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How New Environmental Technologies Can Stimulate Economic Growth

By David Rejeski

The first generation of U.S. environmental laws and regulations enacted in the late 1960s and early 1970s were state-of-the-art public policies at that time. They cleaned up our air and water, and were rightly emulated in much of the developed world. They also gave rise to a new sector of the economy: By 1974, shortly after President Nixon signed landmark Clean Air and Clean Water laws, 50,000 jobs had been created in the construction of water treatment plants and other infrastructure necessary to meet the new environmental standards. Another 75,000 jobs were created in new industries that focused on activities such as cleaning up contaminated industrial sites and developing devices such as "scrubbers" to filter smokestack pollution. But today, those first-generation environmental laws and regulations are increasingly arcane—and our adherence to them is making us a laggard in the growing global market for environmental technologies.[1]

Our once-pioneering laws and policies made us an early leader in the field. But we now find ourselves being beaten on a wide range of environmental technologies, from the wind turbines and photovoltaic panels used to convert wind and sunlight into electricity, to the hybrid engines that power automobiles on a combination of gasoline and electricity. Indeed, the United States is the only developed country that has managed to *reduce* the average fuel efficiency of its automobile fleet for over a decade—an incredible technological feat, but not one that deserves emulation.[2]

We are falling behind because many other countries have enacted less prescriptive, more modern environmental policies that help drive continued technological innovation. For instance, the Netherlands, a leader in the environmental economy, has replaced prescriptive standards with broad national goals and government-industry covenants that allow firms, in consultation with regulators and the public, to develop the most effective and efficient strategies for meeting environmental protection objectives. Such policies hold the key to the future in the global environmental technology market.[3] The Progressive Policy Institute refers to such modern policy approaches as "Second Generation" strategies, to distinguish them from the first generation

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"One person with a belief is a social power equal to ninety-nine who have only interests."

—John Stuart Mill

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of environmental laws and regulations, which tended to follow a more rigid command-and-control framework.[4]

A bipartisan consensus has been emerging in the United States for more than a decade—going back to the administration of President George H.W. Bush—about the need to update our vital but increasingly antiquated environmental laws and regulations with more market-based, information-driven, and community-friendly ways to protect the environment.[5] But the current Bush administration's regulatory rollbacks, softened enforcement strategies, and pursuit of domestic oil and coal rather than clean alternatives have caused the environmental modernization movement to lose momentum.[6] Consider:

- As policies to pass comprehensive energy legislation continue to languish in the U.S. Congress, the German government has embraced wind energy as a "job machine." From 2000 to 2001, the German wind power industry jumped from 60,000 jobs to 100,000, and has since continued to add jobs at a rate of almost 20 percent per year.

- The Bush administration favors policies to increase drilling at home and has advanced poorly funded policies to promote a distant hydrogen future.[7] Meanwhile, Iceland intends to harness its vast geothermal resources to become the world's first hydrogen-based economy sometime between 2030 and 2050. To do so, Icelanders are exploring a wide variety of new potential

uses for fuel cells, including using the technology to power their fishing fleets.

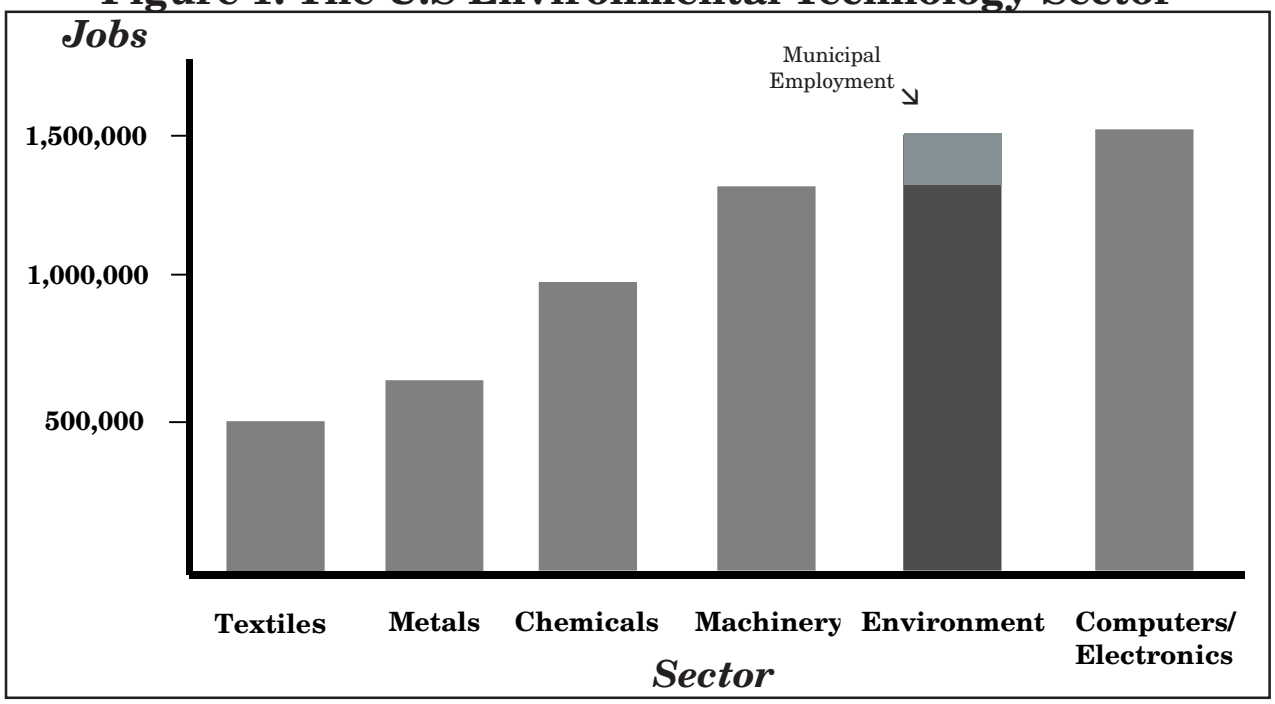
- Americans increasingly agree on the need to achieve greater independence from imported oil. But, unlike the United States, the Japanese government has acted: It has committed ¥123 billion ($1.1 billion) between 1997 and 2004 to subsidize solar panels for residential homes. Government largesse has made Japan's solar industry the world's most vibrant; between 1997 and 2003, the sector grew 90 percent. Today, Japan produces one-half of the world's solar output.

Sadly, while other nations have leapt ahead, growth in the U.S. environmental technology industry has slowed to just 2 percent per year.[8] At that annual rate, we will be lucky if the sector grows 20 percent by the year 2010. That is down from 236 percent growth in the 1970s, 145 percent growth in the 1980s, and 40 percent growth in the 1990s.[9]

Although the pace of growth has fallen dramatically, the U.S. environmental technology sector is still large and important. It generates more than $220 billion in annual revenues and supports 1.6 million jobs in more than 50,000 firms.[10] Contrary to conservative claims that environmental laws cost jobs, the U.S. environmental technology sector is larger than either the steel, textile, or chemical industry (see Figure 1). Of those 1.6 million jobs, 12 percent to 15 percent are in public works (associated with investments in municipal water and waste water treatment, as well as solid waste disposal). The rest are in private firms, many of which are small- and medium-sized businesses—the acknowledged engines of our economic growth.

Environmental technology firms focus on four main areas: clean up, pollution control, pollution prevention, and environmental monitoring.[11] Clean-up activities required under programs such as Superfund range from relatively low-tech removal of soil and groundwater contaminated with hazardous and toxic

Figure 1: The U.S Environmental Technology Sector



SOURCE: Environmental Business International, *http://environmental-industry.com/ebj/dataproducts.html*; and *2002 Statistical Abstracts of the United States*, U.S. Census Bureau, 2002.

chemicals, to the high-tech application of exotic, single-cell bacteria that digest toxic chemicals and render them relatively harmless.

Pollution control, in contrast, tends to encompass costly technological add-ons that ensure compliance with laws such as the Clean Air Act and Clean Water Act (for example, the "scrubbers" that filter pollutants from smokestack emissions). The sector also includes methods and equipment that gauge whether regulated firms are complying with first-generation laws, such as monitors that measure smokestack emissions in real time.

"High-level White House commitment to the concept of a national environmental technology strategy evaporated after the 2000 election, and many of the federal programs put in place in the late 1990s have languished as a result."

More recently, in response to laws such as the 1990 Pollution Prevention Act, a growing number of businesses have adopted processes and products that prevent pollution in the first place. These include better production systems that require fewer toxic chemicals or natural resources, energy-saving computers, photovoltaic devices, generation of solar power, and gas/electric hybrid vehicles.

Many environmental technologies, such as soil-removal or water-saving devices, are low-tech. But the sector is increasingly reliant on advanced technology to deliver its solutions, from biotechnologies that clean up contaminated groundwater, to sophisticated sensors that can detect minute concentrations of harmful agents—an application that could prove valuable to first responders in an emergency.

When developing countries such as India and China begin to seriously control pollution from their booming industrial sectors, there is ample reason to believe the market for environmental technology will blossom. Worldwide, the market for environmental technologies and services is currently worth more than $550 billion (1.8 percent of the global economy) and is rapidly expanding. However, it is unclear at this point whether the United States will continue to be a significant player in this market.[12]

In 1995, the Clinton administration launched the National Environmental Technology Strategy to ensure that environmental laws send the right market signals, and to increase the competitiveness of U.S. environmental technology producers in global markets. The strategy consisted of a broad set of Second Generation policy initiatives intended to spur the development and commercialization of environmental technologies to monitor the environment and clean up existing pollution, reduce waste, and prevent pollution in the future. Created through a national dialogue between industry, environmental groups, academia, and state and local officials, the strategy sought to develop and employ more flexible, market-friendly, and information-rich approaches to reduce regulatory barriers, spur innovation, and increase global competitiveness.

It should have been a no-brainer for the new Bush administration—which was seeking a positive "jobs and environment" message—to build upon that strategy. Unfortunately, high-level White House commitment to the concept of a national environmental technology strategy evaporated after the 2000 election, and many of the federal programs put in place in the late 1990s have languished as a result.

Revitalizing U.S. growth and leadership in this sector will require renewing and redoubling our national commitment to pursue innovative environmental policies that stimulate the creation of cost-effective environmental solutions and their associated high-skilled jobs. Committing to such an effort is especially important now because, while the United States is grappling with environmental problems left

over from yesterday's technologies, a new post-industrial revolution is also underway, both here and in other developed countries. This new wave of post-industrial innovation—built on multiple, converging revolutions in areas such as genetics, informatics, robotics, and nanotechnology—is beginning to transform the U.S. economy and others around the world. Therefore, we have a unique, once-in-50-years opportunity to shape a new industrial and post-industrial infrastructure to make it more economically competitive and less harmful to the environment. But this will not happen without some bold thinking and leadership in environmental and technology policy.

Here is a seven point plan designed to catalyze such efforts. Unlike several competing proposals—which appear to ignore the nation's current fiscal crisis—this plan will not cost billions of dollars to implement.[13] Most of the recommendations in the plan would require no additional funding, just a realignment of existing resources behind a new, high-level commitment to get serious about our environmental future. The plan's seven steps are:

1. **Provide White House leadership to underscore the pressing need for innovation in environmental technology.**

2. **Create a federal one-stop shop to help U.S. companies commercialize environmental technology.**

3. **Boost demand for environmental technologies with an aggressive government procurement program.**

4. **Double the export of key U.S. environmental technologies during the next five years.**

5. **Promote environmental science and technology research.**

6. **Create five to 10 "Centers of Excellence" to drive more modern Second Generation environmental policies.**

7. **Improve the Environmental Protection Agency's capacity to recruit and retain promising young researchers.**

Why an Environmental Technology Strategy Is Imperative

Given the global growth in the environmental technology markets, it might appear that the most straightforward way to resurrect a national environmental technology strategy would be to revive the Clinton administration's original program. But for reasons discussed in greater detail below, that strategy now requires substantial updating and revision. To better understand the underpinnings of the recommendations in this paper, it is useful to first consider where international environmental technology markets are headed, what is driving them, and how policy must be shaped accordingly.

The environmental technology market represents a substantial economic opportunity.

Continued expansion of markets for environmental technology abroad provides a remarkable opportunity for the United States to create new, high-paying, clean technology jobs here at home. The world market for environmental technologies and services can be anticipated to grow for three reasons. First, the rapid and continued expansion of consumer spending and industrial infrastructure in countries such as China will create large demands for environmental products and services. China's environmental market is growing at approximately 10 percent annually

and could represent one-third of the global market in 20 to 30 years.[14] However, U.S. leadership in this emerging market is far from assured because China, along with other countries such as India and Korea, is becoming a scientific powerhouse that soon will have the capability to develop its own technological solutions for environmental problems and potentially compete with the United States in the world market.[15] To retain our competitive advantage, U.S. science and research must move several steps ahead.

Second, the expansion of the European Union has put pressure on companies operating in countries seeking E.U. membership to modernize their industrial infrastructures to meet, or surpass, the environmental standards in the European Union. For example, Eastern European countries entering the E.U. have provided lucrative markets for environmental technology firms in Western Europe.

Finally, as socially progressive, transnational firms push environmental requirements through their global supply chains, they will stimulate demand for environmental technologies and more environmentally efficient processes from their second- and third-tier suppliers worldwide.

The environmental technology sector depends on government action.

It is important to understand that U.S. environmental technology producers are competing against firms from countries such as Sweden and Germany that have progressive environmental policies, world-class science, and well-structured governmental programs to support their environmental businesses in the global marketplace. The United States lost its lead in wind energy technologies to Denmark and Germany not because of inferior science or second-class technologies, but because those countries pursued more aggressive national and regional strategies that supported renewable energy technologies.[16] A similar case can be made for fuel cell technologies—an area where investments by NASA made the United States an early world leader.[17] Even in more traditional technological areas, such as water supply and treatment systems, the United States lags behind Great Britain and France.

As those examples suggest, the environmental technology sector, unlike many other sectors of the economy, is highly dependent on government actions. Such actions include specific funding programs to support the clean up of contaminated sites and provide water and waste-water treatment. They must also include strict regulatory enforcement, which gives industry and investors the impression that the U.S. government is serious about environmental protection. Any regulatory backsliding or lax enforcement sends the wrong market signal to businesses involved in this sector (both sellers and buyers), and to potential investors in new enterprises.

We need a new post-industrial regulatory paradigm that anticipates environmental problems, rather than merely reacts to them.

Rapidly increasing scientific and technological change is the hallmark of our time.[18] When the Clinton administration unveiled its National Environmental Technology Strategy in 1995—just nine years ago—we had not yet sequenced the human genome, nanotechnology was still a curiosity, and the World Wide Web and mobile communication were in their infancy. We have now entered a new post-industrial revolution based on those and other interrelated advances.[19] How this revolution unfolds will shape the environmental agenda for decades to come. There is a chance that emerging technologies will usher in entirely new types of challenges. Some may be environmental in

nature, such as the potential toxic effects of nano-based substances and products, and some may be ethical, such as issues raised by future genetic testing of individuals for sensitivities to chemicals in their environment.[20]

One of the greatest governance challenges we face, therefore, is the need to build a capacity for fast anticipatory learning that can identify and head off potential environmental, ethical, and legal problems in the early stages of developing new technologies. A new environmental technology strategy will need to achieve a difficult balance between providing solutions to existing environmental problems (both here and abroad), and simultaneously shaping the emerging technological infrastructure to avoid or minimize future problems (for instance, the potential health and environmental impacts of nanotechnology or transgenic engineering). As a new technological infrastructure emerges, very early and critical interventions by government or business could have far-reaching and long-term effects on the environmental impact of our future economy.[21] We have a rare opportunity to shape those impacts, but that window will not remain open for long.

The next U.S. environmental technology strategy must "command," but not "control."

If the United States is to regain its global leadership role in environmental technologies, boost job creation here at home, and develop a significantly cleaner environment, the next administration must support strong national environmental standards and vigorous enforcement, but not dictate how the regulated community should meet those standards. In other words, we must "command," but not "control." That is the only way to encourage continuous innovation.

More flexible, less prescriptive regulatory schemes that encourage process improvements in industry—or market incentives that drive the overall redesign of products, or significantly reduce environmental impacts across the entire product life cycle—are imperative. For instance, "cap-and-trade," approaches provide firms with the continued flexibility to choose which technology, or combination of technologies, can cost-effectively reduce pollution.[22] Such Second Generation approaches will help us better address existing problems like urban smog and emerging threats such as climate change.

Seven Steps to a New Environmental Technology Strategy

1. ***Provide White House leadership to underscore the pressing need for innovation in environmental technology.***

As the current lack of presidential commitment to the issue illustrates, the effective revitalization and revision of an environmental technology strategy requires White House leadership. Many of the programs and staff positions charged by the Clinton administration with the development and commercialization of environmental technology remain in existence today, but are largely inactive. They need to be revived.

"A new environmental technology strategy will need to achieve a difficult balance between providing solutions to existing environmental problems and simultaneously shaping the emerging technological infrastructure to avoid or minimize future problems."

The president should direct the White House Office of Science and Technology Policy (OSTP) to develop and administer a new envi-

ronmental technology initiative in the mold of the Clinton administration. To better align technology, job creation, and environmental goals, OSTP should be required to work closely with other White House entities, such as the Council of Economic Advisers and the Council on Environmental Quality.[23]

2. *Create a federal one-stop shop to help U.S. companies commercialize environmental technology.*

As a part of the 1995 National Environmental Technology Strategy, the White House created the Interagency Environmental Technology Office (IETO). Between 1996 and 2000, it functioned as a one-stop shop, providing free services to thousands of companies seeking information on environmental technology programs scattered across various federal departments and agencies. Services included programs that verified whether new technologies were meeting their pollution reduction claims, as well as programs to help businesses promote promising environmental technology products at home and abroad. The presence of such a shop is essential for the environmental technology sector, which is dominated by small- and medium-sized businesses that often lack the resources to navigate the federal government.[24]

The administration should revitalize the one-stop shop as a critical component in the next environmental technology strategy. The president should assign responsibility for the program's development and coordination across the federal government to the OSTP. The new one-stop-shop should offer extensive online resources to help environmental technology developers commercialize promising new products. It should also direct customers to federal programs that test new environmental technologies so they can ensure their products control as much pollution as they claim. To ensure the widest penetration possible, OSTP should create a U.S. government environmental technology Internet portal that links small- and medium-sized environmental technology firms directly to these federal resources (as well as to relevant state and international programs).

3. *Boost demand for environmental technologies with an aggressive government procurement program.*

Many government and state agencies have policies in place recommending, and in some cases mandating, the purchase of energy-efficient products, such as "ENERGY STAR" computers and office equipment. The federal government has enormous potential to drive the demand for new, greener technologies with an integrated public sector procurement program. Such programs matter because the penetration of emerging technologies into the marketplace is often dependent on reaching economies of scale that drive reductions in product costs.

As part of the next environmental technology strategy, the administration—through executive order or legislation—should expand existing federal environmental technology procurement programs and create new ones aimed at promising technologies, such as stationary electricity sources powered by fuel cells instead of fossil fuels, or automotive fleets powered by biodiesel, fuel cells, or gasoline-electric hybrid engines.[25] The OSTP should identify and work with federal agencies most likely to procure such products, including the U.S. Department of Defense (DOD), the General Services Administration, the Department of Energy, the Postal Service, and the Department of Homeland Security.

4. *Double the export of key U.S. environmental technologies during the next five years.*

A new environmental technology strategy must do much more to position U.S. firms to capture a greater share of the global environmental technology market. Although the United States has lost its lead in the development of wind and solar technologies, private companies, environmental groups, and lending institutions, such as the World Bank, are working to promote the sale of clean coal technologies to developing countries such as China, which plans to generate 650 gigawatts of coal-based energy by 2030.

The total U.S. technology exports in this area is about $22 billion per year—11 percent of our total output in the environmental technology sector—while many of our competitors (Japan, Germany, and Great Britain) export over 20 percent. Companies in these countries benefit from aggressive governmental strategies that open markets, guarantee loans, and provide market intelligence.

The next administration should set a goal of doubling our environmental technology exports (as a share of total output) during the next five years. To achieve this objective, the OSTP should be charged with overseeing a clean technology export program. The OSTP should formulate a clean technology export strategy with the help of the Department of Commerce, the Export-Import Bank, the Trade Development Agency, the Overseas Private Investment Corporation, the State Department, the Agency for International Development, the Environmental Protection Agency, and the U.S. Trade Representative.

Finally, because strong standards and enforcement are critical to the success of environmental technology, the next administration must work with our foreign partners to create laws and programs that spur demand for clean environmental technologies, like an international cap-and-trade regime to control greenhouse gases.

5. *Promote environmental science and technology research.*

Effectively promoting research on environmental science and technology will require a multi-pronged approach. Here are several steps the president should take:

❒ **Perform an inventory of the federal government's environmental technology programs.**

Research funded by federal agencies that do not have a direct environmental mandate (such as the DOD or NASA) may nonetheless be highly relevant to addressing our environmental challenges. For years, the DOD has been at the vanguard of fuel cell research, a technology that has the potential to promote energy independence and reduce air and atmospheric pollution. To better identify, develop, and commercialize such efforts, it is necessary to create a robust, ongoing program to locate environmentally relevant technologies in programs funded by agencies and departments that lack a direct environmental mandate.

Such an approach would not only reduce the danger of duplicative research but also help overcome the psychological inertia that forces people to constantly look for solutions in their own area of expertise.[26] The RADIUS computer database (Research and Development in the U.S. Government) maintained by the RAND Corporation tracks all federally funded research and development projects and could serve as an excellent tool to identify projects with potential environmental relevance. The annual cost of such scans would likely be below $200,000. The OSTP should request such analyses and make their results widely available to agencies with environmental missions. Such inventories could also form the basis for targeted public-private research and development efforts.

❒ **Strike a better balance between research aimed at new and existing environmental challenges.**

While much of our environmental research aims to solve existing pollution problems, it fails to anticipate and address future risks to humans and the environment. To improve our ability to anticipate emerging threats, the Environmental Protection Agency (EPA) Science Advisory Board, or another independent body, should evaluate the EPA's research and development budget in terms of fundamental structure and purpose.

Rather than focus on the relevance and adequacy of funding vis-à-vis specific topics—such as particulates or ecosystems—a much broader set of questions needs to be asked about the structure and intent of our environmental research and how it is to be managed in the new, post-industrial era. For instance: How do we adequately address existing environmental problems while maintaining enough flexibility in the research portfolio to address emerging issues? What new roles can the social sciences play in addressing future environmental problems? How can more interdisciplinary work be stimulated between key technology areas such as biotech and nanotech?

"Unintended consequences from technology breakthroughs beyond the environmental realm could have a greater impact—for better or for worse—on our environmental future than the intended consequences of our policies."

A new national environmental technology strategy should also apply such an analysis to environmentally related research portfolios in other agencies outside the EPA, including the National Oceanic and Atmospheric Administration and the U.S. Department of Agriculture.

❒ **Re-establish a federal program to assess emerging technologies.**

In 1995, Congress eliminated the Office of Technology Assessment (OTA). As a result, the U.S. government now lacks any systemic capability to assess the environmental impacts of emerging science and technology.[27] The elimination of OTA leaves a dangerous void, given the rapid rate of technological change, the convergence of multiple disciplines, and the global nature of potential impacts. Unintended consequences from technology breakthroughs beyond the environmental realm could have a greater impact—for better or for worse—on our environmental future than the intended consequences of our policies.

We must create a protocol on technology assessment with a mandate to provide environmental assessments of emerging technologies. It should link technical assessments with policies and produce recommendations for research as needed. To carry out its mission, such a program should require no more than eight to 10 analysts, one-half of whom could come from two-year rotational assignments from various agencies and universities, through the Intergovernmental Personnel Act. In addition to conducting in-house policy analysis, the program should be provided with $5 million to fund analyses by outside organizations, such as think tanks or universities.

❒ **Create an "Environmental DARPA."**

Given existing and anticipated rates of population growth and resource depletion, many future environmental problems will not bend

or yield to piecemeal and incremental solutions.[28] We need the capability to develop and commercialize technologies that promise to provide three- or fourfold gains in resource efficiency and commensurate reductions in cost.

It is time to create an environmental DARPA (the Defense Advanced Research Projects Agency at the DOD, the organization which created the Internet) with a focus on high-payoff, high-risk research in areas critical to the prevention of pollution. Over the past 10 years, DARPA's budget has been about 5 percent of the total DOD budget. Such a figure applied to EPA's research budget would result in about $25 million to $30 million in funding focused on breakthrough research that would not likely be undertaken by the private sector. The program should be staffed using rotational assignments (with two-year to three-year limits) and strive to attract world-class scientific talent.

❒ **Create a venture capital fund to leverage private-sector capital in support of environmental technologies with a high payoff.**

Given the low level of private capital available to environmental technology developers, the government should create an environmental venture fund.[29] A $10 million to $20 million annual investment, if well managed and tightly focused, could significantly spur development of promising new environmental technologies. The investment portfolio should focus on speeding the commercialization of technologies crucial to environmental protection in the near-term. This may include technological systems that help us rapidly screen more new chemicals (a painstaking process that currently only tests a small fraction of the 70,000 chemicals in commerce), or monitor potentially harmful pollutants or biohazards by integrating micro-sensors into our digital communications networks. This fund could be run out of a university (or multiple universities) using the combined expertise of environmental and business programs. Examples of such funds include the Wolverine Venture Fund at the University of Michigan, and the In-Q-Tel program at the CIA.[30]

6. Create five to 10 "Centers of Excellence" to drive Second Generation environmental policies.

To regain our lead in environmental technology, the United States needs to recapture its intellectual leadership in environmental policy. We need a new cadre of environmental professionals capable of creating the basis for new Second Generation environmental protection strategies. To stimulate work in areas such as industrial ecology (which trains students to make our industrial infrastructure more compatible with the natural world) and earth systems engineering and management (which trains scientists and policy analysts to better address environmental problems at a global scale), the National Science Foundation (NSF) should create between five and 10 new Centers of Excellence at leading universities.

The goal of the program should be to foster a long-term and systemic approach to environmental problems. The program should be interdisciplinary, bringing together the natural and social sciences, engineering, law, ethics, business, and public policy. Funding should be $5 million per university and build on NSF's Engineering Research Center program.

7. Improve the EPA's capacity to recruit and retain promising young researchers.

Given the rapid pace at which China and India are developing their own scientific talent,

we will be unable to penetrate their markets with new environmental technologies if we fail to cultivate commensurate, if not superior, scientific stars here at home. But while our need for new environmental researchers is growing, the federal environmental workforce is aging and being depleted by early retirement and new hiring restrictions.

The EPA's Office of Research and Development, for instance, will lose more than 30 percent of its staff during the next five years. In many cases, the skill sets of the remaining workforce are becoming inadequate and obsolete in the face of emerging technological challenges. Furthermore, the government can expect significant competition for scientific talent from the private sector in key areas, such as genomics and computation.[31] If these trends are allowed to continue, they will result in a significant gap in skills between the public and private sectors. The EPA and its state and local counterparts need an aggressive recruitment strategy to prepare the workforce for new scientific and technological challenges and opportunities.

To reinvigorate the EPA's workforce, the EPA should assign its high-level managers to work directly with key university programs that could become feeders for young, new talent (the Government Accountability Office has successfully implemented a similar model). The EPA still ranks high as a desirable place to work within the federal government and the agency needs to capitalize on that perception.[32]

Conclusion

There are currently no plans to either expand or modernize First Generation command-and-control environmental laws.[33] That status quo is perpetuated by unfounded concerns that new or modern regulations to address existing challenges such as global warming, or emerging issues such as nanotechnology, will harm economic growth. Moreover, industry and environmental groups are polarized, and there are ongoing battles between the two leading political parties.

Many observers—including those at PPI—believe that the current environmental gridlock is unnecessary.[34] Gus Speth, the dean of the Yale University School of Forestry and Environmental Studies, recently noted that, "The war between business and the environment should be over. Both sides won."[35] There is no reason that we have to choose between economic growth and environmental protection. The early growth of the U.S. environmental technology sector proves that such a choice is a false one.

In the long run, dominance in the environmental technology sector will go to those countries capable of simultaneously spurring technological innovation and reinventing their public policies. The low-cost, non-prescriptive roadmap outlined in this report will provide U.S. policymakers with a promising start to promote a burgeoning sector of the U.S. economy that happens to be largely comprised of small- and medium-sized companies.

Endnotes

[1] Davies, J.C. and J. Mazurek, *Pollution Control in the U.S.: Evaluating the System*, RFF/Johns Hopkins, 1998.
[2] Because we are falling behind in the environmental technology race, we also are falling further and further behind in the quest to improve efficiency. We lag far behind countries like Japan and Germany in terms of the energy and materials efficiency of our overall economy, using more energy and materials per unit of economic output and creating more waste. The primary energy consumption per dollar of gross domestic product in the United States for 2002 was 10,575 BTUs; in Germany, 5,998 BTUs; and in Japan, 3,876 BTUs. The primary energy consumption on a per capita basis was 339 million BTUs per person in the United States; 173 million BTUs per person in Germany; and 172 million BTUs per person in Japan (source: Energy Information Agency, *http://www.eia.doe.gov*). In addition, the annual total materials requirement per person is approximately 85 metric tons in the United States, versus 45 metric tons in Japan (see*: Resource Flows: The Material Basis of Industrialized Economies*, World Resources Institute).
[3] The global revenues from solar energy equipment and installation are expected to grow from $4.7 billion today to almost $31 billion by 2013. See: "A Different Era for Alternative Energy," *The New York Times*, May 29, 2004, p. B1.
[4] Knopman, Debra, "License to Innovate: An Agenda to Modernize the Tools of Environmental Protection," Blueprint, 2001, *http://www.ndol.org*.
[5] Mazurek, Jan, "Back to the Future: How to Put Environmental Modernization Back on Track," Progressive Policy Institute, April 2003, *http://www.ppionline.org*.
[6] *Ibid.*
[7] Hoffman, Peter and Robert Rose, "Toward Tomorrow's Energy: Speeding the Commercial Use of Fuel Cells and Hydrogen," Progressive Policy Institute, January 22, 2003, *http://www.ppionline.org*.
[8] One reason environmental technology growth is stagnant is that we have taken advantage of most of the obvious opportunities available under our current system of laws. We have entered into a period that is well known in systems analysis, where the large, egregious problems have been solved, and what remains are numerous, diffused, low-level, chronic problems that have large aggregate impacts. A similar pattern is seen in public health, where we have conquered many of the most deadly diseases that kill at an early age, but find our society now plagued by chronic aliments. A good description of this state of affairs can be found in: Tenner, Edward, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*, Alfred Knopf, 1996.
[9] Environmental Business International, *http://environmental-industry.com/ebj/dataproducts.html*.
[10] *2002 Statistical Abstracts of the United States*, U.S. Census Bureau, 2002; and Environmental Business International, *op. cit.*
[11] "An *environmental technology* is a technology that reduces human and ecological risks, enhances cost effectiveness, improves process efficiency, and creates products and processes that are environmentally beneficial or benign. The word "technology" is intended to include hardware, software, systems, and services. Categories of environmental technologies include those that avoid environmental harm, control existing problems, remediate or restore past damage, and monitor and assess the state of the environment." "Bridge to a Sustainable Future: National Environmental Technology Strategy," U.S. Government Printing Office, April 1995
[12] See Davies, J.C. and J. Mazurek, *op. cit.*
[13] For instance, see the recent proposal by the Apollo Alliance that a $300 billion investment in clean energy would yield 3.3 million jobs. "Redefining the Prospects for Sustainable Prosperity, Employment Expansion, and Environmental Quality in the U.S.: An Assessment of the Economic Impact of the Initiatives Comprising the Apollo Project," The Perryman Group, November 2003.
[14] "China Environmental Market Beckons, But U.S. Firms Face Stiff Competition," *Environmental Business Journal*, Vol. XV, No. 11/12, 2003.
[15] Broad, William, "U.S. is Losing Its Dominance in the Sciences," *New York Times*, May 3, 2004.
[16] The state of Schleswig-Holstein in Germany now produces 30 percent of its energy with wind turbines. Firms like Germany's Enercon and Denmark's Vestas have become world leaders in wind turbine and wind park development. See: "Wenn's los geht, sind wir die Besten!" *Die Zeit*, May 6, 2004.
[17] Hoffman, Peter and Robert Rose, *op. cit.*

[18] A wide-ranging analysis of the accelerating rate of change can be found at: *http://www.kurzweilAI.net/law*. See also: Fine, Charles, *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Perseus Books, 1998.
[19] See Rejeski, D., "The Next Small Thing," *The Environmental Forum*, March/April, 2004.
[20] For a discussion of the challenges and opportunities surrounding genetics see: Rejeski, D., "Exploring the Genomics Frontier," *Risk Policy Review*, 2003. Many issues surrounding nanotechnology development have been examined recently by the British Royal Society and Royal Academy of Engineering in a report entitled: "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," *http://www.royalsoc.ac.uk*.
[21] One of the fundamental properties of emergent behavior is that small changes in the initial conditions of a complex system can bring about large effects with long lasting impacts. See: Johnson, Steven, *Emergence,* Simon and Schuster, 2001. A good discussion of technological "lock in" can be found in Arthur, Brian, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *Economic Journal*, Vol. 99, pp. 116-131, 1989.
[22] "Cap and trade" replaces standards that tell polluters what kind of technology to install with a single mandatory limit or "cap" on all firms. Rather than putting a single type of technology into place, firms are free to select the best method(s) to reduce pollution—for example, through burning cleaner fuels. Those who are able to exceed the pollution limits set under the cap can trade excess credits to those who cannot. This approach has been proven effective in the case of acid rain to reduce pollution at lower cost than command-and-control and holds great promise to decrease the emissions of gases implicated in climate change.
[23] In addition, the administration should direct the National Science and Technology Council to create a Subcommittee on Environmental Technologies within the interagency Committee on Environment and Natural Resources. The subcommittee's first task would be to take inventory of government programs focused on the environmental sector, from research to technology verification and export promotion, and to identify significant gaps therein. In particular, the subcommittee should endeavor to identify programs that focus on applied research and commercialization, such as the Small Business Innovation and Research grants, funding tied to international development, and possible support linked to new homeland security initiatives.
[24] Data from Environmental Business International indicates that over 99 percent of the environmental firms surveyed had under 500 employees. These firms accounted for almost 40 percent of the revenues measured. Small firms dominate in some key areas of future importance such as process and prevention technologies and analytical services. Environmental Business International, *op. cit.*
[25] Hoffman, Peter and Robert Rose, *op. cit.*
[26] The tendency for people to seek solutions inside their own institutions or within their own fields of expertise has been well documented (the so-called "Not Invented Here" Syndrome). Soviet patent expert Genrich Altshuler analyzed hundreds of thousands of patents and found that many of the most innovative ones, about 5 percent, drew on knowledge outside the inventor's area of expertise, organization, or industry sector. See: "The Theory of Inventive Problem Solving (TRIZ)," *http://www.mazur.net/triz*. Also: Leonard-Barton, Dorothy, *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*, Harvard Business School Press, 1995; or Garvin, David, "Building a Learning Organization," *Harvard Business Review*, Vol. 71, No. 4, July/August 1993.
[27] Programs run by the National Science Foundation and National Institutes of Health and built on the so-called ELSI model (ethical, legal, and social implications) are inadequate in this regard and should not be seen as a substitute for a well-structured technology assessment capability.
[28] Speth, Gus, *Red Sky at Morning*, Yale University Press, 2004; Ehrlich, Paul and Anne Erlich, *One with Nineveh: Politics, Consumption, and the Human Future*, Island Press, 2004.
[29] Though never high, venture capital investments in environmental firms are now almost non-existent according to information from ACET. For almost a decade beginning in the early 1990's, ACET collected data. In 1993, venture capital investments in environmental technologies were approximately $31 million (in 12 firms) dropping to $25 million by 1995 (in 10 firms) and continuing to deline. "Bridge to a Sustainable Future: National Environmental Technology Strategy," *op. cit.*
[30] In-Q-Tel focuses on the development and commercialization of dual-use information technologies and is funded at a level of $30 million annually.
[31] It is easy to blame government brain drain on pay differentials between the public and private sectors. Studies by the Brookings Institution have shown lack of employee retention is less about the pay and more about the job itself. See: Colin Johnson and Gina Russo, "Give Us A Chance to Do Our Jobs," Brookings

Institution, 2001; Colin Johnson and Gina Russo, "Winning the Talent War: New Brookings Study Finds the Nonprofit Sector Has the Most Dedicated Workforce," Brookings Institution, New Release, October 3, 2002.

[32] Partnership for Public Service on "Best Places to Work in the Federal Government," *http://www.bestplacestowork.org*. The EPA ranked fifth for employees under 40, for females, and for minorities (behind agencies like the National Science Foundation and NASA).

[33] Mazurek, Jan, 2003, *op. cit.*

[34] McGinty, Kathleen, "Environmental Armistice," BLUEPRINT, 2004, *http://ndol.org.* See also: Mazurek, Jan, 2003, *op. cit.*

[35] Speth, Gus, "Creating a Sustainable Future: Are We Running Out of Time," in Rejeski, D. and R. Olson, (eds.), *Environmentalism and the Technologies of Tomorrow: Shaping the Next Industrial Revolution*, Island Press, 2004.