further into the future that we are able to look, the easier it will be to anticipate undesirable outcomes and enact policies that will prevent scarcities, conflicts, the resulting threats to national security, and cumulative and irreversible environmental degradation.

Illustrative Environmental Trends and Technological Challenges

 With present technology, it will be difficult to attain sustainable development given expected levels of population and economic growth. Although population growth is apt to abate, the modification of this trend will occur slowly at best. At the same time, economic activity is increasing rapidly throughout the world. Given these two trends, the only realistic option during the next few decades for lowering environmental pressures is to reduce significantly the per capita environmental impact of individuals. One approach to accomplishing this is to encourage environmental technology and modifications of the institutional infrastructure and social practices that affect technology.

Many factors determine the impact that a nation and its people have on their environment: the ecosystems they inhabit, the types of industry and agriculture they engage in, the extent of environmental regulation, the public's level of environmental concern, and an array of broader economic, social, and political factors. A look at four critical environmental areas—clean water, air pollution, soil erosion, and energy—will illustrate the challenges presented to technology and the need for a new kind of approach.

Clean Water

Lack of access to clean water is one of the world's most pervasive environmental problems. Nearly a billion people in developing countries suffer from water-borne diseases. The United Nations Children's Fund estimates that 40,000 children die every day mainly as a result of preventable diseases.⁸ Unsanitary living conditions—poor quality drinking water in particular—are responsible for a large proportion of these deaths. During the coming decades, Asia and Latin America are likely to make sizable investments in infrastructure for water purification and delivery. This growth will mean increasing markets for firms that provide the necessary equipment and services.

The picture is less clear for many nations in Africa and the Middle East. Millions of the citizens of these regions, where national economies are growing not much faster than the populations, could remain without clean water for decades to come. Water treatment could help these societies prevent the immense human tragedy such trends represent.



Urban Air Pollution

Many environmental problems tend to worsen initially as a nation lifts itself from poverty, and then improve as it grows wealthy enough to purchase pollution control technologies. Problems such as urban air pollution follow this pattern.⁹



For example, sulfur dioxide concentrations, a major source of urban air pollution that results largely from burning fossil fuels, on average tend to rise until per capita income reaches about \$1,500. After that, the concentrations begin to decline due to the use of control technologies.¹⁰

On a per capita basis, the world's richest countries, such as the United States, Germany, and Japan, burn more fossil fuels than any other nations do. Since the 1970s, however, these countries have invested heavily in technologies to control pollution, and their urban air is generally cleaner than that of poorer countries. Nonetheless, the air in many of the cities of the economic superpowers remains damaging to the health of the public and aesthetically unappealing as a result of pollution from stationary and mobile sources. Moreover, many of these cities are finding it

increasingly difficult to implement further reductions in pollution, as they fight population growth and the accompanying increase in vehicular travel.

If current trends hold, most of the world's cities will still be plagued by severe sulfur dioxide pollution during the next 30 years. Some cities that are beginning to invest in control technologies will likely continue to do so, and their air will probably improve, as air quality has in many American cities during recent decades. However, many of the world's largest countries, such as China and India, may grow rapidly for several decades before reaching the level of income where, historically, nations begin to invest heavily in pollution control.

Fortunately, society is not wedded to these trends. Adopting environmental technologies can provide cities with acceptable options to clean the air of sulfur dioxide pollution, particulates, and ozone pollution.

Soil Erosion

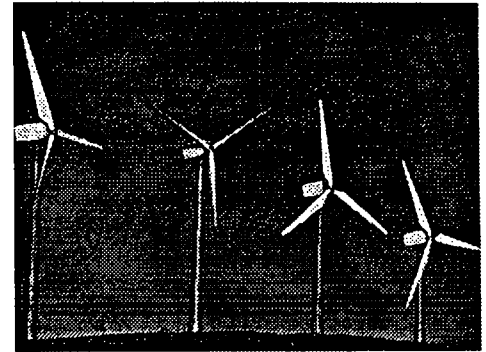
Soil erosion and depletion of soil quality and other natural resources are significant problems in many parts of the world. Soil problems are greatly worsened by intensive cultivation to produce food for growing populations. Sediment from soil erosion is the largest pollutant to surface water in terms of volume, and airborne particulates from erosion are a major contributor to air quality problems. New technologies for improved soil conservation include the use of geographic information systems and geopositioning satellite technologies for land-use planning, "soil-specific farming," new conservation tillage systems, and crop-residue management technologies.

Energy

If nations continue to use more energy as they become more affluent, as past trends suggest, world energy consumption will increase dramatically over the next 30 years. Total energy consumption is rising even though the energy intensity (the amount of energy consumed per unit of economic output) in most developed countries has been falling for decades. In the United States, energy intensity is half what it was at its peak during the first decade of this century. This drop is due to the shift from coal to oil and gas, changes in the structure of the economy (the decline of heavy industries such as steel making), and technological advances that have improved energy efficiency. Total energy use in the developed countries has increased despite these changes because their economies have grown even faster.

A central goal of an environmental technology strategy must be to promote the use of

new and existing technologies that limit the environmental damage from energy consumption. A key means of accomplishing this is to decrease energy use in the developed countries by means of rapid increases in energy efficiency, greater use of renewable energy sources, and increased utilization of low-emission or no-emission energy sources. Another key means is to help developing countries control their energy use as they industrialize so that they will not follow the same path as the developed countries have. The energy example illustrates the options available to decision makers for alternative paths that have widely varying environmental consequences.

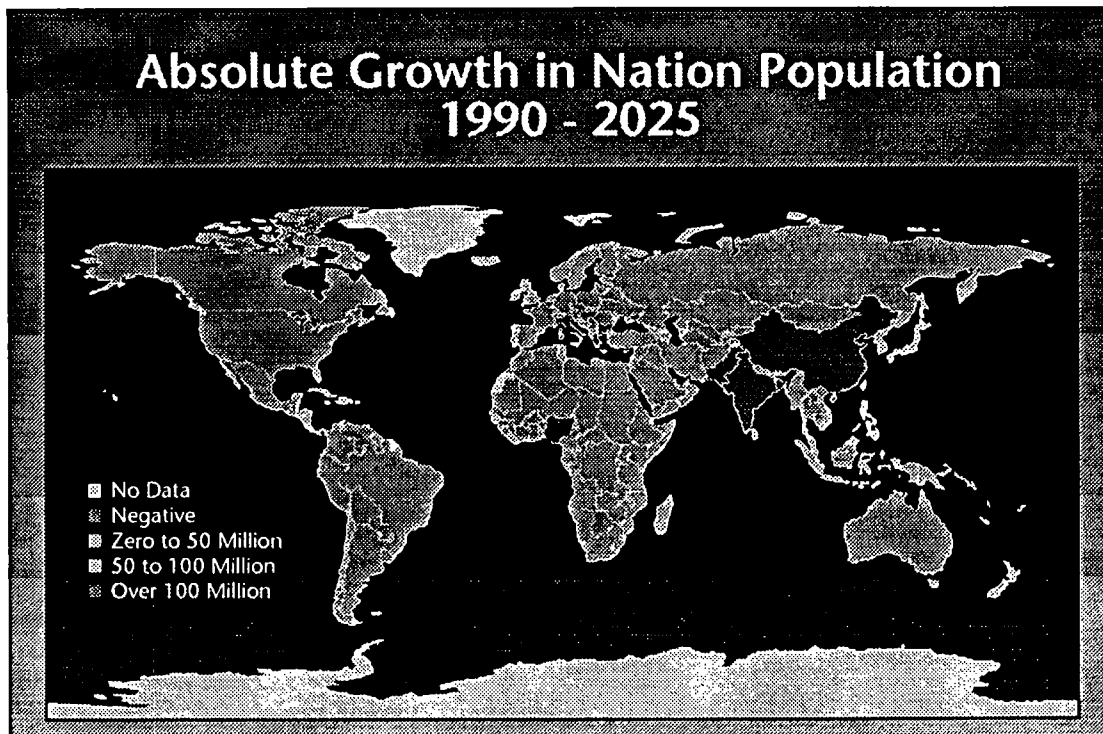


Many environmental problems, such as increased emissions of greenhouses gases, generation of toxic wastes, misuse of pesticides, and generation of solid wastes, follow the same pattern as energy and air pollution—worsening as a society grows richer.¹¹ Environmental degradation of these kinds is particularly difficult to tackle with the single-medium control measures that are prevalent today. Efficiently reducing the toxicity of manufacturing processes, for example, requires re-engineering these processes and products from the ground up. In response to this need, engineers are now beginning to select materials with lower toxicity; to reduce the use of hazardous substances for cleaning, plating, and painting; and to design ways to collect the wastes that are produced so that they can be sold as raw materials for the manufacture of other products.

Population and Economic Trends



By the end of the Second World War, the earth's population was 2.5 billion. Today, it is more than 5.5 billion, and demographers project that by the year 2025 it may expand to approximately 8.5 billion.¹² Projected population changes are depicted in the figure below. These projections are based on current trends; they could be modified sub-



Between 1990 and 2025, the nations that are shaded dark green on this map could increase by more than 100 million people, based on a medium-growth rate projection by the United Nations. Those that are shaded light green may grow by 50 to 100 million, light brown by 0 to 50 million, and dark brown could show slight decreases.¹³



stantially by a variety of factors.

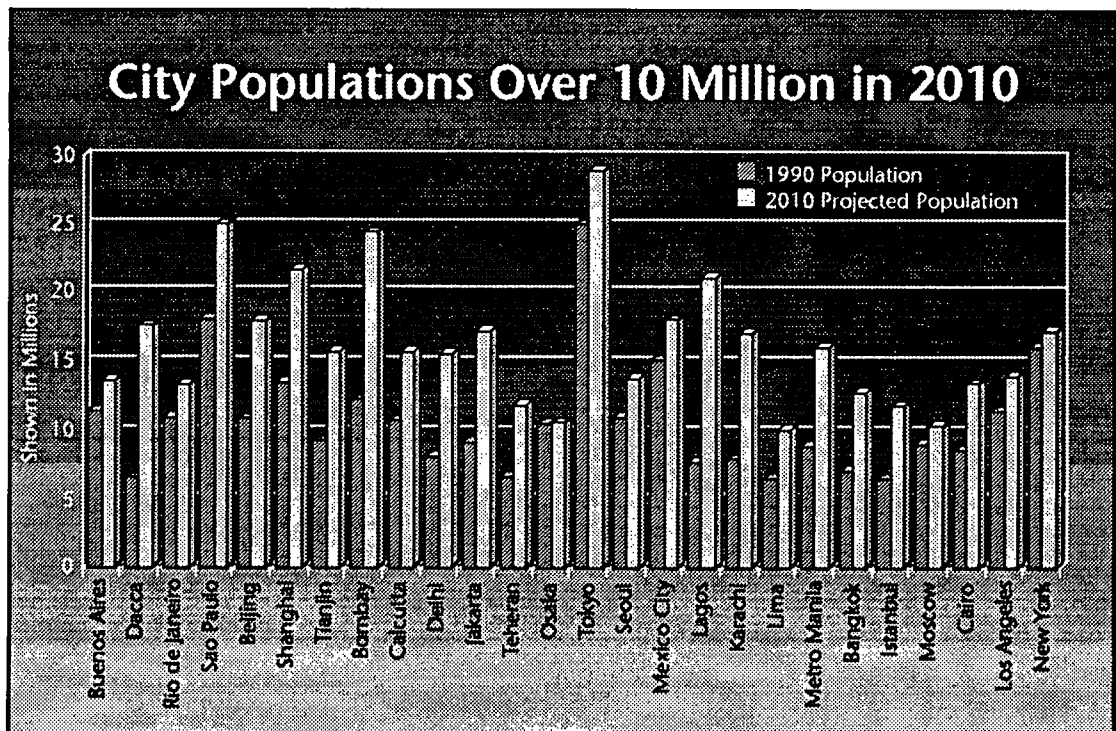
The environmental impacts of population growth will vary since environmental quality is a function of population size, per capita consumption, and the development and implementation of environmental technologies. Given current trends, countries that may double in population by 2025, such as many nations in Africa and the Middle East, will require at least twice as much energy as they use at present and twice as much water and other natural resources.

In addition, expected increases in the intensive cultivation of land to feed growing populations would exacerbate environmental problems that are already serious, such as soil erosion, depletion of soil quality, and loss of biodiversity.

An important dimension of current population trends is a projected worldwide increase in urban populations. By 2025, 60 percent of the world's population is likely to dwell in urban areas, compared with 40 percent in 1990. A total of 13 cities in 1990 had more than 10 million residents; in 2010 there may be 26 of these megacities.¹⁴ (See the figure below.) All but a few of these megacities will be located in developing nations. Between the years 2005 and 2010, the average growth rate of urban areas in developing and post-communist countries is expected to be more than three times that of developed countries.¹⁵ Environmental technologies are critical to attaining sustainability in urban centers throughout the world.

The global economy is growing even faster than the population. Currently, the

In 1990, 13 urban areas in the world had populations of 10 million or more. In 20 years, there may be 26 of these megacities, according to a U.N. medium-growth rate scenario. These huge urban agglomerations face significant environmental problems.¹⁶



world's gross national product (GNP) is approximately \$25 trillion, a fivefold growth since 1950. This compares with a twofold growth in population during the same time frame, so that on average the people of the world are much richer today than they were 40 years ago.

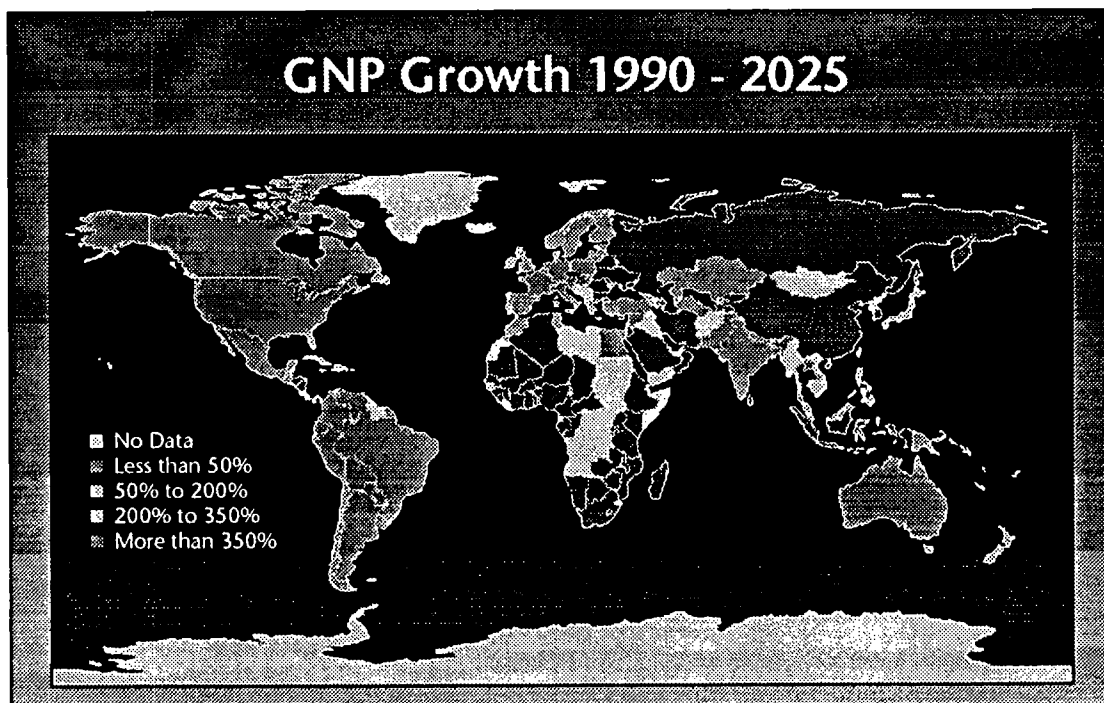
The global GNP is distributed unevenly, however, since only about 1 billion people live in societies that generate incomes above the worldwide average of \$5,000 per capita. If the generally favorable economic climate of the last 50 years holds for the next 30, the world's GNP could increase to approximately \$65 trillion by the year 2025, with the average per capita income increasing to \$8,000.¹⁷

Some regions are apt to fare much better than others. Developing countries in Asia could have economies that are nearly 10 times larger than they are today, and Latin America's could be 5 times larger. And economic growth among nations in a particular region could vary considerably. (See the figure on this page.)

These trends illustrate how population, economies, and environmental technology are linked and how environmental challenges and technology needs vary by region, country, and city. Many developed nations are continuing to increase in wealth but have low population growth, while many middle-income countries are growing in both, and many of the poor developing countries have rapidly growing populations with little increase in wealth. A wide range of environmental technologies, policies, and international cooperation will be needed to meet their diverse environmental needs. Technologies alone, however, cannot solve the global environmental challenges that we face. Forward-looking political, social, and economic policies and actions will ultimately determine whether sustainable development will be achieved.

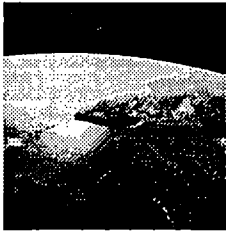
"Without a dramatic technological transformation throughout the economy, economic and population growth will create increasingly severe environmental pressures."

—James Gustave Speth
Administrator, United Nations Development Programme



This map shows estimated changes in gross national product per capita between 1990 and 2025 (using medium-growth assumptions for population and GNP), highlighting regional differences in wealth that may occur, according to current projections. Nations shaded dark brown have low GNP growth of less than 50 percent. Those shaded light brown may increase between 50 and 200 percent, light green from 200 to 350 percent, and those shaded dark green may increase by more than 4 1/2 times.¹⁸

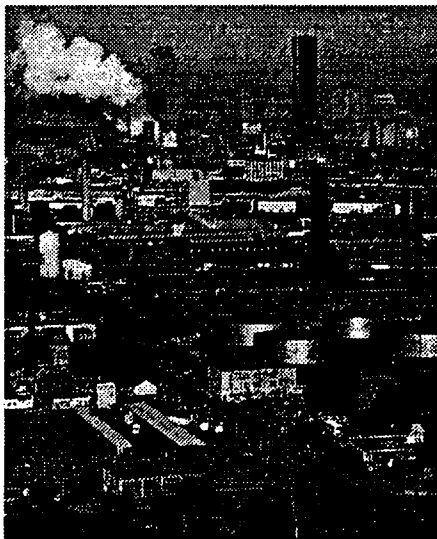
INDUSTRY AND ENVIRONMENTAL TECHNOLOGY



In coming years, two key trends are likely to reshape U.S. industrial activities with respect to environmental technology. First, the largest export markets for U.S. products are currently in Canada and Western Europe. Over coming decades, markets in the developing countries, led by rapid growth in Asia and Latin America, will become as large as those in the developed world.

The other change will be in the emphasis of environmental technology efforts. Today, the focus is largely on cleaning up pollution that is already in existence: building scrubbers that remove sulfur dioxide before it leaves a smokestack, for example, or cleaning up waste sites that are already contaminated. Increasingly, environmental technologies will instead aim at the prevention of environmental harm altogether. Energy systems will shift toward cleaner fuels, such as natural gas or renewables. Manufacturing firms will increasingly adopt products and processes designed from the outset to minimize the use of raw materials and the output of pollutants.

These changes will pose significant challenges for U.S. industry, which must develop new environmental technologies and bring them successfully to markets worldwide. The fast-growing new markets will offer fertile opportunities to those firms that successfully improve existing environmental equipment and services by making them less expensive and better able to serve their customers. Opportunities also will increase for firms that bring to market entirely new technologies that dramatically improve our ability to protect the environment. As environmental pressures grow, the quality of life worldwide will depend on both types of innovations.



A Global Industry

The United States has a large industry dedicated to the avoidance and solution of environmental problems—the largest in the world—with \$134 billion in total estimated domestic and international revenues.¹ The figure could actually be higher because significant activity in avoidance technologies is probably not reflected in these estimates.

Revenues for the remainder of the environmental industry worldwide are \$161 billion,² most of which is concentrated in Japan and Germany. According to the Organization for Economic Cooperation and Development (OECD), production by the United States, Germany, and Japan accounts for approximately two-thirds of total world output of environmental technologies.

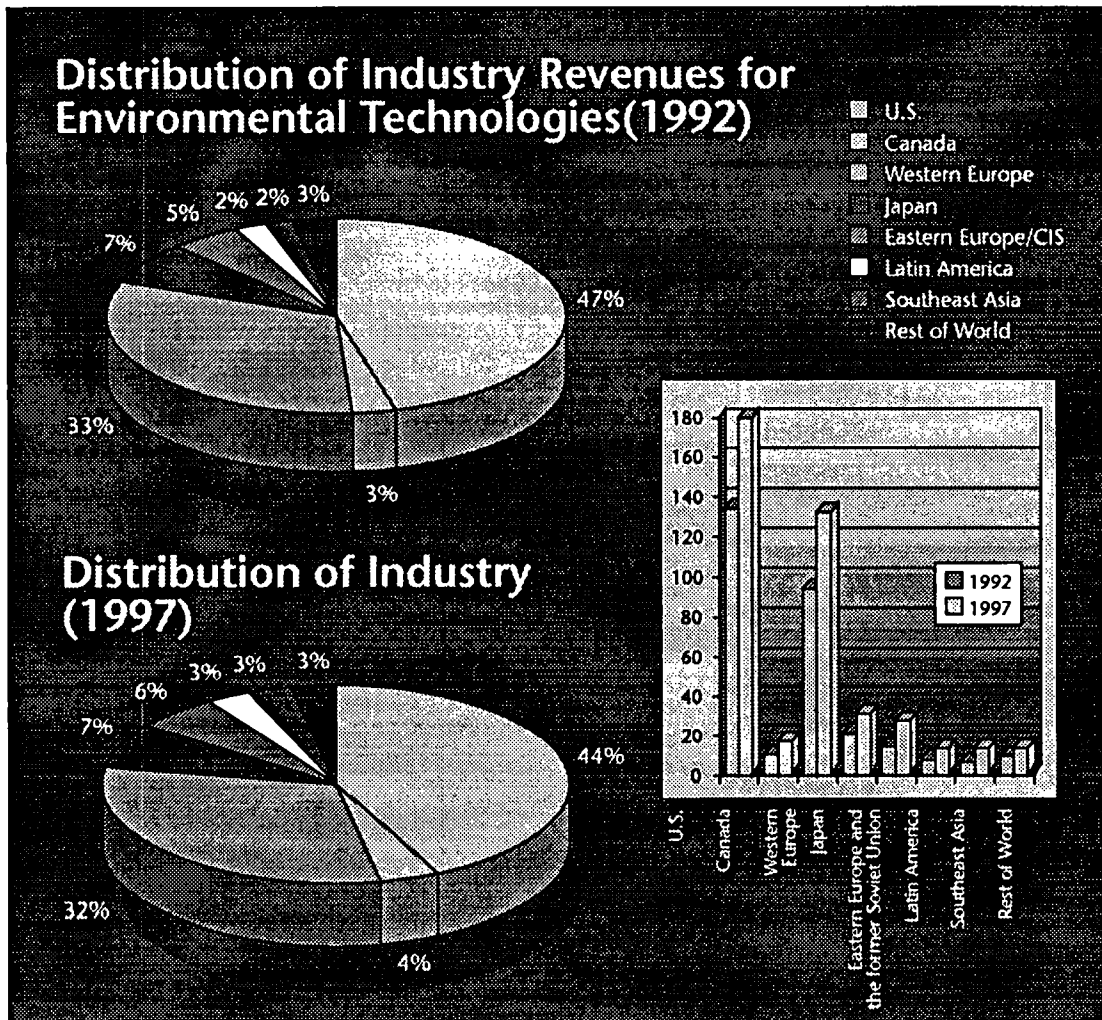
A substantial portion of that output is exported to other nations. The domestic markets in Germany and Japan are relatively

small, but exports from these countries are high. The reverse is true of the United States, which exports at most 10 percent of total revenues.³

The United States leads in some sectors, but Japan and Germany are strong in others. Japan is the top exporter of technologies for air pollution control, whereas Germany leads in water pollution controls.⁴ The developing countries are strong players in some areas as well. For instance, China is a leader in small-scale hydroelectric technologies and a significant producer of photovoltaic solar cells.

Governments play a central role in the advancement of environmental technology because environmental regulations and enforcement shape the industry's markets. In addition, a number of other factors affect demand, including a nation's rate of industrialization, the relative size of its various economic sectors, its degree of urbanization, the extent of state ownership of enterprises, the degree of environmental awareness among its citizens, and the requirements of international environmental agreements and the environmental provisions of trade accords.

As a consequence, the international market for environmental technology is a collection of distinct national and subnational markets. Countries in differing stages of economic development will tend to have differing degrees of environmental awareness. Even those that are at a comparable economic level may vary widely in the stringency of their environmental regulations and the degree to which those regulations are enforced. In addition, the regulatory strictures in some nations may emphasize procedures that are quite distinct from those of the United States.



The U.S. market is, and will continue to be, the largest single market for environmental technologies. However, by 1997, growth in certain regions and nations such as Latin America, Canada, and Eastern Europe/CIS will outpace growth in the United States.

The Domestic Market

The United States spends a greater percentage of its gross domestic product on environmental concerns than does any other country. American demand for environmental quality, as partly expressed through environmental regulations, has played a central role in shaping U.S. industry and environmental technology. For example, the air pollution control industry soared after the 1970 Clean Air Act and its 1977 Amendments and fell during the 1980s when the focus of U.S. regulations shifted toward hazardous waste management. The air pollution control sector is projected to grow again during the coming decade due to the Clean Air Act Amendments of 1990. Similarly, the Superfund hazardous waste clean-up program and the large and growing federal expenditures to clean up facilities such as military bases and federal laboratories have given a boost to the remediation sector.

In the United States, government procurement at the state and local levels also creates significant markets for environmental technology. In fact, these markets comprise 40 percent of the customer base. Equipment for the domestic infrastructure is purchased by water and energy utilities as well. Subsectors such as technologies for hazardous waste remediation tend to include products and services purchased under government contract.

Revenues from environmental technologies developed by U.S. industries are expected to grow from \$134 billion in 1992 to \$180 billion by 1997.⁵ Although the U.S. market for environmental technologies is not expected to increase as rapidly as some overseas markets will, the United States is expected to continue to be the largest single market in the world.

Global Markets

The global market for environmental technologies (including the U.S. market) amounted to nearly \$300 billion in 1992, according to one widely cited estimate, and the global market could grow to roughly \$425 billion annually by the year 1997.⁶

Most U.S. environmental technology exports go to modern industrialized countries,

with Western Europe and Canada accounting for nearly two-thirds of U.S. revenues. Different segments of the industry export in varying degrees. For instance, firms in the environmental energy sources and environmental instrument businesses derive more than half of their revenues from exports. In contrast, U.S. water utility firms report no revenues from outside the United States.

Markets in developing countries differ from the more established markets in developed nations. For example, developing countries place greater reliance on outside financing to pay for many of their purchases. Much of this funding is provided by official development assistance or multilateral development banks.

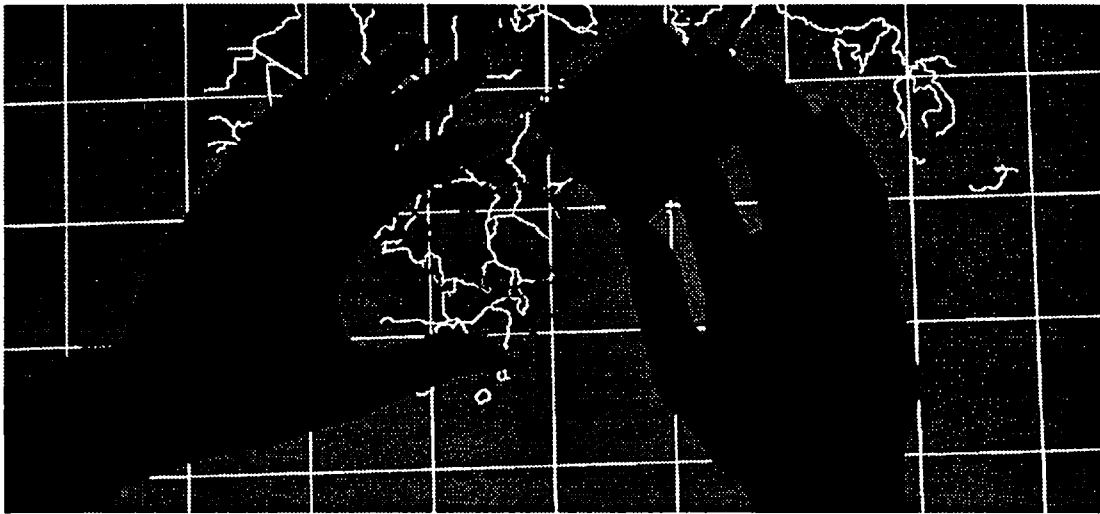
The initial focus of investments in many developing countries is on basic environmental infrastructure, such as equipment for water and waste systems. A significant portion of the total outlay may go for local labor and low-technology components such as concrete and pipe.

In many developing countries, the market for "retrofit" technologies is limited because there is little or no existing industrial and public sector infrastructure. However, this creates the opportunity

to encourage investment in avoidance technologies aimed at preventing environmental harm in the first place. Encouraging such investments by developing countries may require coordinated backing through development banks to provide the appropriate financing, technical assistance, and institution building. Developing countries may exhibit very different demand patterns as their markets for environmental technologies evolve.

"The past 20 years of environmental protection have accomplished a great deal. We no longer have rivers catching on fire. Our skies are cleaner. But many challenges remain. We must develop technologies to prevent pollution, not wait to clean it up. And we must put those technologies to use—both here at home and around the world."

—Carol Browner
Administrator
U.S. Environmental Protection Agency



The highest future growth in demand is expected to occur in Latin American nations such as Mexico, Chile, Argentina, Brazil, and Venezuela, which offer a number of promising markets. Other high-potential markets include China, Republic of Korea, Poland, Taiwan, members of the Association of Southeast Asian Nations, Eastern Europe, and the former Soviet Union.

Evolution to Avoidance

Industry's environmental technology activities can be usefully divided according to four major technology categories—avoidance, monitoring, control, and remediation. (See “Environmental Technology Categories” on the following page.) Each of the categories has a unique structure and is affected differently by government regulations. Dividing the industry into four groups provides a common lexicon for government agencies and the environmental industry.

Precise information on the current size of avoidance, monitoring, control, and remediation activities is difficult to obtain. The data available for industrial activities relating to environmental concerns, in particular for equipment and services, is not nearly as reliable as the information gathered on many other industries. One reason is that no standard industrial codes have been established for the environmental equipment and services industry. Other reasons include the broad scope of the industry, which ranges from activities as disparate as engineering services to hazardous waste cleanup activities; the fact that many environmental firms do business in other industrial sectors as well; and finally the small fraction of environmental firms that are publicly held.⁷ Consequently, most environmental industrial data are collected by private firms, which prefer to focus on product-oriented categories rather than technology-oriented categories.

Control technologies dominate the U.S. environmental marketplace. The second largest area is avoidance technologies. The size of this sector is caused by the large markets that currently exist for resource recovery and environmentally friendly energy. Control and avoidance technologies are followed by remediation, with monitoring comprising only a small percentage of the total market.

An evolution to avoidance technology is underway in the United States, Japan, and Europe. Many firms are experimenting with avoidance practices, and environmental energy sources and resource recovery are projected to be among the fastest-growing environmental technology sectors in the United States. In addition, three factors are encouraging investment in avoidance technologies: new regulatory frameworks in the industrialized countries that emphasize prevention rather than cleanup; new international environmental standards

developed by the International Standards Organization; and economic benefits resulting from efficient manufacturing processes, which are driven by the growing costs associated with hazardous waste disposal, general pollutant liability, and energy costs.

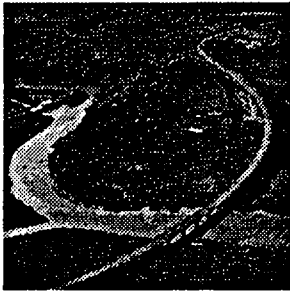
Industry Structure

The environmental technology sector of the U.S. economy, if broadly defined, includes approximately 45,000 firms. The industry is highly diverse; environmental technology companies range from small consulting firms to major multinationals. A few large firms generate approximately half of the industry's revenues.

According to the OECD, this diversity characterizes the global industry as well. A small number of large firms account for approximately half of the total output, and the remainder is attributable to a large number of smaller firms (fewer than 50 employees).

Currently, much of the U.S. industry engaged in environmental activities would not be characterized as "high technology." Most of the equipment that is sold consists of low-technology products such as pipes, filters, containers, and liners. High-technology items include

Environmental Technology Categories



Avoidance

Avoidance technologies avoid the production of environmentally hazardous substances or alter human activities in ways that minimize damage to the environment. These technologies include equipment, processes, and process sensors and controls designed to prevent or minimize the generation of pollutants, hazardous substances, or other damaging materials, as well as technologies used in product substitution or in recycling and recovery of useful raw materials, products, and energy waste streams. These activities usually encompass the use of energy-efficient technologies and clean high-efficiency energy production technologies and practices as well as equipment. They might involve product substitution or the redesign of an entire production process. Avoidance can be achieved by operational changes includ-

ing the use of materials, practices, or procedures that reduce or eliminate waste, or institutional changes including employee training programs, total quality management programs, just-in-time inventories, "green" procurement policies, full-cost accounting, and life cycle analysis. Avoidance may include incremental changes to existing manufacturing infrastructure, such as replacing volatile organic compounds with aqueous cleaning systems, using more efficient motors or lighting, or substituting a less hazardous intermediary. But it may also involve substantial changes in industrial infrastructure, such as near net shape casting, no-coke steel making, or entirely redesigned processes (design for environment). Such extensive changes in production processes usually require development of a new attitude toward doing business. They are labeled with different names in various sectors of the economy. Examples in the manufacturing sector are "design for the environment" or "green design." In agriculture, the descriptive phrase is "sustainable agriculture systems."



Monitoring and Assessment

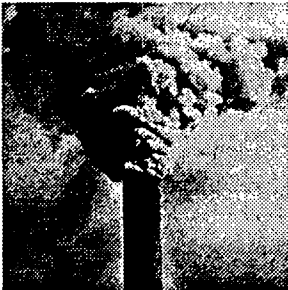
Monitoring and assessment technologies are used to establish and monitor the condition of the environment, including releases of pollutants and other natural or anthropogenic materials of a harmful nature. These technologies include the design, development, and operation of monitoring instrumentation with associated quality assurance and risk evaluation aspects. Monitoring and assessment systems encompass microsensors, chemical sensors, biosensors, space- and aircraft-based remote sensors, ground-based mobile platforms for sensors, sampling services, automation systems for tracking pollutant levels, and advanced techniques for data collection and analysis. These systems may be strategically established to provide information of broad international interest, such as climate change effects on a

instrumentation and a portion of the equipment that is sold for water treatment and air pollution control. The large companies worldwide compete for the markets for these advanced technologies. At present, Japan has the most concentrated high-technology market.⁸

The structure of the U.S. environmental technology industry is likely to change in the future as the industry adapts to the globalization of its markets and the increasing importance of avoidance technologies. However, the nature of this new industry is unclear. For instance, avoidance activities may become increasingly incorporated into the in-house activities of firms predominantly engaged in other industries. Alternatively, firms that are primarily devoted to environmental technologies may provide the bulk of the equipment and services. Important new environmental technologies may originate from existing firms or from small startup ventures.

It is clear that however the U.S. environmental technology industry evolves, it can meet these challenges only if government plays a constructive role. No less than industry, government must adapt to the challenges of globalization and changes in technology. Identifying ways to help the federal government meet these challenges and become a truly supportive partner is the primary purpose of this document.

global or regional scale. They may be very specific, as in the case of a dedicated detector used to ensure compliance by tracking the levels of a hazardous chemical in an effluent. Alternatively, they may also be quite general, as in the case of employing the services of analytical laboratories to assist in identification of pollutants at sites contaminated with an unknown substance.



Control

Control technologies render hazardous substances harmless before they enter the environment. These technologies include the treatment of pollutants or other natural or anthropogenic materials to eliminate or reduce environmental and human health hazards, or the reduction of pollutant/waste material volume or mobility to make subsequent management more effective. An example is the use of precipitators in fossil-fueled power plants to remove particulates from waste gas streams. Subsequent treatment of the pollutants is often required after their removal from the process streams. Another example is the use of catalytic converters on automobiles to convert combustion byproducts to less harmful substances prior to exhausting them. Other control technologies (also called "end-of-pipe" technologies)

include incineration, separation, oxidation, reduction, bioprocessing, adsorption, filtration, and neutralization.



Remediation and Restoration

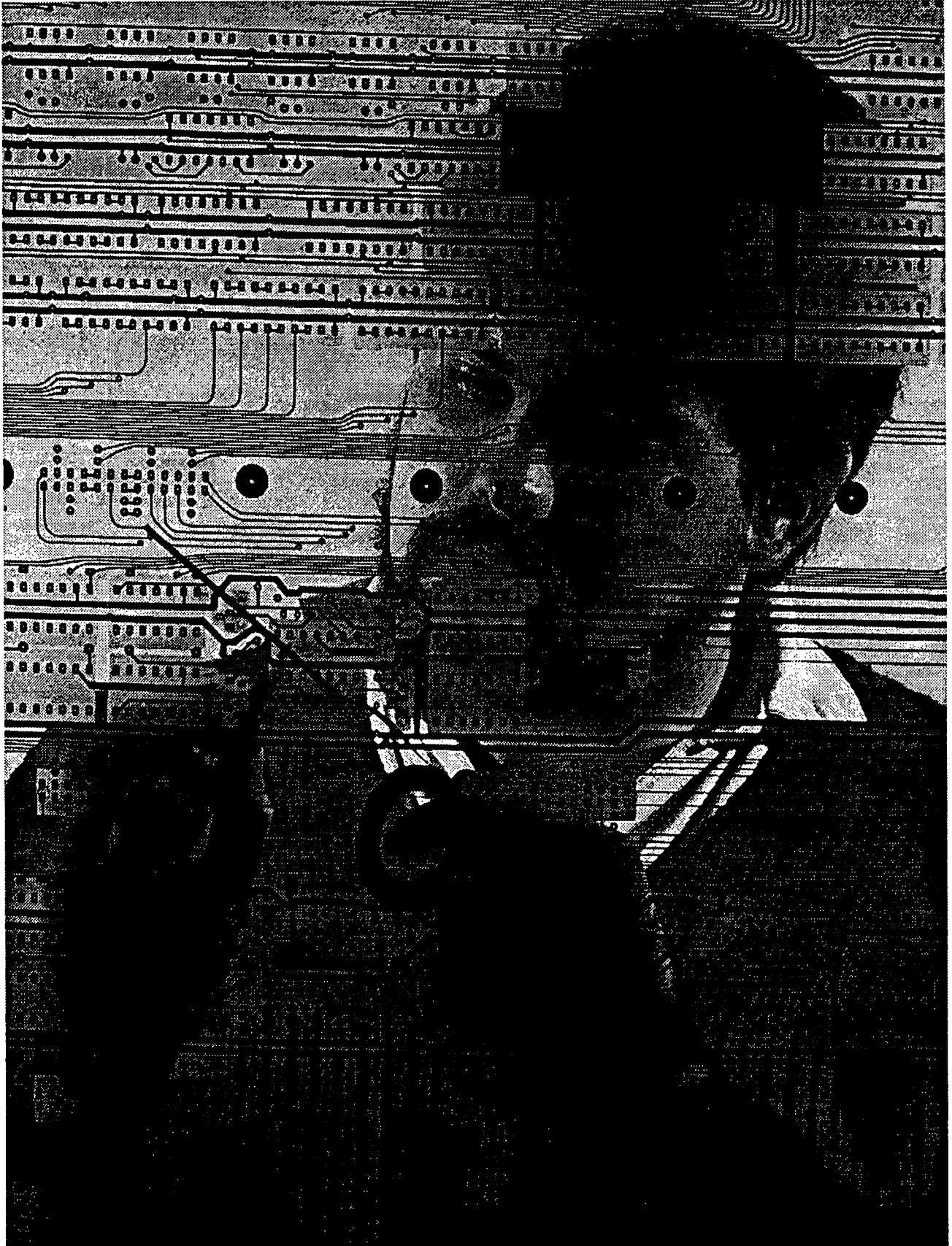
Remediation technologies are those that render harmful or hazardous substances harmless after they enter the environment. These technologies include eradication, encapsulation, and other cleanup technologies that either remove the risks associated with harmful wastes or make them more manageable. An example is the use of bioprocessing to convert polychlorinated solvents found in contaminated groundwater to compounds such as water, carbon dioxide, and salts. Restoration technologies embody methods designed to improve ecosystems that have declined due to naturally induced or anthropogenic effects. As a result, the natural ecosystem processes will be restored and sustained as will their contributions to other ecosystems, human population, and global cycles. Examples include reforestation and

the creation of wetlands and artificial reefs. Ideally, remediation and restoration activities work together to return waste sites to useful purposes. Other examples of these technologies include chemical transformation, incineration, groundwater recharge, soil augmentation, waste extraction, in-situ treatment techniques, and waste stabilization.

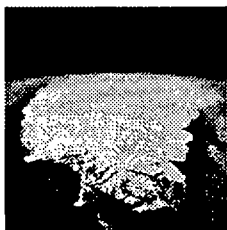
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Part I

Part II

Framework for Advancing Environmental Technology



POLICY PERSPECTIVE



The long-term competitiveness of U.S. industry in the environmental technology area will not be achieved simply by competing on a “technology-by-technology” basis with other countries. We must fundamentally change the way we think about technology, processes, and products and rapidly increase the environmental and resource efficiencies of our entire industrial infrastructure. We must also institute far-reaching changes in the policy framework that fosters technology. We will then be in a better position to deliver advanced environmental technologies to the domestic and global markets of the 21st century.

Other governments are doing a great deal to foster environmental technologies.¹ The European Community (EC), for example, offers advisory programs for locating financial support and provides databanks on environmental market opportunities, standards, and regulations. The EC has several research and development (R&D) programs as well, such as ATHERMIE, which supports projects for the application of new energy technologies that are considered highly risky. Moreover, the EC has established awards for clean technologies, eco-products, environmental technology transfer, recycling, and responsible environmental management.

A number of recent studies have highlighted the need for similar approaches in the United States.² In order to foster a highly competitive environmental industry, the resources of the federal government must be aligned through a policy framework that builds on federal and industrial strengths, corrects inherent weaknesses, and provides appropriate levels of support and technical assistance.

Window of Opportunity



The scientific infrastructure in the United States has been highly successful as an engine of creativity and innovation. It is perhaps the most important reservoir of new ideas that firms worldwide have used to develop new products. A major challenge before us is to turn this flow of new ideas into economic advantage in association with environmental benefits. If we are to create long-term wealth and job opportunities, technological advances must consistently be transformed into economic success.

A unique opportunity presents itself at this moment in history. With the end of the Cold War, we have a chance to rethink the institutions and policies that focused our science and technology on military objectives. We can now pursue a wider range of long-term social, economic, and environmental objectives. A portion of the financial and human resources that were dedicated to defense-related research—presently more than half of our federal R&D budget—can be shifted to the development of environmentally critical technologies.

This window of opportunity opens onto a world in flux. Technological change is being continually affected by the globalization of industry, the increasing scale and specialization

of research, and the fluid nature of financial and intellectual collaboration. We can use these social and political transformations to our advantage if we develop a responsive, flexible, and far-sighted policy and planning framework. In developing this report, we have sought to explore the dimensions of such an approach. Three characteristics of a sound environmental technology strategy are fundamental: a long-range perspective; a focus on anticipation; and integration of technologies, policies, and people.

With the end of the Cold War, we have a chance to rethink the institutions and policies that focused our science and technology on military objectives.

A Long-Range Perspective

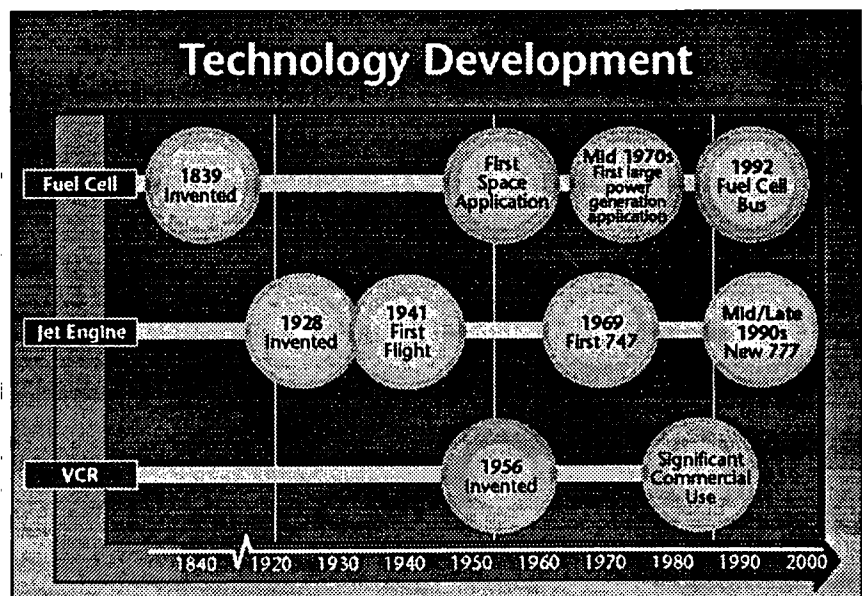
The technology landscape is characterized by incremental changes in products and processes punctuated by breakthroughs that radically alter our lives. Continual competition between "new" and "old" approaches shapes this technological terrain. This landscape cannot be understood, navigated, or managed effectively with short-sighted policies. The long view is absolutely necessary because technologies can take years or decades to travel from initial idea to commercially viable products.

The figure below shows the time horizon required by three familiar technologies to traverse this path. As these technologies developed, they were continually influenced by interaction with other technologies and the general advance of scientific knowledge in areas such as materials, electronics, and biochemistry.

Some sectors of our economy are characterized by even longer time horizons. The shifts in primary energy sources in the United States followed cycles lasting more than 50 years.³ This means that planning for a 21st century sustainable energy infrastructure, with reduced dependence on fossil fuels, must begin now.

The flow of environmentally critical technologies often begins with an idea that is selected for further development and commercialization through an interplay of economic, social, and political forces. The idea is transformed into a technology and eventually into a commodity, which appears many years later on our table, in our garage, or at the nearest shop. This interactive process is continually influenced by our federal and private research, our choice of demonstration projects, our commercialization strategies, our export policies, and our educational system.

Our framework for thinking about environmental technologies should have an upstream focus aimed at the earliest stages of technological development. We should seek to understand the entire development process and integrate this view with policies designed to impact the process at critical points. The first crucial step will be expanding our time perspective to make sure we consider all phases of the process and the linkages. If this is not accomplished, we may ultimately run the risk of sacrificing our long-term competitiveness for short-term gains.



A Focus on Anticipation

A long-term perspective is the precondition for developing technologies that place us ahead of environmental problems and enable the United States to lead the way toward a sustainable global future. Anticipating demographic trends and changes in economic growth, consumption patterns, and technological processes will help us better understand tomorrow's environmental problems and the implications for technology. We must balance the urgent need to address today's environmental issues with the longer-term need to anticipate and avoid future problems.⁴

Accomplishing this will require a new partnership with industry based on a new set of principles. The federal government has relied heavily on environmental regulations to drive the development of environmental technologies. Unfortunately, the regulatory framework

and the technological solutions that result from that framework may lag years behind the environmental problems they were intended to solve. If our goal is to anticipate and avoid future problems, we cannot rely solely on regulatory-driven technology. The federal government should encourage companies to move "beyond compliance," and provide them with the tools and incentives needed for such entrepreneurship. We must facilitate innovation in the private sector through the widest range of cooperative strategies in the key interrelated areas of education, investment, and technology development.

Many pollution controls focus on existing systems of production. Though highly successful, such programs often fail to incorporate long-term trends or anticipate the next "wave"

Recycling Wastewater

Mexico has moved out in front of a potential environmental problem—a water shortage in its capital city. Taking an anticipatory, long-range perspective, Mexico City is now recycling its wastewater for industrial uses.

When the Mexican government opened water utilities to private investment, a consortium of local industries formed a firm, Aguas Industriales de Vallejo, to rehabilitate a municipal wastewater treatment plant. The plant now treats sewage flows for re-use by industry.

This forward-looking approach addresses local issues of rising water prices and untreated wastewater. The treated water is a cost-effective and environmentally sound alternative to industrial use of municipal water supplies.

of material and energy substitutions. As we move into the next century, our strategies should shift from the cleanup of environmental problems to a greater focus on avoiding a new generation of problems. This shift involves moving from what some have termed "dark-green technologies," which are developed to solve particular environmental problems, to "light-green technologies," which are directed at providing environmental benefits. In navigating this transition, we will increasingly move our attention from providing remedies for environmental problems to attacking the sources.

An anticipatory policy framework must create a collaboration between the public and private sectors for environmental excellence. The potential for positive change is at its greatest before companies have made major investments in product development, filed for patents, and calculated their profit margins. A policy and planning framework built on anticipation focuses on products not yet commercialized, processes not yet introduced, and ideas not yet realized. It requires significant public-private sector interactions at the precompetitive stages of technological development when the potential for collaboration is greatest.

An anticipatory policy framework also goes one step further. As we focus on specific environmental technologies, it is important to remember that the broader process of technology development continues, turning out thousands of new products every year. Many of these products may have unplanned and adverse impacts on the environment that we need to address years before such products enter the marketplace. Even the development of so-called green products may be accompanied by significant side effects. For instance, the proliferation of electric vehicles could result in a significant increase in the flow of batteries into the solid waste stream. These batteries must be designed today for disassembly and minimum

toxic impact. They must also be met by a robust recycling infrastructure.

Given the multitude of products and the limited resources for tracking them, we must invest in environmental education. The federal government should use its resources in the areas of education, training, and information dissemination to help instill a desire for environmentally conscious products in consumers and clean production processes in all sectors of our economy: energy, transportation, agriculture, manufacturing, and housing. In addition, we must encourage researchers to consider the long-term impacts of their ideas long before beginning the development process. We must integrate technology with educational policies and create a new generation of environmental scientists and engineers, technicians, and environmentally conscious consumers.

"Previously it's been low-tech or consumer kind of products that have made money in the environmental area. It's now an ascendance of technology—applying advanced technologies—better, faster, cleaner, cheaper technologies to solve environmental and competitiveness problems."

—Jeffrey Leonard
President, Global Environment Fund

Integration of Technologies, Policies, and People

An effective policy framework should look across technologies, across organizations, and across budgets. A narrow focus often misses synergies within our government and between the private and public sectors. The need to bridge institutions is urgent. We need strategies to link scientific, technological, and policy-making communities and to join national and international efforts. Ultimately, the development of green technology must become an integral part of all technology policies and programs.

One important cross-cut must be between the technologies themselves. Historically, one can identify single technologies that have revolutionized warfare, social customs, and economic production. More difficult to discern, but more critical, are points in time when the collision of multiple innovations has resulted in radical technological change. The success of the DC-3 aircraft depended on the integration of five distinct innovations: the variable pitch propeller, wing flaps, retractable landing gear, monocoque body construction, and the air-cooled radial engine. The design and marketing of a useful computer after World War II required the synthesis of a number of technical innovations (the vacuum tube and punch card) with knowledge innovations (binary logic, feedback systems, and a programming language).⁵

Much of U.S. government technology policy is still unidimensional. It is often unable to deal effectively with the intersection of multiple technology tra-

Industry, Technology, and the Environment

*In November 1993, the Office of Technology Assessment, the analytical arm of the U.S. Congress, published **Industry, Technology, and the Environment: Competitive Challenges and Business Opportunities**, the last report in a series of three OTA assessments of American industry and the environment. The 340-page document finds challenges and opportunities for two sets of American industries affected by environmental regulation: the companies that are in the business of making and selling environmental technologies, and the manufacturing firms that are among their major customers.*

The report notes that the years ahead could pose unprecedented opportunities for U.S. environmental firms to expand into new markets as more countries develop or tighten environmental standards. But, at the same time, U.S. companies face strong competition from firms in Europe, Japan, and some newly industrialized countries.

The report concludes that the greatest challenge in the long term will be to integrate environmental concerns into the next generation of manufacturing technologies. Cleaner, more cost-effective production technologies could help U.S. firms lower compliance costs while still meeting U.S. environmental standards.

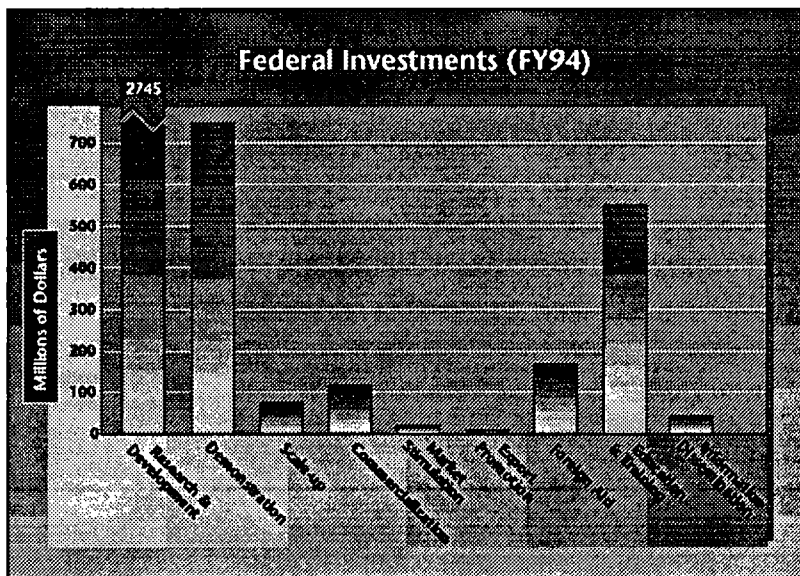
jectories and may miss interdependencies that can determine the success or failure of innovations. This technological compartmentalization is reinforced by the fragmented nature of federal programs and institutions intent on fostering the advance of particular technologies, not systems or clusters of technologies. In the future, our policy and planning framework must integrate innovations that are technologically and economically interrelated. The administration's new initiative to develop a "clean car" is an example of a major step in the integration of multiple technologies for environmental and economic benefit.

Integration of technologies will also require greater collaboration and policy innovation among organizations, both public and private. A significant body of research emphasizes the importance of such "communities of collaboration" in facilitating innovation and shaping technological progress. Too often, technological agendas are developed by single agencies within the government. This often leads to bottlenecks and ineffective handoffs, leaving key technologies "stranded" at a point where they function but are too costly to compete in existing markets. To overcome such problems, we must capitalize on the strengths of federal agencies in key areas such as R&D, demonstration, commercialization, and market stimulation. Through more consistent, integrated, and complementary policies, we must ensure that key environmental technologies find their way from idea to market in the shortest possible time.

The Technology Life Cycle

New technologies flow through a life cycle with inter-related stages that sometimes loop back to previous phases rather than following a linear progression. Idealized, the cycle begins with new ideas fostered by our nation's educational and research infrastructure and developed through synergies created by partnerships. In the case of environmental technologies, the federal environmental policy and regulatory regime plays an important role in stimulating markets, which in turn also function as a catalyst in generating new technologies.

The new technologies then go through a process of research and development, prototyping, small-scale and then full-scale demonstrations, early commercialization, scale-up, and finally national and international marketing. Investment, information dissemination, domestic market promotion, and export promotion and assistance play essential roles at various stages of the technology life cycle.



The federal budget for environmental technology is currently focused on the front end of the continuum—technology development and demonstration—with little funding, in comparison, directed to commercialization, market stimulation, information dissemination, or export promotion. The large investment in education and training is primarily due to USDA activities in this area.

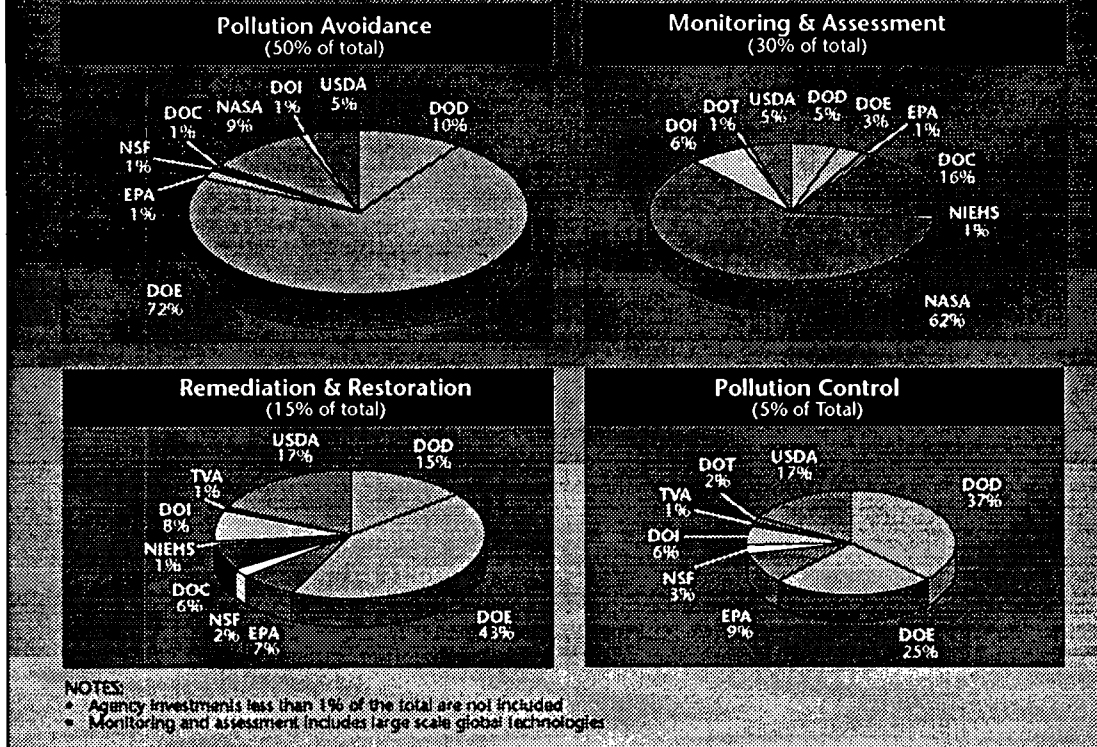
The Federal Environmental Technology Budget

Cross-cutting analyses of expenditures on environmental technologies are useful in order to locate potential redundancies and shortfalls. Because of the dispersed nature of U.S. research and development, integrated overviews are extremely difficult to produce. In preparing this report, however, a budget analysis of federal expenditures for environmental technologies was undertaken with the following results.

The federal budget for environmental technology programs is more than

1994 Federal Budget Estimates

for Research & Development and Demonstration



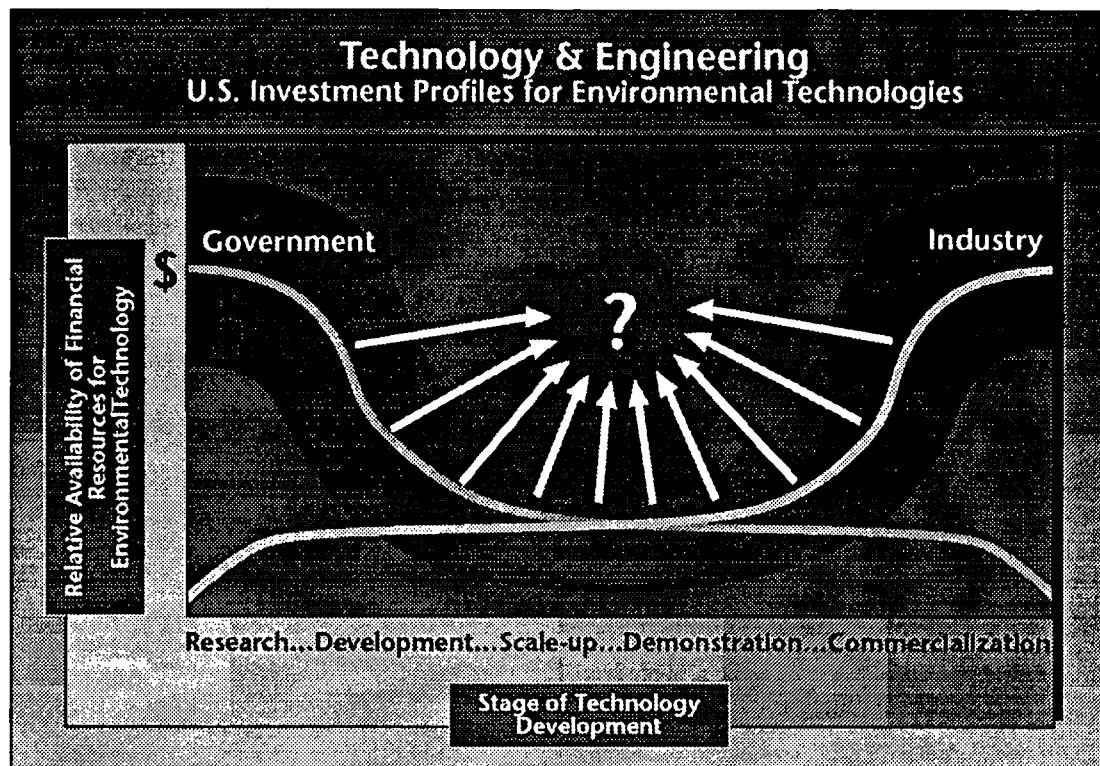
Federal funding for research, development, and demonstration of environmental technology is more than \$4 billion annually. Approximately one half of that is in the area of avoidance technologies, due largely to the energy efficiency and clean energy programs at the Department of Energy. Monitoring and assessment technologies account for the second largest investment, due to the large programs for development of space, aircraft, and ground observational technology designed to monitor the state of the environment.

\$4 billion annually. These programs are primarily focused on the front end of the continuum—technology research, development, and demonstration—with little funding, in comparison, directed to commercialization, market stimulation, information, or export promotion. (See the figure on previous page.) However, in recent years, funding for these areas has been growing.

Avoidance technologies account for approximately 50 percent of federal funding for R&D and demonstration. The energy efficiency and clean energy programs at the Department of Energy (DOE) account for more than 70 percent of these dollars. The Department of Defense (DOD) also funds a significant portion of avoidance technologies with programs that support industrial process changes and material substitutions. Other R&D and demonstration programs in this area include Department of Agriculture (USDA) programs to reduce pesticide and fertilizer use, Environmental Protection Agency (EPA) work in life cycle analysis and clean technology substitute assessment, National Aeronautics and Space Administration (NASA) efforts to develop technologies to reduce engine emission and noise pollution from aircraft, and National Science Foundation (NSF) projects to develop biodegradable materials.

Monitoring and assessment account for approximately one-third of federal spending for environmental technology R&D and demonstration. This high proportion is largely due to sizable programs for development of space, aircraft, and ground observational technology. Examples of these programs, which are designed to monitor the state of the environment, include NASA's Mission-to-Planet-Earth technology R&D program, which includes instrumentation in aircraft and earth-orbiting spacecraft systems to monitor global environmental changes and the Earth Observing Data Information System to provide access to the data for environmental change research, and the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) work to support national networks such as weather service observations and systems, tide gauges, and the national geodetic reference systems.

Government funding for environmental technologies peaks at the research stage, whereas private sector spending is greatest at the commercialization stage. The shortfall at the scale-up and demonstration stages suggests a need for increased integration of public-private efforts.



NASA's budget includes the development of NOAA's weather satellites. Other monitoring and assessment technology funding includes the DOE's sensor technologies; the USDA's ultraviolet radiation monitoring technologies and forest health inventories; EPA's research on technologies to monitor indoor air pollutant exposure, water effluents, and air emissions; and NSF resources for advanced optical and radar sensors for remote sensing.

Control technologies account for only 5 percent of the federal funding for environmental technology R&D and demonstration. Included are DOE programs for controlling pollution from fossil fuels, DOD technology development programs that focus on new efficient equipment and procedures for complying with environmental regulations, and USDA technology programs for reducing pollution through processes that limit the application of chemicals in food and fiber production.

Remediation and restoration technology funding is approximately 15 percent of federal environmental technology R&D and demonstration dollars. DOE programs, which fund more than 40 percent of the work in this area, include remediation of high-level waste tanks; contaminant plume containment and remediation; contaminated soils and buried waste; mixed waste characterization, treatment, and disposal; and facility transition, decommissioning, and final disposal. DOE, along with DOD, have a particular interest in remediation and restoration technologies because of their sizable task involved in cleaning up toxic contamination at their facilities. The USDA also has a substantial program that includes technologies to improve degraded lands and develop biological means to generate wood pulp and degrade wood preservatives. At EPA, resources are used for research in areas such as bioremediation technologies for cleaning up toxic wastes.

Federal funding in post R&D and demonstration areas, while small by comparison with R&D, has been increasing in recent years. Commercialization programs such as the DOD Advanced Research Projects Agency's Technology Reinvestment Program that invests in technologies such as electric and natural gas vehicles and the Department of Commerce's National Institute of Standards and Technology program that invests in environmental technologies aimed at reducing waste in polymer processing and other manufacturing-specific technologies are part of this trend.

There is a substantial federal investment in certain areas of education and training related to environment technology, primarily funded through the USDA Soil Conservation Service's land treatment programs, the Forest Service's Natural Resources Conservation Education Program, and Extension activities that provide training in water quality, pest management, renewable resources, and sustainable agriculture.

The United States spends from \$100 to \$175 million on foreign aid related to environmental technology, mostly through the Agency for International Development. Approximately two-thirds of this funding supports projects in Eastern Europe and the former Soviet Union, and more than half of the total expenditure is directed to the development of technologies to improve energy efficiency.

Government funding is only part of the picture. The private sector provides the bulk of the total investment in development, commercialization, and export of key environmental technologies. Although precise breakdowns are unavailable, emerging evidence indicates that private funding levels vary significantly across key stages of the technology life cycle.⁶ The figure on the previous page illustrates the point at which capital investment from the private sector is low. The private sector investment shortfalls coincide with those in federal funding.

A Commitment to Participation

The development of a long-range, anticipatory, and cross-cutting policy framework will ultimately impact the way we will define our technological choices in the future. We must rely less on our system of defense-related R&D to help supply the technological needs of the civilian sector.

We recognize the need to explore ways of reaching a broad social consensus about our goals and our technological strategies for achieving them. Other countries are already doing this. The Danish government's Technology Board convenes panels of citizens from various backgrounds in a "consensus conference" to discuss the pros and cons of emerging technologies.⁷ Similar models have been implemented in the Netherlands. It is useful to examine these efforts and develop ways to inform and involve a wide range of citizens in our technology debates. A democratic collaboration on environmental technologies will require a high degree of technological literacy on the part of our citizens and openness on the part of government.

The following pages outline potential policy initiatives to advance environmental technologies. The administration has made a commitment to use technology to "make a difference in the lives of the American people."⁸ We look forward to a dialogue that will lead to a long-term strategy that will ensure that future technological progress is consistent with societal needs and values.

To simplify present and future discussions, we have broken the technology life cycle into a four-part multidimensional analysis that is explored in the coming chapters:

- *Facilitating innovation:* research and development and demonstrations;
- *Encouraging new approaches:* regulatory policy, market stimulation, and fiscal policies;
- *Engaging the world:* international commerce and foreign aid and development assistance; and
- *Learning and working together:* partnerships, education, and information dissemination.

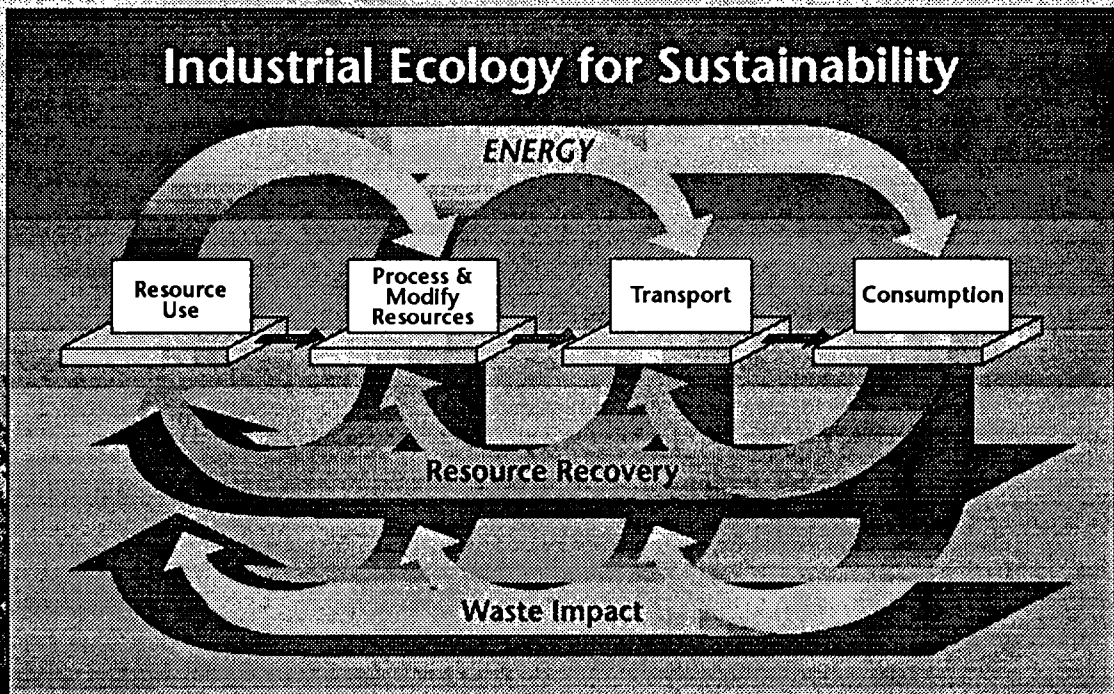
"Industrial ecology contemplates not just the remediation of isolated environmental insults, but the re-engineering of the Industrial Revolution to provide the technological basis for a long-term, stable, and sustainable economy."

—Brad Allenby
Research Vice President, AT&T

The New Paradigm: Industrial Ecology

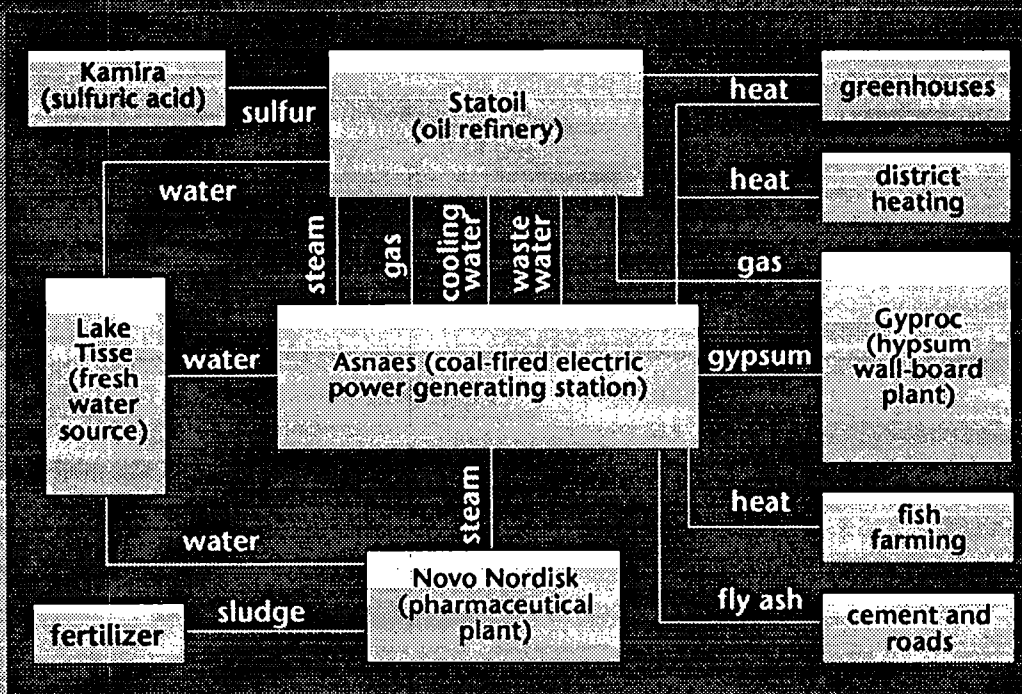
Industrial systems can be compared with natural ecosystems in which plants consume minerals, water, and sunlight, and in turn are consumed by other organisms in interdependent processes that include production of wastes. The industrial ecosystem operates much the same way, consuming resources and producing wastes.

As with natural ecosystems, when industrial systems are small, resources and waste sinks are often considered infinite (and free). But as the relative size increases, resources become more limited (and therefore more valuable). Industrial ecology recognizes this shift and accordingly adopts a no-waste or low-waste approach. In-stream recovery and reuse of materials are crucial tenets of industrial ecology and of the new paradigm of environmental technology. In this new paradigm, environmental considerations are incorporated into all aspects of product and process design, and technology plays a more active and positive role in achieving sustainable development.



Industrial ecology is the study of a closed loop in which resources and energy flow into production processes, and excess materials are put back into the loop so that little or no waste is generated. Products used by consumers flow back into production loops through recycling to recover resources. Ideally, the loops are closed within a factory, among industries in a region, and within national and global economies.

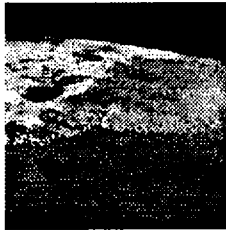
One City's Approach to Industrial Ecology Kalundborg, Denmark



Source: Novo Nordisk

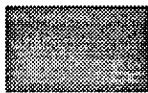
In the city of Kalundborg, Denmark, an experiment in industrial ecology has been evolving for the past 30 years. It involves the reuse of energy and materials by five partners. A refinery provides gas to a power plant and plasterboard company for their energy needs, and the steam from the power plant is passed to a biotechnology company and into a district heating system of the city. Lower temperature energy goes to an experimental fish farm, and the power plant's desulfurization unit produces gypsum that is used by the plasterboard company. By reusing energy and materials, this industrial "ecosystem" is saving 19,000 tons of oil, 30,000 tons of coal, and 600,000 cubic meters of water annually. Yearly savings are estimated at \$12-15 million.

FACILITATING INNOVATION



Successful technological innovation is dependent on an interconnected system of institutional structures, including research and development (R&D) activities, demonstration, regulatory policies, the industrial infrastructure, and tax policies. Every component is critical to the commercialization of innovative technologies. In this chapter, we will look at the government's role in encouraging R&D and demonstration activities in order to foster environmental technologies.

Research and Development



The scope of environmental issues exceeds the capacity of individual institutions or nations to resolve them. Coordination of environmental technology R&D efforts among federal and state agencies, academia, and the private sector is vital to leveraging scarce resources and dealing comprehensively with environmental challenges. The federal government can help by articulating long-term goals and creating a climate in which environmental technology can flourish.

The selection of technologies for R&D is both a bottom-up and top-down process. In the case of fundamental environmental and engineering research, investigator-initiated studies are dominant. Applied research is often driven from the top down, with the objectives defined by the regulatory regime and legislative initiatives, the missions of federal agencies, and industry strategic planning.

Little information is available regarding spending on research and development of environmental technologies by private industry in the United States. However, a report from the Organization for Economic Cooperation and Development provides some indication.

The environmental market is increasingly technology-driven, indicating that suppliers must make continuing large research and development expenditures. The large multinational environment companies are most R&D intensive, spending 8 to 10 percent of turnover on research, while smaller firms in lower-technology environmental sectors may spend less than 2 percent of turnover on research and development. German and U.S. firms have been leaders in basic research on environmental technologies, while Japanese firms have conducted relatively less research to date and have even developed some air pollution control technologies based on German patents.¹

Federal Role

Historically, the need for new technologies to solve environmental problems has been inadequately recognized, and the government's role in encouraging environmental technologies has been underdeveloped.² Traditionally the federal government has chosen to support

basic and mission-driven research and to leave the development and application processes largely to industry.³ Today, diverse policy measures are required, as well as a more active federal government role in promoting technological advance in partnership with private industry.

The President established the National Science and Technology Council (NSTC) in November of 1993 "to establish clear national goals for federal science and technology investments and to ensure that science, space, and technology policies and programs are developed and implemented to contribute effectively to those national goals." Chaired by the President, and including the Vice President, the Assistant to the President for Science and Technology, and the cabinet secretaries and agency heads with responsibility for significant science and technology programs, the NSTC has nine committees charged with reviewing the entire federal research and development budget, setting long-term priorities, and ensuring that federal programs are appropriately coordinated. Environmental technology is one of the NSTC's key areas of interest.

There are many positive features of the existing federal support system for technology development. The federal government has helped advance environmental technology through its support of research and development at universities and government laboratories.⁴ Significant technical assets—personnel and facilities—are available throughout the federal government. Other strengths of the current system include excellent intellectual connections between sectors—fostered by interactions at scientific meetings and other forums—and high labor mobility that enhances cross fertilization.

Less than 10 percent of all U.S. investment in environmental technology innovation is directly attributable to federal and state agencies. However, several agencies, including the Departments of Defense, Energy, Interior, Agriculture, and Commerce, National Aeronautics and Space Administration, and the Environmental Protection Agency, do devote significant technical resources to direct funding of environmental technologies. The government's investment in technology development and demonstration spans all categories of environ-



Innovative Cleanup on Cape Cod

Wildlife has returned to a polluted pond on Cape Cod, thanks to cleanup by wind-powered rafts. The rafts take up contaminated sludge from the pond floor. The contaminated sediments are filtered through plants on the rafts, which remove the toxic substances and break down many of them.

In the pilot project a pond, polluted by toxic substances leached from a landfill, was treated and is showing signs of recovery.

The conventional technology for this type of contaminant removal is invasive and expensive. Traditionally, sediments are dug up and landfilled in hazardous waste sites. Ocean Arks International won an award from the Environmental Protection Agency for this innovative alternative to conventional technologies.

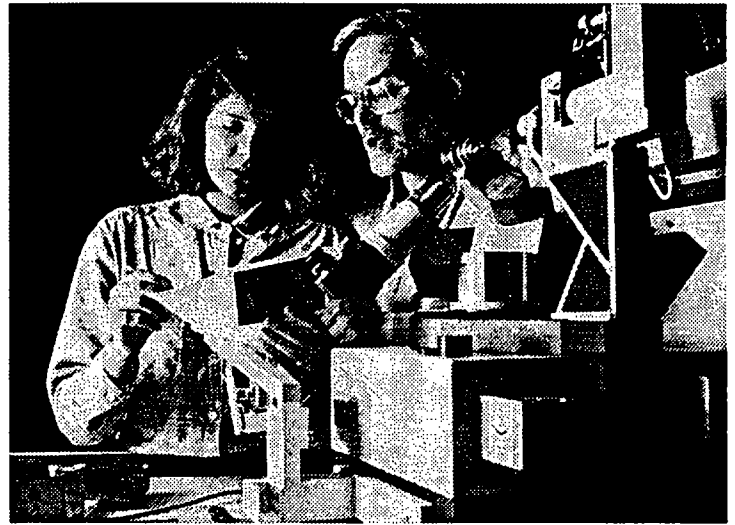
mental technologies, including avoidance, monitoring and assessment, control, and remediation and restoration.

The Department of Energy manages a large proportion of the nation's civilian science and technology development resources, consisting of 9 multi-program laboratories, 11 single-program laboratories, and 11 specific-mission laboratories. This system includes 23,000 scientists and engineers and a wide range of special-user facilities critical to U.S. industry's global competitiveness. By the National Competi-

tiveness Technology Transfer Act of 1989 and other recent legislative initiatives, transferring technology to industry is one of DOE's primary missions. As an integral part of DOE's Technology Transfer Strategic Plan, the scientific resources and facilities of the national laboratories are accessible and encouraged to assist in private sector research and development.

The Environmental Protection Agency (EPA) has five laboratories conducting R&D activities that have an impact on the development and demonstration of environmental technologies: Atmospheric Research and Exposure Assessment Laboratory in Research Triangle Park, NC; Environmental Monitoring Systems Laboratories in Cincinnati, OH, and Las Vegas, NV; Air and Energy Engineering Research Laboratory in Research Triangle Park, NC; and Risk Reduction Engineering Laboratory in Cincinnati, OH. Development of regulations for the major environmental laws administered by EPA plays a key role in environmental technology demonstration. In addition, technical assistance activities carried out by most program and regional offices within EPA affect technology development by industry.

The Department of Commerce (DOC) performs an important function through the National Institute of Standards and Technology. The NIST's laboratory-based research pro-



grams encompass the entire range of environmental technologies, especially in connection with standards and measurement methods.

The Department of Defense (DOD) has the potential to play a key role in environmental technology demonstration and testing, given its experience in technological development for military purposes. For example, the Advanced Research Projects Agency is coordinating the

"Our expertise in environmental technologies creates a natural competitive edge for the United States. Now is the time to seize the lion's share of this market."

*—Hazel O'Leary
Secretary of Energy*

interagency Technology Reinvestment Project, which has proven to be very successful. DOD facilities will be used increasingly as demonstration sites for environmental technologies.

Agencies of the Department of the Interior (DOI) conduct laboratory-based research and demonstration programs on environmental technologies that affect mining and other extractive processes. The National Aeronautics and Space Administration (NASA) devotes significant resources to development and demonstration of space- and aircraft-based remote sensing technologies through its field centers, laboratories, and distributed data access and archive centers. The U.S. Department of Agriculture (USDA) laboratories conduct research in avoidance, control, and remediation technologies. The Department of Transportation (DOT) is promoting the advancement of technologies that will minimize impacts on the environment. And the National Science Foundation (NSF) supports engineering research through its grant programs.

Research and Development: Strategic Directions

The administration's technology strategy, which defined for the first time a post-Cold War technology policy, articulated the following broad goals:⁵ support R&D to stimulate long-term economic growth, create jobs, and protect the environment; support research and technologies that make government more productive and responsive to the needs of citizens and industry; and maintain world leadership in basic science, mathematics, and engineering.

With these overarching objectives as the starting point, federal agencies will pursue three strategic directions for fostering R&D to advance environmental technologies.

- Appropriately balance avoidance, monitoring, control, and remediation technologies, stressing the need for a shift toward technologies that emphasize sustainable use of natural resources and prevention of environmental harm while still maintaining our commitment to remediate past environmental damages.
- Focus federal R&D support on viable technologies that require support to attract private-sector investment because of high technical risk, long payback horizons, or cases where the anticipated returns are not evident to individual firms or distinct industrial sectors.⁶
- Foster international cooperation on understanding, monitoring, and assessing environmental changes and impacts on a global or multinational scale.

Research and Development: Current Initiatives

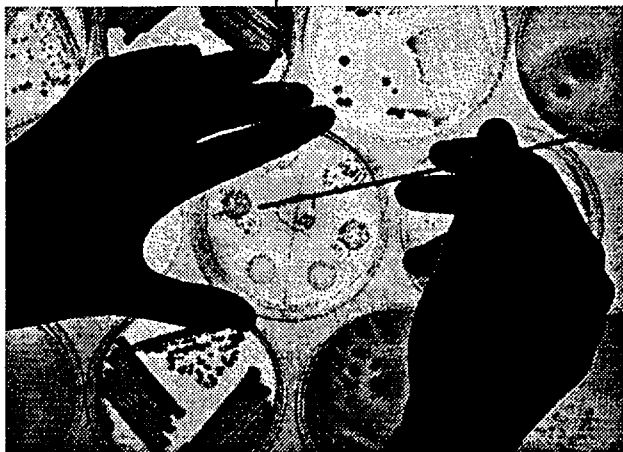
- The administration has launched an interagency Environmental Technology Initiative, coordinated by the Environmental Protection Agency, that is designed in part to leverage private sector funding to promote the development of environmental technologies.
- The administration has substantially expanded the Department of Commerce's Advanced Technology Program to spur industry's development of high-risk, high-payoff commercial technologies.
- The administration launched the Technology Reinvestment Project through the Department of Defense's Advanced Research Projects Agency, the largest multi-agency technology program ever conducted by the federal government. One component of the program is directed to creating new technologies with the potential for commercialization within five years. Environmental technology projects won a significant portion of the most recent set of awards.
- The EPA is strengthening its collaborative efforts with state environmental agencies to support technological innovation.
- A National Biological Survey was created within the Department of the Interior with R&D components in mitigation technology to determine the effects of nonindigenous species on native plants and animals and to develop methods to prevent the introduction of nuisance species into the nation's ecosystems.
- The Department of Energy has revamped its science and technology budget priorities to dramatically increase funding for research and development programs related to energy efficiency, renewable energy, natural gas, alternative fuels, and technology transfer with the private sector.
- The Department of Energy is providing grants under the Small Business Innovation Research competitive grants program to support phased research and

development on advanced concepts and technologies related to energy and the environment.

- The administration has substantially expanded the Department of Energy's Natural Gas Strategic Plan. The plan represents the first credible, long-term federal R&D effort for natural gas. The Natural Gas Strategic Plan focuses on strategic opportunities in end-use markets such as ultra-high-efficiency utility gas turbines, fuel cells for both industrial and automotive applications, and natural gas vehicles.
- The Departments of Defense and Energy are establishing an Interagency Environmental Technology Office to coordinate R&D and technology transfer activities and facilitate collaboration among themselves and other federal agencies.
- The Department of Transportation is sponsoring an extensive research program on the potential for transportation technologies, such as the Intelligent Vehicle Highway System, to advance environmental quality.

Research and Development: Possible Next Steps

- Use the National Science and Technology Council to formulate an integrated interagency technology portfolio that can move toward prevention-oriented technology and can respond to the R&D needs of the nation for addressing the fast-paced growth of the environmental technology industry.
- Consider providing additional support for the development of environmental technologies through public-private technology partnerships. Focus on R&D projects at a precommercial stage of development that have generic applicability and a potentially high social and environmental payoff.⁷
- Build environmental concerns into ongoing government R&D programs by developing new criteria for awarding grants and for justifying intramural federal programs.⁸



- Consider mobilizing a greater proportion of the resources of the federal laboratories to develop environmentally critical technology, and make mandatory an explicit environmental technology component to the technology transfer programs of federal laboratories.⁹
- Evaluate approaches to cooperative R&D to foster a long-term perspective, improve efficiency, address problems of generic applicability, and increase R&D resources among small- and medium-sized firms.¹⁰ Consider providing a forum for cooperation (e.g., cooperative centers) with the private sector; creating intermediary institutions that facilitate technology transfer between the private and public sector or

among private firms; and establishing R&D consortia devoted exclusively to development of environmental technology.

- Develop joint industry, government, and university models that integrate industry-driven expressions of environmental technology needs, joint R&D activities, and government support of high-risk demonstrations.
- Direct more attention to sustainable community development by working to advance environmental systems technologies applicable to domestic and international urban centers.

Demonstration

The necessary link between R&D and commercialization of a new technology is demonstration, or the testing and evaluation of a technology to show that it can meet necessary standards and perform adequately for the purpose for which it was designed. Testing and demonstrations are essential for determining the useful range of performance of innovative technologies and their potential to solve environmental problems.

Impediments to Demonstration

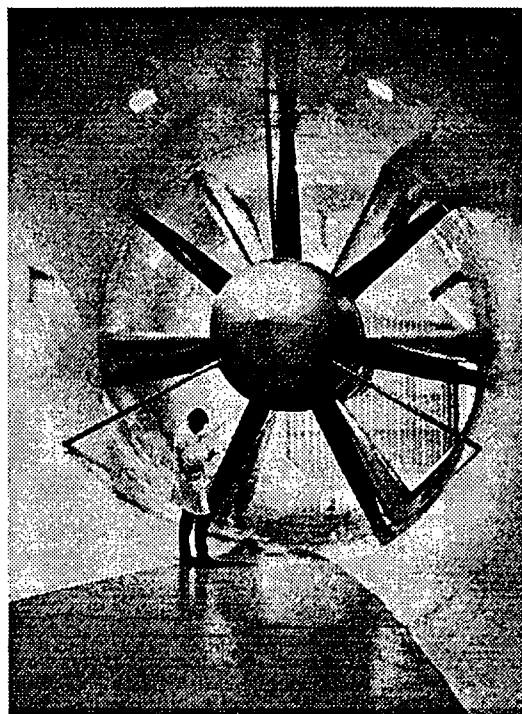
A significant barrier to commercialization of environmental technologies is lack of funding for demonstration activities. These funding shortfalls are attributable to the perceived risk of investing in demonstrations. The challenges include predicting the performance of a technology and, in many cases, forecasting its ability to gain regulatory approval. Despite engineering successes, financial risks remain high because the value of many technologies depends on applicability as determined by regulatory processes and markets. Most innovations trigger regulatory oversight during the R&D or demonstration processes, and all require regulatory approvals before being employed for compliance purposes.¹¹ Financial risks can be carefully evaluated only after a technology is fully developed, full-scale demonstrations are completed, and the technology has received a permit for commercial use as being in compliance with environmental regulations. Innovators often find that these uncertainties prevent them from attracting the large infusion of capital they need to conduct full-scale demonstrations.

The figure on page 22 illustrates the saddle point at which funding needs are high but remain unmet. In the early stages of development, prior to full-scale demonstration, financing needs for innovation are high but generally available. However, a Catch-22 situation arises once full-scale demonstrations are needed. The financial community is reluctant to invest in technologies in the absence of a proven market. Without full-scale demonstrations of reliability and compliance under a number of conditions, technology cannot be marketed. Credible performance data and permits for use are lacking. But full-scale tests require substantial financial investments.

Permitting

Developers of environmental technologies must obtain permits to test and evaluate new technologies. The amount of time needed to complete the permitting process is difficult to predict. As a result, estimating how much investment will be required is problematic.

Media-specific environmental statutes often do not provide for a viable permitting process for testing innovative technologies. Existing permit and admin-



Resins for Water Purification

A federal investment in environmental technology has paid off with a new resin for removing pollutants from water. The resin binds to nitrates when water passes over them during ion exchange treatment. Most resins release the nitrates back into the water being purified.

The new resin was developed through a cooperative agreement sponsored by the Environmental Protection Agency's Risk Reduction Engineering Laboratory. Exclusive rights to the EPA patent on the resin were recently granted to Boyle Engineering, Inc., of McFarland, California. The process is already in use in more than a half dozen full-scale water treatment plants and is expected to be widely used in the future.

Eco-industrial Park

The Environmental Protection Agency is establishing a prototype for an eco-industrial park on the Mexican border. The objectives are to design and develop an environmentally sound industrial park that creates jobs and advances state-of-the-art technology innovation; to provide a forum for piloting flexible, cost-effective approaches to meeting environmental standards mandated by law; to demonstrate in practical terms the principles of sustainable development; and to provide a setting for new approaches to prevention technologies for export to other nations.

istrative processes related to testing and demonstration lack sufficient flexibility for evaluating the performance of promising technologies under safe testing conditions and across the full range of operating conditions.

Permit procedures can magnify the time, cost, and range of testing. For example, the Clean Air Act and the Clean Water Act, as currently interpreted, contain no specific provision for testing and demonstration permits. Neither statute recognizes the unique nature of testing and demonstration, and tests conducted

in accordance with these statutes are implemented under ad hoc mechanisms. The Resource Conservation and Recovery Act does have a statutory provision for testing permits, but the provision has been narrowly construed and is seldom used.¹² Regulatory inconsistency across federal, state, and local governments further complicates the permitting process.

Test Sites

Most tests are conducted on a small scale in research laboratories because of the current lack of satisfactory and non-technology-specific demonstration sites. In a number of instances, full-scale testing is performed at existing industrial facilities that have been issued a permit for a given procedure or process. Such testing is typically limited to technology developed by the company or agency owning the site. Since no regulatory waiver of liability or compliance is provided, this type of testing is limited.

Testing must be performed at all scales before technology designs can be optimized and reliability determined. Consequently, the lack of testing opportunities acts as a significant barrier to development and commercialization of promising technologies.



The capacity to test and demonstrate technologies varies from state to state, and data developed in one state is often not usable in another. For this reason also, lack of a functioning and predictable process for testing and demonstration constitutes a serious limitation to the development of environmental technologies in the United States.¹³

Verification

Within the environmental industry, agreement is widespread regarding the need for verification procedures. Without verification that a technology complies with environmental regulation, there is little incentive to purchase it. The enforcement penalties for noncompliance eliminate any possibility of sales unless credible data exist on the performance of an innovative technology over the range of operating parameters. Equally essential, verification opens the door to investment capital and provides performance data for sales promotions once the product is marketed.

Competitive Disadvantage

If the constraints that impede movement through the technological pipeline in the United States are not resolved, many innovations will remain unfunded or be sold to foreign competitors for development. The absence of an adequate regulatory and administrative process for testing and demonstrating environmental technologies severely restricts the competitive position of the United States.¹⁵

Demonstration: Strategic Directions

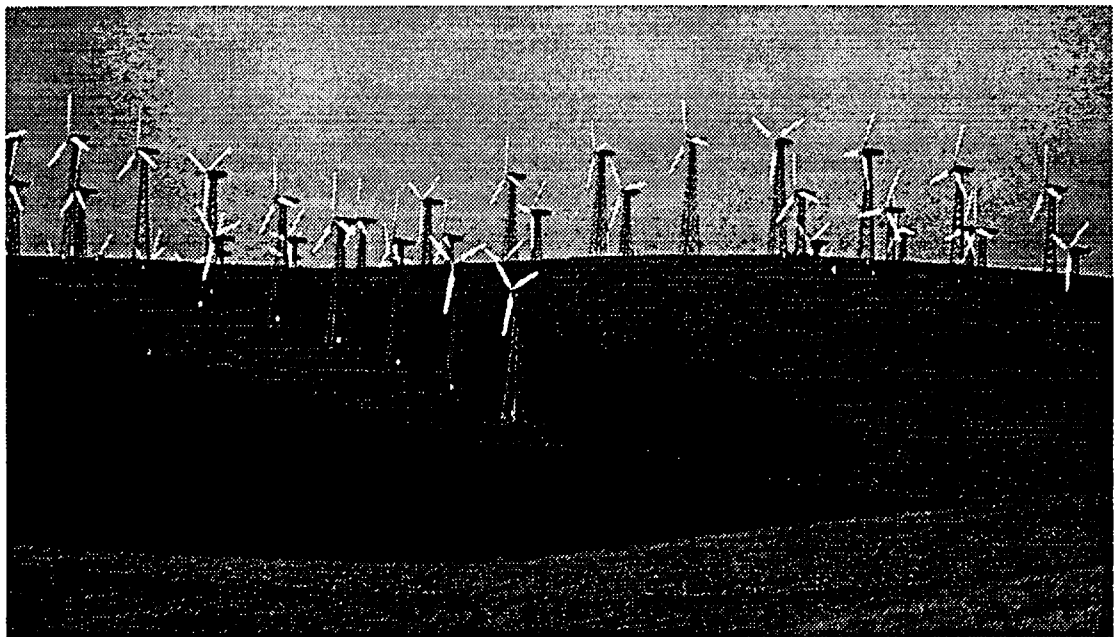
In order to assist developers of innovative technologies, federal agencies will pursue three broad objectives for facilitating the testing and demonstration process:

- Standardize approaches to evaluating innovative technologies to ensure the acceptability, quality, comparability, and transferability of performance data. Use these approaches to establish a verification program for environmental technologies.
- Increase the availability of specialized government facilities so that private industry can take advantage of controlled settings where tests can be conducted safely over a wide range of operating conditions.
- Increase the accessibility of human resources within federal laboratories and establish new procedures and criteria for the use of national facilities and personnel.

Demonstration: Current Initiatives

- A joint federal and state partnership among the Departments of Energy, Defense, Interior, the Environmental Protection Agency, and 20 western states was created in 1992 through an agreement with the Western Governors' Association. The Federal Advisory Committee to Develop On-Site Innovative Technologies, or DOIT Committee, has been established to help implement a five-year cooperative agreement to address technical, training, financial, regulatory, and institutional barriers to innovative technology development in environmental management.

- As part of EPA's U.S. Technology for International Environmental Solutions program under the Environmental Technology Initiative, EPA and other federal agencies will demonstrate U.S. industrial avoidance, control, and remediation technology in Asia, Central and Eastern Europe, Mexico, South America, and other regions.
- The Department of Defense has established the Environmental Security Technology Certification Program to demonstrate and validate innovative dual-use environmental technologies on current and former Department of Defense bases and facilities in cooperation with local and regional regulators and stakeholders.
- The Committee on Renewable Energy Commerce and Trade, an interagency working group of 14 federal agencies, is facilitating the cost-effective use and demonstration of U.S. renewable energy products and services around the world. This program is a strategic partnership between the U.S. government and U.S. industry to finance renewable energy projects worldwide through the Financing Energy Services for Small-Scale Energy-Users (FINESSE) project. Currently FINESSE projects are underway in the Caribbean, Pacific Basin, Mexico, India, Latin America, and Eastern Europe.
- Under the Strategic Environmental Research and Development Program, the Department of Defense recently established the National Environmental Technology Test Site Program to assist in the development of innovative remediation technologies. This initiative will allow new technologies to be compared side by side, using standardized data collection and analysis techniques.
- Clean Cities is a market-driven initiative developed by the Department of Energy to promote the use of alternative fuels and assist in the implementation of the Energy Policy Act. The program works by establishing partnerships between federal, state, and local governments and the private sector, including



utilities, fuel suppliers, fuel distributors, auto manufacturers, and organizations committed to acquiring alternative-fueled vehicles for their fleets.

- The Department of Energy's Clean Coal Demonstration program provides the technical, environmental, economic, and operational data needed by the private sector to make sound decisions about using innovative environmental technologies. The bulk of the expenditures in the program are for demonstrating advanced low-emitting, high-efficiency power systems.
- The National Industrial Competitiveness through Energy, Environment, and Economics program, jointly administered by the Department of Energy and the Environmental Protection Agency, is promoting and demonstrating technology innovations that simultaneously improve energy efficiency, reduce waste generation, and increase economic competitiveness and productivity.

Demonstration: Possible Next Steps

- Identify locations for federal facilities with suitable equipment and personnel to test and demonstrate technologies developed by the government and the private sector.
- Consider expanding the use of pre-competitive technology cost-shared grant programs such as the Advanced Technology Program and Technology Reinvestment Program to encourage increased industry activity in technology demonstration.
- Consider organizing systems-level demonstrations, in partnership with industry, of key technologies.

ENCOURAGING NEW APPROACHES



A number of avenues are available to the federal government for encouraging markets for environmental technologies. Historically, environmental regulations have had the strongest impact, but consumer labeling, government procurement, and fiscal policies are among other important mechanisms. Stimulating a dialogue on policies in each of these areas is one of the most important steps in advancing environmental technologies.

Regulatory Policy

 Markets for environmental technologies are shaped, stimulated, and at times inhibited by environmental regulations. The United States has the most stringent regulatory and compliance framework in the world, which has resulted in strong, comprehensive environmental protection programs. As we look to the future, however, we must find ways to increase the flexibility of our regulatory structure so that it functions to encourage greater innovation.

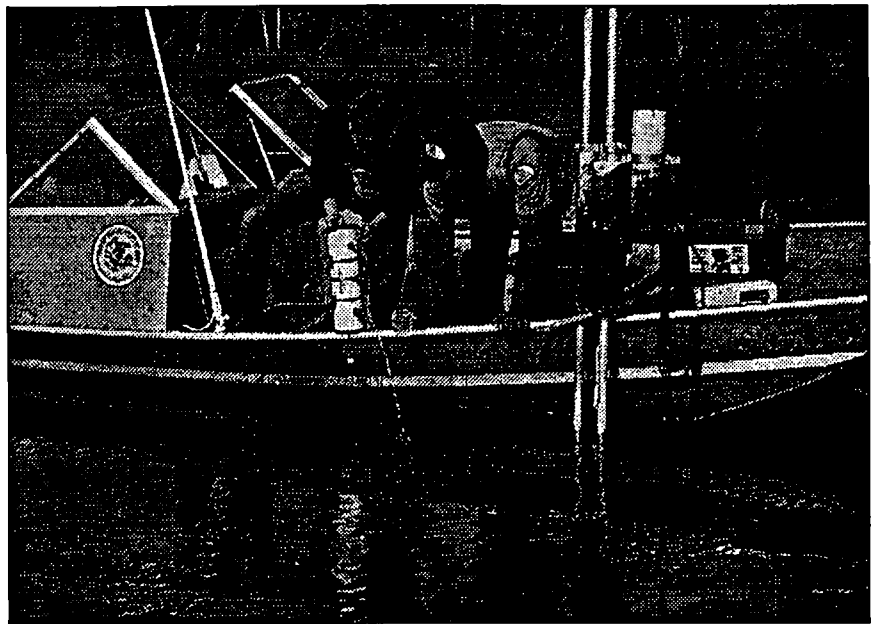
Impacts of the Environmental Policy Framework

One aim of this document is to suggest strategic directions that will help overcome unintentional regulatory constraints to innovation, commercialization, and diffusion. As we move from point sources to systemic solutions, our current regulatory structure will need to become more flexible, more resilient, and less focused on single media (air, water, etc.) solutions.

Standards

Environmental standards have historically provided incentives for firms to buy state-of-the-art technology to meet compliance requirements. With few exceptions, the environmental laws in place today can be characterized as technology-based performance standards. EPA and other regulatory agencies set standards for industry to achieve. The standards are based on the performance of a particular available and well-demonstrated technology. Because the standards are set by technologies already available, there are few incentives to develop or deploy innovative technologies that exceed the performance standard set by the regulatory agency. Instead, occasional strengthening of performance standards has provided a stop-and-go impetus for industry to develop better solutions to environmental problems.

Consider the Resource Conservation and Recovery Act (RCRA), enacted and amended in response to concern over the safe disposal of solid and hazardous wastes. RCRA requires that hazardous wastes, before being subject to disposal, be treated to the levels achieved by the best demonstrated available technology (BDAT) at the time of the regulation. Developers of technology have little incentive to test and commercialize technologies more stringent than those achieved by the BDAT, since performance based on existing technology is codified in the permitting process.



The regulations that implement the major environmental statutes impose a high burden of proof on untried technologies. For many environmental regulations, the acceptable band of performance is so narrow that many technologies perform either too poorly or too well.

Technologies that perform better than older ones are often more expensive in the short term. Without regulatory mechanisms such as market-based incentives, which allow users of the technologies to recapture the extra costs, superior technology cannot be marketed. Regulations that use market-based incentives (instead of command-and-control regulations) make it profitable to reduce pollution. Tangible rewards are thus possible for those who deploy superior technologies—and thus, indirectly, for those who develop them. However, only recently have environmental statutes encouraged or even allowed market-based approaches to pollution control.

Technological “Lock-in”

Technological lock-in occurs when EPA and other federal agencies examine technologies in use today to determine performance standards. Unless those standards are changed, the technology used to generate the performance standard continues to be favored by that standard. Indeed, even when inventors develop improved technologies that satisfy higher performance goals, they may be unable to find buyers of their technologies, who fear risking noncompliance with the statutory requirements.

An example is the Clean Water Act (CWA), which applies primarily to industrial and municipal sources of water pollution. Innovative technologies are encouraged in

Market-based Approaches

Market-based incentives have yielded significant performance results. Recently, in the 1990 Clean Air Act Amendments (CAAA), the United States enacted a stringent market-based control program to reduce sulfur dioxide emissions from power plants by 50 percent. Under this program, those who operate plants that use coal-fired generators can choose from a wide variety of control and prevention options to meet emissions reductions requirements, such as switching to lower-sulfur fuel, buying emissions credits, and installing scrubbers. Although still in its infancy, the acid rain provision of the CAAA, by rewarding superior performance with tradable credits, has led to a variety of innovations in pollution control. For example, U.S. vendors are now guaranteeing retrofit scrubbers at 98 percent control efficiency, whereas the ability to achieve 90 percent control at existing units was in doubt a few years ago. A criticism of market-based approaches is that they may be difficult to enforce and may require new monitoring technologies.

the CWA through the use of waivers: a firm that installs an innovative technology may be granted an extension for compliance with the statute. However, these opportunities have seldom, if ever, been used. For one thing, the extension does not mitigate the effects of failed attempts at innovation. Also, the extension deadlines are perceived by some observers as too brief, and the language in the statute is viewed as vague.

Domestic Market Segmentation

Federal environmental programs establish uniform national standards but leave a great deal of discretion to individual states to decide how to comply with those standards. Many states in turn delegate decision making to local environmental authorities. Although these powers are often granted in order to ensure opportunities for stakeholder input, the decentralized structure has resulted in regulatory requirements that vary by location. When control standards differ geographically, the technologies that satisfy a given requirement vary. The result is that innovators must develop and sell their products in a large number of submarkets with

differing performance requirements rather than servicing a unified national market. These segmented markets may not be large enough to justify investment in new technologies. Innovators also have difficulty making realistic assessments of the size of the markets for new products when faced with segmentation.

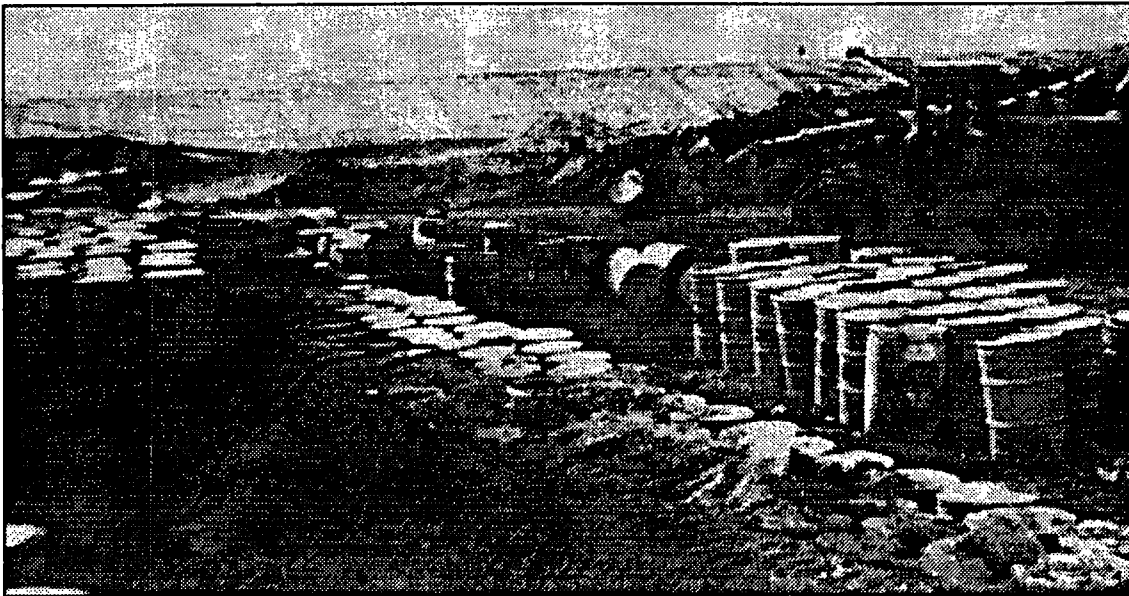
An example of domestic market segmentation is provided by the Clean Air Act. The Act regulates several classes of pollutants including carbon monoxide, particulates, sulfur dioxide, nitrogen dioxide, ozone, and lead (the so-called criteria pollutants), as well as a number of hazardous air pollutants. EPA specifies national ambient air quality standards for the criteria pollutants that must be met throughout the country in addition to industry-specific emissions standards. Reasonably achievable control technology, new stationary sources, and maximum achievable control technology are all uniform national standards, but the rest of the standards laid out in the statute are specified on a case-by-case basis and may differ for each source. Many states must obtain additional emission reductions from existing stationary sources beyond reasonably available control technology in order to meet the national ambient air quality standards. In effect, hundreds of different submarkets have been created in response to the Clean Air Act.

At the same time, the need to comply with stringent regional requirements, such as state water quality standards, can encourage the use of innovative technologies. Examples can be found in California, which has become a recognized leader in the development of environmental laws.

Single Media Focus

Single media regulatory programs tend to favor technologies that are tailored to reducing pollution in one medium (air, water, land) from specific sources, while discouraging investments in cleaner industrial technolo-





gies that efficiently reduce facility-wide pollution. Historically, the compartmentalization of environmental requirements by media (and by source) and the compliance orientation of their administration encourage a short-term focus by regulators and regulated parties. Recent efforts at multiple-media rule making, such as the EPA's pulp and paper cluster rules, represent a more integrated approach to regulation.

Closed Window of Opportunity for Innovation

Government regulations are developed and promulgated in a long open process. This procedure provides an "early warning system" to industry of the need for new technology.

Regulatory agencies can take as long as five years to issue an environmental regulation. Once the regulation is promulgated, requirements typically become effective within a short time frame.

The degree of pollution reduction required by a specific environmental rule is not anticipated by regulators. Rather, the pollution reduction requirement becomes increasingly precise only as promulgation and implementation draw near. No provision is made during the process for a window of time that would allow for technology development and commercialization.

Such a window would decrease the risk that new technologies will lack regulatory applicability. The easier it is for technology developers and users to anticipate performance requirements, the more investment will be encouraged. At present, by the time that requirements become precise and potential markets can be assessed, compliance deadlines are imminent and there is inadequate time for innovation.

"Double Jeopardy"

Users of new technology must pay penalties for noncompliance as well as the cost of installing conventional technology if an innovative approach fails. This constraint reduces the number of firms willing to adopt new technologies. Although such statutes as the Clean Air Act, Clean Water Act (sections 301(k) and 307(e)), and the Safe Drinking Water Act (sections 1442 and 1444) provide waivers and variances for applying new technology, they are rarely used—in part because state and federal agencies often lack resources and incentives for testing new technology on a case-by-case basis. Some states allow environmental technology vendors to post their own performance bonds in order to test market new technologies. These financial mechanisms may be too costly, however, for small businesses.



Lax and Inconsistent Enforcement

The standard of compliance established by environmental regulations and the level of enforcement influence the demand for environmental technologies. Potential buyers delay purchases in an uncertain climate of enforcement. This is particularly true for small, traditional industrial users who have limited resources and view their contribution to environmental degradation as minimal despite the fact that their cumulative effect is quite important.

Inconsistent enforcement of environmental regulations discourages potential investors from lending financial support for the development of new technologies. Consistent, predictable, and flexible enforcement policies will encourage markets for environmental technologies and thus investment.

Inadequate Venture Capital

A spokesperson for the investment banking industry recently testified before Congress that in 1988 nearly every major investment firm planned to commit at least 10 percent of its portfolio to environmental businesses. By 1993 fewer than 15 firms had done so, and less than 10 of these had invested in technology. In 1991 the venture capital industry, with \$40 billion under management, invested in five new technology firms. Many venture capitalists cite uncertainty about the regulatory process as a central reason for reluctance to invest in the environmental industry. Uncertainty about whether a particular technology will be approved or endorsed by regulators adds a significant and difficult-to-analyze dimension to the riskiness of investment projects.

Changes in the Policy Landscape

As nations around the world seek to reduce the risks and costs imposed by pollution, they enact stringent regulations and commit the resources necessary to enforce them. As a result, the global environmental market is larger than ever and growing.

International environmental agreements and standards also stimulate market opportunities for environmental technologies. For example, the Montreal Protocol created a large market for substitutes for ozone-depleting chemicals.

The growing number of international environmental standards under consideration by the International Standards Organization is another potentially significant stimulant. The

standards affect environmental equipment, management systems, test methods, performance levels, and specific products. The form and content of these standards could have implications for environmental technology markets and for the competitiveness of the U.S. environmental industry.

Thus, changes in national and international regulatory policies are increasing the global markets for environmental technologies. At the same time, two important additional changes have occurred in the environmental policy landscape in the past five years. Both have had a tremendous impact on the market and will have an even greater effect in the future.

First, 17 states now have some form of facility planning requirement—usually integrated with a toxics use reduction requirement. These state laws are multi-media and focus on managing wastes on a facility-by-facility basis. They allow more flexibility than traditional regulatory approaches and do not generally require the rule, permit, compliance, inspection, enforcement scenario. The state laws encourage facilities to go through a process of identifying prevention and efficiency opportunities, establishing targets and goals for reductions, engaging the public in establishing these goals, and monitoring performance.

The second change involves the dissemination of information. With the passage of the Toxics Release Inventory, Environmental Protection Agency began to compile data on releases of 312 chemicals (the number is currently being expanded), and the agency released that information to the public on a facility basis. Resulting community pressure, as well as corporate decisions to avoid the glare of publicity, has led to increased investments in reducing emissions, even though those emissions are allowed under command-and-control permit programs.

The international community has expressed interest in the use of information in achieving environmental objectives and is developing similar programs. These programs will stimulate the market, but again they have the advantage of allowing facilities to approach solutions with end performance in mind, rather than a de facto design standard. When combined with technical assistance, recognition, and publicity, these programs have proved a cost-effective way to stimulate investments in innovation. These approaches have produced dramatic results in EPA's Green Lights program. The administration's Climate Change Action Plan is also based on information and voluntary partnerships that capture cost-effective opportunities.

Similarly, preferences of consumers—the so-called “green market”—have substantially shaped the market and will continue to do so. This is particularly true overseas where mercury-free batteries and national environmental labeling programs have followed from consumer interest.

A regulatory and permit focus on single-media problems often leads to suboptimal solutions from a whole facility and environmental perspective. This focus often directs public and private research and investment into treatment or disposal options at the expense of prevention and resource efficiency.

Finally, environmental problems are shaped by transportation, energy, and agricultural activities as well as the manufacturing sector. For example, Mexico City, Seoul, Hong Kong, and Sao Paulo have all registered unprecedented air quality problems associated primarily with transportation. Similarly, between now and the end of the decade, the World Bank anticipates a trillion dollar demand for new energy generating capacity. To the extent that our current regulations focus almost exclusively on the manufacturing sector, we will fail to stimulate research and demonstrations in sectors such as transportation and energy that contribute disproportionately to environmental problems.

“More than is usually the case, government policies play a central role, since regulations both create markets for environmental technologies and the conditions for compliance faced by industry.”

—Roger C. Herdman
Director

Office of Technology Assessment, U.S. Congress

Regulatory Policy: Strategic Directions

The challenge over the coming years will be to fashion regulations that meet aggressive environmental performance goals, while allowing and encouraging innovative approaches to meet those goals. Federal agencies will:

- Continue to review environmental policies and procedures in order to identify specific steps to reduce government-imposed barriers to the development and commercialization of environmental technology.
- Explore existing opportunities to take a sectoral and whole-facility approach to regulations.
- Increase the use of market-based approaches in environmental regulations that will provide tangible rewards to developers of innovative technologies.

Regulatory Policy: Current Initiatives

- The President was issued an executive order requiring agencies to “identify and assess available alternatives to direct regulation, such as user fees or marketable permits.” The executive order also requires agencies to “consider incentives for innovation” and “to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt.” (E.O. 12866, September 30, 1993)
- In connection with the recommendations of the interagency report on *Environmental Technologies Exports: Strategic Framework for U.S. Leadership*, the EPA is working with key federal agencies to review environmental policies and procedures to identify specific steps needed to reduce barriers and stimulate innovation in environmental technology development and commercialization.
- As part of the reauthorization process, the administration has submitted revised language to Congress allowing for greater use of innovative environmental technology under the Clean Water Act, as well as promoting the use of such technology in the administration’s Superfund bill.
- The EPA is streamlining and expediting permit policies and procedures for R&D, testing, and evolution.

Regulatory Policy: Possible Next Steps

- Consider establishing a public-private regulatory review committee to enhance regulatory incentives for the cost-effective development and deployment of innovative environmental technology.
- Consider expanding the use of negotiated rule making to broaden participation by affected parties in promulgating regulations that permit use of a wider range of technologies.
- Develop a verification process for control and remediation technologies and, where necessary, avoidance technologies, that reduces the risk for early adapters of these technologies.
- Consider practicing greater flexibility in the choice of enforcement remedies so as to encourage the use of innovative technologies.

Market Stimulation

 As discussed in Chapter 4, the environmental policy framework shapes the markets for many environmental technologies. Other public policies also have the potential to stimulate or inhibit these markets. A national dialogue should include discussion of how these policy instruments can be thoughtfully and effectively deployed.

Consumer Labeling

Many consumers express environmental preferences in their purchases. Environmentally aware consumers have stimulated markets for dolphin-safe tuna and energy-efficient light bulbs. By including environmental criteria in consumption decisions, such consumers implicitly stimulate the markets for technologies that support environmentally friendly production.

Consumers often find it difficult to obtain the information they need to make thoughtful decisions. Green labeling programs help them to make those choices. As environmentally conscious consumption increases, the government may have a role in providing standards for producers' environmental claims and verifying those claims.

Government Procurement

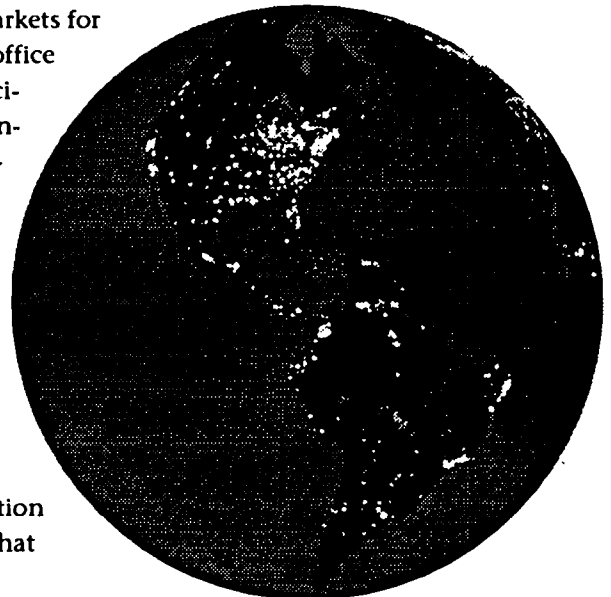
Government procurement at the national, state, and local levels affects environmental technology markets in various ways. Purchases include monitoring and assessment equipment to assess the state of ecosystems and to monitor effluent and emission streams.

Procurement of pollution control technologies, on the other hand, is limited to local water districts, which purchase infrastructure equipment for water treatment. Unlike water pollution, the majority of the equipment to control air pollution is purchased by private firms rather than government.

Federal, state, and local governments are major customers, however, for remediation and restoration technologies. The Departments of Defense and Energy, for example, sponsor programs focused on environmental remediation and restoration of sites impacted in the course of their mission-related activities (e.g., nuclear fuel processing and ordnance and chemical testing and processing).

In addition to direct purchases by government agencies, many procurement decisions by government indirectly affect the markets for environmental technologies. The specifications for a new office building or a public housing unit, for example, include decisions about energy efficiency and lighting. Likewise, government agencies are major purchasers of transportation vehicles and office supplies, and these procurement decisions can have major impacts on environmental technology markets.

In making procurement decisions, environmental considerations are only one among many criteria. Agencies must perform their functions on limited budgets, and procured products must meet performance and cost criteria. At the same time, however, some procurement decisions present an opportunity to demonstrate an innovative environmental technology, producing information on implementation that may be valuable to other parties that are considering adoption.





Clarifying Liability Laws

In the market for control and remediation technologies, liability laws can inhibit the commercialization of innovative environmental technologies. The fear of legal liability in the case of failure of a new technology increases financial risks, sometimes prohibitively. Clarification of legal positions and special provisions for demonstration of innovative technologies could help assuage these fears.

Stimulating Avoidance Technology

The market for avoidance technology, though historically less immediately driven by regulation than other environmental technology markets, is increasingly stimulated by thoughtful environmental policy. For instance, many states and cities in the United States have passed minimum standards for recycled content on paper and plastic materials. Similarly, deregulation of the utility industry at the state and federal levels has paved the way for opening the transmission grid to accepting energy from renewable sources.

Currently, 19 states have passed legislation requiring some form of planning for prevention technologies, solid and hazardous waste reduction, and reduction in the use of toxics. Likewise, in Germany, new regulations are requiring automakers to accept cars for recycling once the vehicles' useful life is finished. In another example, the Netherlands government has negotiated a covenant with Danish industry to reduce the use of packaging material and encourage recycling.

Opportunities other than regulations may be available, however, for stimulating markets for avoidance activities. At present, numerous barriers stand in the way of the widespread adoption of avoidance systems. One of the most important is the striking lack of information currently available to companies for assessing the utility of alternative avoidance systems. In addition, most firms put environmental and energy costs under their overhead accounts. As a result, they do not have accurate information on their current compliance costs and potential savings from avoidance.

In many cases, society lacks the scientific and economic information to make informed tradeoffs between different environmental impacts when designing an avoidance system. The diaper debate is the classic example—is it better to expend energy and water to transport and clean reusable diapers or to transport and fill landfills with disposables? Research and information dissemination will be needed to make such information available to firms, government regulators, and the public at large.

The most effective way to stimulate avoidance activities and technologies is through the price system by means of market-based environmental policies. Once prices fully reflect the social costs of resources, energy, and waste disposal, incentives for avoidance activities will be aligned with environmental goals.

“Let’s not play catch up. Let’s get out in front. I do not want this country to import ideas from abroad. I want it to export American ideas, American technologies, and American products. We cannot afford to wait.”

—Senator Barbara Mikulski

Market Stimulation: Strategic Directions

A number of market failures, particularly lack of information, can inhibit the demand for environmental technologies and their products. Government can stimulate this demand by ameliorating those barriers and by considering environmental criteria in its own procurement decisions. The federal government will:

- Examine market barriers that may inhibit demand for environmental technologies and their products.
- Continue to integrate environmental criteria into government procurement decisions.
- Support the dissemination of environmental information to consumers to allow them to make informed decisions when purchasing products.

Market Stimulation: Current Initiatives

- The President has issued an executive order requiring federal agencies to purchase paper with a minimum recycled fiber content, and another instructing federal agencies to incorporate waste prevention and increase the market for environmentally preferred products through their purchase.
- Another executive order requires federal agencies to improve energy efficiency in federal buildings nationwide. This order is expected to increase investments in renewable energy technologies. Another directs that toxic emissions from federal facilities be reduced by 50 percent by the year 1999. Both orders will spur markets for innovative environmental technologies.
- The President has directed the DOE and EPA to expand the “Golden Carrot” Market-Pull Consortia to additional industries to accelerate the commercialization of advanced, energy-efficient technologies through partnerships with key market players. These partnerships may include contests for new technology introductions, working with government procurement agencies to leverage their purchasing power for certain qualifying products, and working with utilities to create market incentives for new technologies.

- Joint Implementation allows signatories to the Climate Change Convention to undertake public or private projects abroad to reduce greenhouse gases and be “credited” for them at home. The administration has launched a pilot program—the U.S. Initiative on Joint Implementation—to provide a mechanism for investments by U.S. firms and to establish an interagency panel to evaluate net greenhouse gas emission reductions.
- EPA is identifying pilot projects, to be funded by the Small Business Administration, to demonstrate how technical and financial assistance can be provided to small businesses to identify and pay for pollution prevention technologies. These projects will utilize SBA’s Small Business Development Centers.
- The Federal Fleet Conversion Task Force is devising a plan to convert the federal automotive fleet to alternative fuels that are cleaner burning and less expensive. The administration plans to use the federal government’s purchasing power to stimulate the domestic alternative fuels market and to develop a refueling infrastructure for alternative fuel vehicles.
- The Environmental Protection Agency, Department of Energy, and utilities issued a challenge and an opportunity to manufacturers of refrigerators: the company that can build a chlorofluorocarbon-free refrigerator that also exceeds energy performance standards will receive a guaranteed market because the consortium will make up the difference in price between the new super-efficient refrigerator and more conventional units.

Market Stimulation: Possible Next Steps

- Consider expanding development assistance efforts to improve environmental regulatory policy in developing countries and to improve local and foreign investment in the environmental sector of these countries.
- Consider environmental criteria in making a wider range of government procurement decisions.
- Consider establishing federal incentives to encourage states to make green procurement decisions.
- Devise new mechanisms to encourage the adoption of green labeling programs and other activities to provide environmental information to consumers.

Fiscal Policy

The administration is working to improve conditions for capital investment in human and physical resources in the nation's industrial sector, and these efforts are particularly relevant to environmental technology. The development and diffusion of environmental technology will be led by American businesses as they make decisions about research-and-development projects, deployment of clean manufacturing processes, and purchases of environmental equipment. These undertakings can be facilitated—or inhibited—by a variety of fiscal policy instruments.

The administration is also committed to advancing federal fiscal policies and encouraging public-private cooperation in order to improve productivity, standards of living, and competitiveness. Among the goals is greater investment in all stages of the technology pipeline, civilian R&D, workforce training, and modern production processes. For environmental technology, these commitments could increase rates of innovation, speed product development, and facilitate the integration of environmental technology into the nation's infrastructure.

A variety of fiscal policy instruments and tax policy changes have the potential to support these goals. As we consider their merits, we will have to weigh them in the context of other national priorities such as deficit reduction.

Research and Experimentation Tax Credit

The overall objective of the Research and Experimentation Tax Credit has been to encourage companies to make expenditures in research and experimentation (R&E). In 1981, the Economic Recovery Tax Act provided a 25 percent tax credit for increases in R&E expenditures over the base period of a firm's past three years of qualified research expenditures. The Tax Reform Act of 1986 and subsequent legislation extended the credit in six- and nine-month increments through June 30, 1995, while also reducing the tax credit to 20 percent. The Omnibus Budget Reconciliation Act of 1989 changed the base period rules so that taxpayers compute their base amounts using the ratio of their qualified research expenditures to their gross receipts during the 1983-1988 period. The tax credit has had a modest effect on stimulating R&E expenditures.¹

Companies can apply up to 20 percent of new incremental R&E outlays in a given year as a credit against taxes owed. Expenditures qualifying for this incremental tax credit are "in-house" expenditures for R&E wages, supplies, and the use of equipment; 65 percent of payments for contract research; and 65 percent of corporate grants to universities and certain scientific organizations for basic research. The credit does not apply to research conducted outside the United States.

Three potential inadequacies in the current research credit have been identified. First, tax credit extensions are usually granted for less than a year at a time. Since most R&D projects require several years, companies cannot accurately project the net cost of a given R&D project. The administration, in its proposed FY1994 budget, endorsed permanent extension of the credit. The failure to extend it per-





manently reflected budgetary constraints. Second, for those that intend to increase their R&E expenditures, but not increase them over the base amount, the tax credit does not reduce the after-tax price of an extra dollar's worth of R&E. The incremental structure of the tax credit also fails to provide a disincentive for the reduction of R&D expenditures below the base amount. The limitation of the credit to incremental research expenditures is consistent with its basic objective of encouraging additional research rather than subsidizing research that would have been conducted in the absence of the credit.

The current benefit a taxpayer will receive from the research credit is limited to the taxpayer's tax liability. Thus, for startup companies and firms that do not have substantial tax liabilities, the research tax credit may not influence decisions about investment in research and development. This limitation is inherent in using the tax system to subsidize research.

Treasury Regulation

Treasury Regulation TR 1.861-8 was issued in 1977 and established methods of allocation and apportionment of tax deductions for R&D expenditures. Under the provisions of this regulation, U.S. corporations with foreign operations are required to treat a portion of their domestic R&D expenses "as if" they were performed outside of the United States, creating a disincentive to conducting R&D at home. Because no foreign country will allow for a deduction of this U.S.-based but nondeductible R&D, U.S. corporations lose the deduction.

As a result of this regulation, some U.S. corporations have either reduced their global R&D expenditures or transferred R&D abroad so that foreign governments will allow them to take the R&D deduction.²

U.S. corporations may also shift their R&D to foreign countries for other reasons. They may decide to locate close to a university noted for research in their area of interest or close to overseas production plants which make use of their research, or they may move to take advantage of lower wages for research professionals. Whatever the reason, transferring R&D abroad shifts not only the R&D jobs, but the manufacturing and sales jobs as well.

Some believe this regulation poses a problem for high-tech U.S. firms, in that it has unintentionally created an incentive for international U.S. corporations to conduct their R&D outside the United States. Because U.S. firms cannot deduct their nondeductible U.S.-based R&D expenses in the foreign nations where they generate the income, they may transfer their R&D abroad.

Investment Tax Credit

Concern is growing over the lack of adequate capital for investment in environmental and other new technologies, capital investments needed for the deployment of clean manufacturing processes, and purchase of equipment to expand the production of globally competitive technologies. The United States lags substantially behind Japan and other G-7 countries in the percentage of gross domestic product invested in new plants and equipment, a key factor in the creation of jobs, economic growth, and competitiveness.

This underinvestment in future manufacturing capacity is especially acute among the small- to medium-sized firms that characterize the U.S. environmental industry. Other

nations, most notably Japan, offer strong incentives to modernize plant equipment (e.g., a 20 percent tax credit for investment in equipment, with an additional 20 percent credit granted to small firms).

Investment tax credits are viewed by many economists as one of the most effective ways of reducing the cost of capital for the purchase of equipment. Economists are divided, however, over the relative merits of an incremental or temporary investment tax credit and a permanent tax credit.

The administration proposed an investment tax credit in 1993. A permanent credit would have been provided to small businesses, and a temporary incremental credit would have been provided to other businesses. The proposal was part of a stimulus package that was defeated by Congress.

Fiscal Policy: Strategic Directions

In order to remain a leader in the research, development, commercialization, and deployment of innovative environmental technologies and high value-added products, federal agencies will:

- Develop and implement fiscal and tax policies that encourage and facilitate private-sector investments in R&D and the manufacture and deployment of innovative environmental technologies.
- Work to increase the rate of civilian investments in R&D, equipment, and plant infrastructures for environmental technologies.

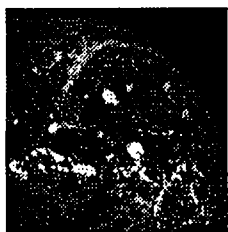
Fiscal Policy: Current Initiatives

- The administration has provided incentives for private-sector research and development and new business formation by extending the R&D tax credit and reducing the capital gains tax for investments in small businesses.

Fiscal Policy: Possible Next Steps

- Consider revising the Research and Experimentation Tax Credit to incorporate a new mechanism for defining the base rate used in determining the credit that will not constitute a disincentive to small companies or startup firms.
- Consider establishing a permanent investment tax credit, focused on providing small businesses with a tax credit for investments in equipment purchases, and a temporary investment tax credit for equipment purchased by larger firms.
- Consider utilizing the tax code to promote the development and use of clean manufacturing technologies, similar to the Dutch model, which allow firms that are installing innovative pollution prevention or control technologies to depreciate their investment in one year rather than 10 years.
- Consider revising the income allocation rules of Treasury regulations so that little or no U.S. R&D expenses are allocated to foreign-source income for the purposes of the foreign tax credit limitation.
- Evaluate the use of policy instruments such as accelerated depreciation schedules and expedited licensing and approval to stimulate investment in environmental technologies.

ENGAGING THE WORLD



Coordination of the administration's export promotion and foreign assistance policies is critical to achieving global environmental stewardship and a strong domestic economy. U.S. industry must capture a larger share of the global market for environmental technologies—more than 60 percent of which lies outside the United States—in order to remain competitive. Markets in countries that do not belong to the Organization for Economic Cooperation and Development are expected to experience the fastest growth, particularly in the Pacific Rim and Latin America. U.S. foreign assistance programs indirectly stimulate these markets by creating the awareness and capacity in these countries to address environmental problems

International Commerce



The rapidly growing world market for environmental technologies presents tremendous opportunities for internationally competitive U.S. firms. Environmental technology companies, however, must face the inherent challenges of an industry largely shaped by government programs and policies, including environmental regulation and international agreements and standards; a unique set of national and subnational markets; and increasing competition from other nations that often provide significant government support for exports. These factors highlight the need for a focused U.S. strategy to assist environmental technologies exports.

The government provides a number of export programs that work with U.S. industry through market assessments and assistance with the identification of financing opportunities. In addition, the government's internal role in assisting U.S. industry includes facilitating international treaties and trade agreements that help shape the markets for environmental technologies.

International Environmental Agreements and Voluntary Standards

After the 1992 Rio Earth Summit, the United States signed several international treaties with important implications for environmental technologies. These include: the Framework Convention on Climate Change, which will encourage worldwide adoption of energy-efficient technologies; the Framework Convention on Biodiversity, which will promote the conservation of biological diversity and the fair and equitable sharing of the benefits gleaned from genetic resources by pharmaceutical and biotechnology firms; and Agenda 21, a list of recommended actions to promote sustainable development, which provides a framework for technology cooperation and environmental technology transfer between developed and

developing countries. The United States has also signed the Montreal Protocol on Substances that Deplete the Ozone Layer, the driving force behind the rapid development of substitutes for the chlorofluorocarbons used in refrigeration, insulation, and many industrial processes. The implementation of these agreements can stimulate worldwide demand for environmental technologies.

Trade agreements such as the North American Free Trade Agreement (NAFTA) and the General Agreement on Trade and Tariffs (GATT) will also promote international commerce in environmental technologies. These agreements will create increased access to international capital and technology. NAFTA will stimulate additional U.S. exports of environmental products and services to Mexico by removing tariffs on most pollution control equipment, enhancing enforcement of environmental regulations, and reducing restrictions on the ability of U.S. environmental engineers and consultants to work in Mexico.

The development of international standards will also have a strong influence on global commerce in environmental technologies. For instance, the ISO 9000 quality assurance standards being developed by the European Community (EC) will affect specifications for all equipment sold to and used by manufacturers within the EC. Such standards could extend beyond processes and products to environmental performance evaluation, auditing, and management systems.

Export Programs

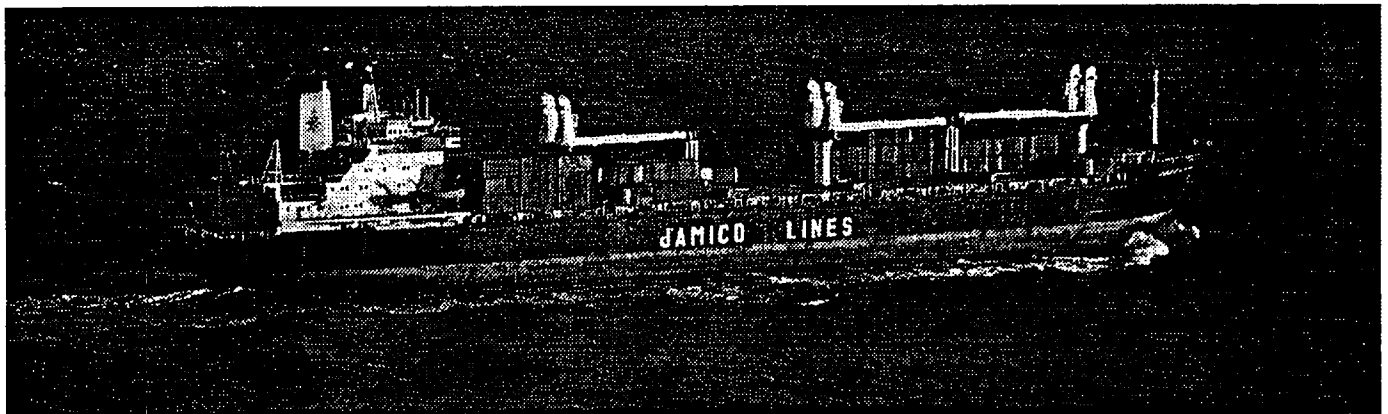
Exporting environmental technologies presents special challenges that create unique needs for information and support. The needs of companies seeking to export environmental technologies include:

- knowledge of the environmental challenges in the target country and the technologies needed to meet those challenges;
- understanding the legal, political, and regulatory structures in the target country;
- contact with the key decision makers in the target country; and
- access to export financing.

The ability of U.S. environmental technology firms to compete internationally hinges on access to markets and corporate marketing strength and presence. Overseas trade leads are provided by a number of Department of Commerce (DOC) programs, as well as the National Trade Data Bank and the Export Contact List Service. Personal contact services are provided

"[T]here is increasing recognition that the fastest growing markets are in developing countries—countries where the demand for environmentally responsible technologies is also growing rapidly."

—Vice President Albert Gore, Jr.





by several delivery mechanisms, including the DOC's Gold Key Service, which custom tailors market research, orientation briefings, introductions to potential partners or buyers, and follow-up services for companies planning a foreign country visit.

The DOC's International Trade Administration conducts Matchmaker Trade Delegations to various countries for companies wishing to export to a particular area or find a local partner. This program is designed for new-to-export or new-to-market firms. Included are in-depth briefings on the economic climate of the countries to be visited, followed by an overseas trip with an intensive schedule of meetings with prospective representatives and distributors.

A number of programs for buyers from overseas are based in the United States. The DOC has a Foreign Buyer Program

that supports major domestic trade shows featuring products and services of U.S. companies with high export potential. The worldwide offices of the U.S. and Foreign Commercial Service recruit qualified foreign buyers to attend these trade shows. The shows are extensively publicized by U.S. embassies and commercial newsletters, foreign trade associations, and chambers of commerce. At each foreign buyer show, an International Business Center provides interpreters, multilingual brochures, counseling, and private meeting rooms.

The Opportunity Bank of the Overseas Private Investment Corporation (OPIC) matches U.S. investors with specific overseas investment opportunities. OPIC's Investor Information Service provides a "one-stop shop" for basic economic, business, and political information and data from a variety of sources on some 120 developing countries and 16 geographic regions.

The Center for Trade and Investment Services of the Agency for International Development (USAID) is the focal point for the collection and dissemination of information on the Agency's programs and activities that support international private enterprise in the developing countries where USAID operates.

The Department of Energy (DOE) participates in overseas demonstrations of environmental technologies to attain high visibility for applications of the department's technologies and to prime these technologies for export. DOE uses overseas facilities as a showcase for its technologies, both to introduce U.S. firms to export markets and to demonstrate solutions to host countries.

Access to export financing and investment support is critical to the international competitiveness of the U.S. environmental technology industry. Four agencies—the Export-Import Bank, Overseas Private Investment Corporation, Small Business Administration, and the U.S. Trade and Development Agency—provide export financing assistance, such as funding for feasibility studies, pre-export working capital, export financing and insurance, and investment insurance.

Support for Smaller Firms

A number of federal agencies have export counseling and support services available to potential exporters, including both major and smaller firms. The DOC's industry and country specialists provide current market assessments. The World Traders Data Report provides a means to check on the reputation, reliability, and financial status of a prospective trading partner. In addition, DOC's Customized Sales Survey program provides custom-tailored research on the marketability of particular products in specific markets. The research includes identification of key competitors, price of comparable products, customary distribution and promotion practices, trade barriers, and possible business partners.¹

The Office of International Trade (OIT) of the Small Business Administration conducts outreach efforts that include "how-to" and market-specific publications for potential

exporters. OIT also has two loan guarantee programs designed specifically for exporters. In addition, OIT organizes export promotion events. The Small Business Administration also maintains a network of U.S. offices to advise small businesses on matters relating to export and maintains data reports on specific product or service information on the top 25 world markets.

Multilateral Development Banks

An impressive level of project funds are made available by the Multilateral Development Banks (MDBs). In 1993 the MDBs (African Development Bank, Asia Development Bank, European Bank for Reconstruction & Development, Inter-American Development Bank, International Bank for Reconstruction & Development) lent more than \$40 billion. Projects receiving funds offer sales opportunities for U.S. environmental technologies, services, and consultants. The MDBs deserve increased attention as a source of information on potential export sales, and the banks themselves devote resources to improve the flow of information.

Federal personnel under the direction of the International Trade Administration are dedicated to the identification of projects, loan analysis, and assistance to firms in developing strategies for bidding on MDB sales opportunities. Their main responsibility is the identification, tracking, and reporting of advance information on current and prospective infrastructure and procurement opportunities. Because of their unique position, these officers can assist qualified and technically capable U.S. consultants and equipment suppliers to increase their exposure to MDB staff and the borrowers of MDB funds.

Export Strategies of Competing Nations

Japanese government initiatives have placed long-term market development at the fulcrum of a series of interrelated export strategies. The most ambitious of the Japanese programs is "New Earth 21," a 100-year agenda designed to provide analyses of environmental problems in targeted regional markets, such as Eastern Europe and the Pacific Rim, and to

"New environmentally sound technologies for products, processes, and services create jobs and growth without environmental harm. Expanding world trade [brings] the benefits of these technologies and knowledge to the rest of the world. Together, they create a reinforcing cycle of sustainable development."

*—Ronald H. Brown
Secretary of Commerce*

Administration Export Strategy

The administration is implementing an environmental technology export strategy developed by representatives of six federal agencies. The strategy, formulated in consultation with business, academia, trade associations, and state and local governments, lays out 18 recommendations for policy changes and new federal activities. Among the recommendations are the following actions:

- *Identify markets and create export marketing plans that focus current export promotion activities on specific markets with potentially high, immediate returns.*
- *Establish effective and coordinated mechanisms to enhance overseas visibility of U.S. environmental technologies and long-term foreign market access.*
- *Strengthen U.S. government presence and environmental technologies expertise overseas by training U.S. and Foreign Commercial Service officers.*
- *Strengthen support for the environmental technologies industry by training appropriate one-stop-shop staff within the Department of Commerce.*

"The global environment is increasingly threatened by rapid population growth, unsustainable industrial activity, and natural resource depletion. To respond in a meaningful way, the United States must bring all its resources to bear—not only its money, but its expertise, its values, its technology, and most of all, the involvement of ordinary Americans."

—J. Brian Atwood
Administrator
U.S. Agency for International Development

promote the diffusion of Japanese technologies as solutions to those problems. The means for fulfilling these goals include official development assistance programs, export advisers, training activities, technology transfer, and research exchanges. Budgeted at \$37.5 million in 1990, New Earth 21 is a visionary program that is aimed at increasing environmental exports over a long period rather than being targeted at short-term sales.

In Germany, individual states have aggressive promotion programs, some of which cover up to half of the expenses associated with trade fairs. This financial support is particularly crucial for small companies. In addition, because of a close working relationship between German firms

and the government's Export Credit Institute, the German companies are able to approach customers with a global package that includes financing. U.S. companies, by comparison, are forced to take a piecemeal approach.

The European Community (EC) has a number of programs to support diffusion of environmental technologies. For example, a program entitled "LIFE" integrates EC financing programs and technical assistance in the Mediterranean and Baltic regions. The EC also has dedicated substantial budgets to helping Eastern Europe deal with its ecological problems and at the same time has supported commercial inroads for the European environmental industry.

Barriers to Export

The foregoing survey of the export programs of the United States and our chief competitors is adapted from work by the Trade Promotion Coordinating Committee, an inter-agency organization comprised of the Department of Commerce, Department of Energy, Export-Import Bank, Environmental Protection Agency, U.S. Agency for International



Development, and the U.S. Trade and Development Agency. The committee identified the following problems that reduce the effectiveness of existing U.S. programs to support exports by the environmental technology industry:

- Serious deficiencies, duplications, and outmoded approaches undermine the U.S. ability to promote exports and provide federal support for exporters.
- Programs to assist environmental technologies, as in other sectors, suffer from the absence of an overarching framework for agency coordination, resulting in duplication of efforts and confusion on the part of the intended beneficiaries.
- Financing for exports remains a special problem for all sectors, particularly for small- and medium-sized firms.

The U.S. government helps businesses of all sizes gain access to vital financing for overseas sales and investment through insurance, loan, and guaranty programs of the Export-Import Bank and the Overseas Private Investment Corporation. However, information about these financing support programs and procurement opportunities created by bilateral and multilateral development agencies often does not reach smaller and new-to-export environmental firms.

International Commerce: Strategic Directions

On Earth Day 1993, President Clinton directed key agencies of the federal government to *"assess the competitiveness of current environmental technologies and to develop a strategy to give U.S. companies the trade development, promotional efforts, and technical assistance they need to increase exports and create U.S. jobs, as well as to promote a better environment."*

In response to this directive, a six-agency Environmental Technologies Export Working Group chaired by Secretary of Commerce Ronald H. Brown authored *Environmental Technologies Exports: Strategic Framework for U.S. Leadership*. This report, released in November 1993, calls for streamlining U.S. export promotion efforts and improving export financing mechanisms. Consistent with the recommendations of this report, federal agencies will:

- Strengthen the technology development and commercialization abilities of the domestic industry.
- Help U.S. businesses succeed in the most important markets today, while developing tomorrow's potentially most valuable markets.
- Coordinate and better focus U.S. government export programs and resources.

International Commerce: Current Initiatives

- The Trade Promotion Coordinating Committee's Environmental Trade Working Group is developing a strategic plan for promoting U.S. environmental exports to the region with special emphasis on Mexico. The plan is to assemble important statistics for enhancing trade, including information on the 50 to 100 most important Latin American environmental infrastructure projects.
- The U.S. and Foreign Commercial Service has established its first four expert assistance centers in Miami, Los Angeles, Chicago, and Baltimore. These shops will foster ties with regional and local environmental technology business

groups and with state and local export promotion programs, and they will help local firms navigate the full range of the federal export facilitation programs.

- The Department of Commerce is training environmental technology specialists who will assist U.S. firms by identifying market opportunities, market barriers, standards issues, and other factors affecting U.S. market share.
- The Trade Promotion Coordinating Committee is establishing regional environmental export councils in five U.S. regions, to work with exporters of environmental technologies for private sector input into the export strategy, export promotion outreach, and information dissemination.
- The Export-Import Bank and Banobras, the national development bank of Mexico, have signed a Memorandum of Understanding for support of wastewater treatment facilities in Mexico. The agreement will allow Export-Import Bank to help finance U.S. exports of environmental goods and services totaling up to \$500 million over the next five years.
- The Overseas Private Investment Corporation will provide \$50 million in loan guarantees for the Global Environment Fund, which will expand commercial opportunities for businesses engaged in alternative energy, water treatment, air pollution control, and waste management in emerging market economies that are growing rapidly. It is projected that the fund will generate \$.5 billion of private investment in environmental enterprises that do business in the developing world.

International Commerce: Possible Next Steps

- Continue to devise comprehensive strategies for promoting near-term exports to the most promising markets, including Latin America and East Asia. The strategies should include collecting vital data and points of contact, facilitating meetings between U.S. firms and potential clients, providing information on government financing support programs and projects that receive bilateral and multi-lateral development assistance.
- Consider establishing coordinated mechanisms to enhance overseas visibility and long-term market access of the U.S. environmental industry by increasing expertise of foreign service officers, utilizing interagency assignments to build knowledge, and facilitating joint research projects, training programs, and technology demonstrations in potential overseas markets.

Foreign Aid and Development Assistance

 Promoting environmental stewardship is a central goal of U.S. foreign aid in the post-Cold War era. The carrying capacity of the earth itself is being challenged as never before by unsustainable population growth, endemic poverty, and natural resource degradation. By the year 2000, four out of five people in the world will live in developing countries—a trend that is likely to continue well into the 21st century. America's interests and markets will increasingly be shaped by events in developing countries.

Accordingly, the administration has identified sustainable development as a key element of its foreign policy and a cornerstone of its international development assistance program. Sustainable development acknowledges the legitimate economic aspirations of developing nations, as well as their responsibility to preserve and protect the environment for future generations. Environmental degradation is often the result of underlying pressures of poverty and rapid population growth—pressures that must be addressed in any comprehensive effort to promote sustainable development. Because the causes of environmental degradation are based in the way that people use resources, U.S. development assistance efforts are focussed on how societies relate to and utilize the natural environment—through technology, institutional, and social practices.

Major reforms are underway within the U.S. government to assure that America's post-Cold War foreign assistance program effectively addresses sustainable development objectives. The administration has submitted to Congress a major revision of the Foreign Assistance Act, entitled the Peace, Prosperity, and Democracy Act of 1994, to reflect new post-Cold War priorities.

Technology Cooperation

It was agreed at the Rio "Earth Summit" that a North-South technology cooperation agenda would be needed to address global environmental challenges. The United Nations Conference on Environment and Development (UNCED) recognized that implementation of Agenda 21, a comprehensive list of recommended actions from the Rio Earth Summit, could not be achieved through official development assistance alone. Instead, it would require significant engagement of the marketplace and the private sector. Within the UNCED-created Commission on Sustainable Development, the U.S. Department of State is working with the G-77 to develop an agenda to implement the UNCED commitment to greater environmental technology cooperation.

"Technology cooperation"

means cooperation between or among countries in developing, commercializing, or transferring technology. It includes needs assessment, information exchange, training and technical assistance, capacity building, financing, and technology development. Technology cooperation involves government-to-government activity that emphasizes public-private risk sharing to build up the infrastructure, wealth-generating capacity, and competitiveness of a country.

USAID's Role

Sustainable development programs undertaken by USAID, the lead agency for development aid, seek to address the root causes of environmental harm, promote environmentally sound patterns of growth, and support improved management of the environment and natural resources. These activities include efforts to address such urgent global environmental challenges as climate change and the loss of biological diversity, as well as significant local and regional environmental priorities.

Environmental problems cannot be divorced from economic development. Broad-based economic growth tends to raise awareness of environmental issues, as well as measuring the resources devoted to addressing those problems. USAID plays a key role in encouraging sound environmental practices in countries struggling with underdevelopment, as well

as in developing countries that face growing public awareness of the need for environmental stewardship.

TDA's Role

The mission of the U.S. Trade and Development Agency (TDA) is to assist U.S. firms in exporting goods and services for major capital projects in developing and middle-income countries. Increasingly, these projects address the improvement of the environmental infra-

structure or have an environmental component. A major segment of TDA's activities is the development of feasibility studies, which have been successful in promoting U.S. exports.

OPIC's Role

The Overseas Private Investment Corporation (OPIC) provides loans, guarantees, and insurance to support U.S. foreign direct investment in developing countries and other emerging markets. Rapidly expanding markets for environmental goods and services have led to an emphasis on environmental activities.

"... a cogent U.S. envirotech export policy ... should link our goals of promoting U.S. competitiveness and environmentally sound development."

—Senator Max Baucus
Chairman, Senate Environment and
Public Works Committee

Other Agency Roles

Several other agencies share responsibility for foreign assistance activities related to technology cooperation. For example, the U.S. Department of Agriculture participates in a number of activities that have assisted other nations in developing environmentally sound policies and production programs.

Building a Sound Framework

Through technical assistance, training, policy reform, and institution and capacity building, the U.S. development assistance program seeks to establish a framework in which sound environmental practices and policies become self-sustaining. This framework must include education and training of in-country personnel and the establishment of public-private partnerships. Likewise, an "enabling environment" of policies, laws, and regulations is of primary importance in ensuring that market forces will be used to protect the environment in developing countries.

The U.S. development assistance program, in collaboration with domestic agencies, takes six approaches to education and training in developing countries: 1) training needs assessments; 2) limited academic training; 3) three- to six-month U.S.-based training courses; 4) in-country workshops and training programs; 5) industry internships; and 6) study tour and industry partnership programs to familiarize developing country personnel with U.S. environmental products and services.

The U.S. supports the creation of public-private partnerships that engage the private sector and NGO community. Considerable federal activity already promotes partnerships, such as USAID's U.S. Asian Environmental Partnership, the USAID-sponsored Energy Partnership programs of the U.S. Energy Association, the Environmental Training Institute's programs, and the Department of Energy's Clean Coal Demonstration Program.

Regulatory policy reform is critical to creating an enabling environment and stimulating developing country markets for environmental technologies. Between 1988 and 1993,



for example, U.S. foreign aid regulatory policy efforts to privatize electric power systems resulted in the installation of roughly 30,000 megawatts of independent power plants in developing countries, representing an investment of more than \$25 billion. The United States is estimated to have captured approximately one-third of this market. The purpose was development, not export, and yet the export impact of this activity—leverage of approximately 1,000-to-1 in exports for federal funds expended—far surpassed the 100-to-1 ratio sought by U.S. export promotion programs. Renewable energy technologies, energy efficiency, and other clean energy technologies depend heavily on independent power as the vehicle to implement them.

“The juncture between agriculture’s impact on our environment and agriculture’s vital role in insuring adequate supplies of foods, fiber, and wood products for the world’s growing population represents a challenge for the U.S. Department of Agriculture, unique in human history.”

—Mike Espy
Secretary of Agriculture

Appropriate technologies

On environmental issues, the policy framework is critical and should be the first priority, but the framework alone will not ensure diffusion of technology that gets the job done. USAID support for environmental technology is oriented toward assisting the host countries to develop and adapt technologies to solve priority environmental problems. Assistance programs include support for research and development, demonstration, and commercialization of appropriate technologies.

Much R&D assistance focuses on adapting existing technologies that are commercially viable in the United States to applications in developing countries. For example, agricultural residues are used widely as relatively clean energy in the United States, but most are usually wasted in developing countries. The U.S. development assistance program, in collaboration with the U.S. sugar and independent power industries, successfully adapted state-of-the-art U.S. techniques for harvesting sugarcane residues to handle hand-cut sugar residues in several developing countries. The result is increased productivity for the developing country sugar industry, much-needed energy for use in rural areas, substitution of clean biomass fuels for greenhouse gas emitting petroleum products, and export opportunities for U.S. independent power producers.

More than 40 percent of USAID’s research budget is used to support international research consortia, such as the Consultative Group on International Agricultural Research. This program, which is responsible for increased agricultural productivity in developing countries, now draws on technological advances in such areas as biotechnology to develop sustainable agricultural methods.

In those cases where technology is key to solving a particular development objective, the United States is prepared to support demonstration projects that help correct market imperfections or lead the way for follow-on private sector activity in a priority area. Demonstrations can be used to spread proven technologies that enjoy only limited markets in the United States into wider markets. Photo voltaics for remote communication is a case in point. Marketing in the developing world provides an opportunity to “scale-up” emerging technologies and thus reduce production costs. This scale-up could in turn expand domestic markets.

A number of joint-venture technology development and commercialization programs link government and private sectors in the United States and developing countries. An important model for these programs is the Binational Industrial Research and Development





"A rising tide lifts all boats: a successful development strategy can and should promote both increased trade and increased environmental trade opportunities for both developed and developing countries."

—Representative Benjamin Gilman
Ranking Republican
House Foreign Affairs Committee

Foundation (BIRD), one of three joint U.S.-Israeli endowed foundations for the development and commercialization of science and technology. The BIRD model has been adapted to India through USAID's Program for the Acceleration of Technology (PACT) and the Program for the Acceleration of Commercial Energy Research (PACER). PACT and PACER, which are joint U.S.-Indian science and technology initiatives, provide funding for research, development, and commercialization of technologies specifically adapted to India's needs.

U.S. commercialization programs also include technology feasibility studies. The Trade and Development Agency is the focal point for feasibility studies, although the Export-Import Bank contributes through its Engineering Multiplier Program. Assessments of marginally com-

mercial technologies, which could include a number of environmental technologies, are also carried out by USAID. These programs have been recognized as very effective in promoting U.S. technology in developing countries.

Leveraging of Resources

The World Bank and other multilateral lending institutions are the major sources of external public finance for infrastructure. Bank policies now require environmental soundness. Such policies are considered by most development experts to be a primary near-term motivation for developing countries to adopt and enforce more stringent environmental regulations. Bank loans also provide a sizable market in themselves. For these reasons, foreign aid agencies—especially USAID and TDA—work closely with the banks to influence their lending practices.

Foreign Aid and Development Assistance: Strategic Directions

Federal programs with respect to foreign aid and development assistance should:

- Foster technology cooperation that incorporates assessment of needs, information exchange, training and technical assistance, capacity building, and technology development.
- Expand efforts to encourage and assist developing nations in identifying and diffusing appropriate environmental technologies.
- Encourage strengthening of environmental, regulatory, and other policies to promote sustainable development while stimulating markets in less-developed countries.

Foreign Aid and Development Assistance: Current Initiatives

- The U.S.-Asia Environmental Partnership was established in 1992 to strengthen environmental protection and promote sustainable development in Asia and the Pacific by mobilizing U.S. technology, expertise, and financial resources.

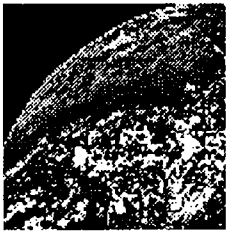
- USAID and EPA have launched the International Fund for Renewable Energy and Energy Efficiency to share the cost of pre-investment studies for site-specific applications of renewable energy and energy-efficient technologies.
- The United States has financially supported the Global Environment Facility during fiscal years 1992 to 1994. Projects will address such global environmental issues as climate change and biodiversity loss/preservation.
- USAID's environmental policy programs are directed towards ensuring that economic development is achieved in an environmentally sound manner. For example, the Environmental Pollution Prevention Program (EP3) promotes industrial pollution prevention and waste minimization through pollution prevention audits, technology cooperation, investment promotion, and pollution prevention training.
- More than half of USAID's budget for environmental technology supports programs to promote energy efficiency. These activities include introducing environmentally benign, energy-efficient technologies and promoting related policy reforms, investment incentives, and energy management and planning.
- The Environmental Protection Agency's U.S. Technology for International Environmental Solutions initiative is promoting the application of U.S. technologies and expertise in solving international environmental problems through international technical assistance, training, and other capacity-building programs.

Foreign Aid and Development Assistance: Possible Next Steps

- Foster greater U.S. technology cooperation activities with developing countries, including articulation of a clear technology cooperation policy.
- Consider establishing an interagency working group on environmental development assistance and include environmental technology cooperation as part of the group's mandate.
- Consider establishing an outreach program to demonstrate the benefits of environmental technology assistance activities to the American people, collaborating with the for-profit and nonprofit private sector and conducting a series of workshops during the first year to publicize the effort and obtain input from business and the public.
- Consider expanding and strengthening collaboration between foreign assistance and domestic agencies, including programs already underway in eastern Europe and former Soviet republics; clean coal, renewable energy, and efficiency programs of the 1992 National Energy Policy Act; the U.S. Asian Environmental Partnership; and the proposed Latin America Environmental Partnership.
- Consider expanding assistance programs in support of strengthening environmental policy emphasizing approaches to prevent or avoid environmental harm.



LEARNING AND WORKING TOGETHER



Innovative working relationships will help ensure that public investments in science and technology are guided toward national goals such as sustainable development. In addition to public-private partnerships, the nation's educational infrastructure will advance public awareness and support of environmental objectives and the role of technologies in achieving them. Furthermore, dissemination of information on environmental technologies will facilitate the adoption of the principles of industrial ecology. In this chapter, we will examine ways to facilitate partnerships, education and training, and information dissemination.

Partnerships and Collaboration

The administration is working to advance environmental technologies by strengthening ties with the private sector. Partnerships between the public and private sectors are one of the keys to leadership in the global marketplace. The private sector plays a vital role in identifying, developing, and applying technology for commercial products and processes. Throughout the development process, the federal government best serves as a catalyst to ensure that the value of America's investment in science and technology, especially in times of fiscal restraint, is maximized. Innovative working relationships will help ensure that public investments in science and technology are guided toward national goals such as sustainable development.

The administration's 1993 Climate Change Action Plan calls for "limited, and focused, government action and innovative public/private partnerships." It also ". . . fosters partnerships with business where focused government guidance and flexible approaches can produce cost-effective emission reductions."

"Since states are often incubators of change in public policy, it is important that federal and state governments work closely in developing a national strategy for environmental technology."

—The Honorable Roy Romer
Governor of Colorado

Partnerships between the private and public sectors permit sharing of resources, experience, data, facilities, and capabilities.

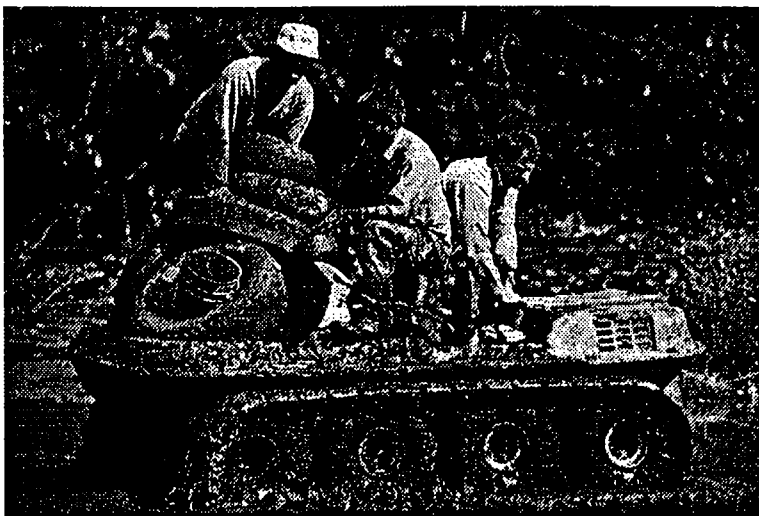
Partnerships vary in kind. The government plays a major role in long-term monitoring of environmental parameters because of the cost, risk, and timeframe. At the other

extreme, industry is the dominant player in commercializing specific technologies into marketable products and services. Strengths at the state and local levels include close involvement with entrepreneurs, small- and medium-sized manufacturers, regional industrial coali-

tions, and local councils that nurture technological leadership.

Private Sector Activities

Numerous private organizations are redirecting their focus to explore closer relationships with government agencies in environmental areas. Reasons for this interest include: developing a public image that is environmentally responsible; gaining access to federal decision makers; participating in forums that allow a venting of concerns and needs; and, in a time of downsizing, sharing resources and facilities. Some examples of these private sector initiatives take place through the Environmental Business Council, the Electric Power Research Institute, the Environmental Technology Export Council, the Electric Council for the Economy, and the Industry Cooperative for Ozone Layer Protection. In addition, nongovernmental organizations can play a very important role in bridging government and industry by providing information and advice to small businesses that are seeking to enter the environmental technology marketplace.



Public-Private Cooperation

Industry Visions of the Future, a program developed by the Department of Energy's Office of Energy Efficiency and Renewable Energy, provides a framework that brings together industry sectors to identify and plan for future scenarios based on legal, demographic, economic, social, and environmental drivers. Through this framework, government and industry can cooperate to formulate policies, strategies, and investments that are optimally leveraged for the development of technologies that recognize the realities of the market, roles and strengths of the public and private sectors, and regulatory and other policies needed to support technical innovation as an economic and environmental strategy. The framework encourages industries to work together and to extend planning horizons well beyond those typically used by U.S. industry.

California Institute for Environmental Technology

The California Environmental Protection Agency and the University of California, San Diego, have created a public-private partnership to establish a new Institute for research and commercialization of environmental technologies. Expected to be fully operational by 1995, the new California Institute for Environmental Technology will establish links with other universities, industry, national laboratories, and state and federal agencies.

USCD's Scripps Institution of Oceanography will provide the Institute with expertise in the areas of remote sensing, monitoring, assessment, data assimilation, and remediation, complementing California's industrial resources in the fields of electronics, biotechnology, advanced materials, and advanced computing and information systems. Research efforts will focus on water and air quality, resource use and management, energy efficiency, and land quality.

"We believe that . . . the American public should be aware of the powerful partnerships for global environmental protection and job creation that are being developed between this industry, the federal and many of our state governments."

*—Donald L. Connors
President*

Environmental Business Council of the United States

International Partnerships

International partnerships and collaborative activities are vital, given the global nature of many environmental problems. One example of a promising project is the Cooperative Program in Europe for Research on Nature and Industry Through Coordinated University Studies (Project COPERNICUS), which is designed to bring European universities together to work on environmental issues facing the world today. This is truly an international program with many private sector players, including U.S. industry.

Another is EUREKA, a program to stimulate international cooperation and to heighten Europe's competitiveness in the world market. Presently representing more than 2,700 companies and institutions, EUREKA helps companies and research institutions pool their resources to develop cutting-edge technology. It may be possible for the U.S. environmental industry to establish global partnerships through EUREKA. To this end, the federal interagency Trade Promotion Coordinating Committee is actively engaging several federal agencies in public-private partnering.

Barriers to Partnership

The private sector and key federal agencies have participated in a number of conferences to address the need for close interactions. The most frequently heard message was a call for partnership. Comments from the meetings focused on problems in three areas.

Statutory and Regulatory

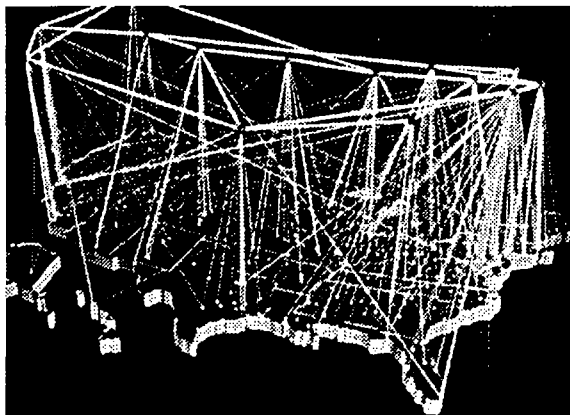
Regulations regarding intellectual property are not consistent among agencies or even between laboratories within the same agency. Liability requirements are onerous, and industry fears that proprietary information cannot be protected from Freedom of Information Act requests. In this regard, it is to be noted that proprietary information that is brought to the partnership under a Cooperative Research and Development Agreement (CRADA) by the private sector is exempt from the Freedom of Information Act. The 1989 amendments to the Federal Technology Transfer Act allow information of proprietary value generated under the CRADA to be exempt for five years.

Process and Procedures

Industry has pointed out that approval times for cooperative agreements are too long, and they have expressed a desire to be involved in the planning, selection, and prioritization of a research agenda. There have been calls for a long-term (greater than four years) commitment to technology partnerships and for strategic plans with specific goals, milestones, and objectives to allow effective evaluation of the success of the partnership, and for standardization of CRADA processes between agencies as well as within agencies.

Communication

A common vocabulary within the technology partnership community is needed; outreach, particularly to small business, is still inadequate; and roadmaps are needed to help potential partners identify the location of a particular capability within the federal laboratory system.



Partnerships: Strategic Directions

Government institutions can play a supportive role in the advance of technological capability and the realization of economic opportunities in the environmental area. Many partnerships with state and local agencies, schools and universities, and the private sector, may effectively support this mission. The federal government will:

- Foster collaborations, where appropriate, at each step in the process of developing and diffusing environmental technologies.
- Work to simplify and streamline the procedures required to establish a public-private partnership.
- Establish both domestic and international frameworks and mechanisms by which partnerships will occur.

Partnerships: Current Initiatives

- Chrysler, Ford, and General Motors have joined with the federal government to establish the Partnership for a New Generation of Vehicles (the Clean Car Initiative), an R&D effort to develop a commercially viable vehicle that can enhance mobility and safety standards while reducing environmental impacts and substantially improving fuel efficiency. This initiative aims to strengthen U.S. competitiveness by developing technologies for a new generation of vehicles that are both safer and up to three times more fuel efficient (80 miles per gallon or better) than today's cars. In addition, the administration launched the Motor Challenge program recently to provide industry leaders with an opportunity to demonstrate how improved efficiency of electric motor systems can enhance industrial productivity and profitability while preventing pollution.
- The National Technology Transfer Center (NTTC) was established by Congress in 1990 as a national clearinghouse to link U.S. firms seeking specific scientific or technical capabilities with federal agencies and laboratory facilities. Through close cooperation with the Federal Laboratory Consortium—an interagency network of representatives from the federal R&D establishment—the private sector is provided access to more than 700 laboratories and 100,000 research professionals.
- The Environmental Protection Agency's Design for the Environment program is a voluntary cooperative program that is helping industry evaluate multiple alternatives, compare their relative performance and risks to the environment in the earliest design stages, and organize collaborative efforts to develop and commercialize these innovative technological opportunities.
- The Department of Agriculture is organizing areawide programs for crop pest control that encourage acceptance of new technologies that limit pesticide use (e.g., Integrated Pest Management). Through this program, extensive collaborations are forged among federal scientists, state universities, the Cooperative Extension Service, state agricultural officials, farmers, producer organizations, bankers that extend loans to farmers, and private sector companies that can deliver the technology.
- Since 1991, the Department of Energy and the United States Advanced Battery Consortium have been partners in a cost-shared R&D program conducting

research on advanced batteries for electric vehicles. The consortium, composed of Chrysler Corporation, Ford Motor Company, General Motors Corporation, and more recently the Edison Electric Institute, is focusing on mid-term and long-term battery needs for cost-effective electric vehicles.

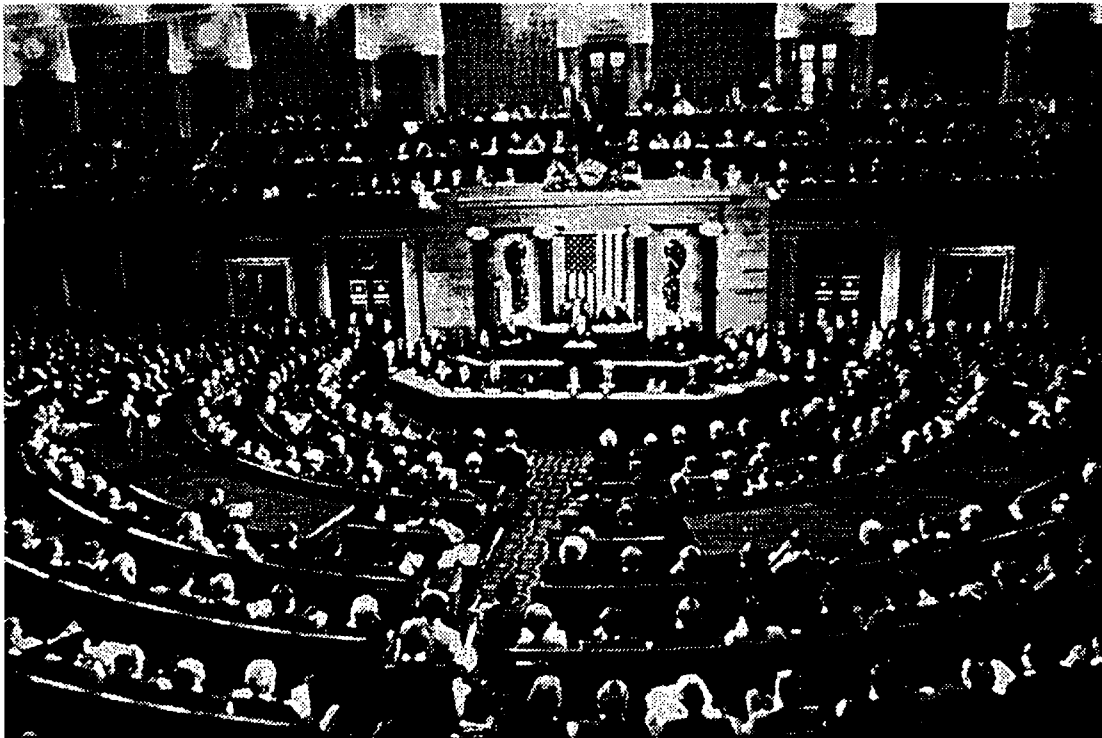
- Environmental Protection Agency, the California EPA, and the Air Force are partnering with Fortune 500 companies to develop innovative treatment systems to address contamination problems of mutual concern at the McClellan AFB in Sacramento, California. The public and private partners are working toward faster identification and implementation of cost-effective permanent treatment technologies, and encouraging community acceptance of innovative alternatives to incineration.
- Under the auspices and efforts of Private Enterprise-Government Interactions, the American Petroleum Institute and the offshore industry have agreed to allow researchers access to offshore platforms to use as bases for conducting environmental research. The unique opportunities provided by such platforms include the ability to make long-term (10 to 20 years) time-series measurements of atmospheric and oceanographic parameters at fixed locations. Measurements could range from the upper atmosphere through the sea surface down to the sea floor regardless of weather conditions.
- Through the National Science and Technology Council, close collaborations with the private sector in the development of environmental technology will be catalyzed by the working group for Private Enterprise-Government Interactions (PEGI). Representing the federal government, PEGI involves not only industry but also academia and non-governmental organizations.

Partnerships: Possible Next Steps

- Redefine the relationships between government and the private sector to incorporate a recognition that the private sector perspective is critical. For example, involve industry in policy, legislation, regulation, and program development from the ground floor; and consider long-term as well as short-term R&D needs in every industry-government partnership.
- Promote state and local alliances among industry, research institutions, and government agencies, working through regional organizations such as the Manufacturing Technology Centers and Agricultural Extension Centers.
- Consider engaging U.S. industry in developing an Industrial Ecology Partnership, a coordinated program featuring research consortia, government-supported R&D, technology demonstrations, regulatory reform, and performance milestones jointly agreed upon by government and industry.
- Consider initiating and maintaining avenues for positive interaction between federal, state, and local government and industry. For example, initiate an outreach program for environmental technology patterned on the Cooperative Extension Service and related university-wide extension programs through specific funding for environmental technology.
- Reduce impediments and disincentives that restrain public-private sector partnerships and inhibit technology development in key areas. Create innovative and flexible arrangements to couple federal and private sector research in key areas of interest to both. For example, provide a basis for decision makers to

update regulations, create as a model for assessing environmental technology programs, and develop a joint government and private sector portfolio for transitioning from present environmental technologies to future ones.

- Task an interagency group to work with appropriate Congressional committees to identify statutory improvements in the Stevenson-Wydler Technology Innovation Act, the Federal Technology Transfer Act of 1986, the Bayh-Dole Act, and the Federal Advisory Committee Act that would eliminate barriers to innovation.



Education and Training



The U.S. educational system, broadly defined, includes K-12, college, and graduate education; informal education at museums of science and industry; and life-long continuing education through businesses, community colleges, and television/telecommunications. These varied delivery mechanisms allow access to numerous audiences to foster increased awareness, technical and problem-solving skills, and creative invention in the field of environmental technology. Primary audiences for infusion of new knowledge fall into four groups: student populations from elementary school through advanced graduate level, individuals who work for environmental technology firms, engineers and managers who work for the broad array of companies that use environmental technologies, and the general public.

Enrollment in technical environmental training programs has increased during the two decades since Earth Day 1970. In addition, instructional materials prepared by professional science and engineering organizations have helped influence elementary and secondary school teachers to raise the sensitivity of their students to environmental stresses and possible solutions.

Approach

Students need conceptual and hands-on skills that will equip them to become productive workers, innovators, and decision makers in the environmental technology field. Many federal programs address innovation in environmental education, but nevertheless development of curricula remains essentially ad hoc. The federal government can act as an effective lever to help strike a balance between the current focus on discrete disciplines and a fresh approach that emphasizes integration of ideas from multiple disciplines.

Curriculum development will be pursued in consonance with the recommendations of the Education and Training Committee of the National Science and Technology Council, as well as initiatives such as Project 2061 of the American



Partnership for Environmental Technology Education

To meet a rapidly growing demand for a trained workforce in science, engineering, and technology, the Partnership for Environmental Technology Education (PETE) was formed as a national public-private partnership organized regionally in all 50 states, Puerto Rico, and the U.S. territories. PETE is creating permanent linkages between the nation's community colleges and the federal laboratories, federal and state agencies, private industry, and professional societies. The partnership's objectives are to develop broad environmental technician curricula at the two-year degree/certificate level; facilitate an education pipeline linking high schools and universities to the pivotal community colleges; and conduct special projects of regional and national interest on environmental education, training, job creation, and public literacy goals. PETE is supported in part by the Department of Energy, the Environmental Protection Agency, and the Department of Defense.

Association for the Advancement of Science; Project 2000 of the International Council of Associations for Science Education; and the National Science Foundation's Engineering Education Coalition program, which emphasizes that engineers need to understand how to factor environmental considerations into their approaches.

To this same end, the World Engineering Partnership for Sustainable Development was formed in 1992 as a global initiative to unify the world's engineering community to facilitate sustainable development. Other groups working for the same objective include the World Federation of Engineering Organizations, the Center for Sustainable Technology, and a number of similar organizations.

Scope

In elementary schools, environmental education should be pursued both experientially through hands-on learning and through an introduction to basic concepts focused on local environmental interests. In later school years, the concepts can be expanded and more abstract ideas can be introduced, evolving out of the earlier experiential foundation.

At the two-year community college level, new approaches to technician development should include merging mathematics and computer skills with first-hand experience, both at private sector locations and federal sites. Two-year colleges can also provide specific continuing education for professional development.

The collegiate curriculum should emphasize in-depth experiential learning by teams of students through integrating the humanities and social sciences with curricula from engineering, mathematics, business courses, and the physical and life sciences.

At the graduate level, practice-oriented master's degrees developed in partnership with the environmental technology industry will fine tune the ability of industry to meet the needs of society. Doctoral study will necessarily focus on reductionist research that creates new knowledge for utilization by industry.

Our educational system can play an important role in imparting knowledge of environmental technologies to foreign nationals who study in the United States. They can then take their skills and interest in these technologies back to their native countries to aid in decision making.

Retraining defense workers for new careers in the application of technology to meet environmental challenges is likewise a significant opportunity.

Education and Training: Strategic Directions

The cultivation of environmental awareness and expertise in the nation's workforce will facilitate the integration of environmental criteria into engineering and business decisions and support the diffusion of environmental technologies. The federal government will:

- Support efforts to develop an appreciation among all citizens for the importance of the environment to their lives through inclusion of environmental concerns and the concept of sustainable development in K-12 curricula.
- Facilitate the training of a cadre of skilled technical workers to help develop, maintain, and operate the increasingly complex environmental technologies.
- Support the development of holistic, multidisciplinary curricula in universities, emphasizing pollution prevention and efficiency in the use of resources.

Education and Training: Current Initiatives

- Through the U.S. Environmental Training Institute, the Environmental Protection Agency and the Department of Commerce are providing environmental technology-related training for officials from developing countries. A related program is providing environmental resource and training materials to U.S. and foreign commercial officers overseas.
- The Partnership for Environmental Technology Education (PETE), supported in part by the Department of Energy, the Environmental Protection Agency, and Department of Defense is designed to support the linkage of community colleges throughout the nation with federal laboratories to advance the training of environmental technicians and engineers.
- The Vice President's Global Environmental Education Initiative—the Global Learning and Observations to Benefit the Environment (GLOBE) program—is designed to involve children throughout the world in monitoring environmental quality. The project is intended to educate children about the environment while using scientific instrumentation to gather and analyze data.
- The Department of Energy's Environmental Management Program is supporting the Waste Education Research Consortium, Historically Black Colleges and Universities/Minority Institution Consortium, and the South Carolina Universities Research and Education Foundation in their efforts to promote environmental education, training, and research.
- The Environmental Management Russian Student and Scientist Exchange Program (in partnership with Department of Energy laboratories) is building a basis for future cooperation and ventures in environmental cleanup and prevention technologies.
- Environmental Protection Agency is selecting specific companies to aid in developing training courses for professionals from industrializing countries.
- NASA's Graduate Student Fellowship in Global Change Research provides support for doctoral candidates in fields relevant to global climate change. The purpose of the program is to ensure the supply of qualified scientists to support rapid growth in the study of the earth as a system. More than 200 fellowships have been awarded since the inception of the program in 1990. Up to 50 new fellowships will be awarded each year, subject to the availability of funds.

- The Technology Reinvestment Project is providing funds for manufacturing education and training to strengthen engineering and workforce capabilities necessary for a competitive industrial base.
- The Department of Defense has initiated an Environmental Scholarship, Fellowship, and Grants Program. The program is designed to provide education and training for dislocated defense workers to enable them to enter the environmental field. The program also assists institutions of higher education with providing environmental education and training at both the undergraduate and graduate levels.

Education and Training: Possible Next Steps

- Consider ways to promote training in environmental technology in the curricula of engineering schools, community colleges, technical schools, worker training programs, and in-house industry training programs, and, where necessary, to support the establishment of centers of excellence, along with a skills audit of worker demand during the next five years.
- Encourage the revision of engineering school curricula to include techniques of design-for-environment, and business school curricula to include training in environmental accounting and manufacture, including an appreciation of business opportunities in the environmental protection area.
- Devise ways to encourage the nation's universities, colleges, and secondary and elementary schools to make environmental awareness an integral part of science and social science curricula, using environmental issues as a key interdisciplinary theme in the voluntary national standards for science education currently under development.



Information Dissemination

Information flows are central to innovation. Only rarely in today's world does a single individual or institution possess all the information needed to bring a new product or service to market. Increasingly, U.S. firms rely on external sources to augment their own research and development activities.¹ These external sources can include other firms (both foreign and domestic), universities, or public sector laboratories. The channels of communication can range from informal discussions among researchers to more formal strategic alliances and partnerships. The most innovative sectors of the U.S. economy are

often characterized by vigorous exchange of information among individuals and institutions.

The federal government can play an important role in enhancing such information flows. For instance, programs such as the National Institute of Standards and Technology's Advanced Technology Program help fund collaborations between firms and researchers in universities. Programs such as the Manufacturing Extension Partnerships help disseminate information about best practice technologies to numerous small- and medium-sized firms as well as catalyze the formation of regional networks of firms that can enhance innovation in an industry. As a new product moves toward the commercialization phase, the necessary investments become more expensive and firms generally require proprietary interest in information specific to its design. Anti-trust policies and the laws

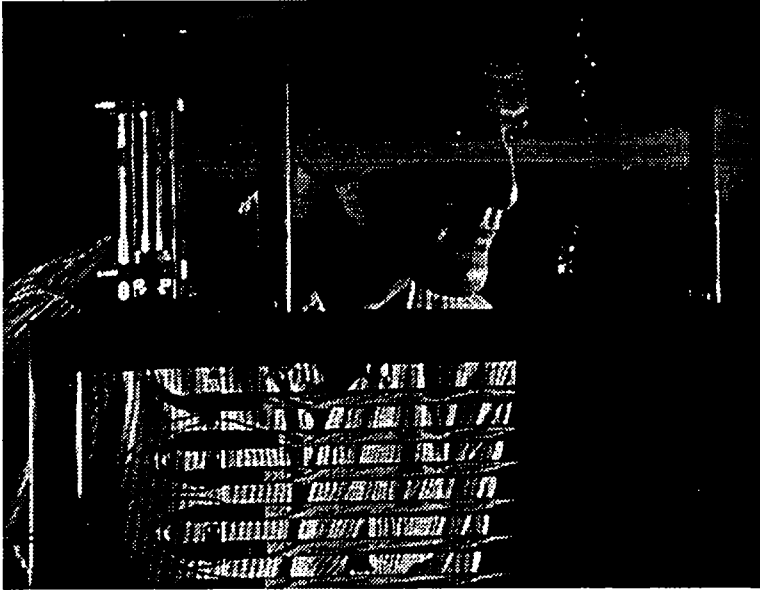
governing the protection of intellectual property thus help set the balance between the free flow of information and private sector investment in new technologies.

Federal government policies can also encourage more vigorous flows of information from government-funded institutions to the private sector. The government uses three primary techniques to disseminate information on technology: publications, databases and associated clearinghouses, and public outreach. The first two are passive techniques, depending on users to access information. The third, outreach, is generally targeted at identified user communities, such as consumers, a specific industry sector, or academia.

Publications

The primary currency for disseminating the information yielded by government-sponsored civilian research and development programs is publication and includes proprietary data and restrictions. At the level of basic R&D, publication in peer-reviewed scientific journals is preferred. This scientific literature is readily accessible since most journals can be obtained at technical libraries and are identified in commercial databases.

Administrative and technical reports, the so-called "gray" literature, are the most common publishing route for applied research and technology development projects supported by government. The American Technology Preeminence Act of 1992 requires that all science and technology-related publications produced by federal agencies or resulting from federal support be submitted to the National Technical Information Service.



Brokering Materials

Believing that one person's trash may be another's treasure, a company in Syracuse, New York, began in 1989 publishing a catalog of up-to-the-minute information on materials wanted and waste resources available. The materials exchange covers acids, alkalies and other inorganic chemicals, solvents, oils, waxes, plastics, rubber, textiles, wood, paper, metal and metal sludges, and post-consumer plastics.

By acting as a materials broker, North East Industrial Waste Exchange is providing crucial information on the type, quantity, and location of waste materials and chemicals. The company publishes a Listings Catalog in printed form and also an on-line computer version.

The goal is to redirect waste resources from disposal and incineration back into the manufacturing process. The service helps companies recover their investments in valuable materials and helps reduce the total impact of wastes in the region.

Databases and Clearinghouses

Government agencies place substantial emphasis on the establishment and maintenance of public databases and clearinghouses. Some contain highly technical data of interest to researchers. Others are important sources of information for monitoring and evaluating programs.

A database that provides performance and test information on environmental technologies certified by the appropriate agency would be very helpful in marketing products and services. Any clearinghouses and databases of test and performance information developed by the government in the absence of industry input, however, are unlikely to have commercial benefits. A major criticism of government programs for technology transfer is their failure to recognize the importance industry places on proprietary information.

Outreach

Among the more effective dissemination techniques developed by government are those associated with outreach programs such as extension activities, which link technology developers and users. Ideas for innovative technology identified by potential users are brought by extension agents to scientists and engineers who attempt to satisfy the user needs. To assist manufacturers, extension personnel also provide information on existing technologies that are in compliance with environmental regulations. The extension model has been very successful with agricultural groups, marine and coastal business communities, and small- and medium-sized manufacturers.

Extension programs are relatively expensive compared with more impersonal dissemination techniques. Trained extension agents are required, and they must have the resources to develop effective education programs. Because of the expense, only the highest priority programs are fully developed and funded.

"The range of environmental technologies, goods, and services offered by California companies is wide—ranging from remediation technologies to environmental consulting services, computer modeling and software products, and information networks."

*—California Environmental
Technology Partnership*



"There is a growing realization that knowledge transfer is not a one way process, flowing only from the discoverers of knowledge to its user. Instead, we recognize that just as science can drive advances in technology, so new technologies can drive scientific progress."

-----Neal Lane
Director
National Science Foundation

incentive to invest in developing a technology when they can wait for someone else to develop it and then copy. Recognition of this problem has resulted in legislation that fosters the protection of intellectual property for certain projects developed with funding from federal resources. Similar recognition of the importance of proprietary information to business has been incorporated into legislation aimed at stimulating technology development.

The scientific community is apprehensive about this new direction. The essence of science is openness and verification. Rarely is there conflict on the need for openness in connection with basic R&D, but determining the fine line when science changes from basic to applied is the challenge. Businesses developing a novel process or technological breakthrough that can provide a competitive advantage are not as willing to make the information public as government-supported scientists or engineers would be. A proper balance is needed between open scientific discourse and business security. If government and industry are to build the partnership needed to sustain a healthy environmental technology industry, this balance must be achieved quickly.

Critical Handoffs in the Technology Pipeline

Information dissemination is one of the infrastructures that maintains the technology pipeline. Information links each component of the pipeline and provides the feedback needed to adjust and modify technology as it proceeds from development to commercialization. Published results of basic research provide the inspiration for new technology such as the

Demonstrations—another outreach activity—can help prove to the regulator and potential customer that a new technology provides compliance. A demonstration must be conducted at a scale large enough to estimate the financial and ecological costs of a full-scale operation. Demonstration programs are discussed in more detail in Chapter Four.

Proprietary Information

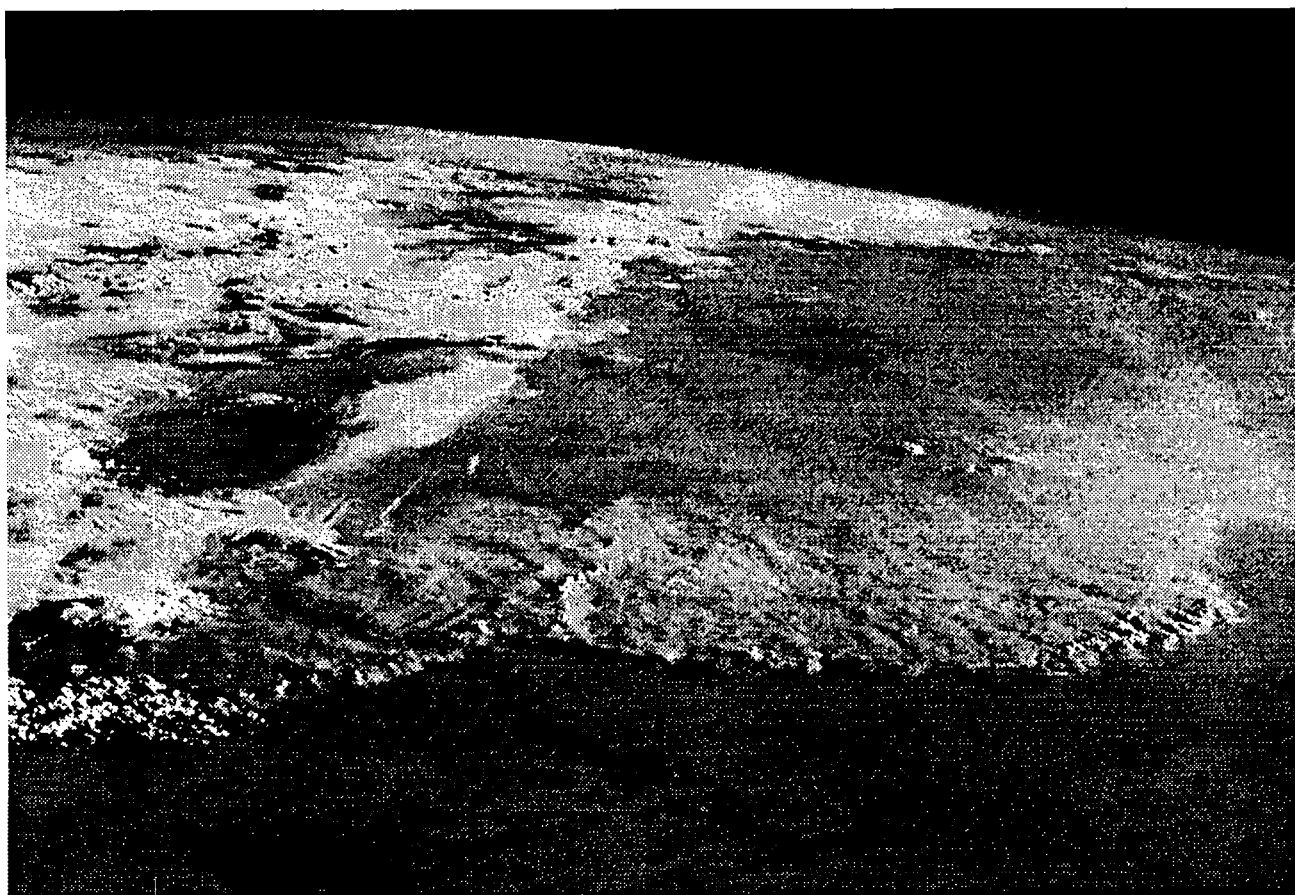
There is a tension between government's demand for openness in connection with activities it sponsors and industry's concern with intellectual property rights. Government policy seeks to ensure access to information developed with taxpayer money, while business frequently wishes to protect its investment.

Proprietary information is the most common stumbling block in technology transfer from government to the private sector. For one thing, proprietary information may not be clearly labeled as protected material. Nor do federal personnel always understand that divulging proprietary information is a criminal offense.

Firms with an interest in government-developed technology find little

engineering of bacteria that are capable of detoxifying contaminated sediments. In other instances, research results inspire the improvement of an existing process such as the development of low-temperature catalysts.

During commercialization phases, information becomes proprietary but still flows within the organization that is developing the technology. Once an environmental product reaches the marketing stage, a great deal of performance information is disseminated to the public through advertising and sales promotions. Operations information is essential to the training and education programs associated with technology installation, maintenance, and repair.



Information Dissemination: Strategic Directions

Broader and more effective dissemination of information will enable individuals and organizations to better satisfy environmental needs, to advance the state of knowledge, and to realize economic opportunities. The federal government can play a constructive role in that process, particularly through collaboration with the private and academic sectors. The federal government will:

- Facilitate the flow of information on environmental technologies among government, industry, nongovernmental organizations, and academia.
- Encourage partnerships, consortia, joint ventures, and personnel exchanges to foster the transfer of information on environmental technologies.
- Provide access to databases supporting global change research and to analyses linking environmental problems with technology needs worldwide.

Information Dissemination: Current Initiatives

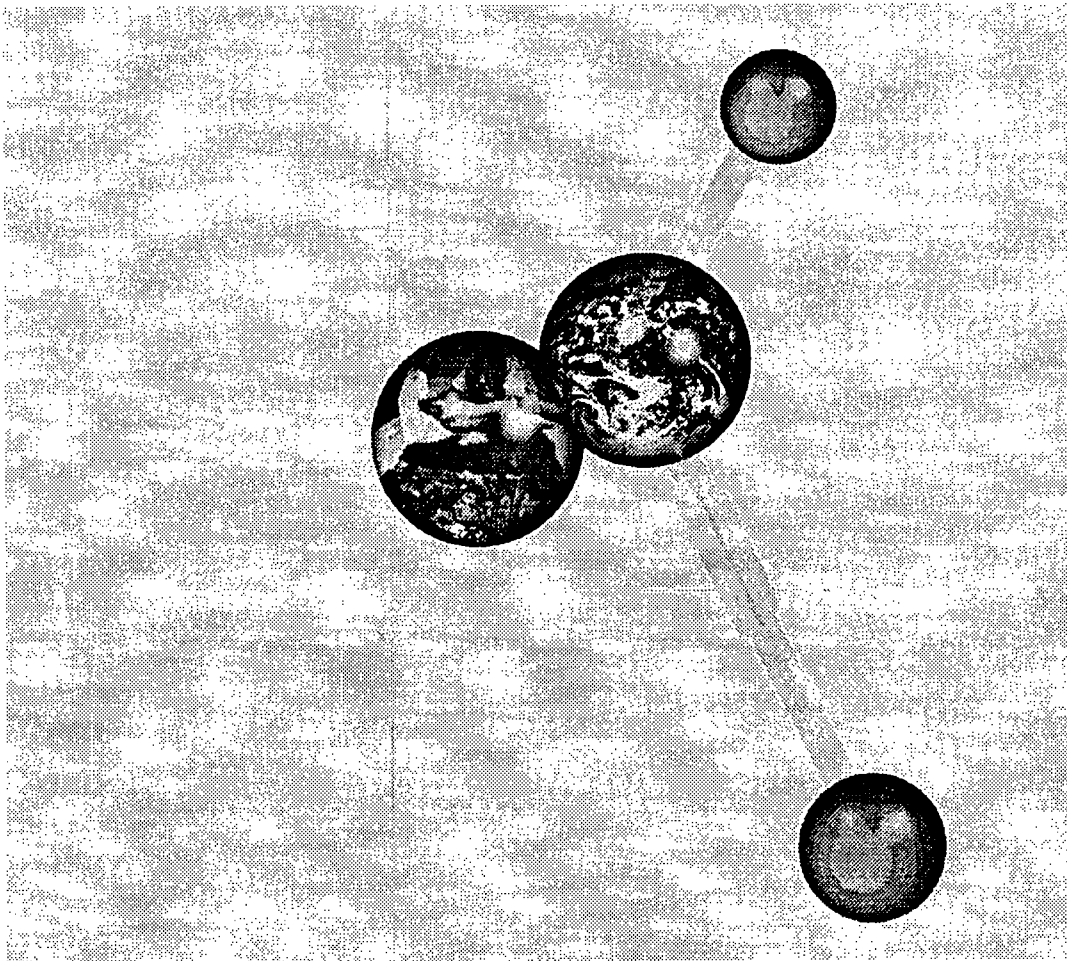
- The Department of Commerce's (DOC) Bureau of Economic Statistics is developing measures of the economic value of environmental assets to supplement its statistics on national output and investment. Initial measures will include the value of nonrenewable resources; the bureau is also developing estimates of economic value of renewable resources and air and water quality.
- The Green Pages are a service to the environmental technology industry to provide potential clients with a detailed listing of manufacturers and service providers by industry sector. The listing, produced by the EPA, DOC, and the private sector, is available through U.S. embassies, consulates, trade centers, and EPA offices.
- The Energy Analysis and Diagnostic Centers program involves local colleges and universities in performing audits of small businesses and manufacturing plants to identify opportunities for energy-efficiency improvements and waste minimization. The administration plans to expand this program, which currently funds approximately 700 audits per year to approximately 2,000 annually by the year 2000.
- NASA is developing the Earth Observing System Data and Information System (EOSDIS) to collect and disseminate data gathered during a 30-year period. These data are essential to global change research and will help to identify areas that would benefit from environmental technology application, as well as providing up-to-date support of disaster response programs.
- Increased dissemination and outreach is available through future public access to clearinghouses through networked databases, such as the 1,300 "gopher" systems worldwide. The Cooperative Extension System of the Department of Agriculture has developed and manages about 20 of the Internet "gopher" systems.

Information Dissemination: Possible Next Steps

- Consider establishing an information clearinghouse for environmental technologies.
- Ensure compliance with recent regulations published in accordance with the American Technology Preeminence Act of 1992 to improve public access to

technical information by establishing procedures for federal agencies to transfer unclassified scientific, technical, and engineering information resulting from federally funded research and development activities.

- Consider using the Manufacturing Extension Center program of NIST to promote the diffusion of best practice avoidance, control, and remediation technologies to small- and medium-sized firms and to provide a one-stop shop offering regional training programs, seminars for bankers and venture capitalists, and access to export promotion programs.
- Examine approaches to developing a database of certified environmental technologies.
- Support the dissemination of information on "green accounting," "design for environment" techniques, and life-cycle costs of technologies.
- Emphasize the dissemination of information on export markets, the state of the environment, technology application and commercialization opportunities, and the environmental performance of products.
- Consider increasing support for mass media communications of advances and capabilities in the environmental technology area.



TECHNOLOGY FOR THE ENVIRONMENT



Technology is applied in countless ways to integrate environmental quality with high standards of living. This chapter presents examples of technological challenges that convey the breadth, potential, and creativity of the environmental technology enterprise. The development and diffusion of solutions to these challenges is likely to yield major environmental dividends.

The examples presented are not comprehensive. Nor do they reflect a government assessment of technological “winners” that merit special support. We put them forward as a starting point for the national dialogue on environmental technology and as examples of the kinds of advances that policy reform can facilitate.

Technological Advances for Environmental Goals



The challenges presented are organized according to major environmental issues. The following seven areas, identified by the Committee on the Environment and Natural Resources of the National Science and Technology Council, form a framework for discussion:

- Air Quality
- Energy Efficiency and Climate Change¹
- Toxic Substances and Hazardous and Solid Wastes
- Resource Use and Management
- Natural Disaster Reduction
- Water Resources, Coastal and Marine Environments
- Biodiversity and Ecosystem Restoration

Technology can play a vital role in helping us respond to environmental challenges. In addition, it is important to note that technological advances in a number of specific areas could yield dividends for many or all of these environmental issue areas simultaneously.

Integrating Technology Needs

Given the interwoven nature of environmental problems, systems approaches are essential if we are to attain sustainable development. Currently, our government—like most governments—is structured to meet economic, social, and national security needs through discipline-by-discipline and single agency approaches. The transition to a systems approach

will be an evolutionary process of integrating the seven environmental areas identified above. This integration will be facilitated by addressing the following macro-challenges.

Energy

Energy needs range from developing low-cost, environmentally benign fuel cells to renewable energy sources and energy-efficient transportation and manufacturing. Cleaner energy could reduce air and water pollution, mitigate climate change and resource depletion, and reduce hazardous waste.

Materials

Many materials will need to be discontinued and new materials employed in order to achieve environmental technologies that conform with the principles of industrial ecology. Advances in the materials used in the manufacturing process and the development of lighter materials for transportation have the potential to reduce the production of wastes, minimize the extraction and use of virgin organic resources, mitigate pollution, and improve energy efficiency. These new materials would have a predictable life-span and, when they are retired from their original use, would be designed to be used for other purposes.



Redesigning Dry Cleaning

In 1992, the Environmental Protection Agency collaborated with the dry cleaning industry to conduct a short-term test of "wet" cleaning, a process that reduces exposure to the chemical solvents used in traditional methods of cleaning clothes.

More than 1,500 garments were collected from employees in several government agencies in Washington, DC, and New York City. The clothes were cleaned using both the standard dry cleaning method and the new wet cleaning. The new method proved to be slightly cheaper than dry cleaning. Labor costs were considerably higher but were offset by lower costs for equipment, hazardous waste disposal, electricity, and supplies. The study also indicated that conversion of existing dry cleaning plants to new wet cleaning facilities is economically viable for some segments of the industry.

Comparisons of customer satisfaction and fabric wear, including factors such as shrinkage, stretching, color change, and odor, found little statistical difference between the two processes, aside from a slight consumer preference for the reduced odor of the wet cleaning process.

Eighty percent of DoD's hazardous materials generation can be tied to weapon systems production, maintenance, and disposal. Therefore, a solution to our long-term cleanup and compliance problems is to design and engineer as much hazardous material and processes out of our weapons systems as possible.

*— Sherri Goodman,
Deputy Under Secretary of Defense for Environmental Security*

Biotechnology

The application of biotechnology to environmental problems has already produced impressive accomplishments in the production of new crops, foods, seeds, fibers, drugs, and environmentally safe energy from biomass. Biotechnological approaches are demonstrating their value in areas such as bioremediation, in which plants and microorganisms are used on-site to clean up pollutants and toxic substances.

Biotechnology-based methods are also being developed for detecting, measuring, and monitoring hazardous wastes, pollutants, microorganisms, and nutrients in marine, terrestrial, and freshwater environments.

Urban Environments

Many of the most significant environmental challenges occur in urban areas, the ecosystems contained within them, and the surrounding ecosystems. Viewed as systems, urban areas are chaotic and poorly integrated. If cities are to become environmentally sustainable and still provide an acceptable quality of life, new technologies that re-integrate complex human and natural systems will be required. This massive undertaking will require re-examining virtually all of our present technology.

Analytical Tools and Institutional Approaches

The following analytical tools will facilitate understanding of environmental and economic relationships. These tools can substantially improve the quality of environmental and technological decisions made by government and industry.

Life Cycle Analysis

Life cycle analysis can help us understand the full cost, potential, and impact of new products and their associated technologies. As a systems approach, life cycle analysis begins with questioning the need for a new product. In order to minimize waste and the use of natural resources, life cycle analysis then requires integration and modeling of the complex relationships among industrial processes. Shifting to an approach that considers all resources, products, and waste as an interdependent system will take time, but government can facilitate the shift by encouraging the transition to a systems approach.

Risk Assessment Technologies

Risk assessment facilitates technological and policy decisions. In evaluating new technologies or questionable old ones, risks to the environment and public health are estimated and compared in order to determine the environmental consequences of the situations, substances, or processes under evaluation. Risk assessment is used to maximize the reduction of risk in the same manner as cost assessments are used to define and minimize economic impacts.

Ecological Value

New measures of ecological value could help us assess the impact of environmental technologies at the individual, ecosystem, and global levels by developing full-cost pricing, improving market-based environmental policies, and including green accounting measures of environmental quality in government spending.

Environmental Technology Infrastructure

Underlying many technology development efforts is the need for an adequate research infrastructure. Laboratories, equipment, satellites, aircraft, ships, and communication systems must be modernized to meet the research needs of today and tomorrow. A key step in the modernization is additional development of information dissemination, storage, management, and decision support systems to allow ready access by all sectors.

Remote sensing from satellites, aircraft, ships, and land- or sea-based platforms; associated geographic information systems; and global positioning systems facilitate monitoring and assessment of environmental change on global, regional, and local scales. New research could focus on detection of changes caused by pollutants, soil erosion, ultraviolet intensity, the electromagnetic spectrum, and precipitation patterns, as well as the effect of species depletion on habitat. Efforts are already underway to establish long-term satellite multispectral data sets to monitor such changes.

Directions

Some of the technologies that are needed will require new basic research to improve our understanding of natural systems. Understanding the social, political, and economic needs of potential users and varying environmental circumstances is also essential during the initial stages of any technological development or implementation decisions. Technologies appropriate to address an environmental problem in one location or region may not be the most efficient and cost effective at another site.

In today's highly selective and rapidly expanding environmental markets, new technologies must be competitive. As an administrator of the Global Environmental Fund recently stated, competitive means "better, faster, cleaner, and cheaper." Technologies that meet these criteria, while also meeting social and political goals, will contribute to achieving a sustainable economy that produces challenging, well-paid jobs in industries that add value to products and services while benefiting the environment.

The Case for Green Urban Planning

Curitiba, a city of approximately 1.6 million residents in southern Brazil, is a showcase of environmentally sound development. The reason is a number of innovative policies aimed at encouraging public transit, promoting preservation of the city's historic core through a "buildings recycling" policy, conserving open spaces for flood control and recreation, promoting effective waste management, and encouraging mixed development by integrating industries, green spaces, housing, transportation, and public services.

In the 1960s, despite the pressures of poverty, inflation, and rapid growth, Curitiba adopted a master plan in which urban growth was shifted from a radial to a linear pattern along five main axes. Each axis is a "trinary" road system in which lanes restricted to buses are flanked by two high-capacity roads, one for traffic flowing into the city and the other for exiting traffic. Land use legislation encourages the development of high-density housing adjacent to each axis.

Many of Curitiba's successes are attributable to relatively simple, small-scale, but novel mechanisms that encourage cooperation by citizens and businesses. For example, in neighborhoods where curbside collection of recyclables is difficult, residents are given bus tokens and parcels of surplus food in exchange for bags of recyclables.

Technology Needs

The examples of needed environmental technologies presented in the following pages are far from exhaustive. It is intended to foster a dialogue among industries that are considering investment in innovative technologies and to guide federal agencies and the National Science and Technology Council toward a mutually beneficial environmental technology strategy. The examples of technology needs are based on a definition of environmental technologies developed by the Subcommittee for Technology, Engineering, and Research (STER) of the CENR.

By this definition, an environmental technology is a technology that advances sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating products and processes that are environmentally beneficial or benign. The word "technology" is intended to include: hardware, software, systems, and services.

Environmental technologies can be divided into four major categories: avoidance, monitoring and assessment, control, and remediation and restoration. **Avoidance** technologies are those that avoid the production of environmentally hazardous substances or alter human activities in ways that minimize damage to the environment. The phrase "avoidance technologies" is used rather than "pollution avoidance technologies" to indicate that additional forms of environmental degradation are intended other than pollution. Avoidance technologies might encompass product substitution or the redesign of an entire production process, rather than simply the use of new pieces of equipment. **Monitoring and assessment** technologies are used to establish and monitor the condition of the environment, including releases of pollutants and other natural or anthropogenic materials of a harmful nature. **Control** technologies render hazardous substances harmless before they enter the environment. **Remediation** technologies render harmful or hazardous substances harmless *after* they enter the environment. **Restoration** technologies embody methods designed to *improve* ecosystems that have declined due to naturally induced or anthropogenic effects.

Technology Needs for Air Quality



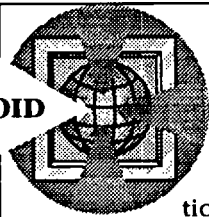
New prevention and control technologies are needed that can deal cost effectively with local and regional problems such as air toxics, indoor air pollution, acid deposition, and ground-level ozone. The technology of today is also inadequate to resolve global problems such as greenhouse gas emissions and climate change. Technology for mobile, stationary, and area sources, as well as for consumer products and agricultural fugitive emissions, will need to be developed to attain the targets embodied in the 1990 Clean Air Act Amendments.

Anthropogenic emissions may be harmful themselves or can be indirectly converted to hazardous atmospheric pollutants. Acid precipitation can damage aquatic and terrestrial ecosystems. Emitted gases such as sulfur dioxide, nitrogen oxides, and carbon monoxide—all relatively short-lived in the atmosphere—

yield the most immediate health impact. Long-lived gases such as carbon dioxide and chlorofluorocarbons are associated with serious long-term atmospheric changes, such as global warming and ozone depletion.

Also of concern are the health impacts associated with indoor pollution. Research has shown that some indoor environments exhibit substantially higher levels of toxic substances than are found in polluted outdoor air. A subtle yet major indoor pollution source is naturally occurring uranium, which can yield carcinogenic radon gas that is capable of infiltrating buildings. Equally important is the fact that people spend, on average, about 90 percent of their time indoors.

AVOID



Avoidance Examples

Many air pollution problems are best addressed through pollution prevention measures. For some of these problems, pollution prevention approaches are the only practical solutions. Many of the technology needs in this area require a major rethinking of our energy sources, energy consumption, material usage, and industrial production. Recently, pollution avoidance has been mandated in several instances, such as the "zero emissions" automobile, which must be on the market in California in 1998.

Indoor Air

- Develop new building materials and consumer products that minimize adverse impacts on indoor air quality.

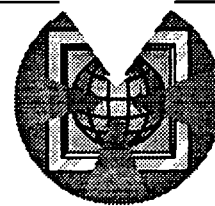
Ambient Air

- Develop automobiles and trucks that emit less volatile organic compounds, nitrogen oxide, and toxic air pollutants. Major emission reductions can be accomplished through radically altered fuel or engine technologies
- Develop environmentally advantageous renewable energy production technologies capable of displacing fossil fuel combustion.
- Develop redesigned industrial and chemical production technology with inherently low potential for air emissions.
- Develop high-efficiency fossil fuel power plants that substantially reduce emissions of criteria pollutants.
- Develop and evaluate new technologies to reduce wind erosion of soils and air pollution by dusts and airborne particulates.

MONITOR

Monitoring and Assessment Examples

Technologies and methods for the monitoring and assessment of airborne pollutants must be improved to help us prioritize and target avoidance, control, and remediation activities, and to facilitate implementation of market-based environmental policies. Monitoring of emission and deposition rates can help identify key pollutants and processes for future actions.



Indoor Air

- Characterize emissions from building materials and consumer products to allow assessments of their potential impact on indoor air quality.
- Develop personal monitors to measure human exposure to chemicals, together with information to characterize the circumstances in which the exposures occur (times, micro-environments).

Ambient Air

- Upgrade emission and activity factors associated with important sources of air pollutants and their precursors, especially emission-estimating methodology for emissions of volatile organic compounds from industrial mobile and area sources.
- Develop reliable emission information for key organic and inorganic sources of air toxics for important stationary sources.

- Develop reliable and inexpensive continuous monitors of toxic emissions from complex sources.
- Develop technologies to determine vulnerability to wind erosion of field surfaces through use of a soils Geographic Information System database and remote sensing of ground surface cover.
- Develop international data protocols, to enable data from different countries to be merged into unified data bases.
- Develop the capability to quantify, with greater certainty, the rate of deposition of pollutants to sensitive ecosystems by both dry and wet mechanisms.

Control Examples

As pollutant loads rise with increasing population and economic activity, more cost-effective control technologies will be necessary to remove or neutralize pollutants from emissions. Pollution control measures must bridge the gap from the time a hazard is identified until pollution avoidance measures are developed.

Indoor Air

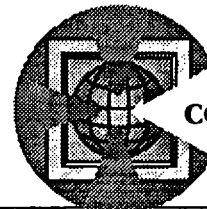
- Develop and demonstrate effective organic and particle cleaning devices that can be economically applied to residential and commercial buildings.
- Develop and demonstrate cost-effective mitigation technology to achieve indoor radon concentrations that approach acceptable levels.

Ambient Air

- Develop and demonstrate low-cost, effective particulate, air toxic sulfur dioxide and nitrogen oxide technology capable of being retrofitted to existing fossil fuel power plants.
- Develop and demonstrate low-cost technology to control volatile organic compounds from

small stationary sources.

- Develop and demonstrate cost-effective nitrogen oxide control technologies for significant residential, commercial, and small-industrial combustion sources.
- Develop and demonstrate controls that can cost effectively mitigate critical air toxic compounds from major sources such as incinerators (dioxin and toxic metals), wood stoves (polycyclic organic material), and iron and steel production (toxic organic and metal emissions).
- Develop technologies to improve control of air particulate pollution from wind erosion by land management systems.



CONTROL

Technology Needs for Energy Efficiency and Climate Change

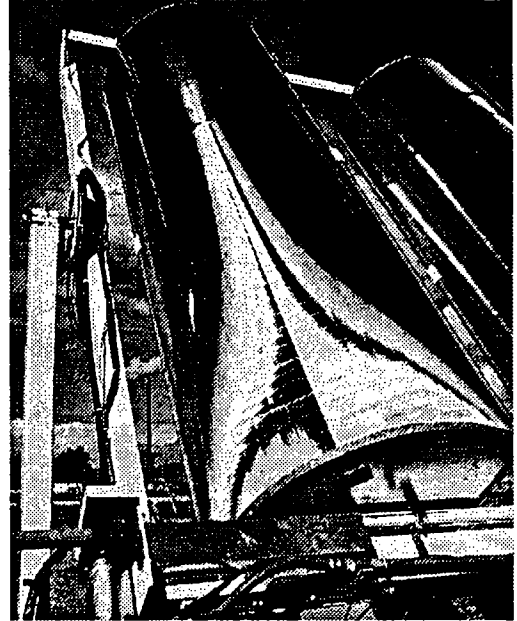
The Climate Change Action Plan released by the administration in 1993 was issued to meet the goals of international agreements on global warming. The plan calls for reduction of greenhouse gas emissions to 1990 levels by the year 2000. The primary means is the development and adoption of technologies that reduce energy requirements. Other measures include conversion to low-carbon fuels, improving agricultural practices, reversing deforestation, and reducing emissions of other greenhouse gases such as methane, nitrous oxide, and hydrofluorocarbons (HFCs). In the near term, emissions can be greatly reduced by improving energy efficiency and making greater use of natural gas.

In the industrialized countries, specific technologies are needed to improve energy efficiency in automobiles, lighting, and space heating. In the emerging economies of Central and Eastern Europe, critical needs include improvements in industrial processes for energy efficiency and rebuilding and modernizing their energy—inefficient infrastructure. The developing countries—still building an energy infrastructure—need to develop low-carbon energy sources such as hydroelectricity, biomass, and natural gas; and reversal of deforestation.

Over the long term, the most important options to control climate change for all regions are low-carbon energy technologies combined with major improvements in end-use efficiencies. Changes in agricultural and forest management technologies could also lead to significant reductions in emissions.

National targets related to the Montreal Protocol on Substances that Deplete the Ozone Layer are driving the current rapid advance in research on substitutes for chlorofluorocarbons (CFCs) in refrigeration, insulation, and industrial processes. The automobile industry is already replacing CFC-12 with HFCs in vehicle air conditioners.

As a result of a joint effort by industry and the Environmental Protection Agency, sub-



Clean Energy for the Future

Fuel cells are highly efficient, electro-chemical devices used to convert hydrogen, methane, and methanol into electricity through reaction with oxygen. Because these technologies do not rely on combustion, they emit little in the way of air pollutants or greenhouse gases. California has therefore issued a blanket exemption from emissions regulations for fuel cells.

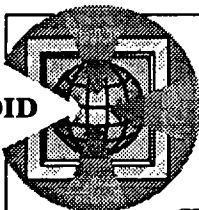
Currently, prototype and early commercial fuel cells are being used to provide power for remote industrial enterprises, and experimentation has begun on using fuel cells in buses, automobiles, and locomotives. Although fuel cells have existed since the nineteenth century, it was not until the space age that the technology matured as a practical alternative for electricity production.

Research by federal laboratories has given the United States a competitive edge in this critical environmental technology. To maintain this leadership will require a commitment to promoting the commercial viability of this truly sustainable technology.

stitutes for CFC-113 and methyl chloroform in electronics cleaning are commercially available. More recently, the development of substitute products or processes to take the place of methyl bromide, a widely used fumigant, has become an international priority.

The technology needs listed below are categorized by energy source (fossil fuels, alternative fuels, nuclear power) and by services (transportation, residential and commercial, industrial).

AVOID



Avoidance Examples

Improvements in energy efficiency and development of advanced technologies for alternative fuels will greatly reduce emissions of greenhouse gases, particularly carbon dioxide. Specific examples of technology needs for efficiency improvements in energy supply and in energy demand (i.e., transportation, residential/commercial, and industrial sectors) are listed below. Improved agricultural practices and agricultural technologies will also reduce emissions of methane and nitrous oxide.

Reductions in chlorofluorocarbon (CFC) emissions will be achieved through the use of CFC substitutes and alternative technologies in refrigeration, insulation, and industrial processes.

CARBON DIOXIDE EMISSIONS

Energy Supply

Renewable Fuels

Biomass:

- Develop improved plant species, particularly woody and herbaceous crops, that provide high yields of dry biomass and have low energy requirements during processing.
- Develop technologies for low-cost recovery of biomass residues.

Geothermal:

- Develop environmentally benign techniques for deep drilling.
- Develop technology to optimize heat storage in subsurface water and soil to facilitate trans-seasonal use of energy.

Wind:

- Develop technologies to increase energy recovery rates.
- Develop utility-grade wind turbines.

Solar:

- Develop advanced photovoltaic materials and more economical production methods.
- Develop commercially competitive solar hot water systems.

Superconductors:

- Pursue R&D on ambient-temperature superconductivity in order to improve the efficiency of electricity storage.

Hydropower:

- Analyze potential for increasing hydro output at existing facilities.

- Develop technologies to reduce impact on river ecosystems.

Ocean:

- Develop technologies to harness energy from waves, tides, and currents.

Non-Renewable Fuels

Nuclear:

- Develop technologies for improving configuration management safety, waste storage and disposal, economy, and fuel efficiency.

Fossil Fuels:

- Improve thermal efficiency of coal-fired plants through clean-coal technologies such as IGCC, pressurized fluidized bed, and indirectly fired cycles.
- Develop low-loss transmission and distribution systems, particularly for natural gas distribution in developing countries.
- Develop new technologies and advanced instrumentation for natural gas recovery.
- Improve coal-gas, natural-gas, and hydrogen-based fuel cells.
- Characterize coal combustion byproducts to provide guidelines for their beneficial use in agriculture and engineering.
- Develop high-efficiency advanced gas turbine systems.

Energy Demand

Transportation sector

- Promote development of technologies related to the Clean Car Initiative.
- Improve efficiency of vehicles powered by alternative fuels such as compressed natural gas (CNG), fatty acid esters, and alcohols.
- Continue R&D on gas turbines and low-heat-rejection diesel engines for use in heavy-duty trucks.
- Develop high-temperature structural materials (i.e., advanced ceramics and metals) for use in high-efficiency engines and economical lightweight materials to reduce vehicle weight.
- Develop intelligent vehicle highway systems (IVHS) to reduce congestion, improve traffic flow, and reduce idling at traffic signals
- Develop more energy-efficient aircraft technologies and more advanced air traffic control systems.
- Promote market-driven R&D and production scale on advanced batteries (i.e., nickel molybdenum hydrogen).

Residential and Commercial Sector

- Develop high-efficiency lighting, efficient appliances, and advanced insulation for walls, windows, roofs, such as new building envelope technology or for easier retrofitting to older structures.
- Improve operating procedures on existing buildings through use of building automation and control technologies.
- Develop high-efficiency gas and water heating.
- Improve cogeneration facilities.

Industrial Sector

- Increase energy efficiency in the industrial sector through improved electric motors, advanced industrial processes for energy-intensive basic materials, recycling of used materials, and cogeneration.

METHANE EMISSIONS

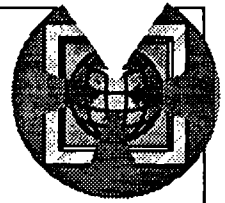
- Improve production and distribution systems to minimize leakage of methane.
- Develop technologies to increase rice productivity and remove crop residues to reduce methane emissions from flooded rice fields.

NITROUS OXIDE EMISSIONS

- Improve the efficiency of fertilizer use through such techniques as better placement in soil and through new fertilizer technologies such as nitrification inhibitors and fertilizer coatings.
- Develop alternative agricultural practices such as intercropping in order to absorb surplus nitrogen from the soil.
- Use biotechnology to reduce herbicide use by developing new crop varieties that require less fertilizer.

CHLOROFLUOROCARBON EMISSIONS

- Alter industrial processes, such as aqueous cleaning in the electronics industry, so that nonhalogenated solvents or water can be used instead of methyl chloroform or carbon tetrachloride.
- Study substitutes for CFC-12 in automobile air conditioners.
- Further develop refrigerant replacements
- Develop new materials to replace CFC-blown foam insulation or develop alternative blowing materials



Monitoring and Assessment Examples

Improved models are needed to predict the impact of increasing emissions of CFCs and each greenhouse gas on the atmosphere and to project the effectiveness of environmental technologies in preventing further atmospheric change. Additional research into the mechanism by which these gases alter our climate is vital.

- Improve field measurements, data collection, and characterization of gases in atmosphere.
- Develop technologies for improved ocean observation to assist early detection of climate change and expand use of existing offshore platforms for atmospheric and oceanic monitoring.
- Further develop technology for remote monitoring of smokestack and other significant emissions sources.
- Develop better understanding of the mechanisms by which CFCs destroy ozone, such as global transport systems.
- Assess how recently developed replacements for CFC-12, such as HCFCs, affect the ozone layer or cause other pollution problems and develop system to track the phase-out of CFCs, including the release of CFCs from products with CFCs as they wear out.

Control Examples

The reduction of carbon dioxide emissions by capturing them from emission sources or by scrubbing them from the atmosphere is presently not economically attractive, but the potentially enormous payoffs justify continuing research. Improved technologies to control other gases are also a high priority.

Methane

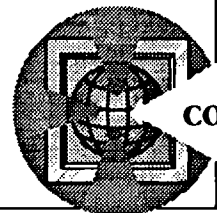
- Develop technologies to reduce or capture methane emissions from natural gas flaring, venting, and leaking during oil production and from coal seams..
- Improve technologies for collection and purification of landfill gas.

Nitrous Oxide

- Develop technologies to recover nitrous oxide emissions.

Chlorofluorocarbons

- Develop cost-effective methods of reusing and recycling CFCs.
- Develop better methods of incinerating CFCs, rather than venting them into the atmosphere.



CONTRO

Remediation and Restoration Examples

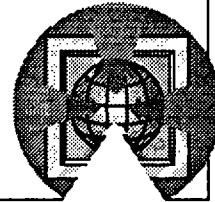
Improved forestry and agricultural practices are the primary technological means of remediation. Reforestation can have a significant impact on the level of atmospheric carbon dioxide.

Reforestation

- Develop improved agroforestry, forest management, and reforestation technologies.
- Pursue R&D on bioengineering to enhance growth and productivity of biomass energy crops.

Trapping carbon dioxide

- Explore the use of forestry management practices and marine biomass for sequestration of carbon dioxide and bioremediation.



REMEDiate



Technology Needs Related to Toxic Substances/Hazardous and Solid Wastes

Pollution prevention is playing an increasingly important role in reducing the formation of toxic and hazardous wastes. Toxic substances are encountered in the wastes produced by industrial and combustion processes. They also result from accidental releases of chemical intermediates and appear in final products as contaminants or as major constituents that are present because they possess a specific attribute required for the product to perform its function. Other chemicals and industrial mixtures require management to protect human safety and the environment because they are radioactive, explosive, and flammable. Special care



must be taken that new technologies implemented to address other areas of concern do not increase toxics problems. For example, electric car batteries will one day need to be disposed of if the batteries are not built to be recyclable.

Many industrial and residential sites are contaminated with toxic pollutants because the adverse impacts were inadequately known at the time of contamination. Under current practices, hazardous wastes are controlled mainly through application of end-of-the-pipe treatment technologies. These physical and chemical separation technologies remove the

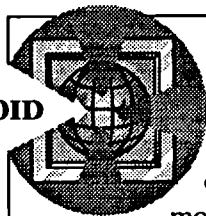
targeted pollutants from waste emissions and effluents. The result is a concentrated sludge or hazardous waste, which is then further treated for ultimate disposal. Organic wastes are usually incinerated, and inorganic wastes and hazardous residues from incineration are stabilized and then buried in a "secure" landfill. Existing systems are relatively expensive, especially in the remediation of Superfund and Resource Conservation and Recovery Act sites.

For this reason, it is desirable to employ technologies that: (1) avoid toxics and hazardous substances where their use is not essential; (2) minimize waste formation and promote recovery, recycling, and reuse; and (3) effect cost-effective management of nonrecycled wastes and their ultimate disposal.



Improved technologies are needed for remediation of contaminated sites to restore environmental quality and secure long-term protection of ecosystems, wildlife, and human health, and for monitoring and assessment to provide benchmarks for estimating residual risk and establishing adequate goals for prevention through substitution of alternate products and processes.

AVOID



Avoidance Examples

Pollution avoidance technology development for toxic substances is currently driven by regulatory restrictions. We need to move toward a more holistic approach that anticipates concerns about toxics exposures. The principal need is to remove or minimize the use of toxic substances in production of goods and in the application of pesticides and other chemical products.

Energy Cycles and Fuel

- Develop pollution prevention-based processes for alternative energy sources and cycles, both stationary and mobile.

Agricultural Practices

- Develop pesticides and fertilizers based on improved chemicals, biotechnology, and improved agricultural management practices, including smart application technology
- Develop smart technology for farm and home use for on-the-move applications of pesticides and fertilizers to optimize application quantities, worker exposure, and environmental contamination.
- Enhance technology for ensuring the safety of food affected by pesticides and fertilizers for farm and home use.
- Develop biotechnology-based time-release systems for fertilizers and pesticides.
- Develop alternatives to nonselective chemical pesticides, including the development of biological control agents, host resistance, and cultural practices that mitigate losses from pests.

Chemical Production

- Develop alternative chemical synthesis routes that use less toxic feedstocks and result in less toxic chemical intermediates and waste products.

Minerals Extraction and Purification

- Develop process technology that restricts production of avoidable pollution during oil and gas drilling and refining and mining, beneficiation, and smelting of iron, steel, and primary and secondary lead, primary aluminum, and minor metals including gold, silver, and titanium.

Manufacturing

- Develop pollution prevention-based technologies and processes that reduce waste, emissions, and resource use in the manufacturing sector, including food and fiber processing, metals forming and finishing operations such as cutting, bending, machining, chemical milling, welding, grinding, cleaning, degreasing, plating, painting, and coating.

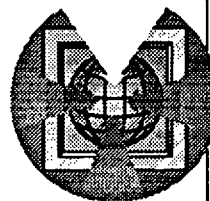
Home Construction

- Improve construction materials and techniques for use in remedial renovations for health safety and protection against chemical and biological agents. Include use of recycled wood fiber in construction materials that meet industry standards.

Cleanup of Nuclear Waste

- Develop technologies that minimize secondary waste generated as existing wastes are treated and sites and facilities are cleaned up.

MONITOR



Monitoring and Assessment Examples

Risk assessment techniques play a particularly important role in addressing toxic substance and hazardous waste concerns. The high costs and risks of handling and disposal of these wastes require that all options are carefully evaluated. Improved environmental monitoring technologies can be used to reduce toxic substance release rates.

Risk Assessment Methodologies

- Enhance techniques and benchmarks for estimating risks and establishing environmental performance goals for control, recycling, dis-

posal, reduction of pollution formation and waste emissions, and comparison of alternatives involving production substitution.

- Enhance risk assessment methods for multiple chemical exposures for humans and ecosystems at various time lengths.

Systems for Hardware Development

- Develop measurement techniques, including sampling and analysis procedures, to aid in the definition of pollution problems and the development of specific control and remedial technologies.
- Develop on-board sensors to determine nutrient content of soil so as to mix and apply needed quantities of pesticides and fertilizers while on the move.

- Enhance imaging technology and smart systems for identifying target pest species with point-of-contact application using single lethal dose technologies.
- Develop the measurement infrastructure to assure accuracy of monitoring techniques through traceability to national measurement standards.
- Develop real-time toxics monitoring and measurement techniques to allow closed loop control of processes and quick decision making for remediation.

Control Examples

Where pollution avoidance is not feasible or cost effective, pollution control measures meet regulatory standards and, it is hoped, broad health and environmental concerns. Control technologies must also focus on toxic waste reduction to reduce risks and costs associated with toxic and hazardous waste disposal.

Industrial Waste Treatment

- Develop advanced systems for effluent treatment of toxic substances formed during chemical synthesis and combustion, mineral extraction, and manufacturing processes.

Industrial Safety

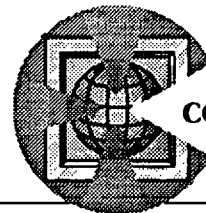
- Enhance technology to improve safety during manufacturing, storage, and transport of toxic and hazardous materials, including containment vessels, process monitoring control, accident avoidance, and emergency and remedial response actions.

Nonpoint Pollution Control

- Develop methods for application of low-cost engineered materials for selective pollutant retention.

Sewage Treatment Systems

- Develop advanced systems that are capable of handling toxic and recalcitrant organics using an engineered anaerobic, energy-efficient digestion stage, and other biotechnology-based systems.



CONTRC

Remediation and Restoration Examples

Current remediation and restoration technologies are very expensive, and more cost-effective techniques are urgently needed. Many current remediation technologies are ineffective and do not completely contain or remove the targeted toxic substance. New biotechnology-based approaches to remediation will be used to stabilize or remove many environmental pollutants.

Oil Spill Remediation

- Develop improved response techniques for oil spills to speed the removal of toxic and other petroleum components that have long-lasting adverse effects on the biosystem and wildlife indigenous to the spill site.

Housing Stock

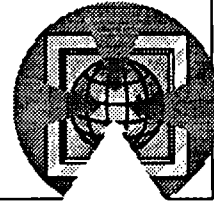
- Improve technology for affordable removal of toxic pollutants, especially lead, asbestos, mercury, and radon, both inside and outside homes.

- Develop technology for cleaning multi-story buildings contaminated by localized fires.

Hazardous and Radioactive Site Remediation

- Develop alternative technology evaluations and hardware systems offering improve cost factors.
- Pursue innovative technologies such as electrokinetics, bioremediation, and horizontal subsurface fracturing to permit *in-situ* treatment.

- Develop improved technologies to decontaminate and decommission excess nuclear facilities, including the re-use and recycling of recoverable materials.



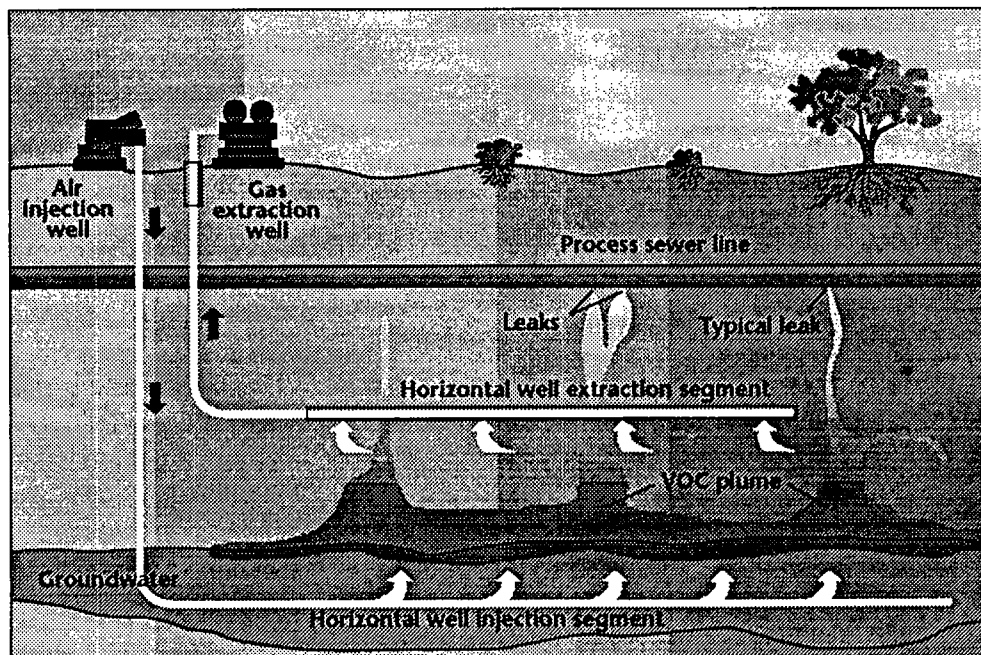
REMEDATE

In-Situ Remediation System

A new remediation technology called in-situ air stripping could significantly lower the costs and shorten the time involved in cleaning up contaminated soils and groundwater. When contamination occurs—perhaps by solvents leaking from a sewer line—the standard treatment involves pumping the groundwater or excavating the soils.

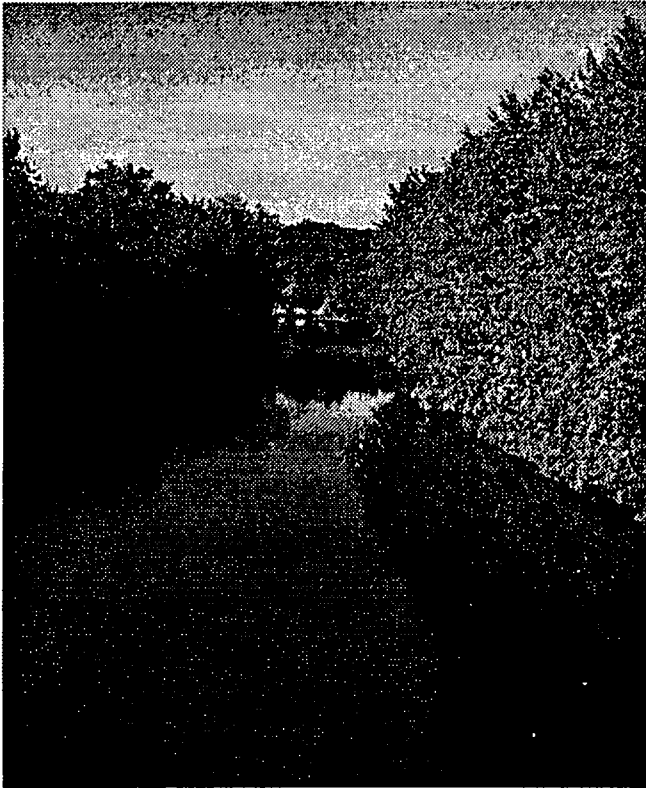
With the new technology, air is injected through a horizontal well. The diffused air, containing the hazardous chemicals, is then transported to the surface via another horizontal well where it undergoes further processing.

Air stripping allows the storage tanks and lines associated with industrial operations to be accessed without demolishing above-ground structures. In addition, the use of two horizontal wells rather than several vertical wells reduces the number of new pathways for contaminants to move deeper into the soil. Finally, air injections may have the serendipitous effect of promoting natural bioremediation. Horizontal well technology is now accepted as the industry standard. Horizontal wells are five times more cost effective than traditional pump-and-treat technology. Fourteen licenses for the technology have been issued to companies of all sizes.



Technology Needs for Resource Use And Management

The challenge in conserving renewable resources (grasslands, agricultural lands, rangelands, forests, fisheries, and wetlands) and nonrenewable resources (oil, gas, minerals, and coal) is to improve quality of life without increasing per capita resource consumption. More than 10



tons of material are extracted per person in the United States annually. Approximately 94 percent of the extracted material is converted to waste, with the remaining 6 percent made into durable products. Many uses of resources are dissipative. Products are degraded, dispersed to the environment, and lost from the standpoint of recyclability. Food, fuel, paints, fertilizers, and soaps fall into this category.

Approximately 75 percent of the extracted material is nonrenewable minerals. Technological solutions should maximize conservation of mineral stocks already circulating in the global economy, thereby reducing demand for virgin resources and minimizing environmental damage from extractive processes. Such technologies include processes that minimize pollutants and recycle wastes internally. Also included are technologies for making mineral-based products more durable, repairable, and recyclable and technologies that improve energy efficiency.

The overarching need is to develop methods to calculate the true cost of using virgin resources taking into account environmental costs throughout

the life of the products. The goal should be to establish publicly accepted and scientifically correct protocols for life cycle assessment that incorporate valid, risk assessment and full-cost environmental accounting.

Cooling Our Communities

Houses of the future will be built with environmentally sound design and construction techniques. One aspect of ecodesign has already gone beyond the idea stage. At Davis-Monthan Air Force Base in Arizona, strategic use of surrounding natural resources is helping reduce energy use.

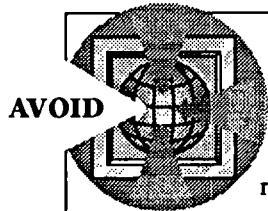
The full-scale research and demonstration project builds on previous studies showing that proper placement of trees and shrubs can reduce the need for air conditioning by 15 to 35 percent. Simply shading a window air conditioner can save as much as 10 percent.

To date, 279 trees have been planted in a treeless residential area of the base. The project is a joint effort by the U.S. Environmental Protection Agency, Departments of Energy and Defense, the USDA Forest Service, and American Forests, a national conservation organization.

The administration has selected the two-year-old program for rollout to 250 cities and 100 military bases by the year 2005.

Technologies are also needed to protect natural resources and sustain the production of goods and services from lands and waters. Fisheries increased the world's food supply by an average of 2 million tons annually from 1950 to 1989, but they may have ceased to be a major source of additional food. Soil erosion is a problem of great magnitude with ramifications for the capacity to provide adequate food and fiber. About 20 percent of cultivated cropland in the United States is considered "highly erodible" and more than 800,000 acres are lost annually worldwide to severe soil erosion and erosion-caused degradation. Also needed are new sources of plant nutrition and pest management that can increase agricultural yields without damaging rivers and lakes, threatening wildlife, or contaminating human food and water supplies.

Extractive and harvesting process technologies are needed that reduce pollution and waste. In many cases new technological solutions exist, but they must be adapted to local or industry-specific conditions. Engineering development for specific applications can be one of the most costly steps in deployment. Often these costs reduce individual firm's incentives to develop and deploy new environmentally desirable technologies.



Avoidance Examples

Pollution avoidance in the sense of resource management means reducing consumptive use of virgin resources and minimizing environmental damage from extractive processes. Technologies for pollution avoidance include pollution and waste-free extractive/harvesting processes; re-use/recycling technologies, including designing products for recycling; and substitution of longer service-life materials and environmentally benign chemicals.

Extractive and Harvesting Processes

- Achieve more selective separations of large but dilute systems through microbial separation and transformation, in-situ selective extraction and processing, and sensors for environmental monitoring coupled with intelligent process control.
- Shorten extraction and processing chains through, for example, bioprocesses such as biopulping and biomimicry for production of advanced materials in a single operation rather than multiple industrial processes that each involve energy consumption, pollutants, and wastes.

High-technology Consumer Products

- Design new materials and products for recycling so that all wastes are reusable (e.g., printed circuit boards made from wood-based biopolymers and lead-free solders).
- Develop recycling technologies using cellulose-based materials to reduce the release of carbon dioxide.

Long Service Life Materials and Environmentally Benign Chemicals

- Develop technology for substitution of input materials and modification of end products to promote cleaner processing.

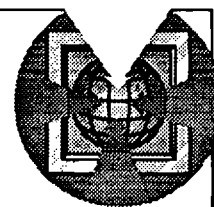
- Substitute long service life materials such as advanced metals, composites, and ceramics, functional gradient materials, and biologically based wood preservatives.
- Develop natural and biologically based pest management strategies and naturally resistant tree species.
- Develop resilient forest ecosystems to reduce the risk of catastrophic depletion resulting from environmental stresses.

Forestry and Agricultural Practices

- Develop crops better able to produce under native soil fertility and moisture regimes.
- Develop integrated farming systems, such as fish farms in which fish pond effluent fertilizes and irrigates crops grown to feed the fish.

Fossil Fuel Utilization

- Develop pollution reduction technologies that convert the sulfur in coal into reusable byproducts instead of sludge, which must be landfilled.
- Characterize coal combustion byproducts to provide guidelines for their beneficial use in agriculture and construction.



Monitoring and Assessment Examples

Methods, technologies, and standards for systematic sampling, evaluation, and inventory of geological and biological resources must be improved. Specific needs include:

Geological and Biological Resources

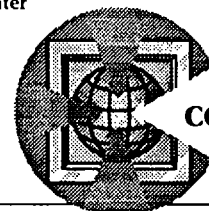
- Develop new technology for sampling aquatic and terrestrial species.
- Improve the use of and the instrumentation for remote sensing of environmental variables.
- Improve information storage and retrieval systems and their use.
- Improve geographical information systems and their use.
- Develop new concepts for analytical technologies, including biosensors, to locate and identify dense, non-aqueous liquids and to characterize multiphase samples.
- Develop new watershed management models utilizing noncalibrated paradigms and computational approaches, together with geographical information systems and remote sensing technologies, especially for management of stormwater and extreme events (floods and droughts) and basinwide reservoirs.
- Promote development, dissemination, and use of new modeling and forecasting analytic tools for integrated watershed management.

Control Examples

Pollution control in the context of resource conservation and management includes preventing damage to healthy ecosystems. Technological solutions are similar to those for control of hazardous wastes (see section on Toxic Substances/Hazardous and Solid Wastes). Specific examples of technological needs include:

Ecosystems

- Develop fertility and pest management practices that avoid negative impacts on ecosystems.
- Develop oil-recovery methods that prevent spills and improper disposal of waters associated with the oil in rock formations.
- Develop land management practices that will reduce runoff and increase water available to plants, aquifer recharge, and base stream flow.



CONTRO

Remediation and Restoration Examples

Technologies to enable an integrated systems approach to management of resources are needed. Damage to natural resources results from catastrophic and long-term events and from natural and anthropogenic causes. Both physical and biological technologies are needed to repair the damage to natural resources.

Specific needs include:

Management of Plant Communities

- Develop technologies to enhance natural recovery of forest and rangeland ecosystems from catastrophic fires and insect and disease outbreaks.

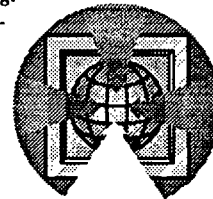
Watershed Management

- Develop a holistic ecosystems perspective and specific management and research tools for the management of watersheds to enable predictive adaptation and response in the context of changing water supplies, water quality, and aquatic ecosystem integrity.
- Standardize ecological and engineering protocols for constructed wetlands and riparian buffer zones designed for low- or zero-level methane emissions.
- Improve technologies for controlling invasions of unwanted plants, animals, and micro-organisms.

- Enhance technologies for ameliorating the impacts of poorly planned or uncontrolled urban sprawl and coastal, riverine, and lakeshore development.

Research Tools

- Develop advanced technologies for cryogenic conservation and long-term preservation of endangered freshwater and terrestrial organisms and plants.
- Improve molecular and biochemical systematics technologies, molecular characterization of species, phylogenetic investigations, and subsequent interpretive and predictive analyses.
- Develop advanced bioengineered organisms for in-situ biodegradation of toxic substances.

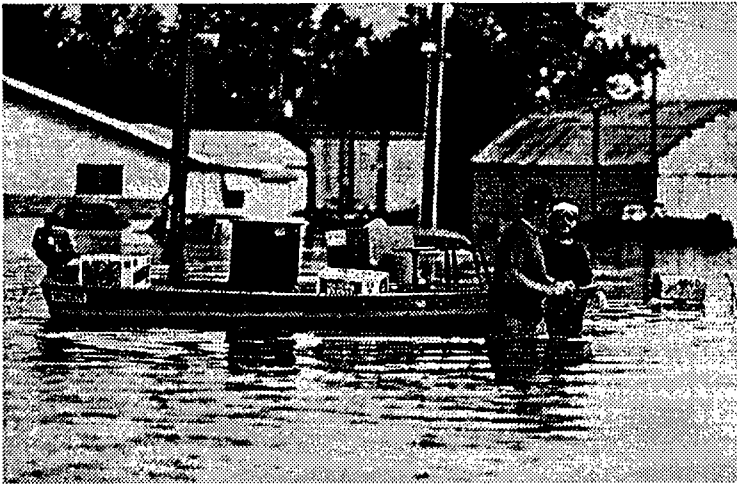


REMEDIATE



Technology Needs for Natural Disaster Reduction

Floods, droughts, hurricanes, tornadoes, earthquakes, volcanic eruptions, landslides, and wildfires result in the loss of thousands of lives and cost billions of dollars in property damage. The number of casualties has declined as a result of improvements in construction technology and warning and evacuation systems. Economic losses, on the other hand, have increased almost exponentially due to growth in urban populations, construction in hazard-prone areas, and the increased complexity, value, and vulnerability of the physical, economic, and social infrastructures of urban sites.



Natural disasters can alter the landscape, either permanently or temporarily. Actual impacts depend on the physical, biological, geological, ecological, and chemical conditions of the affected site. For example, a flood occurring in a river basin not altered by human intervention has very different consequences than the same flood in a system that has been altered by dams or urban development. The Mississippi Rivers floods resulted in the destruction of levees, bridges, and other lifeline systems, as well as the dispersion of biological contaminants and chemical toxic materials due to the inundation of municipal sewage treatment plants, industrial sites, and disposal facilities constructed in the floodplain. The ecological consequences of this flood are still being determined.

The nature, extent, and dimension of environmental and anthropogenic changes profoundly influence the recovery process. Conversely, hazard mitigation procedures and prevention measures may reduce the magnitude of losses. Understanding and evaluating the risks of locating industrial and other structures such as housing, roads, and bridges in hazard-prone areas can lead to better land-use planning. Determining the response of buildings to different types of stresses, e.g., wind or seismic loads, and examining the behavior of various architectural materials under extreme conditions may lead to development of construction techniques, standards, and codes that improve the survivability of buildings and reduce damage.

Four stages occur during the course of a natural disaster, and technology can play a substantive role at each stage:

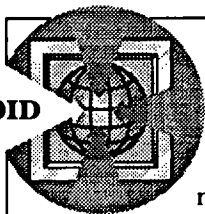
- Pre-disaster prevention and mitigation to alleviate the impact of a potential hazardous event through risk assessment and adoption of improved building codes;
- Preparedness plans for minimizing impact shortly before a disaster, including warning and evacuation systems, plus design and designation of shelters;
- Disaster response actions taken during and shortly after a disaster, such as rescue, distribution of food, and provision of shelter; and
- Post-disaster recovery including cleanup, long-term reconstruction, land management, structural measures, and repairing and retrofitting.

Communication, automation, integration, evaluation, and validation systems for the four stages of mitigation of natural hazards are in need of development and improvement. Knowledge gathered for mitigation and reduction of physical, biological, social, economical, structural, and other impacts resulting from natural hazard occurrences is transferable to mit-

igation of technological hazards. The result is a more resilient and sustainable human and ecological system.

Research by federal agencies has enhanced capabilities for forecasting hurricanes and floods, as well as improving survival of structures and buildings in earthquake- and hurricane-prone areas. Beneficiaries of this research are the insurance and construction industries, local and state administrators, planners and land managers, financial institutions, and researchers in the private sector.

AVOID



Avoidance Examples

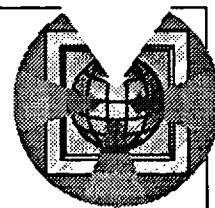
The environmental impacts of many disasters could be significantly minimized by the development and improvement of new materials and containment technologies. Some examples of these technology needs follow.

- Develop new and improved design, construction, and siting technologies for buildings, facilities, and structures.
- Test and use new materials in structural, roofing, and glazing systems.
- Develop new permanent and temporary protective systems, e.g., inflatable levees for use at waste disposal sites during floods, geomaterials for landslides.
- Develop codes and standards for structural elements (roofing, building envelope, openings), mechanical systems (ventilation, lifts), and materials.
- Develop land-use and resources management and nonstructural preventive measures.
- Develop and use biodegradable products.
- Develop and use intelligent materials and structures for controlling structural responses to excessive loads.
- Develop communication, transportation, water, and energy infrastructure capable of surviving natural disasters.

MONITOR

Monitoring and Assessment Examples

Both the minimization and remediation of disaster impacts depend on reliable, timely, and accurate monitoring and assessment capabilities. These technology needs encompass geological, climatological, biological, chemical, and geographical systems. Where these systems can be analyzed comprehensively, disaster response will greatly improve.

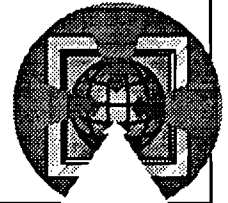


- Develop natural hazard forecasting and prediction systems for impact reduction, remedy, and avoidance for geological hazards.
- Improve natural hazard forecasting and prediction systems for impact reduction, remedy, and avoidance for weather-related hazards.
- Develop methodologies for forecasting the path and spread of pollutants released in disasters.
- Improve models, mapping techniques, the use of remote sensing data, and geographical information systems to assess the natural and technological risks attached to given sites, e.g., urban or rural, inland or coastal.
- Develop new and improved warning systems and control automation.

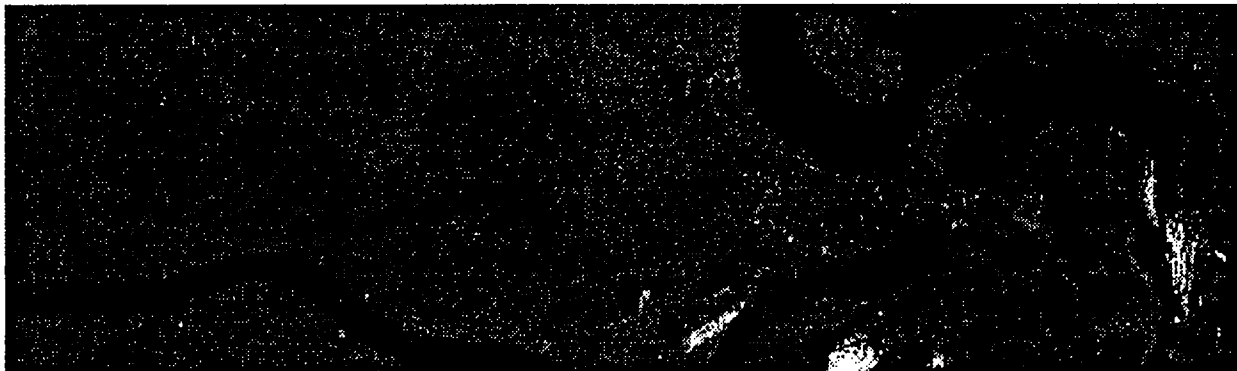
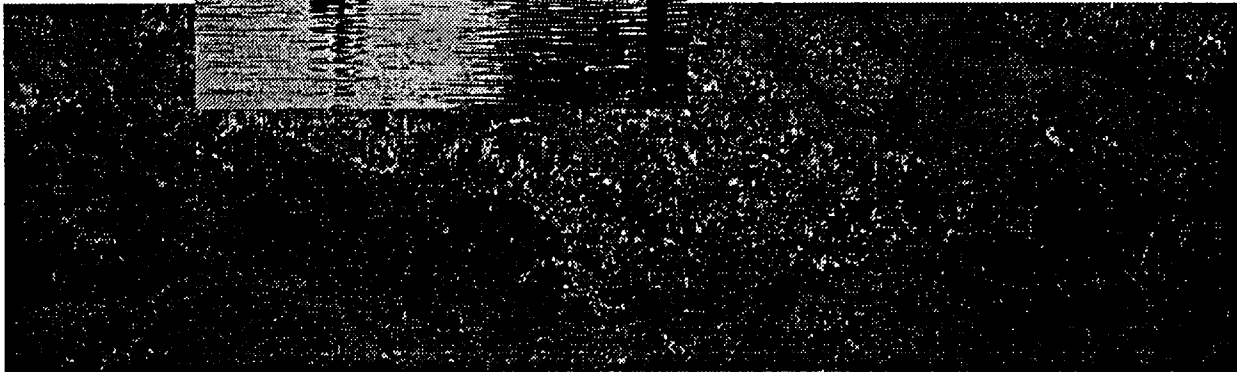
Remediation and Restoration Examples

The impacts of natural disasters often must be remedied quickly to prevent more serious long-term damage. The systems affected are complex, and remediation efforts are hampered by information gaps regarding scope, nature, and impacts of the disaster.

- Develop structural and nonstructural recovery and reconstruction measures applicable to various types of disasters.
- Develop in situ waste and wastewater physico-chemical and biological treatments.
- Develop new and improved control and treatment of dispersed toxic and pathogenic material in soil and water.
- Enhance, develop, and couple disaster models that can be used for damage estimations, risk assessments, and response planning and actions.



REMEDiate



Technology Needs for Water Resources, Coastal And Marine Environments

Population growth along coastlines and inland waterways, increased per capita demands for water, contamination of water supplies, and changes in aquatic systems from introductions of exotic species, loss of biodiversity, and habitat alteration present a need for an ever-improving predictive understanding of water resources— and a need for new technologies.

The sources and causes of impairment of aquatic systems point to the areas where technological innovations and improved policies are most needed (Table 1). In general, agricultural and municipal sources, together with hydrologic and habitat modification, account for most of the impairment. Similar analysis and impact assessment is required of the world's oceans and seas.

Many environmentally important integrated technologies have application to water resources, but research to address these generic needs is too removed from marketable products to be adequately supported by industry and too "applied" for most academic laboratories. One of the biggest challenges is to lower the cost of water and wastewater treatment. In a city of a half million people, the capital costs of an entirely new, modern water supply system run about \$48 per person. Individual household connections cost another \$100 each. A modern sewage system, including a treatment facility, would cost \$300 to \$1,000 per connected household. In low-income economies, the gross national product per capita averages only \$320. It is \$2,220 in middle income economies. Reducing the cost of current technologies or finding other cheaper approaches to water and wastewater treatment is essential if these low and mid-income economies are to have safe and adequate water supplies.

Impaired waters in the United States by causes and sources of pollution.

Percent of surveyed impaired rivers, lakes, and estuaries

Sources of Impairment	River length	Lake area	Estuary area
Agriculture	55	58	19
Municipal	16	15	53
Resource extraction	13	4	34
Hydrologic/habitat modification	13	33	5
Storm sewers/runoff	9	28	29
Silviculture	9	1	2
Industrial	9	8	12
Land disposal	4	27	27
Combined sewers	4	0	10
Sources of Impairment	River length	Lake area	Estuary area
Siltation	42	25	7
Nutrients	27	49	50
Pathogens	19	9	48
Organic enrichment	15	25	29
Metals	11	7	10
Pesticides	10	5	1
Salinity	6	14	
Oil & grease			23

Derived from a 1988 EPA study in which 30 percent of U.S. river miles, 40 percent of lake areas, and 70 percent of estuary areas were assessed (Gleick, 1993).

Affordable Drinking Water

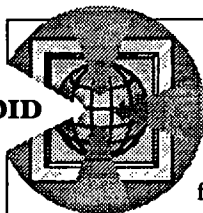
Children die every day around the world because they lack one of the basic necessities of life: safe drinking water. Traditional technologies for obtaining potable water are too expensive for most communities in the tropics. Today, a simple, inexpensive new technology for disinfecting contaminated surface waters has been successfully introduced in the Brazilian state of Pará.

In the new system, water is decontaminated by passing it through titanium alloy plates charged with a very low DC electrical current. The new technology is one-fifth the cost of traditional technologies.

It is also reliable and durable. The government of the state of Pará is implementing a massive potable water campaign using this new life-saving technology.

Small or rural systems make up the bulk of the drinking water and wastewater treatment systems in the United States. Of the 60,000 water systems in the nation, 94 percent serve fewer than 10,000 people, and there are only 642 systems for medium to large cities (> 50,000 persons). Most of the pollution control-related environmental technology challenges in the water area are in improving the performance and increasing the cost effectiveness of small systems.

AVOID



Avoidance Examples

Advanced pollution avoidance technologies would make the most difference in the United States in the agricultural sector, where siltation and nutrient and pesticide contamination are particularly serious for ground and surface waters. Elsewhere in the world, point source pollution, such as that from industrial and mining wastes, is equally serious and may spur markets for pollution avoidance technologies in the former Soviet Union and elsewhere.

Nonpoint source runoff is a serious problem with global dimensions. Engineering solutions alone do not work. Technologies and practices that couple ecological know-how with engineering capabilities in a cost-effective manner should be given more attention.

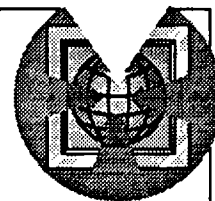
- Develop technologies and practices to prevent agricultural contamination of groundwater through soil erosion, fertilizer, or pesticide runoff.
- Develop alternative technologies for bleaching techniques that produce dioxins.
- Reduce industrial pipeline leaks.
- Develop technologies to reduce surface transportation impacts on aquatic resources.
- Develop new manufacturing processes that do not produce as many toxic byproducts.
- Develop finely calibrated manure and compost spreaders.
- Develop technologies and practices to improve soil quality for preventing erosion and plant diseases.
- Develop cost-effective technologies to conserve water in industrial, agricultural, and residential applications.
- Develop new technologies and cost-effective improvements in existing technologies in the agricultural sector (e.g., irrigation), industrial sector (pulp and paper production, food, fiber, and chemical manufacturing, and iron and steel production), and urban areas (low-flow fixtures in homes, xeriscape technologies for landscaping).
- Develop improved desalination technologies.

MONITOR

Monitoring and Assessment Examples

Advanced technologies for monitoring and assessment are needed for freshwater and marine systems, drinking water, and wastewater.

Monitoring networks and analytical methods are needed for quantifying contaminant concentrations. A particularly significant need in developing nations is the capability to analyze drinking water quickly and inexpensively for possible pathogenic microbes. Our capabilities for evaluating aquatic habitats remotely, and detecting change, are limited at present. This is expected to be a particularly important area for technology development because well-informed decisions regarding aquatic habitats will depend more and more on this type of technology in the future.

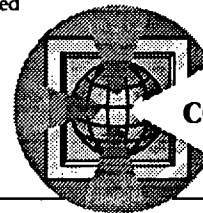


- Develop monitoring networks, analytical methods, and models for quantifying contaminant concentrations, e.g., immunoassays for organic chemicals and metals.
- Enhance capabilities for evaluating the effects of natural and anthropogenic factors on aquatic habitats and detecting change by field observations and remote sensing.
- Improve biomonitoring capabilities, including developing biocriteria and biological monitoring techniques.
- Develop improved capabilities for analyzing drinking water for pathogenic microorganisms and on-line monitoring systems for parasites and trace metals.
- Develop better ability to track back sources of pollutants carried by air deposition.
- Develop improved capacity to determine cause-and-effect relations for pollution problems.
- Develop models and technologies for better understanding the transport of acidic and toxic substances into water bodies and the fate of atmospheric nutrients.
- Improve on-line monitoring instrumentation for treatment plant operations.

Control Examples

Most of the environmental technology challenges in water pollution control are in improving the performance and increasing the cost effectiveness of small systems. Improved strategies and systems are also needed to optimize the operation of existing treatment facilities. New EPA standards are driving needs for new removal technologies that will handle trace impurities. Advanced technologies are needed in several other areas to improve control of water-borne pollutants and pollutants that cross into other media.

- Develop technologies for optimization of control, removal, or degradation of toxic contaminants present in low concentrations in wastewater.
- Improve the capability to detect and model movement of toxic chemicals into groundwater from dump sites and underground storage and disposal sites.
- Develop more effective nutrient removal technologies for wastewater, agricultural runoff, and other nonpoint sources.
- Develop technologies for improved biodegradation of organic pollutants.
- Pursue polishing technologies for dilute aqueous industrial wastes that follow membrane and biotreatment.
- Develop advanced disinfection systems such as UV irradiation and ozone disinfectant/organic removal technologies.
- Improve membrane technologies for drinking water.
- Develop agents that have little or no potential for generation of byproducts to retard microbiological growth in distribution systems.
- Develop cost-effective, low-tech treatment systems, such as constructed wetlands, for use by small utilities.
- Develop advanced technologies for recycling and disposal of biosolids and other residuals, industrial recycling of process water, recycling and reuse of household wastes, and non-potable water reuse for such purposes as lawn watering.
- Develop more effective designs for streamside vegetative buffers.
- Develop low-cost, effective treatment and preventive technologies and practices for reducing urban runoff.
- Develop cost-effective, advanced on-site residential treatment and/or recovery of sanitary and other used water and nutrients.



CONTROL

Remediation and Restoration Examples

Today's world is characterized by degraded streams, rivers, and lakes; polluted groundwaters and estuaries; and human-altered aquatic habitats that no longer provide the valuable goods and services that they once did. Mitigation, restoration, and remediation technologies are needed to respond to the major water quality challenges facing nations throughout the world.

Mitigation

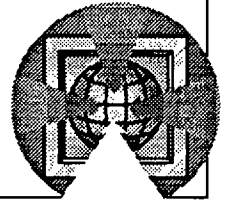
- Develop technologies for mitigating the ecological effects of dams, water diversions, and other structural changes that alter the hydrologic flow path.
- Improve technologies that utilize micro-organisms and plants that concentrate or sequester toxic metals and other pollutants from stormwaters.

Restoration

- Improve technologies for evaluating critical habitats and models to determine the achievable end point of restoration efforts.
- Standardize technologies and protocols for restoration of urban-impacted streams and rivers, chemically contaminated waters, and riparian zones.

Remediation

- Develop advanced remediation technologies for contaminated sediments.
- Develop new technologies for remediation of waste sites in mining and energy production.
- Improve in situ biological and chemical remediation methods for organic chemicals; containment, removal, and degradation of toxic chemical spills and leakage.
- Develop new technologies for contaminant recovery from underground tanks and pipelines.
- Improve groundwater remediation for removal of nitrates, trace organics, and metals.



REMEDiate



Technology Needs for Biodiversity and Ecosystem Restoration

Despite heightened public attention and considerable progress in environmental measures during the past two decades, ecosystem degradation and extinction of potentially important species continues in the United States and worldwide. Specific impacts include: loss of fertile wild or agricultural lands to meet the food, fuel, and fiber needs of present and future generations; increasing government expenditures to compensate for loss of natural ecosystem functions; extinction of species that could have beneficial uses or might impact other species or ecosystems that currently have economic value; impacts on habitats that can no longer take up harmful substances or release beneficial substances or otherwise become dysfunctional within the larger ecosystems; adverse impacts to micro and macro climates; and continuous pollution and degradation of coastal waters so that sustainable levels of fisheries are no longer available.

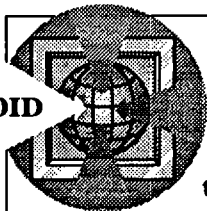


Technology needs include improved assessment analytic methods in biology, economics, and finance. Technologies to control existing rates of loss and damage are needed, as are advances in bioremediation practices.

Selection of technologies also must take into consideration other ecosystem functions such as restoration of hydrological cycles, carbon cycles and sinks, sediment trapping capacities, air and water quality, and flood storage, as well as the improved aesthetics and health benefits that ecosystem restoration can bring to urban areas.

Finally, needs for new remediation and restoration technologies include extension of seed banks, germplasm cryopreservation and in vitro technologies. Improved ecological restoration techniques are needed to assure that the restorations do not negatively impact other segments of the environment. For example, remediation by removing contaminated soils may remove or damage critical species or habitat. Even the creation of habitat (e.g., wetlands) comes at the expense of other habitat, either aquatic or terrestrial.

AVOID

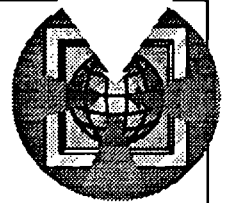


Avoidance Examples

Pollution avoidance needs encompass a variety of technological solutions from improved environmental assessment methods to better environmental control hardware. In addition to the development of improved analytic methods and metrics in biology, economics, and finance, there is a long list of engineering and instrumentation advances that can contribute to stemming the tide of biodiversity loss and protecting threatened ecosystems.

- Develop improved biotic and physical control measures for avoiding introduction of chemicals to aquatic systems.
- Develop improved techniques for preventing erosion and consequent contamination of receiving waters.
- Develop and use new economic and financial metrics, including environmental accounting and gross domestic product with environmental values and adjustments.

MONITOR



Monitoring and Assessment Examples

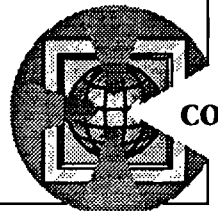
Technologies are needed to aid in generalized mapping and characterization of biodiversity loss and ecosystem degradation. Listed below are examples of technologies that should be developed and enhanced, from genetic mapping to macroscopic representation and visualization to image processing.

- Develop mechanisms to provide early warning for less obvious problems such as low levels of chronic contamination.
- Develop improved tools (sensors, databases, analytical packages, models, display packages) for mapping, classification, and characterization of ecosystems and their components.
- Continue development of sophisticated and powerful space, aircraft, and ground-based sensors for data acquisition and processing.
- Develop improved techniques for image analysis to take advantage of the increased information available from sensors.
- Develop software for use of graphics and visualization techniques.
- Develop linkages among the various hardware and software units involved in data collection and analysis, e.g., among agencies, scientists, and managers, from local to global levels.
- Develop standardized mathematical and sampling approaches for effective determination of population status and distribution of difficult subjects, e.g., wide-ranging but naturally rare species and secretive species.
- Develop technologies to aid in tracking groundwater plumes to determine the extent and likely future of contamination.
- Develop methods for easy and meaningful genetic mapping to allow more effective and efficient planning and monitoring, facilitate decisions that require tradeoffs among species and populations, and help keep options open.
- Improve biodiversity and species prospecting, assays, and inventory techniques and tools.

Control Examples

The technologies noted above are aimed chiefly at avoiding ecosystem degradation *ex ante*. But in addition there are important technology needs in controlling existing rates of loss and damage. Advances in molecular chemistry, bioremediation practices, and applied control technologies are needed, but so is the ability to provide relevant measures or resource amenity values, and incorporate these explicitly into the economic valuation apparatus we use in social decisions.

- Develop improved technologies to contain and abate spills of compounds such as oil and industrial pond contents.
- Develop tools and techniques for economic incentives based on resource value preservation via appropriate measurement of asset value of environmental amenities.

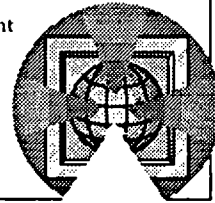


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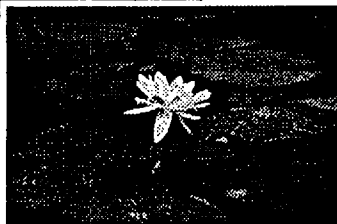
Remediation and Restoration Examples

Remediation and restoration technology needs represent another step away from fighting a defensive battle against biomaterials losses. Improvements in old technologies and development of new technologies, including biotechnology, are both necessary. These can range from continuation and extension of seed banks and other repository institutions to germplasm cryopreservation and in vitro technologies.

- Develop tools that speed system recovery, e.g., mycorrhizal fungi, soil replenishment, and planting techniques.
- Develop greenhouse or culturing techniques in order to make a number of plant species available for use in habitat restoration.
- Develop mapping and analysis tools to help describe historical conditions to aid restoration efforts.
- Accelerate development of pathogens and predators useful for biocontrol of exotic species in the marine environment.
- Develop species-specific biotic controls for exotic species in wetlands and aquatic environments.
- Compile a suite of techniques for system restoration, e.g., removal of unwanted species and introduction of plant and invertebrate materials to achieve the desired ecosystem structure.
- Develop engineering techniques for more reliable soil stabilization and distribution of water at restoration sites.
- Enhance animal breeding programs such as improved cryostorage of genetic materials, fertilization techniques, and in vitro technologies.
- Expand seed bank establishment and maintenance including germplasm cryopreservation, clonal repositories, and landrace technology registry.



REMEDiate



A Showcase of Marsh Restoration

Finding environmentally acceptable sites to put sediments dredged from the Anacostia River in Washington, DC, has been a challenge. Open water placement is not a viable option because the sediments contain heavy metals and pesticides. The normal alternative—upland sites—are at a premium in this highly urbanized setting.

Instead, in 1993, a barren debris-covered mudflats in the Anacostia watershed, known as the Kenilworth Marsh, was transformed into a productive tidal wetlands that will help restore the health of the river. Kenilworth Marsh, the District of Columbia's last remaining freshwater tidal wetlands, is too deep at high tide to support emergent aquatic plants. The U.S. Army Corps of Engineers, in collaboration with local government and the National Park Service, which owns the 73-acre marsh, developed a plan to raise the marsh's elevation using dredged material and double the watershed's acreage of tidal wetlands, creating habitat for fish and wildlife.

Low-impact water tubes and straw bales were used for the first time for temporary containment of the dredged material. Regular radio communications between the dredge operator and work crews in the marsh ensured that the proper mix of sediments reached the right locations. Precise placement avoided the need to contour using heavy equipment. When compared with the traditional practice of building upland placement sites, the marsh restoration was a cost-effective use of dredged material.

WORKING TOWARD SUSTAINABLE DEVELOPMENT

The challenges that humanity faces today are among the greatest in history. Even as environmental problems of unprecedented magnitude and urgency emerge, however, we have entered an era that offers immense promise for finding solutions. The end of the Cold War has allowed a shift in federal resources toward nondefense concerns, including environmental protection. Other promising signs can be found in the rapid emergence of new ideas in a number of fields, with the accompanying probability of productive synergies. Breakthroughs in medicine emerge on an almost daily basis; computer technology has benefited every scientific discipline; and remote sensing by satellite has permitted us to view our home in a wholly new way and gather raw information at a dizzying rate.

We have the opportunity during this period of great creativity to extend that rebirth into other areas of human endeavor. One of the highest priorities should be a re-examination of our social, political, economic, and technological values. The redesign of technology, in fact, and the birth of industrial ecology are already underway.

This report, *Technology for a Sustainable Future*, is intended to facilitate that process by initiating a dialogue aimed at formulating clearly articulated national policies. Such policies will enable the United States to play a leadership role in the global advancement of environmental technologies. To facilitate the dialogue, we plan to hold a series of workshops throughout the nation. These discussions will culminate in a White House Conference on Environmental Technologies, which will be held in the fall of 1994. In the months following the conference, the strategy will be written under the guidance of the National Science and Technology Council, a cabinet-level council representing federal departments and agencies with major research and development responsibilities.

Systems solutions provide the appropriate multidisciplinary integration across all environmental media required to address complex environmental issues. This approach requires partnerships and collaboration between the public and private sectors. The dialogue to articulate our nation's environmental technology policies will succeed if all interested sectors participate in the process. Only if Congress, state governments, industry, academia, nongovernmental organizations, and the broader public join the federal government in a dialogue can we work together to build a broad and effective consensus on future directions.

We hope the issues and impediments addressed in this report will stimulate discussion and debate. Over the coming year, we will develop a forward-looking environmental technology strategy that fosters the integration of federal, state, and private efforts. Our overarching goal is to develop federal policies that will enable the private sector to advance the environmental technologies that will function as a bridge to a sustainable future.

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- 14 United Nations Population Division. "Urban and Rural Places, 1950-2025 (1992 revision)." Database.
- 15 United Nations. 1993. *World Urbanization Prospects: The 1992 Revision. Estimates and Projections of Urban and Rural Populations and of Urban Agglomerations*. New York: United Nations.
- 16 United Nations Population Division. "Urban and Rural Places, 1950-2025 (1992 revision)." Database.
- 17 The data on long-term economic growth are based on *Global Economic Prospects and the Developing Countries* and internal working papers of the World Bank International

Economics Department figures prepared from World Bank Development Report. 1992. *Development and the Environment*, p. 179.

- 18 Critical Technologies Institute (RAND) compiled this map using World Bank GNP data; United Nations Population Division population data; Karasik, Theodore W., ed. 1992-1993. *Russia and Eurasia Facts and Figures Annual*. Volumes 17 and 18. Gulf Breeze, FL: Academic International Press; and Bos. Ibid.

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Chapter Three

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- 2 Carnegie Commission. 1992. *Enabling the Future: Linking Science and Technology to Societal Goals*. New York: Carnegie Commission on Science, Technology, and Government.
- 3 Marchetti, C. 1977. Primary energy substitution models: On the interaction between energy and society. *Technological Forecasting and Social Change*. Vol. 10. pp. 345-356.
- 4 O'Riordan, T. 1989. Anticipatory environmental policy: Impediments and opportunities. *Environmental Monitoring and Assessment*. Vol. 12.
- 5 Senge, P. 1989. *The new management: Moving from invention to innovation*. MIT Center for Organizational Learning; Drucker, P. 1986. *Innovation and Entrepreneurship*. New York: Harper and Row.
- 6 Agersnap, T. 1992. *Consensus Conferences for Technological Assessment*. Proceedings of the 3rd European Conference on Technology Assessment. Copenhagen. (November 4-7).
- 7
- 8
- 9 Henning Grann, Statoil. 1994. "The Industrial Symbiosis at Kalundborg, Denmark." Presented at the NAE International Conference on Industrial Ecology. Irvine, California. (May 9-13.)

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- 1 Organization for Economic Cooperation and Development. ?????? p. 24.
- 2 Heaton, G.R. Jr., R. Repetto, and R. Sobin. 1992. *Backs to the Future: U.S. Government Policy toward Environmentally Critical Technology*. Washington, DC: World Resources Institute.
- 3 National Academy of Sciences (NAS). 1993. *Science, Technology, and the Federal Government: National Goals for a New Era*. Washington, DC: National Academy Press.
- 4 NAS 1993.
- 5 Clinton/Gore National Campaign Headquarters. 1992. *Technology: The Engine of Economic Growth*. (September 11)?????. Clinton, William J. and Albert Gore, Jr. 1993. *Technology for America's Economic Growth, A New Direction to Build Economic Strength*. (February 22). Washington, DC: U.S. Government Printing Office.
- 6 *Technology for Economic Growth: President's Progress Report*. 1993. (November).
- 7 Heaton et al. 1992.
- 8 Heaton et al. 1992. (Correct reference?????)
- 9 Heaton et al. 1992.
- 10 Heaton et al. 1992.
- 11 U.S. Environmental Protection Agency. Office of the Administrator. 1991. *Permitting and Compliance Policy: Barriers to U.S. Environmental Technology Innovation*. Report and Recommendations of the Technology Innovation and Economics Committee, The National Advisory Council for Environmental Policy and Technology (NACEPT). EPA 101/N-91/001. (January). p. 9.
- 12 NACEPT, p. 9.
- 13 NACEPT, p. 9.
- 14 NACEPT, p. 54.

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- 1 Mansfield, Edwin. 1985. Public policy toward industrial innovation: An international study of direct tax incentives for R and D. In R. Hayes et al. eds. *The Uneasy Alliance: Managing the Productivity-Technology Dilemma*. Boston: Harvard Business School.
- 2 Newman, Joel S. 1993. Research and development allocations under sections 861 and 864: An author's query. *Tax Notes*. 60 (6) (August 2): 641-648.

Chapter Six

- 1 These services are particularly important for small- and medium-sized firms—the majority of the U.S. industry—which often have little or no export experience.

Chapter Seven

- 1 Nelson, Richard R. 1993. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.

Chapter Eight

- 1 The actual name of the subcommittee representing this critical environmental area is "Energy Efficiency, Climate Change, and Stratospheric Ozone Depletion."

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Appendices



APPENDICES

APPENDIX 1

Sources of Environmental Technology Information

Many federal agencies and departments have active ongoing programs with the private sector in environmental research, technology development and transfer, commercialization, and export enhancement. Some have established specific offices or designated individuals within their organizations as key focal points. Following is a list of some of these contacts for further information. .

Where possible, information sources have been identified with these codes:

- [1] Technology Transfer Information
- [2] General Technology Information
- [3] Programmatic Information
- [4] Grant Information
- [5] Marketing Information

National Institutes of Health

Mr. Don Christopherson
Acting Director, Office of Technology
Transfer
Suite 325
6011 Executive Boulevard
Rockville, MD 20852-3804
TEL: 301-496-7057
FAX: 301-402-0220

TEL: 202-358-0706
FAX: 202-358-3098

Mr. Richard S. Christiansen
RF/Director (Acting)
High Performance Aircraft and Flight
Projects Division
Office of Aeronautics
NASA
300 E Street, SW
Washington, DC 20546
TEL: 202-358-4598
FAX: 202-358-3557

Washington, DC 20230
TEL: 202-482-2977
FAX: 202-408-9674

John Bullard [3, 4, 5]
Director, Office of Sustainable
Development
NOAA
U. S. Department of Commerce
Washington, DC 20230
TEL: 202-482-3384
FAX: 202-482-4960

National Aeronautics and Space Administration

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NASA Technology Transfer
300 E Street, SW
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Washington, DC 20546
TEL: 202-358-0721
FAX: 202-358-3938
EMAIL: lault@oact.hq.nasa.gov

Department of Commerce

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Washington, DC 20230
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FAX: 202-482-4636

Dr. Steve Clifford [1, 2, 3, 4]
Director, NOAA/ Environmental
Technology Laboratory
325 Broadway, R/E/ET
Boulder, CO 80303-3328
TEL: 303-497-6586

Dr. William S. Busch [1, 2, 3, 4, 5]
Director, Emerging Technologies
Department of Commerce
National Oceanic and Atmospheric
Administration
Office of Global Programs
Suite 1225
1100 Wayne Avenue
Silver Spring, MD 20910-5603
TEL: 301-427-2089
FAX: 301-427-2082

Mr. Granville E. Paules
YT/Director, Office of Technology
Innovation and Advanced
Planning
NASA Mission to Planet Earth
300 E Street, SW
Washington, DC 20546

DOC: National Oceanic and
Atmospheric Administration
Dr. Kathryn Sullivan [1, 2, 3, 4]
Chief Scientist
NOAA
U. S. Department of Commerce

**DOC: National Institute of
Standards and Technology**

Dr. Bruce Mattson [1, 2, 3, 4, 5]
NIST
Room A363, Physics
Gathersburg, MD 20899
TEL: 301-975-3084
FAX: 301-869-2751

**DOC: International Trade
Administration**

Ray Vickery [3, 4, 5]
Assistant Secretary for Trade
Development
U.S. Department of Commerce
Washington, DC 20230
TEL: 202-482-4925
FAX: 202-482-5697

Department of Defense

Dr. C.J. (Chuck) Chatlynne
Program Manager
Domestic Technology Transfer
Office of the Assistant Secretary of
the Air Force
SAF-AQT
1919 South Eads Street, Suite 100
Arlington, VA 22202-3053
TEL: 703-746-8907, EXT 22
FAX: 703-746-8918

DOD: Research and Development

Dr. Joseph V. Osterman
Director, Environmental and Life
Sciences
ODDDR&E (E&LS)
Room 3D129, The Pentagon
Washington, DC 20301-3080
TEL: 703-697-8714
FAX: 703-693-7042
INTERNET: OSTERMJV@AMO-
MEGA.ACQ.OSD.MIL

**DOD: Demonstration/Validation
and Commercialization**

Dr. Daphne Kamely
Assistant Deputy Under Secretary for
Environmental Technology
Room 3E787, The Pentagon
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TEL: 703-697-5371
FAX: 703-693-9393
INTERNET: DKAMELY@AMO-
MEGA.ACQ.OSD.MIL

Dr. David Rossi
Directory, Industry IR&D Directorate
Office of Chief of Naval Research
Office of Naval Technology, Code
ONT26
800 N. Quincy Street
Arlington, VA 22217-5000
TEL: 703-696-4448
FAX: 703-696-5993

Mr. Clifford Lanham
Army Laboratory Command
AMSLC-TPTT

2800 Powder Mill Road
Adephi, MD 20783-1145
TEL: 301-394-4210
FAX: 301-394-5818

Mr. Nicholas Montanarelli
Director, Technology Applications
SDIO/TNI
Pentagon, Room 1E-148
Washington, DC 20302-7100
TEL: 703-693-1801
FAX: 703-693-1695

**Environmental Protection
Agency**

Albert M. McGartland [2]
Director, Economic Analysis and
Innovations Division
Office of Policy, Planning, and
Evaluation
401 M Street, SW
Mail Code 2127
Washington, DC 20460
TEL: 202-260-3354
FAX: 202-260-5732

Alfred W. Lindsey [2, 3, 4]
Director
Office of Research and
Development/Office of
Environmental Engineering and
Demonstrations
401 M Street, SW
Mail Code 8301
Washington, DC 20460
TEL: 202-260-2600
FAX: 202-260-3861

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Acting Deputy Assistant
Administrator
Office of Solid Waste and Emergency
Response
401 M Street, SW
Mail Code 5101
Washington, DC 20460
TEL: 202-260-4610
FAX: 202-260-3527

Daniel R. Abassi [2]
Special Assistant to the Assistant
Administrator
Office of Policy, Planning, and
Evaluation
401 M Street, SW
Mail Code 2111
Washington, DC 20460
TEL: 202-260-4332
FAX: 202-260-0275

Michael G. Moore [1]
Director
Technology
Office of Solid Waste and Emergency
Response
401 M Street, SW
Mail Code 8105
Washington, DC 20460
TEL: 202-260-7671
FAX: 202-260-0036

James A. Hanlon [3]
Deputy Director
Office of Science Technology
Office of Water
401 M Street, SW
Mail Code 4301
Washington, DC 20460
TEL: 202-260-5400
FAX: 202-260-5394

Keith D. Mason [3]
Regulator Impact Analyst
Office of Policy Analysis and Review
Office of Air and Radiation
401 M Street, SW
Mail Code 6103
Washington, DC 20460
TEL: 202-260-1360
FAX: 202-260-9766

Joseph S. Carra [3]
Deputy Director
Office of Pollution Prevention and
Toxic Substance
401 M Street, SW
Mail Code 7401
Washington, DC 20460
TEL: 202-260-1815
FAX: 202-260-1764

Jamison Koehler [3]
Acting Director
International Issues Division
Office of International Activities
401 M Street, SW
Mail Code 2631
Washington, DC 20460
TEL: 202-260-4894
FAX: 202-260-4470

Charles L. Elkins [2]
Associate General Counsel
Cross-Media Analysis and Review
Division
Office of General Counsel
401 M Street, SW
Mail Code 2322
Washington, DC 20460
TEL: 202-260-8069
FAX: 202-260-8392

Department of Transportation

Mr. John Hohl
Office of Research and Technology
Room 9402 (DRT-1)
U.S. Department of Transportation
400 7th Street, SW
Washington, DC 20590
TEL: 202-366-4978
FAX: 202-366-3272

Department of Interior

Dr. Donald Ralston [1, 2]
Chief, Office of Technology Transfer
U.S. Department of the Interior
Mail Stop 6201
810 Seventh Street, NW
Washington, DC 20241
TEL: 202-501-9316
FAX: 202-501-9957

INTERNET: ralston@whq.usbm.gov

Dr. Garrett R. Hyde [3]
Senior Scientist
U.S. Department of the Interior
Mail Stop 6204
810 Seventh Street, NW
Washington, DC 20241
TEL: 202-501-9218
FAX: 202-501-9957

Department of Energy

Mr. Richard C. Burrow [2]
Deputy Director
Office of Technology Policy (PO-40)
U.S. Department of Energy
1000 Independence Avenue
Washington, DC 20585
TEL: 202-555-1709
FAX: 202-555-5342

Mr. Roger Lewis [1]
Director, Office of Technology
Utilization
U.S. Department of Energy
Room 3H-017
1000 Independence Avenue, SW
Washington, DC 20585
TEL: 202-586-5388
FAX: 202-586-8854

Mr. Robert C. Porter [3]
Office of Fossil Energy (FE-5)
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
TEL: 202-586-6503
FAX: 202-586-5146

DOE Environmental Technology
Information Service [3]
U.S. Department of Energy
Office of Environmental
Management
1000 Independence Avenue, SW
Washington, DC 20585
TEL: 800-845-2096

Mr. Jerry Elwood, ER-74 [3]
U.S. Department of Energy
Office of Energy Research
1000 Independence Avenue, SW
Washington, DC 20585
TEL: 301-903-4583

Kay Thompson [5]
Deputy Director
Office of Export Assistance
Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
TEL: 202-586-3843
FAX: 202-586-0823

Ron Logerwell [4]
Director
Office of Acquisition Management
Office of Environmental
Management
Department of Energy

1000 Independence Avenue, SW
Washington, DC 20585
TEL: 202-586-8277

Department of Veteran Affairs

Mr. Ted Lorel
Staff Assistant, Research and
Development
Department of Veterans Affairs
(142/3)
810 Vermont Avenue, NW
Washington, DC 20420
TEL: 202-535-7181
FAX: 202-535-7159 or 233-4535

Agency for International Development

Glenn Prickett
Chief Environmental Advisor
Bureau for Policy and Program
Coordination
NS 3673
Washington, DC 20523
TEL: 202-647-9746
FAX: 202-647-8595

Laura Efros
Office of Energy and Infrastructure
Bureau for Global Programs, Field
Support, and Research
Room 508, SA-18
Washington, DC 20523
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National Science Foundation

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Assistant Director for Engineering
NSF
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Department of Housing and Urban Development

HUD: Building Systems Technology

David Engle [1, 3]
Director
Affordable Housing Research and
Technology Division
Room 8134
Office of Policy Development and
Research
HUD
Washington, DC 20410
TEL: 202-708-4370
FAX: 202-401-1246

HUD: Urban Environmental Systems Technology

Andrew Euston [1, 2]
FAIA Senior Urban Design and
Energy Program Officer
Room 7244
Office of Community Planning and
Development
HUD
Washington, DC 20410
TEL: 202-708-1911
FAX: 202-401-3363

HUD: Housing Systems Technology

Robert Fuller [2]
Office of Single Family Housing
Office of Housing
Room 9184, Mail Code HS
HUD
Washington, DC 20410
TEL: 202-708-4549
FAX: 202-401-5966

Don R. Fairman [2]
Acting Director
Manufactured Housing and
Community Standards Division
Office of Housing
c/o Mail Room B-133 - Mail Code
MM
HUD
Washington, DC 20410
TEL: 202-755-7430

HUD: Land Use Systems Technology

James Hoben [1, 3]
Community Planner
Program Evaluation Division
Office of Research, Evaluation and
Monitoring
Room 8140
HUD
Washington, DC 20410
TEL: 202-708-0574
FAX: 202-619-8360

Department of Agriculture

Robert R. Shaw
Deputy Chief for Technology
USDA Soil Conservation Service

P.O. Box 2890
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FAX: 202-703-7710

Dr. William Sommers
USDA Forest Service
Forest Fire & Atmospheric Sciences
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FAX: 202-205-2497
OMNET: W. Sommers

Julia Jones
USDA Global Change Program Office
1621 N. Kent Street
Room 60LL
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TEL: 703-235-9018
FAX: 703-235-9046
INTERNET: gevans@nalusda.gov

Dr. Richard Parry
U.S. Department of Agriculture

Agricultural Research Service
Room 358A, Administration Building
Washington, DC 20250
TEL: 202-720-3973
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Mr. George Linstead
Administrator
Federal Laboratory Consortium
TEL: 206-683-1005

Mr. Lee Rivers
Executive Director
National Technology Transfer Center
TEL: 800-638-6882

Far West
Robert L. Stark
University of Southern California
TEL: 213-743-6132

Midcontinent
Gary Sera
Texas Engineering Experiment
Station
TEL: 409-845-0538

Midwest
Joseph W. Ray
Great lakes Industrial Technology
Transfer Center
TEL: 216-734-0094

Northeast
William Gasko
Center for Technology
Commercialization
TEL: 508-870-0042

Mid-Atlantic
Lani S. Hummel
Mid-Atlantic Technology
Applications Center
TEL: 412-648-7000

Southeast
J. Ronald Thorton
Southern Technology Applications
Center
TEL: 904-462-3913

APPENDIX 2

Organization/Agency	How to Access	Information Categories (see below)
Energy Science Network	Gopher to gopher.es.net or WWW http://www.es.net : 80/ • DOE's National Energy Research Super Computer Center • Lawrence Livermore Library • Oak Ridge Files	T,R
Environmental Protection Agency	Gopher to gopher.rtpnc.epa.gov :70 • Access EPA (environmental databases) • OAQPS (Technology Transfer Network of Bulletin Boards) • Future Studies Group (Information on Technology Issues and Industrial Sector Activities) Alternately gopher to futures.wic.epa.gov :70 for the Future Studies Group Gopher.	P,T
Environmental Protection Agency On-line Library System	Telnet to epaibm.rtpnc.epa.gov or dial to (919) 549-0720 (E,7,1) Logon as Public	R
Extension Service of USDA	Gopher to zeus.esusda.gov :70 • Sustainable Agriculture • Waste Management • Water Quality	T
Library of Congress On-line Information System	Telnet to marvel.loc.gov or gopher to marvel.loc.gov:70. Logon as marvel	R
NASA Scientific and Technical Information	Gopher to gopher.sti.nasa.gov :70 or WWW at URL= http://www.sti.nasa.gov/STIhomepage.html • NASA Research Connection (NASA RECON) database	P,T,R
National Institute of Standards and Technology	Gopher to zserve.nist.gov :70 • NIST Advanced Technology Policy	P,B
NTIS FedWorld Gateways to federal government systems:	Telnet to FedWorld.gov or direct dial 703/321-8020 (N,8,1) or	
USDOC Electronic Bulletin Board (requires account)	• Telnet to ebb.stat-usa.gov or dial to (202) 482-3870 (N,8,1)	B
EPA Office of Research and Development	• See U.S. EPA Information above	T
EPS Pollution Prevention	• See U.S. EPA Information above	P,T
NASA Small Business Information	• Dial to (800) 547-1811 or (202) 488-2939 (N,8,1)	B
NSF Science & Technology Information	• Telnet to stis.nsf.gov or dial (703) 306-0212 (N,8,1) and logon as Public	P,T
Patent & Trademark Office	• Direct dial to (703) 305-8950 (N,8,1)	L
Small Business Administration	• Direct dial to (900) 463-4636 (fee) or (202) 401-9600 (N,8,1)	B

Organization/Agency	How to Access	Information Categories (see below)
U.S.A. Agency for International Development	Gopher to gopher.info.usaid.gov - Protecting the Environment - USAID Procurement/Business Opportunities	P,T,B,R
DOI/DSGS Global Land Information System (GLIS)	Internet, WAIS, Global Change Master Directory	T,R
USGS on Internet (Mosaic)	Using Mosaic, open ULR: http://info.er.usgs.gov : or can use gopher	T,R
Earth Science Data Directory (ESDD)	Using Mosaic, open ULR: http://info.er.usgs.gov	T,R
Global Change and Climate History Program	Using Mosaic, open URL: http://geochange.er.usgs.gov/gch.html These data sets also are available by anonymous FTP from geochange.er.usgs.gov	T,R
National Stream Quality Accounting Network (NASQAN)	Access through EPA environmental databases. See U.S. EPA information above	T,R
Hydro-Climatic Data Network (HCDN)	Anonymous FTP to directory hcdn 92 on srvirvares.er.usgs.gov (Internet IP number 130.11.51.209) Also available through USGS on Internet	T,R
USGS National Water Data Storage and Retrieval System (WATSTORE)	Contact National Water Data Exchange Office (703) 648-5684 or USGS, 421 National Center 12201 Sunrise Valley Cr., Reston, VA 22092 for information on how to access	T,R
USDA/Soil Conservation	Centralized Data base (CDBS) Dial (503) 326-2843 or 4890 - SCS Climate Data Access Facility - SCS Snow Survey and Water Supply, Forecasting Information and SMOTEL Data Soil Survey Information - INTERNET wals.ngq.scs.ag.gov: - Sample of Soil Survey Geographic Data Base, Federal Geospatial Data Committee (FGDC) - Metadata (STATSGO) Resources Inventory and Geographic Information Systems Division Dial (202) 720-4530 - Natural Resources Inventory National Cartographic Center Dial (817) 334-5559 - State Soil Geographic Data Base (STATSGO)	T, T,R T,R R R

APPENDIX 3

Federal Technology Legislation and Executive Orders

1980 - The Stevenson Wydler Act stated that the transfer of federally funded technology to the private sector is a mission of the federal government and established technology transfer offices at major federal laboratories.

1980 - The Bayh-Dole Act made it possible for small businesses and nonprofit institutions to hold title to patents derived from R&D performed with federal funding.

1982 - Small Business Innovation Development Act requires certain agencies to establish Small Business Innovation Research (SBIR) programs by reserving a statutory percentage of their extramural R&D budgets to be awarded to small businesses through a multiphase process that provides funding for feasibility determination, followed by R&D for successful proposals.

1983 - Presidential patent policy memorandum ordered all agencies to make available to all government contractors, to the extent permitted by then-existing law, the same benefits concerning the ownership of patents derived from federally funded R&D made available to small businesses and not-for-profits under the Bayh-Dole Act.

1984 - The Bayh-Dole Act was amended to provide the same patent ownership rights to university-operated laboratories as were given to small businesses and nonprofit institutions.

1986 - The Federal Technology Transfer Act (FTTA) amended the Stevenson-Wydler Technology Innovation Act to improve the process for private sector commercialization of federally funded R&D. Government-owned, government-operated ("GO-GO") laboratories were permitted to enter into cooperative research agreements with private companies, universities, and others. Title to or licenses for federal inventions could be granted to participants; ownership rights in inventions resulting from collaborative efforts could be waived in advance; and royalties could be received as part of these agreements (at least 15 percent of which must go to the employee responsible for the invention).

1987 - Executive Order 12591, Facilitating Access to Science and Technology, carried out the provisions of the FTFA and preceding legislation; directed agencies to assist in technology commercialization and to award title to inventions resulting from federally funded R&D to all contractors; and required that international science and technology agreements conform to the requirements of domestic law.

1989 - The National Competitiveness Technology Transfer Act of 1989 amended the FTFA to authorize government-owned and contractor-operated Department of Energy laboratories to engage in cooperative research agreements on the same basis as GO-GO labs. It also amended the Freedom

of Information Act to permit federal labs to withhold from disclosure certain types of information developed in connection with cooperative research efforts with private sector partners.

1991 - Defense Authorization Act for FY 1991 established model programs for national defense laboratories to demonstrate successful relationships between federal, state, and local governments and small business; provided for a federal laboratory to enter into a contract or memorandum of understanding with a partnership intermediary to perform services related to cooperative or joint activities with small business; and provided for development and implementation of the National Defense Manufacturing Technology Plan.

1991 - American Technology Preeminence Act extended the Federal Laboratory Consortium (FLC) mandate through 1996, removed FLC responsibility for conducting a grant program, and required the inclusion of the results of an independent annual audit of the FLC annual Report to Congress and the President; allowed exchange of intellectual property between participants in a Cooperative Research and Development Agreement

(CRADA); required the Secretary of Commerce to report on the advisability of authorizing a new form of CRADA that permits federal contribution of funds; and allowed the laboratory director to give excess equipment to an educational institution or nonprofit organization as a gift.

1992 - Energy Policy Act (note that these provisions are currently under review) may provide authority to protect data in a wider range of R&D and technology transfer; may provide Department of Energy (DOE) programs with authority to enter into CRADAs directly without laboratory participation; and may provide additional antitrust protection from treble damages for DOE joint ventures with industry.

1993 - National Defense Authorization Act for FY 1993 extended streamlined small business technology transfer procedures from GO-GO to government-owned, contractor-operated (GO-CO) laboratories; directed the DOE to establish a program to facilitate technology transfer to small businesses and requested "consideration" for spending not less than 10 percent of the R&D budget on technology transfer agreements.

APPENDIX 4

Acronyms

ATP	Advanced Technology Program
BDAT	Best Demonstrable Achievable Technology
BIRD	Binational Industrial Research and Development Foundation
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CFC	ChloroFluoroCarbon
CRADA	Cooperative Research and Development Agreement
CWA	Clean Water Act
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EC	European Community
EPA	Environmental Protection Agency
EP3	Environmental Pollution Prevention Program
FINESSE	Financing Energy Services for Small-Scale Energy-Users
GATT	General Agreement on Trade and Tariffs
GDP	Gross Domestic Product
G-7	Group of 7 Developed Countries
G-77	Group of 77 Developing Countries
HFC	HydroFluroCarbons
ISO	International Standards Organization
MDB	Multilateral Development Bank
NACEPT	National Advisory Council for Environmental Policy and Technology
NAFTA	North American Free Trade Agreement
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTTC	National Technology Transfer Center
OECD	Organization for Economic Cooperation and Development
OIT	Office of International Trade
OPIC	Overseas Private Investment Corporation
PACER	Program for the Acceleration of Commercial Energy Research
PACT	Program for the Acceleration of Technology
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
TDA	Trade and Development Agency
TRP	Technology Reinvestment Project
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

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