# Introduction

Over the past decade, there has been increasing interest in a fundamentally new approach to environmental protection. Rather than focusing on the control or cleanup of waste and hazardous materials, this new approach emphasizes redesigning industrial products and processes to reduce or eliminate the hazards at their source, reducing the amount and toxicity of chemical reactants, hazards of products and by-products, quantities of waste, and energy consumed, often at reduced costs. Proponents suggest that new science and technology can help produce processes and products that are both more environmentally benign and economically attractive.

Both the “pull” of demand and the “push” of technology drive this new approach. On the demand side, environmental policy has made significant advances over the past 30 years, particularly in controlling end-of-pipe emissions from large industrial facilities and key durable goods such as automobiles. But in some areas the trends have not been positive. In particular, the economies of the United States and other developed countries have not shown any consistent dematerialization, that is, a decrease in the total use and emissions of materials. Nor has there been any systematic reduction in the use of hazardous chemicals. For instance, total chemical emissions in North America have shown little change over the past five years. While manufacturers cut their toxic air emissions by 25 percent (153,000 metric tons) between 1995 and 1999, the improvement was largely offset by a 25 percent increase (33,000 tons) in on-site releases to land, a 35 percent increase (58,000 tons) in off-site releases mostly to landfills, and a 26 percent increase (24,000 tons) in releases to lakes, rivers, and streams.[1] Recent studies have found that in Europe the production and import of dangerous chemicals has grown faster than gross domestic product (GDP) over the past decade.[2] Many hazardous materials, such as sulfuric acid and chlorine, do not appear in final products but rather are used and dissipated in the production process. While total material use has not dropped in developed economies, there has been a reduction over the past three decades as a percentage of GDP. This comes largely as a result of some input substitution, that is, the use of new materials in place of old ones, increased efficiency of production, and growth of the service and information technologies’ economies. Nevertheless, the amount of material per product and the hazardous material used in their production has remained relatively unchanged.[3]

Concurrently, traditional approaches to environmental policy, principally command and control regulations but also market-based tools such as emissions trading and pollution taxes, do not

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[1] Hess, Glenn, “Total Chemicals Emissions Show Little Change,” *Chemical Market Reporter*, Vol. 261, No. 22, June 3, 2002, p. 7.

[2] Christian Azar, John Holmberg, and Sten Karlsson, “Decoupling: Past Trends and Prospects for the Future,” in *Report for the Swedish Environmental Advisory Council*, Ministry of the Environment, Stockholm, Sweden, 2002.

[3] The trends are often worse in the developing world, where economic growth is often faster and the rates of dematerialization are less.

seem sufficient to address many of these problems.[4] The interest in new approaches stems from several factors. In part, the sources of many of today's most intractable environmental problems are not well addressed by traditional regulatory tools. Additionally, new attitudes about environmental protection may make it increasingly effective for government to focus on enabling rather than compelling environmental performance.

As an example of the first issue, traditional regulatory tools were designed to control large effluent streams from a relatively small number of large facilities such as electric power generation or chemical manufacturing plants. But increasingly, pollution comes from a large number of small sources. For instance, dry cleaners and automobile paint shops have been a significant source of volatile organic compounds (VOCs) that contribute to smog. Again, in the early 1990s, significant quantities of silver were discovered in the sediment and sea life in San Francisco Bay. The source turned out to be dentists' offices.[5] Traditional regulatory tools are not effective for such point sources, spurring interest in alternative tools.

An increased interest in new approaches for environmental protection may also derive in part from significantly changed attitudes about the environment over the past few decades.[6] Many firms now see an increased environmental consciousness as offering the potential for market niches that emphasize the environmental benefits of products and services. More generally, many firms seek to avoid adverse publicity caused by perceived inattention to the environment. Increasing numbers of corporate executives may begin to see environmental protection as an important part of their corporate responsibility. These shifting attitudes offer the potential for government to supplement mandatory requirements. Such additional actions could encourage and enable firms to act proactively in protecting environmental quality when cost-effective methods are available.

In conjunction with this increased demand for new approaches to environmental protection, there are powerful trends that provide a technology push driving new approaches. Across the economy, advances in the sciences of materials and chemical and biological processes increasingly make possible the redesign, at the molecular level, of the basic products and processes that underlie economic activities ranging from chemical manufacture to energy production to transportation to the disposal of household goods. Combined with information technology, these new technologies have the potential to revolutionize many sectors of the economy. The effects are already seen in the proliferation of new materials in everything from automobiles to sporting goods. Bioprocesses increasingly create new drugs. Many technology forecasters see the coming decades as ones where biotechnology and nanotechnology will provide unprecedented control

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[4]Thomas Dietz and Paul C. Stern (eds.), *New Tools for Environmental Protection: Education, Information, and Voluntary Measures*, Washington, D.C.: National Academy Press, 2002.

David W. Rejesh and James Salzman, "Changes in Pollution and the Implications for Policy" in Dietz and Stern, 2002.

National survey research suggests that there has not been a significant shift among individual attitudes, but rather individuals educated since the 1970s tend to be much more environmentally conscious than individuals educated before that time. See R. E. Jones and R. E. Dunlap, "The Social Bases of Environmental Concern: Have They Changed Over Time?" *Rural Sociology*, No. 57, 1992, pp. 28–47, and C. L. Kanagy, "Surging Environmentalism: Changing Public Opinion or Changing Publics?" *Social Science Quarterly*, No. 75, 1994, pp. 804–819.

over the fundamental building blocks of organic and inorganic matter.[7] These emerging capabilities offer the hope that environmental problems can be increasingly addressed by designing materials and production processes that are intrinsically environmentally benign. Such advances could significantly reduce material use, eliminate reaction with and production of hazardous materials, and offer the promise of substantial new advances in environmental protection at very low cost or even with a net economic benefit. We call the broad class of such technologies “Next Generation Environmental Technologies” (NGETs).

The potential of NGETs to support a new approach to environmental protection raises important questions for both private industry and government policymakers. Can such technologies enable a widespread decoupling of environmental impact from economic growth, or will they remain confined to isolated pockets of success? If the former is indeed possible, what steps must the government and the private sector take to bring NGETs to their full potential? Over the past decade the federal government has pursued a variety of programs to explore the development of these new approaches. These include funding for basic research; partnerships, fellowships, and an awards program in green chemistry; and initial attempts at flexible regulatory reform. Policymakers may now confront the extent to which NGET programs ought to be increased and the extent to which, if possible, environmental policy ought to come to rely more heavily on such a technology-based approach.

Such questions are difficult to answer because many NGETs are relatively young. As with any new technology, future costs and benefits are impossible to predict accurately. To craft policy successfully in this area, policymakers must lay out a range of scenarios for potential impacts, consider a portfolio of potential policy levers, and choose portfolios of policies that will be effective across the range of uncertainty inherent in any new technology program.[8]

This report takes an initial step in framing such a process. It explores 25 case studies of NGETs as a means of surveying the current activity in the field. We examine each technology’s current impact, its potential promise, reasons for its adoption, and the barriers to broader implementation. For readers unfamiliar with NGETs, this report will provide a survey of its promise and weaknesses. For researchers and practitioners creating new NGETs, it aims to provide a broader context for their efforts. For policymakers, it can provide the raw materials for a systematic assessment of the range of potential benefits of NGETs and the portfolio of policies needed to move them forward. The report does not, however, make specific policy recommendations.

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[7]For a proponent’s report on nanotechnology, see K. Eric Drexler, *Molecular Manufacturing: A Future Technology for Cleaner Production, Clean Production: Environmental and Economic Perspectives*, New York: Springer, 1996; for a summary of the potential implications of these new technologies, see Philip S. Anton, Richard Silberglitt, and James Schneider, *The Global Technology Revolution: Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015*, Santa Monica, Calif.: RAND, MR-1307-NIC, 2001.

[8]For a full description of the necessary process, see R. J. Lempert, and M. E. Schlesinger, “Adaptive Strategies for Climate Change,” in Robert G. Watts, ed., *Innovative Energy Strategies for $CO_2$ Stabilization*, New York: Cambridge University Press, 2002.