Preventing Pollution

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Why not prevent pollution, rather than have to clean it up afterwards? This simple question is, increasingly, a starting point for much of today's environmental policy discussion. Traditional environmental protection law has focused on pollution control — the cleanup after pollution has already occurred— rather than on preventing pollution at the onset. Yet, this pollution control policy is costly and often limited in what it can accomplish. More fundamentally, pollution control only treats the symptoms of pollution rather than correcting its cause.

The emerging conventional wisdom calls for a new regulatory approach which emphasizes preventing pollution rather than the

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traditional scheme of controlling pollution after it has been created.¹ Twenty-five years ago the emphasis on control was an understandable response to the public demands for real environmental protection.² As environmental awareness exploded on the national policy scene in the late 1960s, the need was to give teeth to environmental protection law. The general consensus among various congressional committees was that the pollution control efforts in place were weak and ineffective.³ Consequently, these groups called for stricter rules and real enforcement.

Responding to these demands, Congress passed new environmental legislation and established the Environmental Protection Agency ("EPA") to promulgate and enforce regulations.⁴ The rationale was that robust environmental protection law required robust regulations.⁵ Thus, policy makers turned to the regulator and

¹ See, e.g., ENVIRONMENTAL STRATEGIES FOR INDUSTRY: INTERNATIONAL PERSPECTIVES ON RESEARCH NEEDS AND POLICY IMPLICATIONS (Kurt Fischer & Johan Schot eds., 1993) [hereinafter ENVIRONMENTAL STRATEGIES FOR INDUSTRY]. For an good introduction see Nicholas A. Ashford, Understanding Technological Responses of Industrial Firms to Environmental Problems: Implications for Government Policy, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY supra, at 277. See also NATIONAL ACADEMY OF ENGINEERING, THE GREENING OF INDUSTRIAL ECOSYSTEMS (Braden R. Allenby & Deanna J. Richards eds., 1994); NATIONAL ADVISORY COUNCIL FOR ENVIRONMENTAL POLICY AND TECHNOLOGY, UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, TRANSFORMING ENVIRONMENTAL PERMITTING AND COMPLIANCE POLICIES TO PROMOTE POLLUTION PREVENTION (EPA 100/R-93-004, 1993); BEYOND COMPLIANCE: A NEW INDUSTRY VIEW OF THE ENVIRONMENT (Bruce Smart ed., 1992) [hereinafter BEYOND COMPLIANCE]; GEORGE R. HEATON ET AL., WORLD RESOURCES INSTITUTE, TRANSFORMING TECHNOLOGY: AN AGENDA FOR ENVIRONMENTALLY SUSTAINABLE GROWTH IN THE 21ST CENTURY (1991); OFFICE OF TECHNOLOGY ASSESSMENT, U.S. CONGRESS, SERIOUS REDUCTION OF HAZARDOUS WASTE: FOR POLLUTION PREVENTION AND INDUSTRIAL EFFICIENCY (OTA-ITE-317 1986) [hereinafter SERIOUS REDUCTION OF HAZARDOUS WASTE].

² See Braden R. Allenby, Integrating Environment and Technology: Design for Environment, in THE GREENING OF INDUSTRIAL ECOSYSTEMS, supra note 1, at 137.


⁴ ENVIRONMENTAL LAW INSTITUTE, supra note 3, at § 10.02.

⁵ RODGERS, supra note 3, at 129, 252.
her commands, and pollution control was the natural result.

The new legislation authorized regulators to use controls\(^6\) to restrain polluters. Controls fit well with the prevailing attitudes that polluters were bad and should be restrained for the public good. During a period of economic growth, this system\(^7\) has achieved some success at pollution control. However, by focussing almost exclusively on regulations, the pollution control system typically does not require or inspire the initiative and innovation from regulated businesses to develop and implement cleaner technologies.\(^8\) As a result, the control system has missed most of the opportunities to promote pollution prevention.

To promote a prevention policy, we must focus on regulated businesses rather than regulatory agencies. Although regulators can craft and enforce rules designed to control pollution, only industrial and commercial leaders can prevent pollution by the businesses they run. Business people make the decisions about the processes, materials, and products that generate pollution. Preventing that pollution requires business people to make different decisions — to operate their businesses differently. This Article argues that only business can conceive and implement the innovative technological changes that pollution prevention requires. Thus, we must understand the innovation and organizational dynamics of environmental technological change in order to make effective policy to encourage and support them.\(^9\)

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6. Traditionally, controls have consisted of either health-based ambient standards designed to protect human health and the environment from excessive pollution or technology-based emission limits placed on the individual polluters. See ENVIRONMENTAL LAW INSTITUTE, supra note 3, at § 11.01.

7. Under the current system, the EPA is empowered, by applicable statute, to make and enforce regulations designed to control and punish polluters. Cf. Kurt A. Strasser, Pollution Control in an Era of Economic Redevelopment: An Overview, 8 CONN. J. INT’L L. 425, 427-31 (1993).

8. A “regulated business” is any licensed business that is subject to the pollution control measures found in various environmental statutes, including but not limited to, the Clean Air Act, 42 U.S.C § 7401 (1994), and the Clean Water Act, 33 U.S.C. § 1251 (1994).

9. Pollution prevention typically requires new technology that is more environmentally friendly, or, to put it another way, cleaner technology rather than the cleaning technology emphasized today. A forthcoming article will build on this richer understanding of the business realities of pollution prevention and examine
This Article will examine prevention from the perspective of polluting companies rather than regulators. This Article will consider how companies promote prevention and why it presently does not occur more often. It will then discuss the individual and organizational efforts which are needed and what leads to these efforts by some companies and not others. Part I briefly reviews the importance of pollution prevention. Part II considers the kinds of innovative efforts that companies must make to create new technology which will prevent pollution. Part III will then evaluate the organizational support required to fuel these innovative efforts and then to get them implemented. Part IV discusses the industrial ecology and related ideas which offer exciting possibilities for thinking about prevention policy more deeply and with an expanded time horizon.

I. POLLUTION PREVENTION INSTEAD OF POLLUTION CONTROL

A. New Policy Focus and Business Dynamics

Pollution prevention means producing, distributing, and consuming products in an economic society without creating as much or, ideally, any pollution. It usually involves technological change.

how the existing pollution control regulatory system both promotes and retards pollution prevention and environmental technology development. Later work will consider voluntary pollution promotion programs and regulatory requirements for pollution prevention planning. Kurt A. Strasser, Cleaner Technology, Pollution Prevention and Environmental Regulation, 8 FORDHAM ENVTL. L.J. (forthcoming 1997) (manuscript on file at FORDHAM ENVIRONMENTAL LAW JOURNAL office).

10. A number of different terms and concepts are used in connection with the idea of pollution prevention. The usage here is intended to be broad and to encompass all efforts that reduce the creation of waste residuals or that reuse residuals that are created. Thus "prevention" includes: reducing the generation of wastes at the source (source reduction) as well as internal and external reuse of wastes in recycling or other operations. See Ashford, supra note 1, at 278. Both reduction and reuse can decrease the discharge of waste residuals to the environment.

Technological change is typically required, either in using existing technology differently or in creating or implementing new technology. The Amoco-Yorktown Project, found that source reduction made up less than half of the total pollution reduction opportunities available at the refinery. Amoco-U.S. EPA Pollution Prevention Project, Yorktown, Virginia, Project Summary (revised June 1992) at 1-9 [hereinafter Amoco-Yorktown Project].
To understand how to accomplish this, one must compare a pollution prevention policy with the current control policy.

Pollution control requires limiting the discharge of pollutants, which are usually the by-products of either production or consumption, to air, water, or land after the pollutants have been produced. The policy focus of pollution control is on how regulators seek to control pollution and the expectation that regulated entities, largely businesses, will comply with regulators' commands. Policy questions are framed from this perspective. For example, policy questions at the heart of pollution control regulation include the following: the concentration of lead in the ambient air that can be tolerated before adverse health or ecosystem effects result; the degree of pollutant removal from a waste stream which is technologically possible to require; the amount of discharge of biological oxygen a waste stream can absorb without lowering water quality; and, whether a particular waste source has met the lowest achievable emissions rate.

The command process is of central concern, first in issuing regulatory standards and later in surviving the judicial scrutiny of these standards and their enforcement. Pollution control policy tries to pinpoint effective commands rather than focus on the complexity or variety of behavior expected in response to these commands. This approach assumes that, with strong enforcement of the right regulations, regulated businesses will either choose, or be forced, to com-

Controversy and confusion arise because the EPA and others use the term prevention more narrowly to mean only source reduction, with recycling or reuse separate categories. See Pollution Prevention Act of 1990, 42 U.S.C. § 13101 (1994); Environmental Protection Agency Pollution Prevention Strategy, 56 Fed. Reg. 7849 (1991). This usage emphasizes policy preference among a hierarchy of different methods of reducing waste residuals discharge. Prevention is most preferred and the others are ranked under it. This Article prefers the broader usage because it better supports my emphasis on business programs.

Finally, sustainable development is a broad concept and another frequently used term which includes prevention and many other ideas. In encouraging the development of clean technology, pollution prevention can be part of sustainable development. See HEATON ET AL., supra note 1, at vii, 30.

13. Id.
ply.

As noted above, this control system has produced generally cleaner air, water, and land over the last twenty-five years. There have been a few dramatic pollution reduction successes, often the result of stringent controls or outright product bans. However, product bans are usually not a realistic policy option because satisfactory product substitutes are frequently unavailable. Despite some success achieved by imposing technology on industry, most often this command and control system does not adequately encourage new environmental technology and pollution prevention. In

15. See Allenby, supra note 2, at 137.


For example, banning lead from gasoline has resulted in drastically lower levels of lead in the ambient air, and much lower average levels in children's blood. “Between 1985 and 1994 average lead concentrations in urban areas throughout the country decreased 86 percent while total lead emissions decreased 75 percent.” OFFICE OF AIR QUALITY PLANNING AND STANDARDS, EPA, AIR QUALITY TRENDS 6 (EPA-454/F-95-003, 1995) [hereinafter AIR QUALITY TRENDS].

Note that local concentrations, particularly for inner city children, continue to be a major public health problem. The technological responses of business to product bans is reviewed in this Article's companion, Strasser, supra note 9 (manuscript at 58-68). General product bans, when used, have provoked technological innovation by business. Id.

17. For example, banning automobiles powered by the internal combustion engine would produce a substantial improvement in present problems with urban smog and air toxins. However, such a ban is not seriously discussed because, at present, no alternative technology is available.

18. For example, although the process took ten years of legislative, administrative, and judicially ordered delays, the Congressional mandate for cleaner automobile emissions eventually led to technological improvements which have enabled the average vehicle to produce much less pollution per mile. See, e.g., ENVIRONMENTAL LAW INSTITUTE, supra note 3, § 11.06. Unfortunately, the increase in miles traveled has offset much of the net environmental improvement in pollution discharged per mile. The emissions reduction does not address the question of whether pollution was prevented in the manufacturing process. Id.

19. See Strasser, supra note 9 (manuscript at 40-44) (reviewing history of delays). The experience is that, at best, environmental standards usually wind up requiring only the application of known technologies or methods, rather than development of new ones. See, e.g., D. Bruce La Pierre, Technology Forcing and Federal Environmental Protection Statutes, 62 IOWA L. REV. 771, 773-75, 800 (1977). The level of innovation and technological response from business is
contrast, pollution prevention and environmental technology change require a creative response from business which is difficult to mandate through command and control regulation.

Pollution prevention begins by focusing policy on regulated companies rather than regulators and their commands. Prevention seeks to encourage business to make the technological changes necessary to operate with less resulting pollution. We must consider whether business can change its operations, what kinds of changes are required, and how environmental policy can require or inspire them. A careful examination of pollution prevention efforts which have found success in business illustrates the way a prevention policy can effectively lead businesses to employ new technologies.

B. The Advantages of Prevention

Pollution prevention has become the new mantra of environmental policy discourse because it offers, at least in theory, several advantages over the more familiar pollution control strategy. As a backdrop for the rest of this Article, this section will briefly survey the benefits of pollution prevention.

1. A Cleaner Environment At A Lower Cost

Prevention should be a much cheaper strategy for achieving a cleaner environment. This is an intrinsically persuasive idea — "an ounce of prevention is worth a pound of cure." Although this country has worked seriously at pollution control for twenty-five years, with some real success, this success has been expensive, and mixed, depending, among other things, on industry and firm specific factors. See, e.g., Ashford, supra note 1, at 277-78.


21. For example, between the enactment of the Clean Air Act in 1970 and
costs are expected to rise.\(^2\)

In addition, there is a growing consensus that environmental cleanup through the present control system has reached a plateau.\(^2\) While the regulatory system becomes more complex and demanding, the rate of environmental improvement appears to be slowing and perhaps even stopping. An increasing amount of regulatory effort seems to be required for each increment of environmental protection. Continued improvement will require a much more extensive system of controls, which will inevitably become more expensive.

In contrast, prevention offers the prospect of greater environment-

1994, the combined emissions of the six principal air pollutants decreased 24 percent, the U.S. population increased 27 percent, vehicle miles traveled increased 111 percent and gross domestic product increased 90 percent. During this period the introduction of unleaded gas decreased lead emissions by 98 percent. AIR QUALITY TRENDS, supra note 16, at 4. "Low dissolved oxygen levels were a pollution problem in streams and rivers 20 years ago but are rarely encountered today because of an overall reduction in point discharges of oxygen-demanding wastes. In the decade following 1972, municipal loads of biochemical oxygen demand decreased by an estimated 46%, and industrial loads decreased by at least 71%, nationally." COUNCIL ON ENVIRONMENTAL QUALITY, EXECUTIVE OFFICE OF THE PRESIDENT, ENVIRONMENTAL TRENDS, 62-68 (1989).

22. See SCIENCE, ECONOMICS AND STATISTICS DIVISION, EPA, ENVIRONMENTAL INVESTMENTS: THE COST OF A CLEAN ENVIRONMENT (EPA-230-12-90-084, 1990) [hereinafter ENVIRONMENTAL INVESTMENTS]. With enforcement at current levels, the 1990 cost of all pollution control activities is estimated at $115 billion, 2.1% of GNP. Id. at v. By the year 2000 this cost is projected to grow to $171 billion (in 1990 dollars), 2.6% of GNP, with enforcement at current levels. Id.

The impact of this cost on profitability, jobs, competitiveness, and innovation, is less clear. A careful recent review of the evidence concludes that little or no evidence supports the conclusion that environmental regulation hurts either profitability or job creation. See ROBERT REPETTO, JOBS, COMPETITIVENESS, AND ENVIRONMENTAL REGULATION: WHAT ARE THE REAL ISSUES? 19, 22 (1995). In ADAM B. JAFFE ET AL., U.S. DEPARTMENT OF COMMERCE, ENVIRONMENTAL REGULATIONS AND THE COMPETITIVENESS OF U.S. INDUSTRY (July 1993), the authors review more than 100 academic and government studies and conclude that little evidence documents the view that environmental regulation has had a "measurable adverse effect on competitiveness." Id. at iii. See The Challenge of Going Green, HARV. BUS. REV., July-Aug. 1994, at 37, 38-39 (comments of Richard N. Stavins).

23. See Amoco - Yorktown Project, supra note 10, at 1-13. The study cites the opinions of representatives from EPA, Amoco Corp., the Commonwealth of Virginia, and various members of academia. Id.
tal protection from pollution at a lower cost. A cooperative study of
the Yorktown refinery, done jointly by the EPA and Amoco, illus-
trates this point.\textsuperscript{24} Using only the four most attractive prevention
options, the refinery could have eliminated almost as much pollu-
tion as all existing and anticipated regulatory requirements\textsuperscript{25} at less
than one-fourth the cost.\textsuperscript{26}

For business, investing in prevention will typically lead to better
results than simply investing in compliance measures. A Dow inter-

nal study concluded that the environmental funds used to comply
with regulations (ninety percent of total environmental spending)
realized a thirteen percent return on the investment.\textsuperscript{27} In contrast,
the environmental funds allocated to more innovative prevention
efforts (the remaining ten percent of total funds) resulted in greater
than a fifty percent return.\textsuperscript{28} Another study, an internal analysis of
over 700 efforts by DuPont, found that on average "its internally
generated environmental initiatives are three times as cost-effective

\begin{itemize}
\item 24. This peer-reviewed study only included the available prevention projects
    which would exclusively use existing technology. \textit{Id.} at 1-9 to 1-12. Even with
    these limits, prevention was a much cheaper way to reduce pollution discharge. It
    is worth speculating why these projects had not been undertaken anyway, regard-
    less of the regulatory system. However, the regulatory system commanded other
    efforts, and this likely exhausted the resources and initiative available for envi-
    ronmental protection. In addition, these were typically unregulated sources, so
    cleaning them up offered no regulatory benefit. \textit{Id.}
\item 25. 7,300 tons and 6,900 tons. \textit{Id.} at 1-10 to 1-12.
\item 26. $2,400 per ton compared to $500 per ton. \textit{Id.} at 1-11.
\item 27. \textit{Sustainable Development Council Members Discuss Voluntary Business
\item 28. \textit{Id.} Presumably, the more innovative projects were riskier, and a complete
    comparison of returns would have to adjust for this; the risk adjusted returns
    might not have been as high.
\end{itemize}

A 1993 study of six facilities with effective pollution prevention programs
found that, even for these facilities, compliance expenditures were greater than
prevention expenditures. No comparative returns were computed, although most
did require prevention projects to compete for funding on the basis of return on
investment. \textit{AT&T Bell Laboratories Quest Organization, The Business
Roundtable Facility Pollution Prevention Benchmarking Study 12
(1993)} [hereinafter \textit{Benchmarking Study}]. A 1986 OTA study concluded that,
at that time, most environmental expenditures by business were for compliance
rather than prevention. \textit{See Serious Reduction of Hazardous Waste, supra
note 1, at 3.}
as those that respond to government regulations.\textsuperscript{29}

Prevention can be a good investment in its own right.\textsuperscript{30} For example, the Benchmarking Study concluded that to be sustainable most prevention projects had to be cost effective.\textsuperscript{31} In four of the six facilities studied, prevention projects successfully competed with all other capital improvement projects for allocations from the annual budget, based on return on investment.\textsuperscript{32} Similarly, other case studies\textsuperscript{33} have shown that prevention projects are good cost-saving investments.\textsuperscript{34} However, care should be taken not to claim too much: not all prevention projects can be justified solely by comparative return on investment. Nevertheless, when regulatory costs and the public relations value of good environmental performance are considered, prevention is typically still a good investment.\textsuperscript{35}

\textsuperscript{29} The Challenge of Going Green, supra note 22, at 46 (comments of Richard P. Wells).

This was not consistently the case with the Amoco-Yorktown study. Prevention sometimes paid for itself, sometimes not. See Amoco-Yorktown Project, supra note 10, at 1-10. However, the study noted that accounting systems were partly to blame for this — they did not allocate environmental control costs to the activity creating the waste, thus making waste prevention appear less valuable. \textit{Id.} at 1-14.

\textsuperscript{31} BENCHMARKING STUDY, supra note 28, at 10, 24.
\textsuperscript{32} \textit{Id.} The other two set aside 20% of the annual capital improvement budget for environmental projects. However, one of these then required environmental projects to then compete for these funds. \textit{Id.}
\textsuperscript{33} See infra Part II.A.
\textsuperscript{34} This is a particularly robust result considering that many corporate accounting systems do not accurately connect waste generation expenses with waste creation activities, making reduction or elimination of the waste appear to be less valuable than it actually is.
\textsuperscript{35} Compare Noah Walley & Bradley Whitehead, It's Not Easy Being Green, HARV. BUS. REV. May-June 1994, at 46 and James Lis & Kenneth Chilton, Limits of Pollution Prevention, SOCIETY, Mar./Apr. 1993, at 49 (arguing that prevention may not always be a good investment) with The Challenge of Going Green, supra note 22, at 37.
2. Promoting Environmental and Economic Development

Pollution prevention offers a way to ameliorate the tension between achieving environmental protection and promoting economic development. Prevention efforts naturally support creating and implementing new technology, and have the potential to support and enhance company performance programs.\(^{36}\) To prevent pollution, business must rethink how it operates. This includes re-evaluating raw material inputs, production and distribution processes, products, and waste creation. Such critical and innovative activity, essential for pollution prevention, can also serve the goals of maintaining and improving economic competitiveness.\(^{37}\)

Prevention provokes a much different response from business than the typical reaction to traditional pollution control. The command-oriented regulatory system does not foster a business mindset leading to innovation.\(^{38}\) Yet, the regulatory system largely defines the market for environmental innovation and technology development.\(^{39}\) Thus, if the command and control regulatory system does

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36. See infra Part II (arguing prevention requires innovative efforts from business).

37. See Ashford, supra note 1, at 277 and Patricia S. Dillon, *Implications of Industrial Ecology for Firms, in The Greening of Industrial Ecosystems*, supra note 1, at 201, for an excellent discussions of the business responses needed for environmental innovation. For business, the ultimate goal should be to integrate environmental waste reduction into the regular operations of product and process design. Sheldon K. Friedlander, *Environmental Issues: Implications for Engineering Design and Education, in Technology and Environment* 167 (Jesse H. Ausbel & Hedy E. Sladovich eds., 1989). The *Benchmarking Study*, supra note 28, at 10-11, 21, 32, found that effective prevention programs integrate prevention into their business planning, and make it part of the pre-manufacturing decisions and choices in the product research, development, and design process.

38. The general question of the effect of regulatory systems on business innovation is complex and much studied. For an excellent introduction and survey, see Ashford, supra note 1, at 277. The impact of environmental regulation on the creation and implementation of new environmental technology is discussed in detail in Strasser, supra note 9, (manuscript at 35-114).

39. Friedlander, supra note 37, at 167. A Dutch study of environmental innovation found similar effects in the Dutch regulatory control system. Hans Dieleman & Sybren de Hoo, *Toward a Tailor-made Process of Pollution Prevention and Cleaner Production: Results and Implications of the PRISMA Pro-
not require the use of new technology, then business will be less likely to buy it, and, more fundamentally, to develop it.

Consider DuPont’s considerable efforts to find substitutes for the CFCs that are destroying the ozone layer. After a substantial effort in the early 1980s, DuPont reduced its research and development program when it seemed that regulatory controls would not be forthcoming. Without such controls, the market for the substitutes would be small, and therefore, developing substitutes was no longer a high business priority. In the late 1980s, when it became clear that regulatory controls would be imposed, DuPont increased its research and development efforts. Thus, research and development of new technology was prompted by regulatory initiatives, rather than by technological possibilities.

In the DuPont example, the regulatory system used a product ban to inspire technology development. Product bans, however, are less typical than pollution control standards that are set with reference to familiar technological possibilities. Business’s typical response to the traditional pollution control system has been to buy a clean-up gadget, usually for the end-of-the-pipe or the end-of-the-smoke-stack, that implements familiar technology. This device is often expensive, does not otherwise contribute to company performance, and is thus seen as a dead-weight cost. After paying for these

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40. This description is taken from Joseph P. Glas, Protecting the Ozone Layer: A Perspective from Industry, in TECHNOLOGY AND ENVIRONMENT, supra note 37, at 137. Mr. Glas was employed by DuPont and worked in this program at that time.
41. Id. at 142-43.
42. Id.
43. Id. at 147.
44. For a discussion of the use of product bans and the likely business response, see Strasser, supra note 9 (manuscript at 58-68).
45. See Hugh E. Williams et al., Corporate Strategies for a Sustainable Future, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY, supra note 1, at 117, 139.
46. Id.; NATIONAL ADVISORY COUNCIL FOR ENVIRONMENTAL POLICY AND TECHNOLOGY, EPA, IMPROVING TECHNOLOGY DIFFUSION FOR ENVIRONMENTAL PROTECTION, 74-75 (EPA 130-R-92-001, 1992) [hereinafter IMPROVING TECHNOLOGY DIFFUSION]; HEATON ET AL., supra note 1, at 24; see also Dieleman & de Hoo, supra note 39, at 245, 269-70 (similar end of the pipe focus in develop-
devices, industry often loses enthusiasm for any further investment in environmental technology.\textsuperscript{47}

Although the business response has been reactive and defensive, rather than innovative, there are some signs of change.\textsuperscript{48} From 1970 to 1985, a leading study concluded that the attitude of most companies toward environmental compliance was one of "resistant adaptation."\textsuperscript{49} Environmental response was a plant-level issue, treated as simply one more (increasingly onerous) regulatory chore. The business objective was mere compliance, which meant using the most convenient end-of-the-pipe technology. From 1985 to 1992 (the date that this study was published), the authors saw some change in company attitudes toward environmental protection.\textsuperscript{50}

Today, while companies are embracing environmental issues, they are doing so with little innovation.\textsuperscript{51} Environmental issues receive more consideration, but businesses still do not integrate environmental considerations into long-term planning and decision-making.

\begin{itemize}
  \item \textsuperscript{47} Lis & Chilton, \textit{supra} note 35, at 52.
  \item \textsuperscript{48} A recent study of 562 German companies notes some change, but concludes:
    \begin{quote}
      Nevertheless, it is clear that motives for change are more strongly founded on avoiding risk than on grasping new market opportunities. Compliance is still a very important inducement for company behavior. Environmental issues are still connected mainly with production (process modifications) and technical issues. The influence of environmental issues on the full range of company activities is not taken into account — for example, R & D activities are seldom driven by environmental considerations.
    \end{quote}
    Ulrich Steger, \textit{The Greening of the Board Room: How German Companies Are Dealing with Environmental Issues}, in \textit{ENVIRONMENTAL STRATEGIES FOR INDUSTRY}, \textit{supra} note 1, at 147, 164.
  \item \textsuperscript{49} Johan Schot & Kurt Fischer, \textit{Introduction: The Greening of the Industrial Firm}, in \textit{ENVIRONMENTAL STRATEGIES FOR INDUSTRY}, \textit{supra} note 1, at 3, 6-8. An influential 1985 study of 44 source reduction practices at 29 plants in the chemical industry concluded that reduction was typically the last choice, even among these plants that had embraced it eventually, and a choice that was typically motivated by external regulatory or economic stimuli. DAVID J. SAROKIN ET AL., \textit{CUTTING CHEMICAL WASTES} 34 (1985).
  \item \textsuperscript{50} Schot & Fischer, \textit{supra} note 49, at 8-11.
  \item \textsuperscript{51} \textit{Id.}
\end{itemize}
making. Promoting pollution prevention and new environmental technology can lead to increased innovation and the integration of environmental issues more fully into the culture of the organization. To implement effective prevention measures, a third phase of business response is needed.

Real prevention efforts should, over the long run, support and reinforce other efforts at innovation and thereby encourage improved business performance. Prevention often requires investment, but that investment can support other business goals, with the costs frequently recouped in a short time. Seen in this light, it is not surprising that many large companies have publicly embraced pollution prevention as a policy and implemented many specific projects and programs geared toward prevention. 52

3. Prevention Encourages Business To Use Knowledge To Support Environmental Protection

A new business approach to environmental protection goals highlights a third advantage of pollution prevention. A prevention policy encourages a business to use its knowledge, energy, and initiative to support environmental protection, rather than obstruct it. Our present control system gives a business strong incentives to use its knowledge to argue for more permissive standards in the regulatory process. 53 Indeed, there is substantial scholarship showing that our present pollution control system tends to set standards at some variant of the best available technology, only to discourage development of cleaner technology. 54 In contrast, a prevention approach

52. See infra Part III (discussing company programs and policies that support prevention).

53. Schot & Fischer, supra note 49, at 8-12. The statement in the text, while generally accurate, is overbroad. Firms within an industry that have superior cleanup technology can argue for stricter standards to secure a competitive advantage over their less advanced competitors. In addition, firms outside an industry that design and make cleanup gadgets have an obvious incentive to argue for a standard that their gadget can meet. Ideally, these firms seek a standard that only their gadget can meet.

54. See, e.g., Natalie M. Dersko, Using Intellectual Property Law and Regulatory Processes to Foster Innovation and Diffusion of Environmental Technologies, 20 HARV. ENVTL. L. REV. 3, 19-21 (1996); Strasser, supra note 9 (manuscript at 144-50) (discussing the impact of traditional environmental regulation on
encourages business to design, build, and use increasingly cleaner technology by offering the rewards for doing so.

4. More Effective Environmental Protection

Finally, pollution prevention offers the prospect of more effective environmental protection. In some instances, our present command and control system results in simply shifting pollution from a more carefully regulated medium to a less carefully regulated one. In this situation, shifting the pollution is cheaper than developing new technology to prevent it. Such shifting can, in a particular set of circumstances, result in compliance with the requirements of the regulatory system, because the requirements differ for the various media without offering actual environmental protection. The environmental impact of such inter-media transfer can be negative and there is no a priori reason to assume that it will be positive. Preventing, rather than shifting, pollution offers real environmental protection.

These advantages demonstrate that a prevention strategy would be more effective than the present control strategy. The end result, at least in happy theory, will be a cleaner environment, achieved at lower cost, involving less regulatory interference with business operations, and with environmental protection policy supporting and encouraging improved business competitiveness. Considering all these advantages, it is not surprising that pollution prevention is the current policy favorite.

Implementing this attractive theoretical possibility, however, has not proven to be a simple task. To effectively support pollution prevention and the associated environmental technology, policymakers must expand their understanding of business and organizational realities. The remainder of this Article will discuss these business realities.

56. Id.
II. THE VARIETIES OF INNOVATION IN POLLUTION PREVENTION

Effective pollution prevention demands a creative, innovative response from business. The variety of such responses range from simple, straightforward housekeeping changes, to changing a cleaning solution or other material input, to more fundamental redesign of industrial processes and, eventually, redesign of products. These technological changes are potential sources of pollution prevention. Examples of such technological change, most dealing with cleaning parts during industrial operations, illustrate this range of responses. This section will discuss changes in the production processes and the next section will consider redesign of products.

57. The term innovation presents a semantic difficulty here. In the economic analysis of technological change, three distinct stages are separated for purposes of analysis. Invention, the first stage, involves creating new scientific or technological knowledge. The second stage, conventionally labeled innovation, is the development of this invention through the prototype stage until a commercially viable product or technology results. The third stage, diffusion, is the spread of this innovation effort. This Article uses the term innovation in a broader, more popular sense, to refer to any of the three processes as they relate to accomplishing pollution prevention.

58. See infra text accompanying notes 67, 68.
59. See infra text accompanying notes 70-76.
60. See infra text accompanying notes 77-85.
61. See infra Part II.B. For a brief general discussion of all of these various approaches see SERIOUS REDUCTION OF HAZARDOUS WASTE, supra note 1, at 78-83.

62. These examples are selected from a vast literature, some of it rather technical. For excellent non-technical introductions, see BEYOND COMPLIANCE, supra note 1, at ch. 2; CHANGING COURSE, supra note 20, at chs. 7, 15 and 16.

Two studies, prepared by Abt Associates for the EPA, collected references and data for all the case study literature through January, 1994. POLLUTION PREVENTION AND TOXIC SUBSTANCES, EPA, ABSTRACTS OF POLLUTION PREVENTION CASE STUDY SOURCES (EPA 742-B-94-001, 1994) collects all the literature discussing both single and multiple case studies. POLLUTION PREVENTION AND TOXIC SUBSTANCES, EPA, SUMMARY OF POLLUTION PREVENTION CASE STUDIES WITH ECONOMIC DATA (BY SIC CODES) (EPA 742-S-94-001, 1994) presents basic economic data from 207 specific case studies in tabular form. The EPA's Pollution Prevention Information Clearinghouse ("PPIC") and its Pollution Prevention Information Exchange System ("PIES") offer a large number of case studies.
There is evidence that changes in production processes are the most common and the most straightforward pollution prevention efforts. A 1992 study of source reduction efforts in twenty-nine chemical industry plants found these to be the most frequent changes in the 181 projects studied.\textsuperscript{63} Forty-four percent of all projects involved process changes, thirty-four percent involved operations changes, and eighteen percent involved equipment changes.\textsuperscript{64} The projects were successful: each type of change eliminated approximately seventy percent of the waste stream involved. More innovative changes were less frequently applied, with chemical substitution being used in only ten percent of the projects and product changes in only five percent.\textsuperscript{65} Chemical substitution prevented only forty-eight percent of the waste. Product changes, however, were 100 percent successful in eliminating the waste stream in the three projects where they were used.\textsuperscript{66}

Good housekeeping is the simplest and least expensive pollution prevention process change. "For example, the proper operation and

\textsuperscript{63} Mark H. Dorfman et al., Environmental Dividends: Cutting More Chemical Wastes 48 (1992). This study incorporated the results of an earlier effort, Sarokin et al., supra note 49.

In six facilities studied in the Benchmarking Study, there were more opportunities for pollution prevention by doing chemical substitutions in chemical-using facilities than in chemical-manufacturing facilities. Benchmarking Study, supra note 28, at 12. Process changes redesign the way the manufacturing system is set up. Operations changes involve the way the process is conducted. Finally, equipment changes involved installing new equipment. More than one may be involved in a particular innovation.

\textsuperscript{64} Id.

\textsuperscript{65} Chemical substitution entails the replacement of certain chemical agents with alternative agents in order to reduce the resulting waste stream. EPA has advocated listing and tracking prospective chemical substitute strategies. See Reporting: TRI Expansion Proposal Gains Steam; Materials Accounting Information Eyed, 18 Chemical Reg. Rep. 787 (1994).

\textsuperscript{66} Product changes entail the substitution of products, or specific features of products, with alternatives intended to reduce the product's consumption of non-renewable energy, the degree to which the product pollutes, or both. See General Policy: Senate Hearing Examines Technology Issues Related to Environmental Protection Rules, 23 Envtl. Rep. 2837 (1993).
regular maintenance of equipment can often substantially reduce leakage and overuse of materials. Improvements in housekeeping practices, which can often reduce pollution between a quarter and a third, usually do not require large capital expenditures. In addition to maintaining equipment and good operating practices, monitoring the use of raw materials and their impacts, as well as more effective inventory controls, can also provide important pollution prevention support.

1. APS Materials, Inc.

A change in cleaning solutions offers a slightly more complex example of a technological change. APS Materials, Inc. used 1,1,1-trichloroethane ("TCA") and methanol to clean orthopedic implants before they were to be coated with a titanium alloy. There is widespread use of TCA by businesses because it is a most effective cleaning agent. However, TCA is also one of the environment's chemical villains. The amount of TCA which evaporates leads to smog, promotes global warming, and is sometimes toxic. In addition, its use often generates a solid chemical waste that is hazardous, as it did at APS Materials' operation. APS's primary goal was to eliminate this toxic waste, as disposing of it was becoming "increasingly difficult." This demonstration project substituted a water based cleaner that would not result in hazardous waste. Coincidentally, although not the articulated justification for this project, reduced use of TCA also led to substantial air quality benefits.

In this case, use of the new solvent required some equipment modifications, at a total capital cost of $1,793. No separate cal-

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67. CHANGING COURSE, supra note 20, at 101.
68. Id. at 101-02.
69. Chemical Substitution for 1,1,1-Trichloroethane and Methanol In An Industrial Cleaning Operation, in POLLUTION PREVENTION CASE STUDIES COMPENDIUM, at 18-19 (EPA-600/R-62/046, 1992) [hereinafter CASE STUDIES COMPENDIUM].
70. Id.
71. Id.
72. Id.
73. "A heater was added to the old ultrasound bath. A deionized water system was purchased along with a stainless steel bath and immersion heater. A heat gun
calculation was made for management and engineering time used to
decide on, evaluate, and implement the change, presumably because
these services were available in-house and did not require a sepa-
rately identifiable expenditure. Performance testing showed that the
new solvent cleaned the parts satisfactorily and even slightly im-
proved the bonding of the coatings.\textsuperscript{74} In this situation, environ-
mental protection also produced economic benefits: the annual
savings of $4,800 paid the $1,793 capital cost within four and a
half months.\textsuperscript{75} While not universal, a quick return on investment
often makes pollution prevention efforts also attractive business
investments.\textsuperscript{76}

2. General Dynamics Pomona Division

A much more substantial investment was required in the pollution
prevention demonstration project at the General Dynamics Pomona
Division ("General Dynamics") in July, 1988.\textsuperscript{77} At General Dyn-
amics, the particular problem was cleaning newly-manufactured
computerized printed circuit boards. Previously, General Dynamics
immersed the circuit boards in rinse tanks, which generated sub-
stantial wastewater from the tanks. Chemcut Corporation then in-
stalled a new plating system, including a timed spray rinse that
reduced wastewater from sixty gallons per minute to ten.\textsuperscript{78} Other
changes in the printing operations not only improved the quality of
the copper plating but also improved the recovery of copper used in
the process, decreasing the amount of waste that required dispos-
al.\textsuperscript{79} As a result, the costs of waste treatment, water usage, and

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\textsuperscript{74} Id. at 19.
\textsuperscript{75} Id. at 21.
\textsuperscript{76} Id.
\textsuperscript{77} \textit{See, e.g., Freon Recovery Stills, in CASE STUDIES COMPENDIUM, supra
note 69, at 14-15 (payback period of slightly more than 6 months on a $270,000
investment). See generally, supra notes 34-37.}
\textsuperscript{78} \textit{Computerized Printed Circuit Board Plating System, in CASE STUDIES
COMPENDIUM, supra note 69, at 4-6.}
\textsuperscript{79} Id. at 5.

\textsuperscript{79} "Copper spheres in anode baskets are also used in the new system instead
of a conventional anode bar and hook system that was utilized in the old plating
system. This allows a 1:1 ratio of anode to cathode for a very even plating across
annual operating expenses all declined. It was calculated that the new system's $4,100,000 cost would be paid back in 8.3 years.\textsuperscript{80}

This example clearly shows both the potential and the demands of pollution prevention and the associated technological change. Much more than just material substitution was required. Rather, the pollution prevention effort required General Dynamics to install new equipment and to implement major operational changes in materials used, manufacturing processes, and material recovery. These substantial changes in the operation required General Dynamics to invest in more research, planning, and resources. They also presented a greater business risk if any or all of them did not perform as planned. However, although the payback time was unfortunately longer, the total pollution prevention payoff was much greater.

3. Zytec Corporation

A third example is the even more ambitious effort undertaken by Zytec Corporation ("Zytec"), also in the context of cleaning its newly manufactured circuit boards.\textsuperscript{81} During the manufacture of these boards, Zytec used a "flux" to improve the soldering process and create better connections. However, after soldering, the excess flux had to be cleaned off the circuit board. The specific environmental problem was that the cleaners in widespread use, and often required by government and other circuit board buyers, contained CFCs that harm the atmospheric ozone layer.\textsuperscript{82} Zytec's problem

\begin{footnotesize}
\begin{itemize}
  \item \textsuperscript{80} Id. at 4, 6.
  \item \textsuperscript{81} BEYOND COMPLIANCE, supra note 1, at 26-28.
\end{itemize}
\end{footnotesize}
was that it needed to produce high quality circuit boards, and then to clean them, without emitting CFCs. Fundamental technological change was needed.

The easiest and most straightforward solution would have been to look for another cleaner, as was done in the examples above. However, Zytec successfully conceptualized the situation more broadly than just as a cleaning problem and devised a more innovative and fundamental solution. It not only developed and implemented a new flux that left less residue to be cleaned, but they were also eventually successful in getting their customers and suppliers to embrace the new approach in contract specifications. The result, good circuit boards with less pollution, was achieved through well-organized widespread commitment to a new approach.

The development of Low Solids Fluxes (LSF) for soldering electrical assemblies required several procedural and organizational modifications. Because of the reduced chemical activity of the solder flux, it became necessary to pay more attention to improved soldering practices. These included greater cleanliness of incoming circuit boards, improved solderability of electronic components, expanded utilization of first-in-first-out (FIFO) inventory control, enhanced storage facility temperature/humidity control, and elimination of potentially harmful packaging materials.

The manufacturing organization was modified by using the talents of Zytec’s Value Analysis (VA) group for technical support of all soldering operations. The visibility of the VA group increased as they became more involved with performing soldering process-optimization experiments, interacting with suppliers and customers, and providing documentation for publication.

Value Analysis allowed central information gathering for dealing with suppliers, customers, and other interested parties. It soon proved necessary also to accumulate supplier data for a host of available solder fluxes, review the information, and propose additional experiments or production trials.

Each customer presented unique requirements for quality, reliability, appearance, and other final product performance parameters. VA correlated customer specifications with available performance data. Finally, the VA group assisted in publicizing Zytec’s efforts by:

83. BEYOND COMPLIANCE, supra note 1, at 27.
— publishing technical papers,
— making presentations at appropriate conferences,
— assisting with media announcements and articles,
— making presentations to customer groups, and
— conducting tours.\textsuperscript{84}

The project was a success and all customers approved the use of the new processes. In addition to meeting the company's "zero use" goal for CFCs, the project lowered costs, improved product quality, and reduced water and electricity usage.\textsuperscript{85}

This example shows even more clearly what pollution prevention can do, and also the depth of technological change and organizational adaptation that may be required to achieve it. The company made basic technological changes in its manufacturing processes, necessitating managerial and operational changes. Customer approval and education was essential and required substantial effort. Several different units of the company eventually became involved, including top management. There were quite substantial business risks if the new process had not worked well and potentially disastrous business consequences if customers had not been willing to accept the change. A great deal was required of the company, but a quite substantial environmental gain resulted.

4. Beyond Zytec — Supplier and Consumer Pollution Prevention

Zytec's involvement with its customers also shows how, in addition to supporting innovation in a business's own operations, pollution prevention efforts can extend to suppliers and customers. S.C. Johnson Wax reports an outreach effort to encourage source reduction and recycling efforts among its suppliers, and initial reactions have been positive.\textsuperscript{86} Dow Chemical reports ongoing efforts to promote responsible use and disposal of its products, with substantial technical assistance to encourage pollution

\textsuperscript{84} Id. at 27-28.
\textsuperscript{85} Id. at 28-29. The project also simplified processes and enabled better use of factory floor space. All information about the project is taken from the company's case history statement. Id. at 26.
\textsuperscript{86} Id. at 170-71.
PREVENTING POLLUTION

prevention among its customers. Smith & Hawken, a small direct-sales retailer of gardening supplies and lawn furniture, eventually had to change suppliers to ensure that the furniture it was selling was made from tropical woods that had been responsibly harvested as part of a sustainable development effort. The 1993 Benchmarking Study of six facilities notes that, in these effective prevention programs, suppliers and customers are also used as a source of prevention ideas.

Efforts to encourage pollution prevention by a company's customers can be particularly effective when the seller's knowledge of the technology related to the product's use is much greater than the buyer's knowledge. For example, consider two electric utilities, Southern California Edison ("SCE") and Pacific Gas and Electric Company ("PG & E"). Both have reported substantial efforts to help their customers use less electricity, and thus help themselves to reduce the pollution that generating this electricity would entail.

The companies' efforts center on developing new technology and applications and then educating customers to encourage their adoption. Rather than encouraging customers to sacrifice by settling for less, new technology is aimed at achieving the same or

87. Id. at 174-76. Bank of America reports that it is developing a commercial credit policy to "weigh the degree of environmental responsibility displayed by potential borrowers and their affiliates as a significant part of our decision on whether or not to grant credit." Id. at 172-73. The policy does not specify pollution prevention as the desired environmental performance. The substantial difficulties in applying such a policy are noted and discussed. Id.

88. CHANGING COURSE, supra note 20, at 285-89. Jacqueline Cramer & Johan Schot, Environmental Comakership Among Firms as a Cornerstone in the Striving for Sustainable Development, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY, supra note 1, at 311, report on the results of two Dutch studies. There is substantial, although ad hoc, information exchange on environmental issues in supplier-customer relations now, and they predict that this will grow and that there will be much more substantial joint efforts aimed at environmental improvement through product requirements and product design and life cycle analysis. Id. at 316.

89. BENCHMARKING STUDY, supra note 28, at 11, 32. Other parts of the business were an even more frequent source of ideas. Id. at 32.

90. BEYOND COMPLIANCE, supra note 1, at 47-52. Both companies have additional pollution prevention efforts as well.
better results for customers than the previous technology did. Efforts are aimed at both businesses and individual consumers. At first blush, it may seem irrational for a company to encourage its customers to buy less from it. However, in each case, utility regulators have set rates and other incentives to make the conservation programs profitable if they are successful. The result should be both less pollution as a result of less electric power generation, and lower costs to customers from the savings (although purchasing the new technology will surely entail increased costs initially).

Extending pollution prevention efforts to suppliers and customers can encourage business to reach further and to consider the environmental impacts of a product's entire life cycle. A product life cycle analysis considers all of a product's environmental impacts, from raw materials extraction or creation, through product manufacturing, distribution and use, and finally into recycling

91. PG & E has reported substantial savings from these efforts:
1991 CEE [Customer Energy Efficiency] activities throughout PG & E resulted in savings of about 607 million kilowatt hours (kwh) of electricity, equal to the annual use of about 100,000 PG & E area households; 37 million therms of natural gas, equal to the annual use of 50,000 PG & E area households, and offset the need for 119 mw [megawatts] of electric generating capacity, enough to serve an area of about 120,000 people. These savings come from all groups of customers and a variety of measures taken in 1991 including lighting efficiency improvements that will save more than 200 million kwh per year; agricultural programs, including, pump repairs and adjustments, modern irrigation pipe and greenhouse heating curtains that will save more than 100 million kwh per year; heating, ventilation and air conditioning that will save more than 70 million kwh per year; high-efficiency refrigerators for home use that will save more than 4.5 million kwh per year, and industrial process improvements such as more efficient motors and better boilers that will save more than 40 million kwh per year.

Id. at 50-51 (quoting PG & E 1991 Annual Report Page).

92. Patricia S. Dillon & Michael S. Baram, Forces Shaping the Development and Use of Product Stewardship in the Private Sector, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY, supra note 1, at 329 (reporting on the results of two American studies with a specific emphasis on technology transfer); BENCHMARKING STUDY, supra note 28, at 11, 32.
or disposal as waste.\textsuperscript{93} Life cycle analysis is inevitably concerned with product design, as well as with process changes. However, this analysis is new and difficult. Furthermore, a single company often does not control the entire life cycle of a particular product. Because different companies often operate at different stages of the cycle, businesses must coordinate their efforts to achieve responsible product stewardship. In addition to these cooperative efforts, an industry-wide program such as the Chemical Manufacturer’s Responsible Care program can set standards and encourage better stewardship.\textsuperscript{94}

\textbf{B. Redesigning Products and Product Life Cycle Analysis}

Product design, or redesign, offers great opportunities for improving environmental technology and preventing pollution. The importance of product design cannot be overstated: the National Research Council estimated that it determines seventy percent of the total cost of a product’s development, manufacture, and use.\textsuperscript{95} While product design has great potential for effective pollution prevention efforts which a company can make, these efforts are also likely to be the most expensive and challenging. For example, customer acceptance, critical to marketplace success, can be dramatically influenced by product redesign, whether the customers are individual consumers or large organizations buying according to predetermined specifications.\textsuperscript{96} Product design also presents a particularly attractive target for pollution prevention and environmental technology policy because it is a constant, ongoing part of normal business activity, irrespective of environmental considerations. The Organization for Economic Co-operation & Development (“OECD”) reports that “if present trends continue, 50 percent of the products that will be used in 15 years’ time do not yet exist.”\textsuperscript{97} Thus, today’s product design decisions

\textsuperscript{93} See infra Part II.B.
\textsuperscript{94} Dillon & Baram, supra note 92, at 335.
\textsuperscript{95} U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, GREEN PRODUCTS BY DESIGN: CHOICES FOR A CLEANER ENVIRONMENT 35 (OTA-E-541, 1992) [hereinafter GREEN PRODUCTS BY DESIGN].
\textsuperscript{96} Id. at 93-97.
\textsuperscript{97} Organisation for Economic Co-Operation & Development (OECD), THE
will have an enormous impact on tomorrow’s environment. Business can make a greater positive impact by incorporating environmental considerations into ongoing product design activities. The ultimate goal of prevention is to design products that require or are compatible with clean technology, in contrast to product design that depends on the existing cleaning technology frequently employed today.\footnote{98}{While pollution control only treats the symptom, design for the environment can eventually treat the cause — the creation of pollution. Ignoring environmental implications of design can have substantial implications for both environmental and monetary costs in both the short and long run.\footnote{99}{Product design traditionally considers a number of variables that must be accounted for in the final design. This is called design for X (“DFX”), in which X may be one of a number of variables, downstream from the design process, that must be considered.\footnote{100}{The goal of pollution prevention is to incorporate environmental protection factors into product design—to add one other factor to the X group. The result is design for the environment (“DFE”). DFE will not be easy to learn because it requires product designers to make new analyses that consider unfamiliar factors. However, in adding one more element to an existing and familiar conceptual methodology, DFE should prove possible to learn and implement over time.\footnote{101}{The EPA has established a DFE promotional program that establishes partnerships with industry to promote environmentally friendly design.\footnote{102}{}}}

\begin{footnotes}
\item [99] Robert C. Pfahl, Jr., \textit{Design for Environment: An R&D Manager’s Perspective}, in \textit{The Greening of Industrial Ecosystems}, supra note 1, at 208 (discussing three cases studies that amplify this point). See Kathleen Dechant & Barbara Altman, \textit{Environmental Leadership: From Compliance to Competitive Advantage}, 8 \textit{Academy of Management Executive} 7 (1994).
\item [100] Allenby, supra note 98, at 139-41.
\item [101] For a clear and practical review of the techniques for implementing design for the environment, see id. at 141-47.
\item [102] \textit{Office of Policy, Planning, and Evaluation}, EPA, \textit{Sustainable}
Environmentally friendly design can be usefully subdivided by recognizing two different, although related, goals: design for waste prevention, and design for better materials management.\textsuperscript{103} The objective of the first goal, design for waste prevention, is to reduce waste over the product’s entire life cycle. Of course, considering the entire life cycle is difficult because a particular product may generate waste at many different points during the cycle.\textsuperscript{104} Thus, the analysis must consider waste resulting from raw materials, product manufacture, distribution, use, and disposal, as well as the associated packaging waste.\textsuperscript{105}

Evaluating these additional factors is both important and complex, as illustrated by designing for product life extension. Longer product lives have the potential for obvious environmental benefits — they reduce the waste needed to produce replacements. However, they may also delay introduction of cleaner products, such as new, more environmentally friendly cars.\textsuperscript{106} Careful analysis of specific situations is essential. Design for energy efficiency is also very important because energy production most often involves some resulting waste.

One of the success stories of waste minimization product redesign is the removal of phosphates from household detergents. In

\begin{footnotes}
103. Green Products by Design, supra note 95, at 37-43.
104. \textit{Id.} at 60-61 (discussing the difficulties of implementing a full life cycle analysis). In addition to problems of tracing all of a product’s upstream and downstream life cycle impacts, there are conceptual problems in weighing the environmental significance of these impacts, and the data requirements can swamp the entire analysis. Despite these problems, a limited life-cycle analysis is a useful environmental product design strategy because it at least asks the right questions and uses the answers available. The answers should become better over time, with further research.

Allenby favors a gradualist approach, designing for only some environmental factors and then gradually expanding the list, because it offers the opportunity to learn by doing. \textit{See} Allenby, supra note 98, at 137.

105. According to Allen Aspengren of 3M, the company must be concerned with the challenging question, “What waste are we creating for our customers?” Changing Course, supra note 20, at 110.

106. This point is made by Rolf Buchheim of VW in discussing the environmental life cycle impacts of cars. \textit{Id.} at 306.
\end{footnotes}
Europe, the efforts of Henkel, the German consumer products and specialty chemicals company, clearly show that gains are possible, but also that substantial efforts are required. While phosphates do improve the performance of cleaning products, they also contribute to substantial water pollution problems. The phosphates are fertilizers, and excessive levels can promote algae growth which can lead to eutrophication of water bodies.

After developing new phosphate-free detergents, Henkel faced the substantial challenge of persuading consumers that these cleansers worked just as well. Despite initial resistance, the company persevered and, for a while, marketed both regular and phosphate-free formulations of its leading detergents. Consumers were eventually persuaded that the phosphate-free formulation was just as good a cleanser and better for the environment. The gradual but widespread movement of consumers toward more environmentally friendly products supported the change, and Henkel was eventually rewarded with an increase in market share as well as positive public relations benefits. This success ultimately moved the entire market in this direction:

Due to overwhelming consumer acceptance of the new Persil [the phosphate-free formulation], all Henkel's major competitors launched phosphate-free detergents within a few months.... Nonphosphate powder detergents now have a 100-percent market share in Austria, Germany, Italy, the Netherlands, Norway, and Switzerland. The same situation applies in Japan, while in the United States, Congress has proposed legislation that would require all detergents sold there to be phosphate-free by 1996.

107. Id. at 297-301.
108. Id. at 297.
109. Id. at 299-300. "Earlier versions of clean lakes legislation provided for a phase out of phosphates in household laundry detergents. In the past several years, there have been dramatic declines in the volume of phosphates in household laundry detergents and recent actions by major manufacturers will reduce phosphate use even more." Id.

Congress recognized this movement in 1994. "In response to this new evidence, the [Water Pollution Prevention and Control Act of 1994] does not require a phase out of phosphate in household laundry detergents, but does direct EPA to evaluate alternatives to phosphates in nonlaundry and industrial detergent products and make recommendations to Congress concerning appropriate actions." Water Pollution Control Act of 1994, S. REP. NO. 257 (to accompany S. 2093)
This success, however, did not come without effort. Product redesign requires fundamental changes in the business and its relationships with customers. Research to develop the new products took over a decade and over 200 people were involved at the height of the project. Finally, success came slowly: consumer testing began in 1976, and the eventual market triumph did not occur until 1991.\textsuperscript{110}

Life-cycle analysis in the design stage leads to a broader, longer term view, with the potential to realize pollution prevention opportunities over the entire production-consumption-disposal cycle. The analysis considers the product’s resource requirements and other environmental implications. Proctor & Gamble, the American consumer products multinational, has developed and applied a partial life-cycle analysis in reducing the ultimate packaging waste from several of its products.\textsuperscript{111} For example, a study it commissioned on the packaging of its Downy fabric conditioner (marketed as Lenor in Europe) considered seven different packaging systems. Surprisingly, the study concluded that recycling and reuse of the current polyethylene plastic bottles offered only minimal environmental benefits because of the increased wastewater that resulted from washing the bottles.\textsuperscript{112} The study found that packaging the product in paperboard cartons and soft pouches, and selling it in a concentrated triple strength formulation promoted for its environmental friendliness could achieve a ninety-five percent waste reduction.\textsuperscript{113} While the concentrated version had been available in the United States years before, it had not been successful. With consumer education and increased environmental awareness, its renewed attempt to market the concentrated detergent fared much better. “In less than a year, the [triple strength paperboard] refill had taken nearly 40 percent

\textsuperscript{110} CHANGING COURSE, supra note 20, at 298-300.
\textsuperscript{111} Id. at 290-94.
\textsuperscript{112} Also, effective recycling required consumer commitment, existence of efficient local recycling programs, and the existence of viable end-use markets. However, as recycling is increasingly pursued in the United States and elsewhere, these conditions will present less of an obstacle. Id.
\textsuperscript{113} Id.
of Downy sales in the United States. The response to concentrated products in Europe [in soft pouches] has been equally strong.\textsuperscript{114}

By carefully considering waste reduction in product and packaging design and selection decisions, real environmental gains are possible. However, substantial investments of time and resources are typically needed. Because environmental gains can only be realized from greener products that consumers or other users actually buy, customer acceptance is crucial. Of course, increasingly green consumers may well provide at least some of their own momentum toward greener products.

The design examples considered thus far have all been concerned with waste management issues, rather than with design for materials management. A product’s intrinsic characteristics often determine whether waste management or materials management is the most important environmental design concern. Design for better waste management is particularly important for products which are “low design/high-material items, such as packaging, consumer personal care items (e.g., soaps and shampoos), and bulk chemicals . . . ”\textsuperscript{115} With these types of products, materials (except for their packaging) tend to be depleted during consumption rather than discarded.

In contrast, the design of products that incorporate many different materials creates a greater environmental concern.

Associated upstream and downstream product and manufacturing process implications of changes to such a product or its associated manufacturing systems make the analysis far more complex than

\textsuperscript{114} Id. at 293-94. The Swiss grocery and retail chain, Migros, has also had success in implementing a partial life-cycle analysis. The system assigns negative “eco-points” for each negative environmental impact, and product and packaging decisions are then based on the best score in “eco-points.” For example, conventional tin coffee containers earn 98 negative eco-points while the alternative aluminum coated paper container earned only 12, making the choice for the aluminum system a simple one. Product managers are also given a target of eco-points they are not to exceed in product selection decisions, thereby sending a clear message of the company’s values and priorities throughout the management hierarchy. Id. at 294-96.

\textsuperscript{115} See Allenby, supra note 98, at 138 (explaining this distinction in more detail).
in the case of low-design/high-material items. Moreover, the supplier/customer networks for high-design/low-material products tend to be far more complex than those for low-design/high-material products.\(^{116}\)

Automobiles, electronic and communications equipment, and airplanes are all examples of "high-design/low-material products."\(^{117}\)

The prime prevention issue with complex products is thus design for materials management, which is the second group of design related environmental impacts. Once again, the product’s entire life cycle should be considered to the extent this is possible. Environmental issues, however, direct attention to a different group of design questions concerning materials management issues:

Examples of design for better materials management include making products that can be remanufactured, recycled, composted, or safely incinerated with energy recovery. Broadly speaking, these management options are listed in order of preference, both from a business perspective and an environmental perspective. One model of plastics management, for instance, envisions a life cycle in which virgin plastic components are reused as long as possible, then the materials are repeatedly recycled through lower and lower value-added applications until the plastic is finally incinerated to recover the chemical energy.\(^{118}\)

Environmentally sensitive product design for complex products starts by focusing on the product and its environmental attributes, "within the constraints of the existing production/consumption network."\(^{119}\)

Although product design begins with a product-centered approach, the eventual goal is to create a systems-oriented approach by extending the frame of reference to the whole production/consumption network.

The first option [product focus] is easiest, since it can be accomplished within the context of an individual firm. The second

\(^{116}\) Id. at 139.

\(^{117}\) Id. at 138.

\(^{118}\) GREEN PRODUCTS BY DESIGN, supra note 95, at 40. This model of plastics management was proposed by GE Plastics, Pittsfield, Mass. Id. at 40, n.20.

\(^{119}\) Id. at 53.
[systems focus] is more ambitious, because it implies a new way of looking at products, and may require new patterns of industrial organization, such as the formation of cooperative relationships among suppliers, manufacturers, and waste management providers.  

1. AT & T

AT&T's ongoing efforts to design and make a greener telephone illustrate the potential, and the problems, of design for the environment with a complex, high-design/low-materials product.  

First, the project had to define what was environmentally preferable for stages of design, manufacture, use, and disposal. Green design required the consideration of a number of factors, including: using materials that were reusable or recyclable, identifying materials (especially plastics) to ease recycling, employing alternative methods of holding the product together that would ease disassembly, as well as utilizing adhesives, pigments, and flame retardants.  

Manufacturing not only generates inherent waste streams and materials reuse questions, but it also presents environmental questions related to the packaging of components assembled into the telephone. Use of the telephone did not present many critical environmental issues: its use consumes minimal amounts of energy, and in many situations may well substitute for more energy intensive transportation. However, the telephone's end-of-life phase presented many environmental questions, and much work on them continues. Materials recycling is one very important and complex issue. In addition, AT&T has the infrastructure for reconditioning whole telephones for reuse, a legacy of its days as a regulated monopoly supplier that leased rather than sold telephones.  

Ultimately the project must also evaluate the environmental merits of leased rather than purchased telephones, although the company's policy "must be economical to

120. Id.
122. For a complete list of the factors considered by green design, see id. at 174.
123. Id.
support the reality of being in an unregulated, highly competitive business." The product’s complexity makes “greening the telephone” a difficult design process, but one in which progress is being made.

2. Volkswagen

Volkswagen’s efforts at recycling more of the parts of its scrapped cars offer a second instructive example. Seventy-five percent of the weight of a car is steel, most of which is already recycled. Yet, prompted by both its environmental values and the threat of stricter regulation, Volkswagen has initiated a program to reach most or all of the remaining twenty-five percent. Plastics present the greatest challenge, and one that will only increase as they find greater use in new cars. In 1990, Volkswagen began operating a pilot recycling plant in Leer, Germany, to learn more about the processes and problems:

At Leer, each car goes through a careful dismantling process, separating the various waste streams. First, all oils and other liquids are drained off; the company quickly realized that items such as closed gear boxes hampered this process. Batteries are removed so that the metals, plastics, and acid can be recovered. Plastic parts are removed, reground, and then transported to suppliers. Catalytic converters, which contain valuable precious metals, are also separated and processed. Finally, after the glass and rubber have been extracted, the remainder is shredded for use in the steel industry. . . .

VW’s experience at Leer has shown that no longer is the cost of production the sole consideration in design and materials choices; “the costs of reuse must also be included” says Buchheim [VW’s manager of research and development]. This means reassessing existing designs and materials. Some broad lessons have already been learned. Simplification is a great aid to recycling. All major plastic parts are now marked for easy recognition during disassembly; clips are favored instead of screws, and the number of different components and materials used for a particular module of the car is minimized where possible. There have already been some design improvements; for example, the fuel tank of the old Golf

124. Id. at 176.
125. CHANGING COURSE, supra note 20, at 305-308.
model had 32 different parts, made from several different types of plastics. The fuel tank for the new Golf model contains only 16 parts in an integrated design. Disassembly time has been cut from seven to three minutes. Even small parts like engine bearings have been redesigned to facilitate recycling.

In addition to better design, VW hopes to improve its recycling rate through choosing materials that can operate within a closed-loop system. Materials recyclability is now included as one of the design goals for each new model at VW, and "as a matter of principle, new materials are only given the go-ahead for full scale production if they are integrated in a self-contained recycling concept."126

A number of other automobile companies and their suppliers have recycling efforts underway.127 The efforts are quite varied, although all seek ways to avoid the waste from the disposal of cars, and most companies have implemented pilot projects to gain firsthand knowledge. These efforts rely on extensive networking with suppliers and others, as well as developing and implementing of existing technologies. One radical technological alternative is Mercedes-Benz' experiment with a "melt reactor" process to extract raw materials from the automobile hulk without shredding.128 While much is yet to be learned, three central factors account for the companies' differences in strategies. First, the companies' different market positions create different economies of scale and scope for the collection, processing, or recycling options in particular situations. Second, the differences in strategies of rebuilding some parts for resale reflect different market values of the rebuilt parts from different manufacturers. Third, the companies are subject to the varied demands of different national

126. Id. at 307-08. See also Richard L. Klimisch, Designing the Modern Automobile for Recycling, in THE GREENING OF INDUSTRIAL ECOSYSTEMS, supra note 1, at 165 (discussing the recycling of cars). Klimisch notes that the tradeoffs in environmental consequences of alternative designs are hard to measure. Id. at 169. The piece does not discuss the possibility of redesigning the process to make plastics separation easier, indicating that burning them for their energy value may be a superior solution.

127. See generally, Frank den Hond & Peter Groenewegen, Solving the Automobile Shredder Waste Problem: Cooperation Among Firms in the Automotive Industry, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY, supra note 1, at 343.

128. Id. at 353.
governments, which creates diverse pressures for more environmentally friendly design.\textsuperscript{129}

There is a substantial and growing body of evidence that opportunities for pollution prevention abound.\textsuperscript{130} Of course, most of the evidence is either individual or collections of case studies, rather than broadly gauged studies that measure across the whole economy. In addition, much of the information originates from the companies, who are less likely to publish business literature about any unsuccessful efforts.

Despite these qualifications, the available information indicates that real opportunities are widespread. The success stories involve two critical components. First, pollution prevention requires a creative effort — the innovative spark — to find new ways of doing things. Because innovation is so essential, pollution prevention efforts are varied and diverse, as are the motives for undertaking them. Any serious pollution prevention policy must embrace and build on this diversity. Second, pollution prevention also requires the company to invest time and resources to bring this creative spark to full flame. Innovation alone is not enough; there must also be an organizational commitment to pollution prevention and an organizational structure capable of supporting it.

III. COMPANY PROGRAMS AND POLICIES TO SUPPORT PREVENTION

A. Successful Programs and Corporate Culture

Pollution prevention, and adopting the requisite new environmental technology, requires changing the behavior of people within business organizations, and this necessarily depends on the organization’s programs, structure, values, and innovative and creative insights. First, the organization must foster an atmosphere that is conducive to creative thinking. Second, the organization must support innovative ideas and develop, evaluate, and hopefully implement them with human, financial, and technologi-

\textsuperscript{129} Id. at 362.
\textsuperscript{130} See supra notes 1, 20, for a survey of sources discussing pollution prevention case studies.
cal resources. As leading companies increasingly see the value of pollution prevention and environmental technology efforts, their supporting policies are becoming formal, organized, and highly developed.\textsuperscript{131} The following two examples illustrate the most ambitious and developed of these efforts, and this section will discuss the general lessons that have been learned.

3-M is well-known for its pollution prevention and environmental technology efforts and it is often cited as a paradigm example. It's 3P program — Pollution Prevention Pays — dates from 1975 and was certainly one of the first such efforts.\textsuperscript{132} The program is based on the premise that pollution is a wasteful, inefficient use of resources, so that preventing it is good business. The program is a voluntary effort to motivate employees to find, promote, and implement ways to eliminate pollution before it is created. Any employee or group of employees can identify a need and develop a project. To be recognized as an approved 3P project, the proposal must meet four criteria. It must (1) reduce pollution through product or process change, or other prevention means, (2) reduce energy or raw materials usage, or improve natural resource use, (3) involve a technical innovation, and (4) offer monetary benefit through reduced costs, including environmental compliance costs, or increased sales.\textsuperscript{133}

\begin{itemize}
\item \textsuperscript{131} Dechant & Altman, \textit{supra} note 99, at 9.
\item \textsuperscript{133} The case history quotes 3M policy concerning the qualifications of a proposal for a 3P project:
\begin{itemize}
\item It must, through process change, product reformulation, or other preventive means, eliminate or reduce a pollutant that currently is a problem or has the potential to become a problem in the future.
\item It should exhibit, in addition to reduced pollution, environmental benefit through reduction in energy consumption, more efficient use of raw materials, or improvement in the use of other natural resources.
\item It should involve a technical accomplishment, innovative approach, or unique design.
\item It must have some monetary benefit for 3M. This may be through
\end{itemize}
\end{itemize}
The vice president of the Environmental Engineering and Pollution Control ("EEPC") staff group is responsible for 3P. The members of this group assist individual operating units. Approval and funding of specific projects is usually within individual operating units. In 1992 3M reported that, since 1975, more than 3,000 approved projects have prevented more than 575,000 tons of pollution and saved the company more than $530 million.134 In accordance with company policy, 3M does not profit from air emission credits earned by its programs, these credits are generally returned to environmental agencies.

Building on this record of solid success, 3M expanded the 3P+ program in 1989. The goals of this effort are, by the year 2000, to make a ninety percent reduction in all non-hazardous releases and to reduce all waste by fifty percent. "Beyond the year 2000, 3M's goal is to come as close to zero emissions as is technically possible."135 This new program combines the efforts of a central pollution prevention staff in the EEPC Department with those of new waste minimization teams within every operating division to identify source reduction and recycling opportunities.136 This summary is taken from the company case history, and thus it reflects enthusiasm for promotion of the program's successes. However, even with this qualification, the record of real achievement is clear and commendable.

Dow Corporation's Waste Reduction Always Pays ("WRAP") program is another success story, although a more recent one.137 Begun in 1986, the program aims to control costs and improve public image by preventing the production of wastes rather than treating them at the end of the pipe. The program is overseen by a senior management committee, with a WRAP coordinator in

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134. Id. at 14.
135. Id. at 15. Challenge '95 is a new corporate productivity program that sets interim goals for reduced waste generation and energy use by 1995. These goals will be in addition to the 50% energy use reduction accomplished since 1975. Id.
136. Id. at 15-16.
137. See CHANGING COURSE, supra note 20, at 265-70.
each of Dow's five operating divisions in the United States. Every plant develops an index of pounds of waste per unit of production, and these are regularly reviewed and evaluated. Employee participation provides the creative spark:

employees are encouraged to seek out waste reduction projects and are appropriately rewarded for their efforts through personal recognition from peers and management. . . . A major goal of the WRAP program is to broaden the thinking of employees so that they look beyond individual plant boundaries and understand the total environmental impact of their chemical processes. They must never assume that some other part of the organization will handle their waste streams.138

The program's accomplishments are impressive. Reductions in materials lost, transportation and disposal costs, and emissions have been achieved. By 1992, air emissions in the United States had been cut in half since 1985 and less than one percent of Dow's hazardous waste went to a landfill.139 Dow has also been a primary participant in voluntary government efforts to reduce emissions of toxins, particularly the 33/50 program.140 Dow's WRAP program is generally judged a success, both for its specific pollution prevention accomplishments, and its support of changing employee's attitudes about pollution prevention.

Some general conclusions are possible from these and other company programs.141 First, the chief executive officer must show clear and demonstrable support of the project with a clear expression of commitment to a corporate environmental policy. In Chevron's case, for example, this took the form of Chevron Chairman George Keller's 1987 speech that called for corporate

138. Id. at 267.
139. Evaluation figures are presumably supplied by the company, as no independent sources are cited. See id. at 266-67. See also BEYOND COMPLIANCE, supra note 1, at 17 (discussing the program favorably).
140. CHANGING COURSE, supra note 20, at 268.
141. See BEYOND COMPLIANCE, supra note 1, at 104 (offering several more useful case studies). See also Dechant & Altman, supra note 99, at 9-15 (surveying a number of successful programs and presenting a general analysis of the important characteristics); Dillon, supra note 37, at 203-05 (presenting an excellent discussion of the important organizational requirements for a successful prevention program).
environmental policy to move beyond compliance, in which he said:

Today, we are in a very real sense a society of environmentalists. We all want clean water and pure air and wilderness and wildlife. . . . At Chevron, we’re very proud of a corporate environmental policy that says we comply fully with the letter and spirit of all laws affecting our operation. But as long as our environmental philosophy is framed by the concept of compliance, we won’t get much credit for our positive actions. Compliance means that the moral initiative lies elsewhere — outside of industry.\(^\text{142}\)

Senior company management sets the tone and establishes the real goals of a business organization for all the successful programs. Further, the commitment of senior company management is essential to a meaningful pollution prevention policy.\(^\text{143}\)

Second, successful programs must be structured to establish the importance of pollution prevention at the corporate level, and to preserve initiative at the plant level. To emphasize its importance, prevention must become the day-to-day responsibility of a high level, respected company management official. Many of the officials chosen to head the effort are top level company vice presidents with long company service; typically, they report directly to the chief executive officer.\(^\text{144}\) Using such high-level personnel sends the entire organization a clear message about the importance of prevention. However, the management role, while crucial, must not become too intrusive. A 1993 study of six suc-

\(^{142}\) BEYOND COMPLIANCE, supra note 1, at 102. See also id. at 98 (similar “Monsanto Pledge” announced by Chairman and CEO Richard Mahoney on Jan. 30, 1990).

\(^{143}\) Dillon, supra note 37, at 201. See also Dechant & Altman, supra note 99, at 9-10 (discussing the importance of a mission statement that clearly articulates corporate environmental values); BENCHMARKING STUDY, supra note 28, at 2, 12 (noting the importance of support for the program at the corporate level).

Thomas N. Gladwin, The Meaning of Greening: A Plea for Organizational Theory, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY, supra note 1, at 37, 52-54, discusses environmental problems as an opportunity for “transformative leadership” by corporate management, revising the organization’s paradigm view of environmental compliance and optimal performance.

\(^{144}\) For example, Nicholas L. Reding is Executive Vice President for Environment, Safety, Health and Manufacturing of Monsanto. BEYOND COMPLIANCE, supra note 1, at 140. See generally, id. at 97-120.
cessful facility level programs concludes that the most effective management roles were to establish goals, to support pollution prevention technology development and facilitate its transfer across the company, and to forecast upcoming compliance issues. Finding the right balance to preserve local flexibility and initiative was equally important: "Facilities were successful when they were not told how to approach pollution prevention. The freedom to choose the best method to reach pollution prevention goals was key to their success."

Within each facility, leadership and support are equally important. The 1992 study of source reduction programs in twenty-three chemical industry plants found that, where a management level employee had responsibility for the program, the number of projects more than doubled, and this increase was statistically significant. Successful programs demonstrated management commitment, both in giving employees the time and resources to do the job, as well as by direct participation by management in the program itself.

In addition to management support, successful programs typically use teams that cut across company functional lines and departments. Conceiving, developing, and implementing prevention programs will require considering a diverse array of questions including environmental regulatory, legal, technical, engineering, financing, and marketing issues. Cross-functional teams or some other integrating mechanism, geared to the company’s specific business, market, and internal operating culture, will be essential. Interestingly, despite this need for diverse expertise,

145. BENCHMARKING STUDY, supra note 28, at 3.
146. Id. at 6.
147. DORFMAN ET AL., supra note 63, at 31-32. The management officials were either the plant’s manager or its environmental officer. Similarly, the 1993 study found that, at four of the six successful programs studied, either the plant manager or the environmental management staff was held accountable for pollution prevention. BENCHMARKING STUDY, supra note 28, at 27.
148. BENCHMARKING STUDY, supra note 28, at 20.
149. Id. at 23; Dillon, supra note 37, at 201. See also Dechant & Altman, supra note 99, at 10-12 (discussing the need for such a framework and surveying several examples of programs); Friedlander, supra note 37, at 180 (arguing that prevention must ultimately be incorporated into engineering design to be effec-
the 1993 Benchmarking Study found that none of the six successful programs studied used outside consultants for the program or specific projects.\textsuperscript{150} While each firm had the necessary expertise for pollution prevention, end-of-the-pipe compliance efforts often required the use of outside consultants to supplement the firm's expertise.

The 1992 Inform study of twenty-nine chemical plants offers some substantial evidence that a structured program at the plant level enhances the prospects for success.\textsuperscript{151} This study evaluated the source reduction program at each of the plants based on eight different criteria.\textsuperscript{152} While none of the programs included all eight elements, the fourteen plants that adopted half or more of them had, on average, two and a half times as many source reduction projects as those that did not.\textsuperscript{153} Thus, the more structured plant level programs had greater source reduction success.

The organizational structures employed vary from Monsanto's new Environmental Policy Committee to Chevron's less formal study teams.\textsuperscript{154} However, regardless of the details, an ongoing, structured program is required. Unlike the programs discussed above, the more typical pollution prevention effort is ad hoc and episodic.\textsuperscript{155} Section II above reviewed the variety of prevention efforts, from straightforward housekeeping, through process changes, up to product redesign. As specific prevention projects become increasingly ambitious, they will require the long-term, continuing support of an organizational structure and commitment of resources to be effective.

The third characteristic of successful programs is that they enlist the support and initiative of widespread rank and file em-

\textsuperscript{150} \textit{Benchmarking Study}, supra note 28, at 12.
\textsuperscript{151} \textit{Dorfman et al.}, supra note 63, at 30.
\textsuperscript{152} The factors were (1) a written source reduction policy, (2) materials accounting, (3) materials balance, (4) cost accounting, (5) leadership, (6) employee involvement, (7) environmental goals, (8) environmental program. \textit{See id.} at 29.
\textsuperscript{153} \textit{See id.} at 28.
\textsuperscript{154} \textit{Beyond Compliance}, supra note 1, at 100, 102.
\textsuperscript{155} \textit{See Dillon, supra} note 37. The tendency of firms to focus on ad hoc, end-of-the-pipe control technology is discussed \textit{supra}, Part II.A.
ployees and provide rewards for outstanding contributors.\textsuperscript{156} The same 1992 study of source reduction programs at twenty-nine chemical industry plants found that the number of projects more than doubled with employee involvement, a statistically significant increase.\textsuperscript{157} Many specific pollution prevention ideas must come from rank and file employees, whose cooperation and support is required for a successful implementation. Ideas and support will be forthcoming only if they are encouraged, recognized and rewarded within the organization. Pollution prevention has not been a traditional value and way of doing things for most plants. To change these internal values and procedures requires recruiting employees throughout the organization and involving them in the program. Fortunately, these may prove easy since many employees are also concerned about the environment.

Fourth, successful programs relate pollution prevention to other values traditionally stressed by the corporation. For example, Xerox related its prevention effort to its traditional preoccupation with quality to establish the importance of environmental protection.\textsuperscript{158} Further, all the programs stress the relationship of pollution prevention to long term competitiveness and profitability. Pollution prevention means less waste, more production, and often innovative solutions to other problems at the same time. The 1993 Benchmarking Study concluded that prevention programs were only sustainable if most of the projects undertaken pursuant to them were cost effective.\textsuperscript{159} 3M's theory is that all manufacturing operations should be rethought and redesigned regularly to enhance competitiveness.\textsuperscript{160} The employee innovation that pollution prevention programs demand and support will

\begin{footnotesize}
\begin{enumerate}
\item \textsuperscript{156} \textit{BEYOND COMPLIANCE}, supra note 1, at 101, 105; \textit{BENCHMARKING STUDY}, supra note 28, at 9.
\item \textsuperscript{157} \textit{DORFMAN ET AL.}, supra note 63, at 31.
\item \textsuperscript{158} Chevron's program was related to its traditional emphasis on protecting health and safety. \textit{BEYOND COMPLIANCE}, supra note 1, at 101-04. See Dillon, supra note 37, at 205; Dechant & Altman, supra note 99, at 10-12; \textit{BENCHMARKING STUDY}, supra note 28, at 26.
\item \textsuperscript{159} See \textit{BENCHMARKING STUDY}, supra note 28, at 24. Four of the six programs studied required prevention projects to compete against other capital improvement projects on the basis of return on investment. \textit{Id.}
\item \textsuperscript{160} \textit{Id.}
\end{enumerate}
\end{footnotesize}
also enhance such a productivity effort.

Finally, the most successful prevention programs look beyond the boundaries of the company's own operations to consider relationships with suppliers, customers, and other potential partners. Considering the environmental performance of suppliers and customers to evaluate their prevention efforts is a good start. Beyond this, partnerships with them can lead to joint efforts to exchange information or technology that improve performance, using each party's product, process, and environmental knowledge. With complex products, such as cars, improved prevention and recycling efforts will mandate cooperative efforts among suppliers and manufacturers. Of course, looking beyond the boundaries of the organization will present an additional set of challenges, and likely require some additional personnel and skills for particular projects.

Taken together, these factors show that nothing less than a change in an organization's culture is needed to establish successful pollution prevention and environmental technology programs. On environmental issues, most corporations have evolved a "compliance-deterrence" culture, reflecting business' mindset that merely reacts to the commands of the regulatory system. However, such a culture will direct the thinking of all its

161. See id. at 32; supra notes 83-94 and accompanying text.

162. See Dillon & Baram, supra note 92, at 338-40 (discussing the possibilities for such efforts to achieve technology transfer over the product life cycle, based on two American studies); Cramer & Schot, supra note 88, at 319 (discussing information exchange in supplier-customer relationships, based on two Dutch studies).

163. den Hond & Groenewegen, supra note 127, at 343; Klimisch, supra note 126, at 167.


The 1993 study also noted the opposite effect; successful programs allow for and adapt to the organization's culture. BENCHMARKING STUDY, supra note 28, at 10.

165. See Strasser, supra note 9, (manuscript at 267) for a survey of the litera-
participants toward compliance with existing control requirements, usually focusing on familiar technology. In so occupying the minds of the relevant business (and regulatory) actors, the creative, innovative processes required for pollution prevention and embracing technological change are overlooked.\textsuperscript{166}

Pollution prevention efforts within business organizations today are more limited by organizational culture than by available technology.\textsuperscript{167} The processes frequently required for adopting existing technology, and perhaps even developing new technology, can only be supported by a different organizational culture. Changing the organization’s culture involves a multilevel process of articulating values and commands, changing structure and personnel, and rewarding the desired behavior. Most importantly, this type of change takes time and sustained effort throughout the organization. While there are many barriers to this innovative effort, management attitudes and information, and the resulting conceptual barriers, are clearly among the most critical ones.\textsuperscript{168}

One careful study of two prevention programs at different facilities within the same company, presented as thinly disguised hypothetical situations, showed the crucial role played by internal organizational culture and program design at each facility.\textsuperscript{169} The programs were each aimed at reducing the amount of waste on the compliance-deterrence culture.

\textsuperscript{166} Id. (manuscript at 235). Similar changes will also be needed in the organizational culture of regulatory organizations. See id.

\textsuperscript{167} "In most cases, technology probably will not be the limiting factor, a lesson learned in recent years as companies have adopted pollution prevention practices. Rather, cultural and organizational changes within industry (as well as changes in the behavior of consumers and government agencies) will most likely present greater obstacles." Dillon, supra note 37, at 202.

\textsuperscript{168} Ashford, supra note 1, at 292-96, emphasizes the importance of management attitudes in implementing pollution prevention (offering a comprehensive list of barriers to prevention). Dieleman & de Hoo, supra note 39, at 258-65, discuss the barriers to prevention that the Dutch PRISMA project encountered, emphasizing the conceptual barriers as key. Dechant & Altman, supra note 99, at 15-18, discuss the importance of managing change and directing human resources to achieve prevention results.

\textsuperscript{169} Peter B. Cebon, The Myth of Best Practices: The Context Dependence of Two High-Performing Waste Reduction Programs, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY, supra note 1, at 167, 168.
that required disposal. The more successful program was structured around a competition among junior engineers to conceive, design, and implement prevention projects.\textsuperscript{170} The engineers were enthusiastic about the program because it would lead to internal recognition and career advancement, even though no special monetary compensation was awarded.\textsuperscript{171} Their supervisors also supported the program, as good training for the engineers and as a source of additional capital for the operation, as well as for the general recognition afforded those associated with successful projects.\textsuperscript{172}

The second program, while successful to some degree, was not judged to be as successful as the first.\textsuperscript{173} It focused on machine operators, rather than engineers, as a result of top management's current concerns with employee empowerment.\textsuperscript{174} As a result, the program tended to generate much smaller, less ambitious projects.\textsuperscript{175} Furthermore, its structure caused it to be seen as a competitor for scarce capital, rather than a source of additional capital, thus making it less popular with plant management.\textsuperscript{176} The organizational context and program design made it impossible to replicate the successful first program in the second program, emphasizing the importance of these organizational dynamics in general.

The core lesson was that program success depends on the particular organizational context. Some other general lessons also emerged:

The data presented here suggest that there are a number of very important principles that managers must keep in mind when designing programs. . . . For example, participants need something to motivate them to participate. However, we cannot say, a priori, whether that should be a financial reward, a pat on the back, a veiled promise of promotion, an appeal to the health and welfare

\begin{itemize}
\item \textsuperscript{170} Id.
\item \textsuperscript{171} Id.
\item \textsuperscript{172} Id. at 175, 184-87.
\item \textsuperscript{173} Id. at 171.
\item \textsuperscript{174} Id. at 181-84. The second program was implemented several years later than the first. Id. at 175-77.
\item \textsuperscript{175} Id. at 171-72.
\item \textsuperscript{176} Id.
\end{itemize}
of the community, exhortations from top management, or an opportunity for a diversion from routine work.

Another important principle is that a program cannot violate the territory of the people who supervise the participants. Furthermore, a good program offers something that will make these people want to actively support it. It will also offer something to people from other functional groups.177

While this study focuses on the characteristics that lead to success in these two specific programs, in doing so it clarifies the requirements for a program that will generate successful individual projects. Prevention must be imbedded in the values, the structure, and the incentive and reward system of the organization, for parties to make the efforts that it entails.178

**B. Accounting Systems and Pollution Prevention**

Accounting systems are one aspect of corporate culture that have quite substantial implications for pollution prevention and implementing environmental technology. On the surface, accounting systems inspire images of numbing detail and mundane reality that seem to be in sharp contrast to the conceptual expansiveness of the corporate culture discussed above. However, accounting systems are a very important part of the business organizations' culture because they provide crucial information flow and are a part of the organization's language.179

However, traditional accounting systems are one reason that the traditional business culture has not been favorably disposed to pollution prevention and environmental technology. Such technology requires investments in specific projects, as well as in the

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177. *Id.* at 193-94.

178. Different parts of the organization's culture provide support for invention, innovation and diffusion. Prevention often involves diffusion of known technology and this part of the process should be the focus of much business and policy activity. See *Improving Technology Diffusion*, *supra* note 46, at 85-86.

organizational program that supports them, as discussed in Part III.A. In a business context, however, companies make investments only if they expect a resulting profit. Typically this requires that the project or program demonstrate that it generates a better return than other competing alternatives. In exceptional cases, some of the expected return may be in the form of less immediate and precise benefits, such as improved environmental performance, even if these cannot be measured with precision. Whether an investment in pollution prevention and environmental technology is projected to lead to a positive return largely depends on how the company does the accounting for savings of traditional pollution control costs. Unfortunately, in many organizations today, accounting systems do not account for environmental costs well, often failing to identify them or to allocate them to the cost creating activity.

The goal of accounting systems is to identify costs and allocate them to the activity that causes them to be incurred. However, this allocation process is itself often complicated and, as a result, costly. Consequently, imperfect compromises frequently occur. Furthermore, most accounting systems were created primarily for financial management and reporting; traditionally, they have not been very concerned with accurately reflecting environmental costs. Historically, environmental costs charged to the busi-

181. Costs, as used here are only the internalized expenditures paid by firms, in keeping with the focus of this Article. While there may well be environmental impacts that impose social costs not internalized by the firm, it is unlikely that a firm will respond to these general social costs until forced to internalize and pay them. For a general discussion of broader environmental social costs that a general analysis would consider, see THE ECONOMICS OF PROJECT APPRAISAL AND THE ENVIRONMENT (John Weis ed., 1994).
182. See FACILITY POLLUTION PREVENTION GUIDE, supra note 180, at 33.
183. Daryl Ditz et al., Environmental Accounting: An Overview, in GREEN LEDGERS: CASE STUDIES IN CORPORATE ENVIRONMENTAL ACCOUNTING 1, 9 (Daryl Ditz et al. eds., 1995) [hereinafter GREEN LEDGERS]. Two similar studies by the Tellus Institute develop these themes and propose specific policy responses. OFFICE OF POLLUTION PREVENTION AND TOXICS, EPA, TOTAL COST ASSESSMENT: ACCELERATING INDUSTRIAL POLLUTION PREVENTION THROUGH INNOVATIVE PROJECT FINANCIAL ANALYSIS (EPA 741/R-
ness have not been large, so they have received even less attention. Thus, conventional accounting systems often overlooked environmental costs all together, particularly in specific project appraisal, or treated them as overhead to be allocated arbitrarily.\textsuperscript{184} As a result, the cost saving benefits of specific pollution prevention and environmental technology projects often receive little consideration in accounting systems. These effects are particularly pronounced when the environmental costs and benefits arise after the product leaves the shop floor, which is often the case.\textsuperscript{185}

Many environmental costs are simply never identified as such.

Consider a firm that uses a particular chemical in production. The accounting system already tracks the purchase of the material. But the costs associated with its use do not stop there. The costs of storing the chemical may be higher due to environmental considerations. The company may incur larger costs for treating contaminated rinse water or managing the resulting sludge. Securing the necessary permits, monitoring compliance, and subsequent reporting also represent real costs. Depending on the nature of the facility, use of this material might also force the company to pay for additional worker training.

The point is that decisions as common as choosing a process chemical can give rise to various environmental costs that can be difficult to recognize or quantify. A product designer, purchasing agent, or product manager might well select one chemical that appears less costly than another, but that entails higher overall costs for the firm. The situation is considerably more complicated for larger firms that manage hundreds of materials at multiple facilities. Most firms have only a rough idea of how much a specific product or process contributes to facility-wide environmental costs.\textsuperscript{186}

\textsuperscript{92/002, 1992} [hereinafter TOTAL COST ASSESSMENT]; \textsc{Allen L. White et al.}, \textsc{New Jersey Department of Environmental Protection, Alternative Approaches to the Financial Evaluation of Industrial Pollution Prevention Investments} (1991) [hereinafter ALTERNATIVE APPROACHES]. For an introduction, see \textsc{Martin A. Spitzer, Calculating the Benefits of Pollution Prevention, in Pollution Engineering}, Sept. 1, 1992, at 33.

\textsuperscript{184} \textsc{Ditz et al., supra note 183, at 9.}
\textsuperscript{185} \textsc{Rebecca Todd, Zero-Loss Environmental Accounting Systems, in The Greening of Industrial Ecosystems, supra note 1, at 191.}
\textsuperscript{186} \textsc{Ditz et al., supra note 183, at 10.}
A recent case study of the Yorktown refinery came to some unexpected conclusions on their costs. First, the unrecognized costs were, proportionately, much larger than expected. For example, among all costs attributed to environmental issues, the maintenance costs exceeded wastewater treatment costs, although maintenance had never been considered to be an environmental cost before. Overall, environmental costs were much higher than expected once they were more accurately identified. Previous estimates were that environmental costs would be three percent of operating costs; after a six month study and reallocation, they were calculated to be twenty-two percent.

Environmental costs will not be well managed where accounting systems do not identify and allocate them to the business activities that cause them. Indeed, managers may be unaware of their environmental costs, or what decisions have led to them. Even when aware of them as general overhead, individual managers have little accountability for them and hence little incentive to reduce or eliminate them. Further, where allowing for environmental costs affects profitability, it may also influence management compensation, so there may be little incentive to gather and allocate the information. Without specific accountability, individual managers have no incentive to minimize them.

187. Miriam Heller et al., Environmental Accounting Case Study: Amoco Yorktown Refinery, in GREEN LEDGERS, supra note 183, at 47, 79.
188. Id. at 79.
189. Id.
190. Id.
191. Id. The 22% figure was probably understated in that it did not include any allowance for potential future liability for waste disposal. A Dow facility study published in the same collection found that environmental costs, as defined, were only 3.2% of manufacturing costs. Ajay Maindiratta & Rebecca Todd, Environmental Accounting Case Study: Dow Chemical, in GREEN LEDGERS, supra note 183, at 105, 106. However, this represented only the costs of waste disposal and treatment. Environment related components of operating labor, managers’ salaries, planning, and capital investment were not included. Id.
192. Todd, supra note 185, at 191.
193. Id.; Ditz et al., supra note 183, at 39. In addition, collecting the information may give visibility to regulatory reporting obligations that are otherwise neglected.
This problem can extend beyond the domain of individual managers to bias corporate decisionmaking against pollution prevention and environmental technology projects. The benefits of such projects are often savings of real but unmeasured or unallocated current costs. Those benefits may include reduced compliance and waste disposal expenditures, as well as reduced operating and management expenses; yet the environmental component of these reductions are often not allocated to the specific operation.

There are other, often indirect, long term benefits, although the projects that achieve them impose direct, immediate costs. Thus, pollution prevention and environmental technology projects may well reduce the company’s exposure to future liability for injuries or waste cleanup. However, these kinds of savings are not only indirect, but they are uncertain and contingent to a degree, and thus hard to measure in present value. As a result, these benefits may be discounted, or unmeasured entirely, in deciding whether to undertake specific prevention projects. However, waste disposal, regulatory compliance, and future liability exposure are quite likely to become more expensive over time, thus making their reduction even more valuable.

The solution is better accounting systems that identify all the environmental costs and allocate them accurately to cost generating activities. A number of specific methodologies have been proposed; all share four central characteristics. First, the inventory of environmental costs must be expanded beyond waste treatment and disposal; allocation is important for environmental labor, management, operating costs, indirect liability costs, and less tangible benefits such as company image. Second, a lon-

194. See ALTERNATIVE APPROACHES, supra note 183, at 2.
195. Todd, supra note 185, at 196; TOTAL COST ASSESSMENT, supra note 183, at 19; ALTERNATIVE APPROACHES, supra note 183, at 16.
196. For detailed discussion of specific methodologies see TOTAL COST ASSESSMENT, supra note 183, at 23-36, app. B; ALTERNATIVE APPROACHES, supra note 183, at 28-45, app. C; FACILITY POLLUTION PREVENTION GUIDE, supra note 180, at 58-64 (offering a manual for specific company adoption). See also Ditz et al., supra note 183, at 29-42 (an excellent introductory guide to implementing better systems).
197. See ALTERNATIVE APPROACHES, supra note 183, at 67.
ger time horizon must be considered. Traditionally, project evaluation will cover a two to five year time period. However, many of the important indirect costs may only become evident over ten to fifteen years.\(^{198}\) Third, long term financial indicators must be evaluated to determine the present value of costs and benefits over this longer time horizon.\(^{199}\) Finally, cost allocation must be improved to connect costs and benefits with the activities giving rise to them.\(^{200}\)

The resulting Total Cost Assessment ("TCA") will be challenging to work out, but the business and environmental payoff for doing so should be large.\(^{201}\) TCA will usually favor pollution prevention and environmental technology projects, because it may identify and allocate the real environmental costs that these projects can save. Of course, it may not always do so, for it will also include other costs and benefits now overlooked. The case study of environmental accounting at the Yorktown refinery offers a clear illustration.\(^{202}\) When the study began, environmental costs were estimated to be three percent of operating costs;\(^{203}\) in such a situation, it is not surprising that these were not a major target of management attention and cost control programs. However, when environmental costs were calculated to actually be twenty-two percent of operating costs, they became a much more visible and attractive target for attention.\(^{204}\) Costs of this size require that the company rethink its decisions about processes, operations, and products that cause the costs. Further, the accounting project will have identified where the environmental costs are caused, thus offering a better informed sense of the relative priority of different projects.

One study provides substantial evidence that adopting a TCA approach will have a dramatic effect in promoting prevention.\(^{205}\)

This 1992 study of source reduction programs at twenty-nine

\(^{198}\) Id. at 65.

\(^{199}\) Id.

\(^{200}\) Id. at 66.

\(^{201}\) Todd, supra note 185, at 199-200.

\(^{202}\) Heller et al., supra note 187, at 79.

\(^{203}\) Id.

\(^{204}\) Id.

\(^{205}\) DORFMAN ET AL., supra note 63, at 31.
chemical industry plants considered the importance of cost accounting in those programs. "Plants with some type of cost accounting program (full or partial) had an average of three times as many source reduction activities . . . as plants with no cost accounting system." This difference was found to be statistically significant. Improved accounting, although not very glamorous, is a most important feature of prevention programs.

Several states now mandate pollution prevention planning; a few of these include a requirement of financial planning. For example, New Jersey, as part of its mandated planning for pollution prevention, requires that companies make:

- a comprehensive financial analysis of the costs associated with the use, generation, release or discharge of hazardous substances which occur as a result of current production processes at the industrial facility, including the costs of generation of non product output [wastes], the savings realized by investments in pollution prevention and the more efficient use of raw materials, the cost of the treatment and disposal of hazardous waste, and the cost of liability insurance.

The crucial question is whether such a mandate will be effective in changing the way businesses think about pollution prevention and environmental technology investments. While preparing a specific accounting report can be required, mandating the actual use of it in discretionary business decisionmaking is much more problematic. In the state of Washington, however, limited case study evidence shows that at least some of the companies subject to the requirement found it to be a useful contribution to their

206. Id.
208. See, e.g., Pollution Prevention Act, N.J. STAT. ANN. § 13:1D-41b(12) (West 1991); WASH. REV. CODE ANN. § 70.95C.200 (West 1992). See also Christopher H. Stinson, Accounting for Pollution Prevention in Washington State, in GREEN LEDGERS, supra note 183, at 157 (discussing the response to Washington State's Pollution Prevention planning requirements by four companies); ALTERNATIVE APPROACHES, supra note 183, at 4-6.
IV. INDUSTRIAL ECOLOGY

Most of the policy discussion about pollution prevention and environmental technology, including this one, have directed attention to individual firms, their plants, and the expansive reach which extends to their suppliers and customers. Industrial ecology is a new, broader way of thinking about the environmental consequences of production and consumption. Using an analogy to natural ecosystems, industrial ecology places individual firms and their economic activities in a conceptual industrial ecosystem. Such thinking, as it presently emerges in environmental engineering literature, emphasizes large systems, long time horizons, and broad consideration of all the environmental implications of industrial activities. Industrial ecology is still developing as a discipline and, at this point, it is more suggestive of possibilities than prescriptive of outcomes. An example can illustrate the rich conceptual possibilities.

One central idea of industrial ecology is that waste streams from one industrial operation can serve as raw materials for another. This idea is an obvious suggestion once one begins thinking in terms of ecosystems, because natural ecosystems typically use the wastes of one organism as a nutrient or other energy source for another. Of course, in the industrial system, users of raw materials may have quite specific requirements, and wastes may require substantial treatment or refining before they can be useful. Ultimately, waste streams might be designed with reuse in mind, so they could be tailored to meet the requirements of a particular raw materials buyer.

209. Stinson, supra note 208, at 158.
210. See supra notes 1, 20, 62.
211. An excellent discussion of the ecosystem image is in Robert U. Ayers, Industrial Metabolism, in TECHNOLOGY AND ENVIRONMENT, supra note 37, at 23.
212. An excellent introduction can be found in THE GREENING OF INDUSTRIAL ECOSYSTEMS, supra note 1, and especially in Matthew Weinberg et al., Industrial Ecology: The Role of Government, id. at 123; Deanna J. Richards et al., The Greening of Industrial Ecosystems: Overview and Perspective, id. at 1.
214. Id. The article focuses on specific metals, noting that the relative concen-
Ecochem, a joint venture of DuPont and ConAgra, is a success story concerning the use of a waste stream as raw material for a new product. ConAgra produced cheese whey, a high protein waste that resulted from other operations. Together with DuPont it developed an innovative technology to make the whey into lactic acid which could then be made into bio-degradable plastics known as polylactides. These plastics have the potential to be much more environmentally friendly packaging material. A production pilot plant opened in 1992 and a full scale plant, applying the lessons learned, was scheduled to begin operating in 1994; the total investment will eventually reach $100 million.

But forming and operating the joint venture was not always easy. Within DuPont, there was some resistance to the new plastics, based on the fear that they might displace sales of existing products. In addition, some feared that this effort might detract from DuPont's ongoing recycling efforts, particularly in the early stages when the environmental benefits of polylactides were less apparent. Finally, there were differences between the two corporate cultures that had to be bridged:

The initial DuPont "champions" were essentially engineers, eager to exploit the new degradable polylactide technologies, while the "champions" within ConAgra were entrepreneurs with a strong bias toward low-cost production of commodity products. The joint venture also had to accommodate some differing approaches of the parent companies. Traditional DuPont wisdom about new technology development and commercialization is that "good science and engineering" requires large research and development spending over a long time. ConAgra, however, has an investment creed of carefully controlling capital and achieving their stringent 20-percent return on equity standard in a relatively short period. Thus the partners had to reconcile very different perspectives on investment levels and payback schedules.

...
Executives at both DuPont and ConAgra have learned a number of lessons from the Ecochem experience. Special effort is needed to turn sustainable development opportunities into profitable reality. New forms of business alliances may be required. Furthermore, while the two companies believe that sustainable business projects can be profitable, returns may not emerge immediately.\textsuperscript{220}

When ConAgra and DuPont join forces to turn a waste material into a new product’s raw material, they are acting like organisms in an industrial ecosystem. Industrial operations can be seen as part of a larger industrial ecosystem. It appears obvious to use wastes as raw materials, and indeed eventually design them with such use in mind. The potential environmental benefits are great, but so are the challenges to achieve them. The individual firms and plants — the organisms in this ecosystem — will have a whole new basis for interaction with each other and will doubtless have to develop whole new ways of conducting those interactions. The organizational structure and culture of businesses will certainly have to evolve and adapt to achieve this potential. Equally significant changes will ultimately be required of regulators.

V. CONCLUSION

Preventing pollution is a tantalizing prospect — it offers great promise for achieving better, cheaper environmental protection while supporting business competitiveness. However, prevention requires a great deal of initiative and commitment from companies — more than traditional pollution control. Control steers companies toward buying end-of-the-pipe cleanup technology. In contrast, pollution prevention requires companies to rethink their operations, their products, and their technologies to make them cleaner, rather than to clean up afterward. The center of attention moves from the end of the pipe to the inside of the plant, and the demands on the company’s initiative and innovation are much greater.

Prevention also requires that policy thinking shift away from the traditional emphasis on regulator’s commands and enforcement. Control approaches are regulator centered, since getting

\textsuperscript{220} Id. at 282-83.
standards written and enforced is the central task. Prevention shifts the center of attention to the company decisions that create wastes in the first place. This shift of emphasis, from regulator commands to company innovations, results from the kind of company decisions and actions that prevention requires.

This survey of the successful programs so far shows that two kinds of business efforts are needed. First, there must be a creative, innovative spark to conceive how things can be done cleanly. This spark might then illuminate possible changes at several different levels. It might mean change in basic operations, or it could mean incremental or wholesale redesign of industrial processes. Even more fundamentally, it can mean redesigning the company’s products. Most broadly, the whole product life cycle, from raw materials use through production, to product use and disposal can be rethought. However, innovative sparks are not enough; successful prevention efforts require company policies and organizational programs to bring such sparks to full flame. The programs must have commitment shown by top management, a supportive organizational structure, and they must involve employees firm-wide, relating prevention to the organization’s core values. Broader and different environmental cost accounting will be a key. A change in the organization’s culture will ultimately be required.

Such fundamental changes in the way business thinks about the environment can be influenced by many factors. The values and expectations of all the stakeholders are certainly important — employees and managers, stockholders, customers, suppliers, and others. Yet, to pursue prevention as a policy, we must proceed with a clear idea of the kind of business behavior it requires, and use whatever — admittedly incomplete — knowledge we have to encourage and support that behavior.

To maintain the focus on developing a richer sense of the business realities and opportunities of pollution prevention, this Article has avoided consideration of the traditional environmental law regulatory system and its impact on pollution prevention. The variety and complexity of business efforts that prevention requires, as developed here, show that they may be difficult for regulators to directly command. Creative thinking, organizational commitment, and cultural change can be more easily inspired
than required. However, the traditional regulatory system does create many environmental performance incentives for business. The conventional theory asserts that pollution control regulation uniformly discourages new environmental technology and pollution prevention. However, the accumulating but still incomplete evidence is much more mixed, and some recent efforts have been launched to make the control system more hospitable to prevention. Beyond accommodating prevention in the traditional regulatory apparatus, many recent policy efforts have sought to promote prevention directly, and later research will consider these programs in light of the business efforts that prevention requires.