Pollution Prevention, Cleaner Technology, and Compliance 8

Historically, environmental compliance efforts in the United States have focused principality on treatment of pollution once it has been released (end-of-pipe approach) rather than on prevention or recycling, two approaches that in many cases offer a lower cost means of attaining compliance. End-of-pipe methods often result in increased costs with no appreciable benefits to the firm in the form of enhanced materials or energy efficiency. In contrast, pollution prevention and recycling investments often not only lower energy and material usage but also reduce end-of-pipe treatment costs, resulting in decreased disposal expenditures, possible reduced paperwork, and lower liability and insurance costs, Greater emphasis on prevention and recycling can thus lower environmental compliance costs for U.S. manufacturers.

Congress, in the Pollution Prevention Act of 1990, established a hierarchy of preferred options, from elimination or reduction at the source (including in-process recycling), to out-of-process recycling (on-site and off-site), pollution control, waste treatment, and, finally, land disposal.[1] This chapter discusses pollution prevention and cleaner technology from the standpoint of the manufacturing firms that must comply with environmental regulations, building in part on prior OTA work[2] and on contract

[1] F. Henry Habicht II, Deputy Administrator, U.S. Environmental Protection Agency, Memorandum "EPA Definition of 'Pollution Prevention, ' " May 28, 1992.

[2] U.S. Congress, Office of Technology Assessment, Serious *Reduction of Hazardous Waste: For Pollution Prevention and Industrial Efficiency, OTA-ITE-317* (Washington, DC: U.S. Government Printing Office, September 1986).

research undertaken for this assessment.[3] Special emphasis is given to three industrial sectors facing high compliance costs and significant environmental challenges--chemicals, pulp and paper, and metal finishing. The chapter also discusses barriers to pollution prevention, and Federal and State government assistance to manufacturers in the United States to meet environmental requirements, particularly pollution prevention.

MAJOR FINDINGS

Pollution Prevention and Recycling

- Compared to conventional treatment alone, pollution prevention and recycling investments are usually more cost-effective, often resulting in reduced energy and material usage and lower end-of-pipe treatment costs. Pollution prevention can produce significant environmental benefits as well, including reduced cross-media transfers and reduced environmental impacts from avoided energy and materials usage.
- However, while increased reliance on pollution prevention and recycling offers a means to reduce the conflict between environmental protection and industrial competitiveness, it does not eliminate it. While many pollution prevention and recycling options yield net positive rates of return equaling nonenvironmental investments, many others do not, and often cost money. However, in most cases the expense is lower than alternative end-of-pipe approaches.
- While source reduction is normally preferred on environmental grounds, and usually yields the lowest cost option for reducing pollution, there are cases where recycling is preferred on economic grounds. Depending on the material, the size of the facility, and the industry, recycling can be a more economical way of reducing waste than source reduction. Moreover, recycling can be the preferred option if it is less intrusive to the production operations.
- Emphasis on pollution prevention can also lead to beneficial organizational and technological changes. It can speed technical change within an industry, leading to increased investment in new plant and equipment. Moreover, integrating pollution prevention into industrial operations can lead firms to pay closer attention to the efficiency of their production processes and is consistent with new management approaches, including total quality management.
- A variety of evidence suggests that, while industry has increased its pollution prevention and recycling efforts, particularly since the late 1980s, significant pollution prevention opportunities still exist, especially those related to process modifications. A number of organizational and capital accounting factors within firms and aspects of the regulatory system retard greater progress.

Pollution Prevention Technology Development and Diffusion

- As the simpler steps for pollution prevention become widely adopted, a significant source of environmental improvement will lie in new manufacturing process technologies that are cleaner, and often more productive. Many of these approaches to waste reduction are still underused and are just now being explored.
- In spite of the importance of clean process technologies, little Federal environmental R&D support goes to this area.[4] Moreover, no federally supported institution has taken a broader policy role with regard to clean technology development, although some agencies are interested in doing so.

[3] Information on three industries was provided to OTA by outside contractor reports: Neil McCubbin Consultants, Inc., ' 'Environment and Competitiveness in the Pulp and Paper Industry' David Allen, "Clean Chemical Manufacturing Technologies: Current Practices and Long Term Potential"; F.A. Steward, Inc., "Environment and Competitiveness in the Metal Finishing Industry. '

[4] One exception is the Department of Energy's Clean Coal Technology Program, funded at $415 million in fiscal year 1992 (see ch. 10).

- While new technologies are necessary for fundamental gains in pollution prevention, widespread diffusion of existing off-the-shelf technologies will go a long way to reduce pollution. While many in industry want to reduce pollution, a significant share do not know how to move beyond the simplest measures; some, particularly small businesses, may not even be aware of pollution prevention options.
- Technical assistance efforts can help these firms implement pollution prevention and recycling measures. Yet existing programs are very small and many do not adequately meet manufacturers' needs. Most importantly, by considering pollution prevention separately from other manufacturing needs, such as productivity and quality improvements, most programs fail to develop the vital synergies and working relationships with manufacturers that are essential to drive both pollution prevention and increased manufacturing competitiveness.

Financial Incentives

- Government financial support to industry for the cost of environmental compliance can lessen the competitive impact of environmental regulations. A number of other countries provide more financial incentives (tax incentives, loans, grants) to help companies comply with domestic environmental requirements than does the United States.

THE RATE OF ADOPTION OF POLLUTION PREVENTION AND RECYCLING

Because of the dearth of careful studies, it is difficult to document the extent of adoption. However, while industry has increased its pollution prevention and recycling efforts, particularly since the late 1980s, the evidence suggests that significant pollution prevention opportunities remain, particularly those related to process modifications.[5]

Some industries have made more progress than others. For example, such methods have been extensively exploited in many major chemical manufacturing operations.[6] A study of pollution prevention projects in 21 chemical plants found that, while a few projects date back a decade or more, the majority were launched after 1985.[7] The study argues that significant opportunities for pollution prevention are still possible, even at plants that have been implementing pollution prevention for many years. For example, Hoechst Celanese has committed to reducing Toxic Release Inventory (TRI) emissions 70 percent from 1988 to 1996, and expects that over three-quarters of these reductions will come from pollution prevention, with one-half of the total coming from source reduction.[8]

In the metal finishing industry, pollution prevention housekeeping practices have been known for over 20 years, but many firms have not adopted them, as older facilities tend to perpetuate old operating habits. Only a small fraction of metal finishers, principally the larger facilities, appear to have taken advantage of some of the

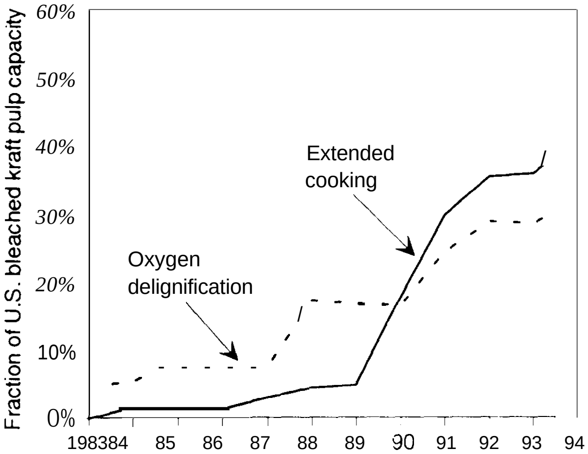
[5] There arc many similarities between energy conservation and pollution prevention. Each is driven by external costs, both are applied at the margin, neither is done in isolation, and both are part of other productivity improvements in labor, equipment, and materials. When U.S. firms first began to focus on energy conservation they focused first on the "low-hanging fruit' and then moved to more expensive changes based on new technologies and processes. However, many companies continue to find new, relatively easy energy-saving opportunities. It is possible that pollution prevention will follow this same path. (See U.S. Congress, Office of Technology Assessment, *Industrial Energy Efficiency, OTA-E-560* (Washington, DC: U.S. Government Printing Office, August 1993.)

[6] Allen, op. cit

[7] Mark H. Dorfman, Warren R. Muir, and Catherine G. Miller, *Environmental Dividends: Cutting More Chemical Wastes* (New York, NY: Inform, 1992), p. 14.

[8] Discussion with James Connor, Environmental Division, Hoechst Celanese, Apr. 20, 1993. (Under Section 313 of the Emergency Planning and Community Right To Know Act, certain manufacturers must report releases or transfers of over 3(?0 toxic chemicals.)

Figure 8-l—Adoption of Selected Cleaner Technologies in U.S. Kraft Pulp Mills



SOURCE: N.McCubbin Consultants Inc., 1993.

promising opportunities, such as use of advanced concentrate and return technologies (e.g., reverse osmosis, evaporation, ion exchange) for the return of excess solution (dragout) to plating baths. Of the installations that could achieve a 3-year payback, one estimate is that less than half have installed the equipment.[9]

In pulp and paper, there has been a slow increase in the share of pollution prevention technology adopted. In 1984, 25 percent of water pollution control investments were for in-process measures, increasing to 30 percent in 1989 and 56 percent in 1991.[10] Much of this increase has been driven by the need to reduce organo-chlorines in waste water. One way to do this is through extended cooking in bleached kraft pulp production. Use of this technique has increased significantly since 1989; currently over one-third of all pulp is made with this process. In contrast, the adoption of oxygen delignification systems has been slower, with about 27 percent of bleached kraft production now using it[11] (see figure 8-l),

Overall, the share of environmental investments in in-process pollution control appears to be similar in Europe and the United States (table 8-l). Contrary to conventional wisdom, the Japanese do not appear to have made significant effort in industrial waste-related pollution prevention. However, because of high energy prices and aggressive government policies, Japanese industry has made significant strides in adopting energy-efficient technologies, which provide both direct and indirect environmental benefits.

POLLUTION PREVENTION, AND RECYCLING AND ECONOMIC PERFORMANCE

■ Cost Savings From Pollution Prevention and Recycling

There is disagreement on exactly how economical pollution prevention is. Some claim that pollution indicates wasteful and inefficient practices and that, therefore, firms generally save money by engaging in pollution prevention. In fact, there are numerous widely publicized industrial case studies of very successful pollution

Table 8-l—Estimates of In-Process Changes as a Share of Pollution Control Investments

Belgium*	20%
France"	13%
Germany[a]*	18%
Netherlands	20%
United States**	25%

a One study suggests that pollution prevention investments in Germany between 1975 and 1985 ranged from 16 to 24 percent (Christian Leipert and Ucfo E. Simonis, "Environmental Damage-Environmental Expenditure. Statistical Evidence on the Federal Republic of German," paper by Wissensehaftszentrum Berlin Fur Sozialforschung gGmbh, Berlin.).

SOURCES: •Commission of the European Communities, *Panorama of EC* Industry 1990 (Luxembourg: Office of Official Publications of the European Communities, 1990), p. 134.
•* U.S. Bureau of the Census, *Pollution Abatement Costs and Expenditures, 1990* (MA200), *1992.*

[9] **Steward, op. cit.**

10 U.S. **Bureau of** the Census, *Pollution Abatement Costs and Expenditures* **(Washington DC: Government** Printing Office, various years).

11 McCubbin, op. Cit.

Table 8-2—Case Examples of Pollution Prevention Savings

Industry	Savings or payback period	Option	Source of savings
Ice cream	4 months	Housekeeping	Material savings
Trailers	4 months	Paint reuse, use of water-based cleaner	Avoided paint purchases, lower disposal costs
Valves	1.4 years	Aqueous parts cleaning	Avoided solvent purchase, lower disposal costs
Chemicals	3 years	Evaporation equipment for ammonium sulphate	Avoided EOP, sales of recovered chemicals
Tobacco products	6 months	Solvent recycling	Avoided solvent purchase, lower disposal rests
Nylon fabrics	5.5 years	Dye substitution, process changes	Reduced wastewater treatment charges
Furniture	1 year	Solvent recycling	Avoided disposal costs
Furniture	2 years	More efficient paint spraying	Paint savings, avoided disposal costs
Furniture	$70,000	Painter training	Reduced paint use
Printing	Immediate	Water-based inks	Lower ink costs, avoided disposal costs

SOURCES: Information provided by the Center for Industrial Services, The University of Tennessee; the North Carolina Department of Environment, Health and Natural Resources, Pollution Prevention Program; *Case* Summaries *of Waste Reduction by Industries in the* Southeast (Raleigh, NC: Waste Reduction Resource Center for the Southeast, July 1989); Karf S. Tsuji, Energy and Environmental Analysis Group, Los Alamos National Laboratory, "Waste Reduction in the U.S. Manufacturing Sector, A Survey of Recent Trends," unpublished paper, November 1991.

prevention projects, some with payback times of well under a year.[12] But some in industry view these highly successful projects as relatively rare, and there are elements of truth in both sides of the argument.

However, pollution prevention projects do not need to generate a positive rate of return to be successful. Because most pollution prevention solutions are cheaper than treating or disposing of wastes, a greater emphasis on prevention can reduce environmental compliance costs, regardless of whether pollution prevention is profitable even in the absence of regulatory requirements.

The few studies on the economics of pollution prevention suggest that while there are cases where prevention yields net positive rates of return equaling nonenvironmental investments, more yield either positive, but low, returns, or negative returns.[13] In controlling pollution, firms normally have a range of options with a range of economic paybacks. In a few cases the paybacks are large enough to justify action solely on the economic merits[14] (see table 8-2.) One study found that, where payback information was reported, companies were able to recoup their investments rapidly, in 6 months or less, for

[12] For example, see "Case Summaries of Waste Reduction by Industries in the Southeast,'' Waste Reduction Resource Center for the Southeast, Raleigh, NC, July 1989; Karl S. Tsuji, "Waste Reduction in the U.S. Manufacturing Sector, A Survey of Recent Trends," Los Alamos National Laboratory, November 1991; Dorfman et. al, op. cit.;"Leaders in Hazardous Waste Reduction, 1989 & 1990, " Pollution Prevention Program, North Carolina Department of Environment, Health and Natural Resources; *Pollution Prevention* Case *Studies Compendium*, U.S. EPA, Office of Research and Development, April 1992.

[13] As discussed below, firms do not always adequately account for all benefits (and costs) from pollution prevention, including reduced long-term environmental liability.

[14] For example, see Cleaner Production Programme, *Cleaner Production Worldwide* (Paris: United Nations Environment Programme, 1993).

two-thirds of their investments.[15] However, since companies are more likely to implement pollution prevention projects with larger rates of return, such findings may be skewed and not represent the entire universe of projects.

In other cases, while paybacks maybe positive, they are not high enough to be justified on solely commercial grounds. Finally, in many cases the returns are negative, but often represent savings over alternative end-of-pipe approaches. Companies would normally not invest in these projects without some kind of regulatory pressure.

For example, 3M's gross savings of $516 million from 1975 to 1992 in the United States through its Pollution Prevention Pays (3P) program is often cited as evidence of potential savings from pollution prevention.[16] However, 3M has also spent over $220 million on pollution prevention capital investments, and an additional, unspecified, amount on labor to design and implement these measures. Moreover, not all the projects had net positive rates of return.[17]

Approximately half of the projects in Dow Chemical's Waste Reduction Always Pays program (WRAP) cost more to implement than they save.[18] The chemical company Hoechst Celanese analyzed over 200 projects in its Waste and Release Reduction Program, focusing on SARA 313 releases. The company found that about 20 percent of the projects had a positive net present value; the majority showed small but negative net present value; and 20 percent had large negative net present values. As expected, end-of-pipe treatment projects often yielded the worst returns, with source reduction and recycling showing the best returns .19

Finally, pollution prevention does not eliminate the need for end-of-pipe treatment: these firms still expend significant amounts on environmental compliance. While 3M saved $47 million from its 3P program in 1992, it also spent over $200 million on environmental compliance.[20] The chemical company Monsanto has spent $100 million to reduce toxic air emissions through end-of-pipe and prevention measures, and only some of the projects were economically positive.[21]

Economics of pollution prevention differ by industry. In the pulp and paper industry, prevention is cheaper than end-of-pipe treatment, because far less pulpmaking chemicals are used. For example, if a new pulp bleaching plant is installed in a greenfield mill or in rebuilding an existing facility, the net capital cost of oxygen delignification systems generally will be close to zero. The system eliminates the need for a chlorine-based bleach stage and reduces chlorine dioxide consumption. In cases of a retrofit, the capital costs typically range from $10 to $20 million, depending on the site. However, operating costs will be reduced by around $10 per metric ton of pulp, equivalent to about $1.5 to $4 million a year at typical production rates. In addition, oxygen delignification generally reduces biological oxygen demand (BOD) emissions by about 25 percent, lowering water treatment costs by a small

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15 Dorfman et. al., Op. cit.

16 It is difficult to determine actual savings, Actual savings may be lower since 3M calculates projected Savings at the time Of project initiation and not after implementation. On the other hand, because savings are only estimated for the first year ioperation, actual savings may be greater.

17 Interview with 3M official, January 1993.

18 "Attacking Wastes and Saving Money. . .Some of the Time," *Industry Week*, Feb. 17, 1992. Full cost analysis may not be done for all projects, resulting in underestimation of savings,

19 Discussion with Hoechst Celanese official, Apr. 20, 1993.

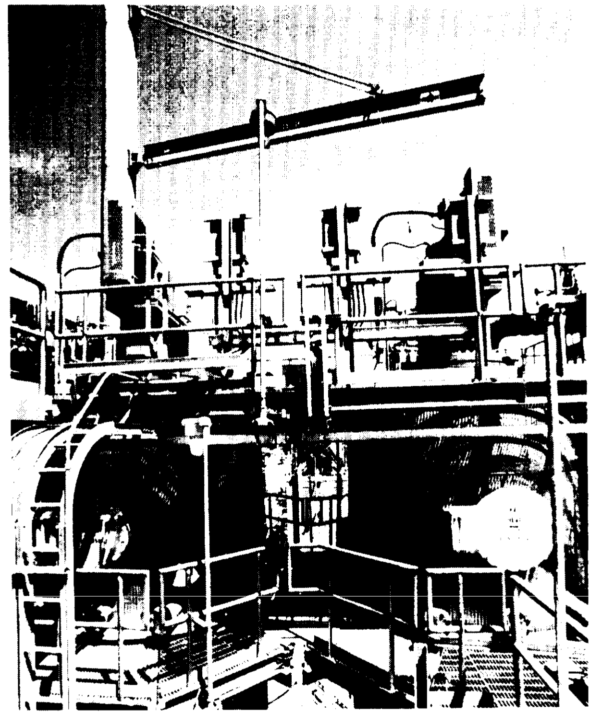
20 Data provided by 3M.

21 Marc Reisch, "Monsanto's Environmental Progress Comes at High Cost," *Chemical and Engineering News*, Dec. 14, 1992, p. 16.

Table 8-3—Capital and Operating Costs for Selected Pollution Prevention Measures in the Wood Pulp Industry

Process option	Capital cost ($ million)	Annual savings ($ million)
Base case example mill	0.0	0.0
Maximum substitution with EOP & existing ClO_2 capacity	2.8	0.5
Extended cooking (if batch digesters exist)	45.6	3.4
Extended cooking (if older continuous digesters exist)	32.6	2.8
Extended cooking (if suitable continuous digester exists)	4.6	3.7
Oxygen delignification	27.5	3.3
100% substitution without EOP	15.9	(7.1)
50% substitution without EOP	5.0	(1.9)
1OOO/. substitution with EOP	13.6	(3.2)
Extended cooking with EOP	47.0	3.3
Oxygen delignification with 100% substitution	34.7	2.0
Extended cooking with oxygen delignification	71.6	6.0
Extended cooking with 100% substitution	54.5	0.1
Extended cooking with OD and 1OOO/. substitution	75.2	4.6
Extended cooking with OD & EOP	73.0	4.4

Values in parentheses are negative. Savings in parentheses represent costs.
OD=oxygen delignification.
EOP=caustic extraction reinforced with oxygen and hydrogen peroxide bleaching.
Substitution-substitution of chlorine with chlorine dioxide.
SOURCE: Neil McCubbin, *Proceedings,* International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper Opportunities & Barriers, Washington, DC, Aug. 18-20, 1992.



Oxygen reactors, part of an oxygen delignification system in a pulp mill.

AHLSTROM RECOVERY, INC.

amount.[22] If this negates the need to upgrade the treatment system for mill expansion or to comply with regulatory changes, capital savings of several million dollars can occur. Finally, oxygen delignification frees up chlorine dioxide generating capacity, allowing the excess capacity to be substituted for formerly purchased chlorine bleach (table 8-3).

In metal finishing operations, some facilities saved significant amounts of money using pollution prevention technologies. However, many of these firms are plating with more valuable metals (e.g., gold, silver) where metal recovery makes more economic sense. Advanced recovery systems are sometimes more expensive than traditional end-of-pipe treatment, although recovered metals and chemicals and avoided sludge disposal costs do provide savings. Such systems appear to be more economical in the larger metal finishing facilities and for more valuable stable baths and in many cases can provide reasonable payback times (less than 3 years).

22 Similarly, in the electric utility industry, investing in heat rate improvements can reduce scrubber and waste disposal expenses, more than offsetting the costs. Robert C. Carr, "Integrated Environmental Control in the Electric Utility Industry," *Journal of the Air Pollution Control Association,* vol. 36, No. 5, May 1986, pp. 652-657.

Future increases in sludge disposal costs or in costs of input metals and chemicals would make these operations more cost-effective. For example, Freon 113 is becoming more expensive due to the tax aimed at reducing use of ozone-depleting substances. As a result, some pollution prevention solutions that had once been too expensive are now cost-effective.[23]

Organizational and Technological Change and Pollution Prevention

A focus on pollution prevention can sometimes lead to beneficial organizational and technological changes. A driving force for new productive investments is often technological obsolescence. Improved environmental performance of production technology often goes hand in hand with increased productive performance. As a result, a focus on pollution prevention can speed technical change within an industry, leading to increased investment in new plant and equipment.

In some industries, process technologies are relatively mature, with only slow rates of evolutionary change. However, increased concern with reducing pollutants, particularly at the source, can lead to reexamination of long-used technologies and practices and may induce more rapid rates of technical change.[24] For example, pulp and paper technology evolved relatively slowly between the 1940s and 1970s. Increased concern with environmental performance has led to renewed interest in the production process, with a number of major new process innovations being developed within the last decade, and further developments likely to occur in the 1990s. The innovations can involve improvements in productivity or efficiency.

In the drive to become more competitive, many U.S. manufacturers are organizing technology and production processes in new ways (e.g., computer-integrated manufacturing, just-in-time (JIT) delivery, and lean production) and rethinking their management systems (total quality management or TQM).[25] Pollution prevention is consistent with these approaches.[26] For example, the environmental waste reduction program of the textile firm Milliken grew out of its TQM program, which received the Malcolm Baldridge Quality Award in 1989. Similarly, as some firms have moved to JIT delivery systems, they have been able to eliminate decreasing and other cleaning steps. Moreover, there is some evidence that an increased focus on pollution prevention can encourage production workers to present ideas for improvement to process engineering managers.[27]

There are a number of similarities between pollution prevention and TQM/manufacturing modernization[28] (see table 8-4.) In both, firms examine their production process in great detail

23 For example, managers at the GE compressor plant in Columbia, Tennessee replaced their freon degreaser with a $600,000 aqueous washing unit, Without the increase in cost of 113 freon to $84 per gallon (from $45 recently) the new unit would not be cost-effective under the company's cost accounting system.

24 previous OTA work has found that "a new focus on pollution prevention offers an opportunity to reappraise and modernize plant process technology." *Serious Reduction of Hazardous Waste,* p. 30.

25 U.S. Congress, Office of Technology Assessment, *Making Things Better: Competing in Manufacturing*, OTA-ITE-443 (Washington DC: U.S. Government Printing Office, February 1990); and U.S. Congress, Office of Technology Assessment, *Worker Training: Competing in the New International Economy,* OTA-ITE-457 (Washington, DC: U.S. Government Printing Office, September 1990).

26 In a study of pollution prevention in a large multinational firm, the units that had strong TQM programs in place undertook more wide-ranging and effective pollution prevention efforts than divisions with less commitment to TQM. (Ann Rappaport, *Development and Transfer of Pollution Prevention Technology Within a Multinational Corporation,* Dissertation Department of Civil Engineering, Tufts University, May 1992.)

27 Andrew King, "Cooperatively arning Between Pollution Control and process Engineering Departments in the Printed Circuit Fabrication Industry," paper presented at The IEEE International Symposium on Electronics and the Environment May 10-12, 1993, Arlington, VA.

28 For example, see Alvin Alm, "Pollution Prevention and TQM," *Environmental Science and Technology, vol. 26, No. 3, 1992;* also Gene Blake, "TQM and Strategic Environmental Management," *Total Quality Environmental Management,* spring 1992.

Table 8-4-Organizational Aspects of Pollution Prevention and Total Quality Management

Factor	TQM and pollution prevention
Central focus	Focus on continuous improvement of the production process (goal of zero defects and zero emissions)
Source of improvement	Quality and pollution prevention built into the production process
Desired results	Increased efficiency and reduced waste (scrap and pollution)
Measurement process	Benchmarking progress
Internal coordination	Cross-departmental cooperation/coordination
Decision process	Workers at all levels (including shop-floor) involved in decision making
Accounting system	Activity-based and full-cost accounting

SOURCE: Office of Technology Assessment, 1993.

and focus on continually improving the process to improve quality and productivity and reduce scrap and pollution. Both practices incorporate new cost accounting and measurement to assign all costs to particular products or production processes. Benchmarking progress is encouraged in both.[29] In TQM, firms strive for zero defects, while in the best pollution prevention efforts, firms strive for zero discharges.

The process of decisionmaking is also similar. Both practices aim to involve all parts of company, rather than just the quality or environmental departments. For example, in pollution prevention, representatives from purchasing, marketing, R&D, production, and design are all encouraged to work together to find ways to prevent pollution. Similarly, both stress the importance of workforce involvement and the key role of shop-floor workers in improving quality and preventing pollution. Many programs report that their best suggestions to prevent pollution come from the shop floor employees.[30] Both pollution prevention and manufacturing modernization efforts succeed best when shop-floor employees are involved.

In summary, when firms focus on pollution prevention it facilitates the better focus on the broader task of continuous productivity improvement.[31] Preventing pollution through source reduction requires managers to improve materials, energy, and resource efficiency.

POLLUTION PREVENTION OPTIONS

Strategies for reducing waste generation in manufacturing include: good housekeeping, maintenance, and operating practices; product reformulation and raw material substitution; relatively simple process modifications employing currently available technologies; and, perhaps most importantly, more fundamental process modifications, many requiring technological innovation.[32]

29 Ann C. Smith, "Continuous Improvement Through Environmental Auditing," *Total Quality Environmental Management*, winter 1991/92.

30 Similar results have been found with regard to energy conservation. (See *Employee Participation in Energy Conservation: The U.S. and Japan Experience.* University of Michigan, Institute of Labor and Industrial Relations, 1983).

31 There are a number of components of ISO 9000 (the International Standards Organization standard for quality management) that are consistent with pollution prevention. For example, both stress the importance of working with suppliers.

32 R.L. Berglund and C.T. Lawson, "Preventing Pollution in the CPI," *Chemical Engineering*, September 1991, pp. 120-27; also Harry Freeman et. al. "Industrial Pollution Prevention: A Critical Review" *Journal of Air and Waste Management Association*, vol. 42, No. 1, May, 1992, pp. 618-656.

Good Housekeeping and Innovative Management Approaches

Perhaps the simplest and easiest-to-implement pollution prevention strategy is to adopt good housekeeping, maintenance, and operating practices. Frequently characterized as low-hanging fruit, many different industries have used such methods in varying degrees to cut waste economically.

General improvements in manufacturing efficiency can reduce pollution. For example, statistical process control programs, a TQM element, take some variance out of processes that generate waste. Other improvements include, for example, metal finishing opportunities such as operating at lower concentrations in the bath, better racking or barrel designs, draining over the tank, reduced water usage, and use of simple drag-out stations to catch and return drag-out solution.[33] Such good conservation and process control measures can reduce drag-out by 50 to 60 percent and extend the life of stable baths.

Innovative management approaches to waste minimization include working with customers and suppliers to redefine product needs so that less-toxic chemicals or less-polluting processes are required, renting of chemicals where the supplier takes them back after use, and improved operations management procedures like better inventory control.[34] Similarly, better attention to preventative maintenance to eliminate spills, leaks, and the like, can reduce emissions. Often employee training programs have objectives (e.g., reducing scrap and waste) that bring pollution prevention benefits.

Product Reformulation and Raw Material Substitution

Coating and cleaning operations are a principal area for raw material change. A significant amount of effort has gone into replacing chlorinated solvents with other, often aqueous-based, solvents. In painting, alternatives to volatile organic compound (VOC)-based paints include water-based paints, which can obviate the need for end-of-pipe VOC controls. For example, the Saturn automobile plant uses a water-based base coat that gives off no VOCs. In metal finishing, research is underway to find alloy coating materials that would be acceptable substitutes for cadmium and chromium.[35] On a broader basis, the shift from metal parts to plastic parts in a number of products has reduced the amount of metal finishing required. Substitutes, however, do not always provide identical performance or qualities of the materials they replace.

Process Modifications Using Existing Technologies

While many pollution prevention opportunities represent relatively unique modifications not generalizable between facilities (e.g., fine-tuning process computer control systems to lower waste),[36] many process modifications involve relatively generic process changes. For example, ultrasonic cleaning can greatly reduce solvent usage .37 More efficient paint transfer operations can reduce VOC emissions and paint sludge. In metal finishing, relatively standard technologies, such as improved drag-out tanks and ion exchange, can be employed economically, especially in the larger

33 Many of these measures focus on ensuring that as much of the metal finish is applied to the part as possible, and as little as possible is lost as parts are taken out of the plating bath.

34 Personal conversation, Jack Eisenhauer, Energetic, Columbia, MD, June, 1993.

35 Department of Energy, LOS Alamos National Laboratory, *Electroplating Waste Minimization,* paper presented at the Office of Industrial Technologies Industrial Waste Reduction Program Review, Washington DC, May 21, 1992,

36 For example, a Sara Lee plant reprogrammed its process control computers to reduce water use 65 percent, and in SO doing avoided installation of a $5 million pretreatment system. (Discussion with Roy Carawan, North Carolina State University, Department of Agriculture, March, 1993.)

37 John A Vaccari, "Ultrasonic Cleaning With Aqueous Detergents, " *American Machinist,* April 1993, pp. 41-42.

operations.[38] More efficient process controls can reduce variations in industrial processes, leading to reduced emissions.

Fundamental Process Modifications, Requiring New Technologies

Strategies involving more fundamental process technology modifications, many requiring technological innovation, can be employed. Many of these approaches to waste reduction are still underused and are just now being explored. However, as simpler steps for pollution prevention become widely adopted, a significant source of environmental improvement will lie in new generations of manufacturing process technologies that are cleaner, and often more productive, than older generations. In addition, many of the innovative clean technologies in the process industries to date have focused on individual processes, whereas process industries are a complex web of interconnected processes. Making each individual process as clean as possible may not be as effective as finding the collection of processes that could make an entire industry cleaner.

Process modifications are usually industry-specific+ specially in industries that process raw materials into intermediate materials (e.g., chemicals, oil, rubber, pulp and paper, steel) .39 For example, new methods of pulp delignification to reduce chlorine bleaching are specific to the pulp and paper industry. Similarly, developments in catalysis to produce higher chemical yields are specific to the chemical industry (see box 8-A). A number of new technologies are possible candidates to replace electroplating, including mechan-


HUGHES AIRCRAFT CO.

Water soluble flux for soldering electronic circuit boards developed by an aircraft company allows reduced use of CFC-based solvent cleaners.

ical plating, physical vapor deposition, and thermal spray processes.

Other applications may, with some modifications, be used by a number of industries, particularly fabrication and assembly industries (e.g., electronics, transportation equipment, fabricated metals). These include near-net shape metal forming,[40] laser metal cutting, alternative coating procedures (ion implantation, powder coating), better separation and filtration devices, leak-proof pumps, alternative cleaning (e.g., supercritical cleaning, no-clean soldering), and design tools, such as process simulators.[41]

Some fundamental changes in technology may reduce the need for processes that are highly polluting. For example, in the steel industry, the shift away from hot rolled ingots to automated continuous casting, followed by cold working and

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38 Ishwar K. Puri, *"The Metal Finishing and Allied Industries-Issues for Pollution Prevention" (unpublished manuscript, University of Illinois, Chicago, 1993).

39 American Petroleum Institute, *Waste Minimization in the Petroleum Industry: A Compendium of Practices* (Washington, DC: API, 1991).

40 Noel Greis, *Waste, Energy and Raw Material Reduction Potential of Near Net Shape Metal Forming Processes* (Worcester, MA: Kinefac Corp., Nov. 15, 1991).

41 Jack Eisenhauer and Shawna McQueen, *Environmental Considerations in Process Design and Simulation*, A Jointly Sponsored Workshop by the U.S. Environmental Protection Agency, U.S. Department of Energy, and the Center for Waste Reduction Technology, Dec. 8-9, 1992.

Box 8-A—Pollution Prevention in the Chemical Industry[1]

The U.S. chemical industry generates over $250 billion in annual sales and runs a trade surplus of $19 billion. However, the industry also generates large amounts of pollution and is the dominant source of hazardous waste in the United States. As a consequence, the chemical industry spent $4.8 billion in 1990 to control pollution and will spend increasing amounts throughout the 1990s to comply with new, tougher environmental standards.

Over 80 percent of air and water pollution abatement capital expenditures went to end-of-pipe treatment equipment. There are, however, significant opportunities to control much of the pollution through pollution prevention in all major unit operations of chemical processing, and in so doing to potentially lower compliance costs.

Storage Vessels-Methods for reducing tank bottom wastes, fugitive emissions from tanks, and residuals in shipping containers are abundant and relatively simple. Mechanical mixing or emulsifying agents can help solubilize tank bottoms and reuse the wastes. Fugitive emissions from tanks can be reduced with a number of fairly simple technologies, including floating roofs, insulated walls, and tanks that can withstand high pressures, but many of these technologies are expensive and the amount of material saved will not always cover the capital costs. Such actions as proper location of drainage valves and dedication of storage containers to specific uses can reduce emissions from shipping containers.

Piping and Valves-The most significant environmental problem associated with valves, pumps, compressors and other pipe fittings are fugitive emissions. Leak Detection and Repair (LDAR) programs can significantly cut fugitive emissions. While such programs are expensive, they can yield significant savings in material. For example, in a study of pollution prevention options at Amoco's Yorktown Virginia refinery, a quarterly leak detection program was projected to yield a 19 percent annual rate of return due to savings from reduced material loss.[2]

Reactors-Reactors are a key element in any chemical manufacturing process and are particularly important in waste generation. There are several levels of analysis to be considered in improving reactor designs, including selectivity, contamination, and vessel design. However, a particularly promising area for reactor improvements involves catalysis. For example, anew selective catalyst increased the yield of linear polypropylene (product) relative to nonlinear polypropylene (a waste), and hence reduced waste polypropylene by 90 percent. Similarly, a catalyst system developed for use in making acetaldehyde cuts chloro-organics formed by over one-hundred-fold. Controlling attrition and limiting deactivation of catalysts can also decrease wastes. Finally, integration of both reaction and distillation in a single vessel (e.g., catalytic distillation) can offer opportunities to cut waste and possibly reduce capital and operating costs. However, the development and new catalysts and reactor designs to lower wastes is still in its infancy and new reactor designs are generally only economically feasible with new plants or major retrofits.

Heat Exchangers-Heat exchangers can be a source of waste when high temperatures cause fluids to form sludges. Steam-based cleaning produces significant quantities of wastewater. Alternatives include sand blasting with dry ice or recyclable sand. In addition, use of adiabatic expanders to mix high and low pressure steam to achieve optimal heat transfer temperatures is a relatively low-cost method of minimizing waste.

Separation Equipment--Since separation units are designed to further purify products and isolate contaminants, they are by nature waste-generating, although sometimes unreacted feedstocks or

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1 This box is based principally on a contractor report to OTA written by David Allen, Professor of Chemical Engineering, UCLA.

2 *Amoco-U.S. EPA pollution Prevention Project, Yorktown, Virginia. Project Summary,* June 1992, p. 3.22.

byproducts may be reused or used elsewhere. It is difficult to generalize about separation, while in some cases waste can be reduced economically, while in others it is quite expensive.

Flowsheet restructuring-Much of the focus on pollution prevention in the chemical industry has been on individual unit operations. Another set of methods for waste reduction involves completely reconfiguring the entire process flowsheet within a facility. Such dramatic process modifications are done only rarely, but they do offer significant pollution prevention potential.

Byproduct reuse-Some of the waste products from chemical processes may have other uses. For example, Arco's Los Angeles refinery sells its spent alumina catalysts to Allied Chemical and its spent silica catalysts to cement makers. These were previously characterized as hazardous wastes and disposed of in a landfill at high costs.[3] Solvent recovery also can allow solvents to be reused within the process.

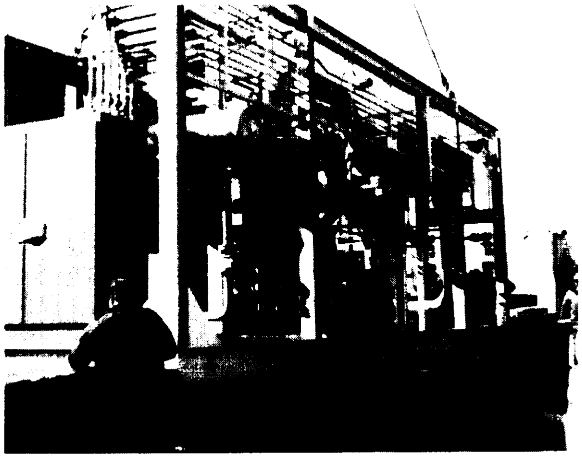
Industry-wide analysis--Selection of particular processes to make individual chemicals is quite complex and will have different energy requirements and rates of waste generation. Moreover, the selection will influence rates of waste generation in the rest of the chemical industry. For example, if methanol is produced via carbon monoxide, it maybe possible to generate carbon monoxide through partial oxidation of a material that is currently wasted. On the other hand, to convert carbon monoxide into methanol requires hydrogen, which is an energy-intensive material. There have been few system-wide analysis of the energy and environmental impacts of chemical processing to inform such choices.

Table 8A-1—Reducing Wastes From Unit Operations in Chemical Processes

	Examples of Process Modifications for Waste Reduction		
	Changes in operating practices	Currently feasible process modifications	Process modifications requiring technology development
Storage vessels	Use of mixers to reduce sludge formation	floating roof tanks, high pressure tanks, insulated tanks	Process specific changes to eliminate need for storage, particularity intermediates
Pipes and valves	Leak detection and repair programs for fugitive emissions	Leakless components	Process designs requiring the minimum number of valves and other components
Heat exchangers	Use of anti-foulants; innovative cleaning devices for heat exchanger tubes	Staged heat exchangers and use of adiabatic expanders to reduce heat exchanger temperatures	Heat exchanger networks to lower total process energy demand
Reactors	Higher selectivity through better mixing of reactants, elimination of hot and cold spots	Catalyst modifications to enhance selectivity or to prevent catalyst deactivation and attrition recycle reactors for catalyst recycling	Changes in process chemistry; integration of reactors and separate units
Separators	Reduce wastes from reboilers	Improvements in separation efficiencies	New separation devices, efficient for very dilute species

SOURCE: David Allen, "Clean Chemical Manufacturing Technologies: Current Practices and Long Term Potential ;" contractor report prepared for the Office of Technology Assessment, May 1993.

3 Robert A. Frosch and Nicholas E. Gallapoulos, "Strategies for Manufacturing," *Scientific American*, September 1989, p. 144-152.



U.S. DEPARTMENT OF ENERGY

Brayton cycle heat pumps allow recovery of solvents and energy from industrial processes. DOE's Office of Industrial Technology supports development of this technology.

atmospheric annealing, significantly reduces both the quantity of scale left on the steel's surface, and the amount of acid needed for pickling. Over the long term, it is quite possible that technology will allow metal goods to be manufactured in such a way that the surface does not require separate finishing, eliminating much metal finishing and the pollutants it generates. If technically and economically feasible, direct steel making will eliminate the highly polluting coke process.

Some technological changes are unlikely to occur in the near future, but hold significant promise. For example, the design and operation of bleached kraft pulp mills without any aqueous effluent, except clean cooling water, is a realistic goal.[42] However, little research is being done on this. Other possibilities may emerge in the longer term, such as developing plastics with built-in catalysts allowing them to be broken down into their constituent chemical components and recycled.

External Recycling

In the last two decades, businesses have made greater efforts to deal with wastes. However, these efforts have been highly atomistic, with little interfirm or interindustry coordination in the area of materials and waste management, and with little consideration of wastes and products at the ends of their useful lives as potentially useful inputs to some other industrial process.[43]

The term 'industrial ecology' refers in part, to the better use of waste and materials among firms.[44] Increasing the rate of recycle and reuse is normally more economical than treatment, and, even pollution prevention in some cases. Moreover, with regard to materials use, exchange of waste products among firms may prove more efficient than source reduction. optimizing an individual plant with respect to waste reduction may be less efficient than optimizing the industrial system with respect to that material.[45]

Similarly, it may sometimes be cheaper to treat pollutants centrally than to install treatment or waste reduction technologies in the individual plants (see box 8-B) For example, when publicly operated treatment works (POTWs) have excess capacity, it maybe cheaper to have them treat and dispose of some industrial wastes than have the individual firms pre-treat their wastes.

There are several sources of savings from recycling. First, firms generating these materials no longer have to pay for their treatment or disposal. Second, and perhaps more important, use of processed materials can generate less

42 McCubbin, op. cit.

43 Robert A. Frosch, "Industrial Ecology: A Philosophical Introduction," *Proceedings of the National Academy of Science*, February 1992, p. 800.

44 C. Kumar N. Patel, "Industrial Ecology," *Proceedings of the National Academy of Science,* February 1992; also Matthew Weinberg, Gregory Eyring, Joe Raguso, and David Jensen, "Industrial Ecology: the Role of Government' *Greening Industrial Ecosystems* (Washington DC: National Academy of Engineering Press, forthcoming, 1993).

45 The Department of Energy Waste Utilization and Conversion Program focuses on these kinds of material reuses issues. (Office Of Industrial Technologies, *Waste Utilization and Conversion: Program Plan,* Washington, DC: U.S. Department of Energy, Apr. 16, 1993).

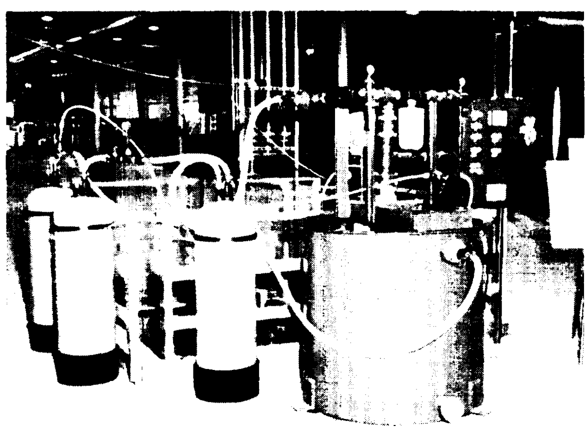
Box 8-B–External Recycling in the Metal Finishing Industry

Many wastes from metal finishing processes are too small, too low in value, or require treatment/recovery technologies too complex to be feasibly processed on-site by the generator. However, because of economies of scale, there are good opportunities to process many of these wastes at an off-site centralized plant that services numerous generators. Such a facility can extract metal and other chemicals from the wastestreams and purify them to commercial standards to produce articles of commerce. The economics of such an operation are only minimally dependent on the value of the recovered metal or chemical. Rather, the primary factor making such a central processing plant economically feasible is the cost to t he waste generator (monetary and on-going liability) for the disposal of waste.

Currently, there are two types of external recycling in the metal finishing industry. Some metal-bearing sludges (e.g., copper, nickel) are sent to smelters, who refine them along with other metal inputs. In a centralized facility, metal finishers segregate their waste and ship it to a facility where it is recycled and treated. in the mid-1980s, when new effluent standards were being promulgated for the metal finishing industry, several communities explored establishing centralized facilities before their metal finishing firms invested in expensive in-house treatment. However, a number of problems, perhaps most importantly an unwillingness by EPA and state regulators to support these projects in many cities,[1] has meant that only one such facility has been developed in the United States, in Minneapolis.[2] In contrast, there area number of such facilities in Japan and Europe.

While operating costs appear to be the same or slightly higher for firms that manage wastes internally versus those that use a centralized facility, the latter are able to avoid large capital expenditures for environmental equipment and instead use the capital for expanding or modernizing production equipment. In addition, they can rely on the centralized facility to professionally manage their wastes. This is especially critical for smaller shops that do not have (and cannot afford) the operation/regulatory expertise to effectively operate in-plant systems.

The economics of a centralized facility are such that it depends on fees for a significant share of revenues. Recovered chemicals and metals (e.g., copper, copper oxide, nickel carbonate) are generally a small share (1 O to 20 percent) of revenues. Recovery at such facilities is in many ways, analogous to recycling elements of municipal garbage. The feasibility of the effort depends in part on the marketability and price of the product produced. Some low value streams, such as those made of commingled metals, will not be economically recyclable, even on a very large scale, until sludge disposal rates increase significantly.



U.S. FILTER RECOVERY SERVICES, INC.

A waste recovery and treatment company places these ion exchange canisters in industries to remove waterborne hazardous wastes for further processing and recovery at its centralized facility.

[1] Stephen Basler, *Central Treatment and Recovery Facilities for the Metal Finishing Industry: A Five City Comparison,* (Chicago: Center for Neighborhood Technology, June 1989).

[2] The facility is a division of U.S. Filter Corporation, Inc., and is known as U.S. Filter Recovery Systems, Inc.

pollution and requires less pollution abatement spending than the production of virgin materials. For example, pollutants generated from secondary fiber pulping using recycled paper are quite low compared to conventional bleached kraft pulp production.[46] Third, in some cases wastes of one process can be used as inputs to another. For example, Dupont found a market in the pharmaceuticals and coating industry for hexamethyleneimine, a by-product of nylon manufacturing. The market is now so strong that in 1989, Dupont had to find a way to manufacture what had formerly been a waste. Dow Chemical recovers excess hydrochloric acid, which it either reuses or sells on the open market, making a profit of $20 million annually.[47] While these examples are not the norm, it is possible to design processes that accept the wastes from other processes as inputs and produce their wastes as inputs to other processes.

Even though there are many environmental and economic advantages to both in-plant and external recycling, the regulatory framework often gives little credit to recycling. Some advocates of source reduction argue that by providing firms with the option of external recycling, they will reduce their efforts at source reduction. It is not clear the extent to which this may be true. While source reduction should be the first option examined, there do appear to be cases where external recycling is in fact cheaper.

Some types of pollution cannot yet be prevented and must be treated or disposed of. Some prevention solutions may be relatively risky or unstable under different operating conditions. And some end-of-pipe (EOP) controls allow manufacturers more flexibility in production. As a result, there is always likely to be a need for EOP treatment and disposal of pollutants and wastes. Because of this, and because current EOP technologies are often expensive, advances in EOP technologies are still necessary, particularly for those that lower cost and improve performance (see ch. 10).

FACTORS LIMITING THE ADOPTION OF POLLUTION PREVENTION

To adopt pollution prevention options, firms must first find opportunities, identify solutions, and then authorize and implement them.[48] Because there can be impediments at each of these stages, there are a number of reasons why U.S. manufacturing firms have not made greater strides in pollution prevention[49] (see table 8-5). Not all firms will face the same impediments, which can differ by industry, firm size, and management practices.

Finding Opportunities

Pollution prevention is strongly influenced by the regulatory system. Regulation creates incentives by imposing a cost on polluting, which firms can possibly reduce through pollution prevention. Some regulations, such as the Toxic Release Inventory reporting requirements, focus public attention on emissions and provide an incentive for reduction, particularly the relatively easy-to-

46 Waste paper plants typically produce BOD in the range of 5-10 kg. per metric ton and no organochlorines, and use few chemicals as compared to typical bleached kraft mill, which produces 20 to 50 kg of BOD per metric ton and some organochlorines. (McCubbin, op. cit.)

47 Frosch and Gallapoulos, Op. cit.

48 Peter Cebon, ''Organizational Behavior as a Key Element in Waste Management Decision Making, *The Environmental Challenges of the 1990s* (Washington, DC: Environmental Protection Agency, 1990).

49 Many of the reasons are similar to those found for not implementing cost-efficient energy conservation measures in industry. See, for example, James R. Ross, "Energy Conservation in Sewn Products Plants," paper presented at the 1979 American Institute of Industrial Engineers annual conference; also Peter Cebon "High Performance Industrial Energy Conservation: A Case Study' Kurt Fischer and Johan Schot (eds.) *The Greening of Industry* (Washington DC: Island Press, 1993).

50 The recent changes in TRI reporting, where emissions are reported even if they are treated, will most likely push pollution prevention even more.

Table 8-5-Barriers to Pollution Prevention

Barrier	Decision process affected: Identify opportunities	Identify solutions	Implement solutions
Informational			
Lack of knowledge of wastes	x	—	—
Bias toward end-of-pipe (EOP)	x	—	—
Lack of knowledge of alternatives	—	x	—
Equipment vendors focused on EOP	—	x	—
Environmental managers focused on EOP	—	x	—
Organizational			
Environmental managers may not fully understand production processes	x	—	—
Individuals may not be rewarded for pollution prevention	x	x	—
Worker involvement may be limited	x	x	—
Buyer process specifications may hinder pollution prevention	—	—	x
Technological			
Appropriate technologies may not be available	—	x	—
Existing solutions may negatively affect process or product	—	x	—
Regulatory			
Firms have hands full with compliance	x	x	—
Regulatory definitions of waste limit efforts	—	—	x
Regulatory enforcement patterns may raise risks of trying innovative solutions	—	—	x
Regulations may require EOP solutions or mandate certain sources be controlled	—	—	x
Regulations provide few incentives for going below the standard	—	—	x
Accounting			
Firms may not measure solutions' costs/benefits	—	—	x
Firms may incorrectly measure costs/benefits	—	—	x
Financial practices			
Existing discretionary funds may go to EOP regulatory projects	—	—	x
Firms may not invest in all profitable projects	—	—	x
Corporate hurdle rates may be too high	—	—	x
Plant investment may not be fully amortized	—	—	x
Some industries may grow slowly with low investment rates	—	—	x

SOURCE: Office of Technology Assessment, 1993.

reduce emissions.[50] Similarly, Superfund liability provisions encourage firms to reduce, rather than treat, emissions.[51] However, incentives may not be directed at the most appropriate people or departments within a firm.[52]

Moreover, while the regulatory system as a whole provides an incentive for pollution prevention, certain aspects of the current system dampen this incentive, and in some cases provide a disincentive. An important barrier to pollution prevention is the single-media, command-and-control focus of the regulatory system.[53] The single-media statutory directives, rules, and reward systems for EPA personnel reinforce pollu-

51 However, it is important to note that pollution prevention options inspired by these provisions may not always be the most economically rational.

52 OTA, *Serious Reduction of Hazardous Waste,* op. cit., p. 5.

53 National Commission on the Environment, Choosing a *Sustainable Future* (Washington, DC: Island Press, 1993).

tion control efforts, and provide only token incentives for actively pursuing pollution prevention.[54] While EPA top management has promoted pollution prevention, translating this initiative into action by middle managers has proven more difficult. Moreover, EPA funding is geared toward end-of-pipe, not prevention, programs. Firms are often too busy responding to single-media or end-of-pipe regulatory requirements to devote much attention to prevention.

Many firms are unaware of pollution prevention opportunities or their relative merits over end-of-pipe solutions.[55] Small and medium-sized firms seldom analyze their wastes streams to identify prevention opportunities. Moreover, many firms lack the time and inclination to make their way through the complex regulatory maze in order to identify what is and isn't allowed.

Finding Solutions

In contrast to end-of-pipe treatment, which can be applied without specific operational knowledge of the production process, pollution prevention requires those with intimate understanding of the production process—line workers, managers, and engineers-to contribute their knowledge. However, responsibility for finding pollution prevention solutions may not rest with those most capable of doing so.[56] The tendency of organizations to allocate responsibility for pollution prevention to a few agents in the organization is a common source of many barriers. For example, most plant managers are rewarded for getting product out the door, not for reducing waste. As a result, they may oppose prevention solutions for fear they will divert resources from production projects. Production supervisors may fear that pollution prevention will negatively affect product quality or create interruptions. Engineers may see prevention as diverting them from more interesting and valued work. Production line workers may not be rewarded for initiating prevention solutions, and management may ignore solutions generated. Moreover, buyer specifications may require the use of certain processes, making shifts to pollution prevention difficult.[57] Most environmental managers have been trained in end-of-pipe practices and thus may overlook opportunities for prevention.

Organizational structures can also impede pollution prevention. Environmental management is often the responsibility of a separate department that is physically and strategically peripheral to the production organization. Cross-departmental communication may then be impeded by the physical isolation of the environmental personnel, or by their low status and authority .58

Even when all levels of the organization are involved, many firms, particularly small and medium-sized firms and relatively autonomous branch plants of large corporations, may either lack the knowledge of technical alternatives or not possess the engineering expertise needed to redesign processes. For example, a survey of Wisconsin hazardous waste generators found that insufficient information about how to reduce waste successfully was a significant barrier to

54 The National Advisory Council for Environmental Policy and Technology, *Transforming Environmental permitting and Compliance Policies to Promote Pollution Prevention* (Washington DC: U.S. Environmental Protection Agency, Office of the Administrator, February 1993), p. 25.

55 For example, see *Industry Survey 92: Barriers to Pollution Prevention* (Baton Rouge, LA: Louisiana Department Of Environmental Quality, 1992); also "Response to Questions for Top Hazardous Waste Generators and TRI Releasers" (Austin: Texas Water Commission, Task Force 21, Nov. 5, 1991).

56 For example, see Manik Roy, "Pollution Prevention, Organizational Culture, and Social Learning," *Environment/ Law*, vol. 22, No. 149.

57 For example, both military specifications from DoD, as well as specifications from large corporate buyers or sellers, can be inflexible.

58 Andrew King, " Cooperative Learning Between Pollution Control and Process Engineering Departments in tbe Printed Circuit Fabrication Industry, " op. cit.

further waste reduction.[59] Moreover, firms may doubt that pollution prevention opportunities or technologies exist.

To overcome this, some fins, particularly small and medium-sized ones, tend to rely on vendors or consultants for information about pollution prevention. Anecdotal evidence suggests that these may steer companies away from prevention in favor of more generic end-of-pipe equipment. This may in part be due to the fact that most environmental consulting, focuses on end-of-pipe treatment, while most environmental equipment vendors sell end-of-pipe equipment.[60]

Finally, many firms overlook sources of savings such as energy reduction and pollution prevention, reorientation of materials flow, reduced inventory, and improved quality, in favor of either increased output or direct cost reductions related to production.[61] This may be because they believe that their core production process is already efficient. While top level management might understand the importance of profit maximization, operating managers often emphasize output maximization, making it hard for them to give priority to pollution prevention investments when other matters occupy most of their attention. Investments in these cost-saving activities are often seen as tying up capital that could be used for other things, including expanding output. Moreover, because pollution prevention projects offer high levels of risk and low rewards for decisionmakers (if they succeed the process continues as usual, but if they fail the managers can get in trouble), managers will often not make the change.

As discussed in chapter 9, regulations require strict compliance with a standard and seldom provide firms with innovation waivers or tradable pollution allowances for implementing pollution prevention solutions that almost attain the standard. Moreover, because pollution prevention solutions, particularly those based on more complicated process redesign, can take a long time to develop, and because regulations often give firms short lead times to meet regulatory requirements, firms often invest in end-of-pipe.

Finally, some prevention solutions may be relatively risky, particularly with new projects. In addition, some end-of-pipe controls allow manufacturers more flexibility in production. For example, the Saturn automobile plant installed a state-of-the-art carbon adsorption unit, which gives them the ability to use many types of coatings on the car, including those with higher VOC content.

Authorizing and Implementing Solutions

Once managers identify and design pollution prevention solutions, firms must still authorize their implementation and provide resources. Top management commitment is important in implementing pollution prevention.[62] One reason why the chemical industry has more aggressively adopted pollution prevention practices is that top management has made it a priority. Likewise, studies have shown that when educated and provided with organization position and effective technology, environmental managers can be pow-

59 *Reducing Hazardous Waste In Wisconsin, Report V: Barriers and Incentives to Hazardous Waste Reduction* (Madison: Bureau of Research, Wisconsin Department of Natural Resources, August 1992).

60 "WC Firms Position For Prevention," *Environmental Business Journal,* vol. 6, No. 8, August 1993.

61 OTA, *Industrial Energy Efficiency,* op. cit. Also, B. William Riall, "Nontraditional Equipment Justification Methods and Their Applicability to the Apparel Industry," prepared for The U.S. Defense Logistics Agency, November, 1988.

62 "Preventing Pollution: Focus on Organization and Management," Technology, Business and Environment Program, MIT, September, 1991; also Robert Bringer and David Benforado, "Pollution Prevention as Corporate Policy: A Look at the 3M Experience," 1989, pp. 117-126.

erful advocates for pollution prevention.[63] Notwithstanding, there are still a number of impediments to implementing solutions.

REGULATORY BARRIERS

The characteristics of the current regulatory system may encourage companies to control pollution from specific sources (e.g., boilers) with end-of-pipe reference technology. As a result, firms may have little incentive to reduce pollution from other sources that might be less stringently regulated or to use pollution prevention to reduce releases below the regulatory standard. Moreover, because end-of-pipe controls are often the defacto standard, firms choose the path of least resistance and install these, rather than pursue prevention. While permit writers normally understand generic control technologies, they often do not adequately understand industrial processes and pollution prevention techniques.[64]

CAPITAL ACCOUNTING

Economic theory holds that managers of an enterprise will attempt to optimize production to maximize profits.[65] Wastes, as one of several cost factors, should be treated in a fashion in which marginal investments are made in pollution prevention until the point where marginal returns on investments in other areas are higher. However, others argue that in practice, projects yielding competitive paybacks are routinely ignored. There are several reasons postulated for this.

First, a large proportion of firms do not conduct discounted cash flow analysis on all investment projects, particularly for pollution prevention investments often seen as mandatory environmental projects that historically cost the firm money.[66] Another barrier is that many firms use simple payback measures, even though the former count against pollution prevention projects that normally have longer term benefits.[67]

Second, conventional discounted cash flow methods can underestimate the benefits of pollution prevention projects. These benefits can include reduced waste disposal costs, regulatory compliance costs, insurance and liability costs, and improved public image. One problem in demonstrating the cost advantage of pollution prevention investments is the inability of some fins' accounting practices to allocate end-of-pipe costs to specific product lines or processes. Moreover, firms can underestimate labor savings from pollution prevention.

There have been several efforts made to develop better accounting practices to credit for the full cost of pollution. Referred to as Total Cost Accounting (TCA), such methods attempt to include all costs including direct capital and operating costs, indirect or hidden costs (e.g.,

63 Andrew King, "Innovation From Differentiation: Environmental Departments and Innovation in the Printed Circuit Industry," in *International Product Development Management Conference on New Approaches to Development and Engineering (Brussels,* Belgium: EIASM, 1992).

64 Regulations from other agencies can hinder pollution prevention. For example, pharmaceutical firms must receive regulatory approval from the Food and Drug Administration to change their processes.

65 Adam B. Jaffe and Robert N. Stavins, "The Energy Paradox and the Diffusion of Conservation Technology,' (draft), Harvard University, unpublished manuscript, Feb. 12, 1993.

66 For example, 'Amoco's project evaluation approach has usually viewed environmental projects in the limited context of meeting specific regulatory requirements within a freed timeframe.' *Amoco-U.S. EPA Pollution Prevention Project, Yorktown, Virginia. Project Summary* (jointly published by Amoco Corp., Chicago, IL, and U.S. Environmental Protection Agency, Washington, DC: June 1992). See also Allen L. White, Monica Becker, and James Goldstein, *Alternative Approaches to the Financial Evaluation of Industrial Pollution Prevention Investments,* prepared for the New Jersey Department of Environmental Protection, Division of Science and Research, November 1991, p. 20.

67 Ross feud that for small energy conservation projects financial analysis is usually relatively simple and is supplemented by informal adjustments. The result is that for many firms only the most profitable small projects are undertaken. Marc Ross, "Energy-Conservation Investment Practices of Large Manufacturers," in *The Energy Industries in Transition, 1985-2000, Part 2,* edited by John P. Weyant and Dorothy B. Sheffield, Washington, DC: The International Association of Energy Economists, 1984.

compliance costs, insurance, on-site waste management, operation of pollution control equipment), future liability (penalties and fines and payments due to personal injury and property damage), and less tangible benefits (e.g., revenue from enhanced company image).[68] Some costs are difficult if not impossible to quantify, such as improved company image or reduced liability. However, excluding them completely from cost analysis unfairly disadvantages pollution prevention projects.

Case studies applying TCA suggest that in some cases, TCA analysis can improve the internal rate of return of pollution prevention projects to make them competitive with alternative investments. In addition, as an accounting method that leads firms to more accurately measure and assign costs and savings, TCA is consistent with other improved accounting methods, such as activity-based accounting[69] and full-cost accounting,[70] that have been advocated for helping firms make more rational decisions regarding investments generally.[71] However, preparing a TCA analysis can involve considerable effort, limiting its use to larger firms implementing projects with considerable costs and savings.

INVESTMENT PRACTICES

Even if firms accurately measure costs and benefits of pollution prevention investments, capital accounting practices and capital availability may limit the adoption of even profitable pollution prevention projects. Many small and medium-sized firms find it difficult to get financing for pollution prevention projects, in part because banks may not understand the projects and view them as not generating a cash flow. Many larger firms prefer to fund small capital projects (like pollution prevention) from retained earnings, in part to preserve credit ratings. Moreover, large firms often adopt capital rationing systems where divisions and plants are given limited amounts of capital for small projects, regardless of how many profitable projects they have.[72]

Even without capital rationing, small projects are commonly subject to more stringent hurdle rates. The result of both practices is that much less discretionary spending is undertaken than would be justified by conventional analysis. In such circumstances, waste reduction projects (characterized by a high number of small-scale investments) with rates of return higher than the corporate cost of capital may not be funded if other projects have even higher rates of return. Moreover, because waste reduction projects are optional and are often proposed by low-status environmental managers, they are more likely to lose out.[73]

This lack of assertiveness in investing in positive pollution prevention projects may be part of a larger pattern of lack of investment in a wider range of productivity-enhancing technologies. The problems in funding profitable pollution prevention (and energy conservation) projects may be symptomatic of deeper problems in U.S.

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68 White, Becker, and Goldstein, op. cit.; the Northeast Waste Management Officials' Association in conjunction with the Massachusetts Office of Technical Assistance have also developed a manual for TCA, *Costing and Financial Analysis of Pollution Prevention Projects.*

69 Robin Cooper, "Implementing an Activity-Based Cost System,' *Cost Management,* spring 1990, pp. 33-42.

70 Full cost accounting assigns all costs to specific processes or product lines. TCA is concerned with both this more accurate allocation of costs as well as the expansion of cost items beyond traditional concerns. (White, Becker, Goldstein, op. cit.)

71 For example, many argue that conventional accounting methods do a poor job of accurately measuring the savings from implementation of flexible automated production equipment. See R.H. Hayes and R. Jakumar, "Manufacturing Crisis: New Technologies, Obsolete Organizations,' *HarvardBusiness Review,* September-October 1988; also B. William Riall, op. cit.; also Robert A Howell and Stephen Soucy, *Factory 2000+ Management Accounting's Changing Role* (Montvale, NJ: National Association of Accountants, 1988).

72 Marc Ross, "Capital Budgeting Practices of Twelve Large Manufacturers, " *Financial Management,* winter 1986.

73 John Erhenfeld, ''Technology and The Environment: A Map or a Mobius Strip, " paper presented at the World Resources Institute Symposium, "Toward 2000: Environment Technology, and the New Century, " Annapolis, MD, June 13-15, 1990.

business financing that lead U.S. firms to underinvest in the assets and capabilities required for competitiveness (e.g., projects with moderate-term paybacks in energy, technology, training, and productivity) .74

SOCIAL BENEFITS

When firms do invest in pollution prevention, there is evidence that expected corporate rates of return eliminate some of projects that would be justified from a societal perspective because of the external costs of pollution. Ross estimates that if firms applied a longer time horizon to investments (a lower capital recovery rate of 16 percent, instead of the current rate of 33 percent) that energy conservation measures would result in consumption of approximately 20 percent less energy.[75] Similar pollution prevention projects also appear to be overlooked.[76] If this is true, the optimal investment practices of companies will not maximize societal welfare. High hurdle rates are often a hedge against high risk, yet pollution prevention investments often have low risks, possibly deserving lower hurdle rates.

INVESTMENT CYCLES

Finally, some firms and industries do not invest heavily. Some managers are more cautious, focused principally on survival; others aggressively seek out innovation and new investment. Some industries with mature markets and equipment and low profits (e.g., metal finishing) invest less in new facilities, so adding on new environmental equipment is harder. In addition, the recession has further diminished new investments in pollution prevention equipment.

One reason for slow implementation, particularly in the more capital-intensive process industries, is that many firms have large investments in fixed capital. Firms may wait until the capital equipment nears the end of its useful life (sometimes as long as 40 years) before investing in newer, cleaner processes. Moreover, in many industries most firms have invested in pollution control facilities. For example, virtually every metal finishing firm in the United States has a functioning wastewater discharge system.[77] In the absence of new regulations, equipment replacement, or addition of new production facilities, it often makes little sense for firms to invest in new pollution control equipment.

POLLUTION PREVENTION TECHNOLOGY DEVELOPMENT

Considerable gains in pollution prevention are possible through wider deployment of existing technology. Greater gains are possible through development of new technologies. These environmentally preferable process technologies exist or could be developed in all manufacturing sectors, and hence may be critical to U.S. manufacturing competitiveness in an environmentally constrained world.[78]

Only a small share of environmental R&D is for pollution prevention technology development. Of the estimated 1.7 billion dollars the Federal Government spent in 1992 on environmental technology R&D, less than 4 percent ($70

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74 Council on Competitiveness and Harvard Business School, *Capital Choices: Changing the Way America Invests in Industry* (Washington DC: Council on Competitiveness, June 1992).

75 For most government projects, OMB requires a real discount rate Of 10 percent, while EPA requires a real discount rate “5 percent ‘or evaluating projects under its jurisdiction. Steven R. Booth, Linda K. Trocki, and Laura Bowling (Los Alamos National Laboratory), “A Standard Methodology for Cost Effectiveness of New Environmental Technologies, ’ paper presented at the Hazardous Materials Management Conference and Exhibition Atlanta, Georgia, Oct. 2-4, 1991.

76 For example, in the Amoco oil refinery at Yorktown, Virginia, 2 of 11 pollution prevention projects had rates of return greaterthan 10 percent. (Amoco/U.S. EPA, op. cit.)

77 F.A. Steward, op. cit.

78 George Heaton, Robert Repetto, and Rodney Sobin, *Transforming Technology: An Agenda for Environmentally Sustainable Growth in the 21st Century* (Washington, DC: World Resources Institute, April 1991).

million) went to pollution prevention R&D. Academic research patterns are similar. A survey of 38 academic research organizations in the United States involved in hazardous waste management found that only 28 of 529 projects could be described as pollution prevention.[79] Moreover, little of the pollution prevention research focuses on the fundamental changes in manufacturing processes and methods that may be required to meet long-term goals for environmental improvement at lower cost.

Pollution prevention R&D needs tend to be poorly defined; if defined, they are only now being acted on. The chemical industry has made perhaps the greatest effort to identify R&D needs. The Center for Waste Reduction Technologies developed a list of R&D needs related to chemical process industries.[80] Extensive research will be necessary to fully exploit pollution prevention opportunities.

As the importance of in-plant measures increases, environmental R&D will need to be better integrated into the ongoing R&D of industrial materials and capital goods suppliers. In addition to helping U.S. manufacturers produce more cleanly and cheaply, this R&D can stimulate economic growth by making the capital goods sector more competitive internationally, selling ''green' machinery and equipment.

Two kinds of R&D will be needed to further pollution prevention technology. The first is more basic research, particularly into chemical processes and reactions.[81] The second need is for more applied research in new industrial processes in two areas: infrastructural or generic technologies, where industry tends to underinvest because no one company can appropriate the full economic benefits (e.g., environmentally benign cutting fluids); and strategic environmental R&D, where business risks and financial constraints combine to slow the development of technologies important to environmental performance and industrial competitiveness (e.g., direct steelmaking, effluent-free pulp mills). Public and private R&D on environmental technology, including pollution prevention, is discussed in chapter 10.

TECHNICAL ASSISTANCE FOR POLLUTION PREVENTION AND ENVIRONMENTAL COMPLIANCE

Widespread diffusion of existing off-the-shelf technologies and management and process technology changes will go a long way to reducing pollution. However, many firms, particularly small and medium-sized ones, are not aware of these measures.[82] Technical assistance can help these firms identify and implement pollution prevention measures. Yet existing programs are small. By focusing only on prevention, most programs fail to develop synergies and working relationships with manufacturers that could contribute to pollution prevention and increased manufacturing competitiveness.

Government Pollution Prevention Technical Assistance Programs

Most States and a few localities have programs that provide information and direct technical assistance to firms on how to reduce pollution, The Federal Government provides a small amount of funding and technical support to these programs.

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79 New York State Center for Hazardous Waste Management, *Research and Development in Hazardous Waste Management* (Buffalo, NY: State University of New York, 1990).

80 Energetic he., *Report on the CWRT Workshop on: Waste Reduction R&D Opportunities in Industry* (Washington, DC: U.S. Department of Energy, Office of Industrial Technologies, September 1991).

81 These areas include understanding the chemical reaction processes at the molecular level, including advances in reaction engineering, thermodynamic modeling, and particulate formation. Other important technological areas include catalysis and reaction path selectivity, particle technology, process synthesis, and recycle theory. (Allen, op. cit.)

82 OTA *Serious Reduction of Hazardous Waste*, op. cit., p. 33.

STATE AND LOCAL PROGRAMS

Nearly all States have programs to help industry prevent pollution.[83] In addition, a number of localities, including at least 10 in California, have established pollution prevention programs. Most programs offer a variety of services, including information and referrals on State and Federal regulations and pollution prevention opportunities, including case studies, reports, and journals. Many have developed waste reduction manuals for particular industries, such as metal finishing, printing, etc. Programs also conduct seminars, workshops, and mailings to inform industry of opportunities for waste reduction. Finally, most programs provide some technical assistance to industry, either through telephone consultation or on-site visits. The latter often takes the form of detailed waste audits to help firms identify pollution prevention opportunities. These audits are often conducted by full-time program staff, but many programs also employ part-time retired engineers to conduct audits.

EPA EFFORTS

EPA supports State and local technical assistance through the Pollution Prevention Incentives for the States program (funding of $8 million in fiscal year 1994). EPA provides a small amount of funding for three hazardous waste minimization assessment centers located at universities in Colorado, Tennessee, and Kentucky. EPA also maintains a clearinghouse. Finally, EPA's Risk Reduction Laboratory Pollution Prevention Research Branch publishes manuals, fact sheets, and waste audit guides. EPA also offers indirect assistance by providing some flexibility in media-specific State grants for pollution prevention work.[84]

Limitations of Current Efforts

These pollution prevention efforts, while helpful, have significant limitations.

SMALL SIZE

In comparison to the need, State and local pollution prevention programs are very small with the average State program having three to four fill-time staff.[85] (e.g., Los Angeles' pollution prevention program conducted 100 on-site technical assistance visits in 1991. At that rate it would take them 200 years to reach all of the county's approximately 20,000 manufacturers.) Given the magnitude of the problem and opportunity, these programs are too small to have an appreciable impact. Moreover, the lack of funds has meant an emphasis on technical assistance, with relatively little going to applied R&D and demonstration and testing projects.

One reason programs are understaffed is that few charge fees for services, in part because they fear that their services would not be utilized and that they would be seen as unfairly competing with private sector consultants. However, this first fear may stem more from the fact that most programs do not have a long-term relationship with the manufacturing community. Among those that do, such as the Cleveland Environmental Services Program (see box 8-C), manufacturers pay a share of the cost.

These programs get little government money, because they generally receive low priority in EPA national and regional offices, as well as States, in relation to enforcement and compliance

133 For more information on State programs see: U.S. EPA, *Pollution Prevention 1991: Progress on Reducing* Industrial Pollutants, October, 1991; Robert E. Deyle, *Hazardous Waste Management in Small Business: Regulating and Assisting the Smaller Generator* (Westport, CT: Greenwood Press, 1989); and John Hodges Copple, "Strengthening State Pollution Prevention Programs" Southern Growth Policies Board, January 1990.

84 Memorandum from F. Henry Habicht II, Deputy Administer, EPA, "State Grants Guidance: Integration of Pollution Prevention," Nov. 12, 1992.

85 Leslie Scott and Renee Shatos, "Waste Reduction Technical Assistance Study," Social and Economic Sciences Research Center, Washington State University, spring 1991.

Box 8-C-Pollution Prevention Integrated Into Existing Industrial Extension Programs

At least 28 States have established, sometimes with Federal assistance, programs to help small and medium-sized manufacturers modernize their production processes and adopt new technologies. As these programs have gained experience in serving the needs of manufacturers, many have begun to broaden the range of services they offer. Several programs, such as Tennessee's Center for Industrial Services and the Cleveland Advanced Manufacturing Program, help firms address environmental requirements, including pollution prevention.

The Center for Industrial Services (CIS), a part of the University of Tennessee, was established in the early 1960s to help firms solve technical problems related to manufacturing. In the mid-1980s, firms started asking the Center for help on addressing RCRA hazardous waste matters. The center now employs 13 full-time waste reduction staff (and 20 part-time retired engineers) in addition to its regular extension staff. Its pollution prevention program is integrated into the industrial extension program, and it hires staff with plant and process engineering backgrounds. The center's extension field agents are trained in pollution prevention so they can spot opportunities and refer firms to CIS's pollution prevention staff for further consultation, In 1992, the program claims to have saved Tennessee industry$12 million through pollution prevention.

The Environmental Services Program (ESP) is a division of the Cleveland Advanced Manufacturing Program (CAMP). The state of Ohio formed CAMP in 1984 as one of its nine Edison Technology Centers. The center, through three university affiliates, provides research, application, and training in new manufacturing technologies. In 1989, CAMP was awarded a grant from the National Institute of Standards and Technology to establish and operate the Great Lakes Manufacturing Technology Center (GLMTC), one of seven NIST-funded manufacturing technology centers. GLMTC helps manufacturing firms adopt modern technologies by providing in-depth, 1 to 5-day evaluations conducted by an experienced, technical staff of 20 individuals.

Through consultation with industry, the staff became aware that their client companies were finding compliance with environmental regulations a major problem. They came to believe that pollution prevention was a logical extension of the continuous improvement philosophy associated with the manufacturing modernization process, and that as a result, they would have a significant capacity to provide services in this area. Toward that end they formed ESP in 1990.

In some ways, the environmental program is indistinguishable from the manufacturing modernization program. Both have an assessment component with a distinct protocol. ESP conducts an initial audit of environmental compliance procedures, followed by a pollution prevention assessment with recommendations. If a firm wishes to adopt the recommendations, ESP can work with the firm on implementation, which may involve applied development work.

SOURCE: Office of Technology Assessment, 1993.

activities. When measured against the resources devoted to Superfund and hazardous waste issues, EPA efforts in pollution prevention are quite small and ad hoc. The statutory mission of EPA and State regulatory agencies is to implement national laws and as a result, these efforts receive higher priority.

LACK OF TRUST

Because many firms are inherently suspicious of working closely with regulators, the fact many State pollution prevention programs are housed in regulatory agencies means that these programs must devote much effort to convincing firms to trust them.[86] Since a key component of successful technical assistance is the establishment of trust between the service provider and the recipient, firms must feel confident that information they reveal will not be provided to regulators. Moreover, many of the programs focus on the process of pollution prevention, rather than on industry-specific technical processes and how pollution prevention fits into them.

REACTIVE POSTURE

Many programs provide assistance to any requesting firm, even facilities that emit little pollution. Moreover, programs often respond to a fro's definition of its problems, when a redefinition might be more realistic. For example, to reduce the use of CFC-based cleaning solvents, programs sometimes help firms find solvent substitutes rather than examine whether solvents are needed at all.[87] The opportunity to help firms expand their capacity to look at the production process in new ways thus may be lost.

LACK OF FOLLOW-UP

Most programs visit firms only once and provide little follow-up to help implement recommendations.[88] As a result, the success rate of these interventions is often low. In many state programs without extensive follow-up, only about one-third of the firms assisted make any changes after consultation.[89]

LACK OF COORDINATION

With so many Federal, State, and local pollution prevention activities, duplication of effort is a danger. Programs do not share specific information on a regular basis. In an effort to increase coordination, EPA developed its Pollution Prevention Information Clearinghouse. The Clearinghouse provides a substantial amount of information on federal, State, and local pollution prevention efforts. However, many State and local users complain that the information is overly general and out-of-date. EPA is aware of most of these criticisms and is trying to add technical case studies. However, even with these changes, passive electronic clearinghouses normally play a limited role in information dissemination and coordination.

INADEQUATE TARGETING

The majority of pollution comes from larger firms in the materials producing industries. Yet EPA and State programs have emphasized pollution prevention efforts for small and medium-sized firms in fabrication and assembly industries. The technical requirements of working with firms in materials industries (e.g., chemicals, steel) is much greater but State programs cannot gain this level of expertise easily. One reason for targeting small and medium-sized firms is the belief that large firms have the technical and financial resources to support pollution prevention efforts, while small and medium-sized firms do not. However, large fins, particularly in some branch plant operations, are not as strong in prevention as these programs may believe.

86 One survey of State pollution prevention programs reported that 10 of 11 programs indicated that they felt business was hesitant to seek assistance from them because of their location in a regulatory agency. Washington State University, op. cit. Similar comments have been reported about the OSHA consultation program, which often has difficulty working with firms since technical assistance providers working with the fii cannot guarantee that they will not report OSHA violations.

87 Robert B. Pojasek, ''Is Your Quest for Solvent Substitutes Preventing You From Evaluating Other Options,'' *Pollution Prevention Review* winter 1991/92.

88 Robert B. Pojasek and Lawrence J. Cali, "Contrasting Approaches to Pollution Prevention Auditing," *Pollution Prevention Review,* summer 1991.

89 For example, Rhode Island found that one-third of the firms it assisted made changes. Similarly, about One-third Of the firms assisted in the Blackstone Project in Massachusetts made changes. In Florida, about 40 percent of the firms made changes, Washington State University, op. cit., 1991.

FRAGMENTED SERVICES

In many States, more than one program provides pollution prevention technical assistance; some specialize in different kinds of waste (e.g., air, water, hazardous waste). EPA's own efforts contribute to this duplication, as evidenced by a recent EPA proposal to create a separate hazardous waste extension service. The new State technical assistance programs mandated in the Clean Air Act will add to the proliferation of assistance efforts by creating new programs aimed solely at air pollution, although some States are trying to avoid duplication of effort.

In addition to multiple pollution prevention programs, other government programs also aim to modernize production processes. In fact, at least three emerged before the interest in pollution prevention. In the 1970s, State and Federal Governments established programs to help manufacturers save energy, including adopting energy-efficient process technologies and modification of existing process and practices. In the absence of a visible energy crises, government funding for these programs declined, but funding by utilities has increased. In the mid-1980s, partly in response to the increased competitive threat to U.S. manufacturing, States and the Federal Government established programs to help manufacturers modernize their production processes. Some States also assist firms with training workers, especially when adopting new technologies or work practices. Funding for these programs is increasing. Finally, in the area of worker health and safety, OSHA funds State technical assistance programs to help manufacturers develop safer work practices.

Methods for providing technical assistance to small manufacturers for energy conservation, boosting productivity, improving safety and health, and reducing waste are similar.[90] All four activities focus on the manufacturing process. Much of the work involves convincing companies of the merit of change. Each area involves assessment, often usually using a standard protocol. The best approaches generate worker input and involvement, provide workforce training, focus on continuous improvement, and address both fundamental and incremental changes.

In spite of the considerable similarities in functions, these services are almost always provided by separate programs with little or no coordination.[91] These programs remain separate in large part because neither the various Federal Government departments nor the States think of them as part of an overall manufacturing strategy. Instead, they see each program as serving a specific government objective-+. g., energy conservation, environmental protection, or job retention.

This fragmented approach causes several problems. Separate programs make it hard for industry to turn to one source for technical assistance and makes it hard for programs to market their services to industry. Moreover, it becomes more difficult for programs to establish the *long-term* working relationships so important to instituting both pollution prevention and manufacturing modernization as a continuous process. Perhaps most importantly, single issue programs may fail to identify and promote cross-cutting solutions that promote more than one goal.

■ Pollution Prevention Built Into Comprehensive Industrial Service Organizations

Because of the similarity in process, and because of the significant advantages of combining industrial services in one organization, one

90 Kitty Weisman, David Harrison, and Alice Shorett, *Taming the Toxic Threat: Strategies To Reduce Hazardous Waste Generation in the Northwest* (Pacific Northwest Policy Center of the University of Washington, September 1990).

91 OTA interviewed several State pollution prevention officials who were not aware of manufacturing modernization technical assistance programs m their States, even though there was considerable similarity of function and potential for coordination. While many of the manufacturing modernization officials knew of the pollution prevention programs, none of them had contact with them.

TENNESSEE CENTER FOR INDUSTRIAL SERVICES

Waste minimization engineer from the University of Tennessee works with an equipment manufacturer's environmental coordinator and operator to reduce waste from a cleaning tank.

option for increasing the effectiveness of existing State pollution prevention programs would be to combine them with existing industry extension programs. These programs can have several advantages. First, many already have existing relationships with industry to help them solve technical and management problems. Second, this relationship can serve as the means by which other problems, including pollution prevention and environmental control, are addressed. Finally, these programs can bring firms together into cooperative networks to collectively solve environmental problems.

Sectoral and Industrial Network Approaches to Pollution Prevention

While industrial service organizations might provide pollution prevention services more effectively, most organizations still provide services to one firm at a time. Hence, meaningful ways of reaching out to more firms are still necessary. Several approaches can extend the range of these programs.

First, some programs have developed manufacturing net works to help firms cooperate in providing common services, such as training, joint bidding on contracts, joint purchasing, and common facilities and equipment. The area of pollution prevention is ideally suited for network cooperation. Firms in the same industry or same process can benefit from joint R&D, share solutions to reducing waste, and even exchange waste. A few networks have begun to address environmental problems. For example, Massachusetts' Center for Applied Technology convened a group of 6 firms involved in metal stamping, ranging from Gillette to a small firm with 20 employees, to examine the issue of lubricant replacement. Their goal is to identify a set of lubricants that optimize tool performance yet are environmentally preferable. Another example is the Pennsylvania Foundryman's network, which has developed a jointly owned corporation that runs a landfill for foundry sand contaminated with heavy metals, and is exploring pollution prevention solutions.

Firm networks can also be the basis of local industrial ecologies where the wastes of one firm become the inputs of another. In the United States this practice is facilitated by a number of formal waste exchanges. For example, the Northeast Waste Exchange in Syracuse, New York helps firms with wastes identify other firms that might want to use these wastes as useful inputs to their production process. However, while these programs are helpful, they essentially rely on passive information sharing-in a sense, waste want ads. More effective approaches are those that actively try to match fins. (See ch. 1 for a discussion of an innovative local waste network in Denmark.)

Second, there are economies of scale from focusing on the technological needs of firms in the same industry. Moreover, many of the technological issues in pollution prevention are unique to particular industries. As a result, sectorally based centers might provide a focus for pollution prevention.

These sectoral approaches are more common in Europe. For example, the Centro Ceramico in Bologna, Italy helps its members solve environmental problems. The Center is a research/ industrial services center funded by the 500 ceramics firms in the Bologna area that account of 70 percent of Italian ceramics production and 30 to 40 percent of the world market. The center conducts research aimed at quantifying the environmental impact of ceramic processes and to develop clean ceramic production technologies and technologies for sludge and residue reuse. In addition, the center works one-on-one with member firms to measure and reduce releases, solve individual plant problems, and help them come into compliance. It has developed close cooperative relationships with the local and national environmental regulatory agencies. The center also provides research and technical assistance to help firms reduce energy consumption, develop new materials and products, and put in place more efficient processes.

Most technical assistance in the United States is organized on a regional, rather than sectoral, basis. However, some sectorally based efforts may be emerging. For example, North Carolina State University Agricultural Extension program recently organized a meeting of the environmental managers of the major food processing firms in the nation to identify common problems and needs and discuss how a environmental food processing center could help solve them. There may be opportunities for such sectorally based centers are developed in a number of industries, including chemicals, lumber and wood processing, petroleum refining, pulp and paper, and steel.

Other Approaches to Technical Assistance

Even if existing government technical assistance programs are improved, other approaches to encourage adoption of pollution prevention practices will still be necessary. There are three major nonregulatory approaches: integrating technical assistance into the permitting and inspection process, using government procurement to stimulate pollution prevention, and encouraging private sector pollution prevention technical assistance efforts.

INTEGRATE TECHNICAL ASSISTANCE INTO THE PERMITTING AND INSPECTION PROCESS

State and Federal environmental permit writers and inspectors visit manufacturing plants routinely; some might be able to provide basic technical assistance. For example, the State of Maine is interested in having its inspectors promote pollution prevention and has approached EPA for guidance.

There are, however, several institutional barriers to this. First, in the past, some regulatory agencies, particularly EPA, have not actively supported combining enforcement and assistance roles. If State inspectors visited sites to provide technical assistance, EPA's formal policy was to not count these towards the inspection commitments made by the State in its EPA inspection grant.[92] In part this reflected EPA's traditional end-of-pipe, regulatory culture, which makes it difficult for them to move towards a more assistance-oriented role. However, recent guidance from EPA to the regional offices suggests that this policy may be changing.[93] Second, inspectors and permit writers may lack the expertise to provide technical assistance, although a number of State pollution prevention programs have begun to provide such training to regulatory staff. Still, some inspectors do not feel that they should even make referrals to technical assistance programs. Finally, even if permit writers and inspectors provide minimal levels of assistance, this will not take the place of the more in-depth assistance provide by extension programs.

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92 See for example, letter from Julie Belaga, Regional Administrator, EPA Region 1, to Dean C. Marriott, Commissioner, Maine Department of Environmental Protection, *Mar.* 18, 1992. However, EPA may be softening this policy,

93 Memorandum from Henry Habicht H, op. cit.

FEDERAL PROCUREMENT

Federal procurement, particularly by DoD, could encourage companies to undertake pollution prevention.[94] However, DoD procurement practices often discourage pollution prevention. For example, an increasing number of fins, such as Allied Signal, Hughes, IBM, and Motorola, are using no-clean soldering systems to produce commercial electronics products. These systems save considerable money in avoided cleaning and flux costs, reportedly have as good or superior performance, and reduce environmental releases. However, DoD has not formally recognized these methods as acceptable alternatives to resin-based soldering .[95]

Unlike commercial industry, typical DoD specification changes take 3 months for simple administrative alterations and up to 3 years for complex, technical changes.[96] There are large numbers of specifications that contain environmental implications, such as the approximately 9,500 military specifications that contain either references or requirements for use of ozone-depleting solvents.[97] Many firms use a program-by-program, piecemeal approach of either applying for waivers or changing specifications one at a time. However this is a very time-consuming, paperwork-intensive process, dependent in part on the technical capacity and motivation of the involved industry and DoD personnel. As a result, the need to modify military specifications for materials and processes to cope with changing environmental requirements serves as a bottleneck in promoting pollution prevention among military contractors and subcontractors.

Recent Executive Orders issued by President Clinton have the potential to enlarge the role of Federal procurement in energy efficiency and some areas of pollution prevention. One order directs agencies to revise their practices to reduce procurement of substances that deplete the stratospheric ozone layer. Another directs agencies do procure energy efficient computers.[98]

ENCOURAGE OTHER ORGANIZATIONS TO PROVIDE POLLUTION PREVENTION TECHNICAL ASSISTANCE

Some private sector organizations have an interest in helping firms prevent pollution. Encouraging these efforts can expand the scope of current pollution prevention efforts.

Electric Utility Efforts-Many public utilities have tried to boost local economic growth, often by trying to convince industry to move to their service area.[99] However, recently, a small number of utilities have begun to focus instead on improving the economic competitiveness of their existing manufacturing customers, usually by helping them save energy, but increasingly by helping them prevent pollution.[100] For example, Duke Power established an electro-manufacturing technology center, located at North Carolina State University, to help textile firms adopt cleaner technologies.

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94 U.S. Congress, Senate on Governmental Affairs, Subcommittee on Oversight of Government Management, *Hearings on Buying "Green": Federal Purchasing Practices and The Environment*, S. Hrg. 102-563, Nov. 8, 1991.

95 Mark Crawford, "pentagon Resists New Soldering Technology, " *New Technology Week*, Monday, Mar. 22, 1993, p. 7.

96 Karla M. Boyle, "Implementing Environmental Alternatives on Military Hardware, " Hughes Aircraft Co., Corporate Environmental Technology.

97 Ibid.

98 Executive Orders 12843 and 12845, respectively. *Weekly Compilation of Presidential Documents*, Monday, Apr. 26, 1993, pp. 638-643. President Clinton also signed an Executive Order encouraging procurement of alternative fueled vehicles or conversion of existing vehicles to alternative fuels, and announced plans for an executive order for procurement of recycled materials,

99 For example, eight public utilities actively try to recruit companies to move out of California. *Business Climate in Southern California* (Rosemead, CA: Southern California Edison, November 1991.)

100 Di_me De Vaul and Charles Bartsch, "How Utilities Can Revitalize Industry, " *Issues in Science and Technology*, spring 1993, pp. 50-56.

Southern California Edison fears that it could lose a significant component of its industrial rate base as firms either move or go out of business in response to the strict regulations. As a result, they developed the Customer Technology Applications Center (CTAC), which demonstrates new clean technologies and works with industry to solve technical problems, mostly with cleaner coatings technologies, such as ultraviolet curing, infrared curing, radio frequency and microwave drying, and powder coating. For example, Fender Guitar Company was having trouble meeting air quality standards for its coating process. CTAC came up with a new finish using a water-based coating with infrared drying that not only meets requirements but also has a significantly faster drying time and increases productivity.

Public Waste Collect ion, Treatment and Disposal Services-Publicly owned water treatment works (POTWs) receive and process sewage and wastewater. Under the Federal Clean Water Act, POTWs have authority to restrict industrial pollutants from the waste water they receive by establishing pretreatment programs. Through these programs, POTWs can require generators of waste water to reduce the toxicity of the water they send into the treatment plant. The 1,500 pretreatment POTWs, while representing only 10 percent of the total, treat 80 percent of the Nation's indirect industrial wastewater.[101]

POTWs often have significant contact with industry, and their wastewater inspectors often have extensive understanding of industrial process operations. As a result, they are well-positioned to promote pollution prevention.[102] For example, seven of North Carolina's POTW's provide technical assistance to industries as a routine part of compliance inspections. The Neuse River Waste Water Treatment Plant in Raleigh recommends, when possible, alternative compounds and processes that eliminate toxics discharges. Other POTWs, including those in Milwaukee, Austin, and Orange County, have also made significant efforts.

In spite of the potential for promoting pollution prevention, many pretreatment POTWs have not implemented aggressive pretreatment programs either because they do not know how, or because they don't want to impose requirements on local industry. Moreover, those that do restrict pollutants often encourage end-of-pipe treatment. In addition, beyond a small grant program to POTW's for source reduction initiatives, EPA does little to promote POTW pollution prevention activities. In fact, EPA management of the pretreatment program leads POTWs to focus on meeting narrow regulatory requirements that are sometimes not related to actual environmental performance, serving as a disincentive for them to aggressively and creatively pursue pollution prevention.[103]

Customer/Supplier Linkages-In the last 10 years some U.S. manufacturers have begun to form closer links with their suppliers to help them improve quality, lower cost and in a few cases prevent pollution.[104] For example, Motorola is now working with its suppliers to ensure that they eliminate the use of CFCs. The Big Three U.S. automakers, with several State and Canadian provincial governments, have established a program to reduce persistent toxic substances that are contaminating the Great Lakes; as part of this

101 "POTWs, Pretreatment, and pollution Prevention," unpublished paper, U.S. Environmental Protection Agency, June 1992.

102 National Advisory Council for Environmental Policy and Technology, State and Local Environment Committee, *Building State and Local Pollution Prevention Programs* (Washington, DC: U.S. Environmental Projection Agency, December 1992); also, Local Government Commission "Reducing Industrial Toxic Wastes and Discharges, The Role of POTWs,' Sacramento, CA, December 1988.

103 National Advisory Council for Environmental Policy and Technology, January 1992, op. cit.

104 Michael Robe rt Berube, *Integrating Environment Into Business Management: A Study of Supplier Relationships in the Computer Industry,* Master's Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, February 1992.

program they are encouraging their suppliers to meet the same goal through pollution prevention.

Trade Associations-Because of their close contact with industry, industrial trade associations have the potential to assist their members with pollution prevention. European trade associations have been more active in this area. For example, the Cologne (Germany) Chamber of Commerce advises its members on the selection of clean technologies and provides referrals to universities and private consultants to solve environmental problems.[105]

Most U.S. trade associations provide relatively little technical help to their members in solving environmental problems. A few trade associations have become interested in promoting pollution prevention, although they usually lack the staff or resources to do more than provide general information. For example, the National Association of Metal Finishers has distributed to its members a pollution prevention checklist developed by California for the plating industry, and is developing a pollution prevention handbook. The Chemical Manufacturers Association (CMA) created its Responsible Care initiative to help member companies improve performance in the areas of worker health and safety and environmental quality. The initiative includes specific codes of manufacturing practices in a number of areas, including pollution prevention. Each CMA member is required to make good faith efforts to implement the program elements.[106] The American Petroleum Institute has a similar effort for its members.

EPA is working more with trade associations to promote pollution prevention. For example, in conjunction with EPA, members of the Ecological and Toxicological Association of the Dyestuffs Manufacturing Industry developed a pollution prevention guidance manual for the dyestuffs industry which they distributed to their members. However, it is not yet common practice for EPA and the State pollution prevention programs to involve either trade associations or industry consultants.

FINANCIAL ASSISTANCE

Government financial support to industry for the cost of environmental compliance can lessen the competitive impact of environmental regulations. There are two principal possible sources of support, tax incentives (e.g., tax credits and accelerated depreciation) and direct financing (e.g., loans, loan guarantees, and grants).

However, there are possible tensions between financial assistance for polluters and the "polluter-pays principle. OECD adopted some conditions under which they are not incompatible. Financial assistance should be limited to: target groups where severe difficulties would occur otherwise; well-defined transitional periods; and situations where international trade is not distorted significantly.[107] Supporting development and diffusion of innovative equipment and clean technologies is not inconsistent with the polluter-pays principle.

As discussed in chapter 7, a number of other countries, including Germany and Japan, take the approach that if firms cannot pay the full costs of implementing needed environmental technologies, the government can legitimately help them through tax incentives, funding R&D, or direct subsidies. In the United States, however, Federal financing of pollution control equipment for private industry has diminished. A number of other countries offer more generous accelerated depreciation schemes. In addition, the limited

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105 Alan C. Williams, "A Study of Hazardous Waste Minimization in Europe: Public and Private Strategies to Reduce Production of Hazardous Waste," *Boston College Environmental Affairs Law Review,* vol. 14, winter 1987, p. 210.

106 See "Responsible Care: Small Chemical Companies Struggle to Meet the Program's Daunting Challenges," *Chemical and Engineering News*, Aug. 9, 1993, pp. 9-14.

107 Organization for Economic Co-operation and Development *OECD and the Environment* (Paris: 1986).

U.S. tax incentives favor end-of-pipe equipment over pollution prevention.

It is unclear the effect of government financing programs on environmental behavior. Because the limited U.S. support tends to be tied to environmental investments required by law, the effect appears to minimize financial hardship, rather than stimulate increased environmental investment. An OECD study suggests this maybe the case in many member nations.[108] However, OECD argues that while financial assistance for industry in complying with regulations is being reduced, financial support for clean technologies is likely to continue. While it is not clear that the Federal Government should do more in this area, its relative lack of support compared to some of our major industrial competitors could have a detrimental competitive impact, however small. Moreover, it appears that more could be done, without violating the polluter-pays principle.

Environmental Issues in Private Sector Lending

Many smaller enterprises lack the capital needed to invest in new environmentally sound technologies. Because pollution control loans are low collateralized loans, marginally profitable ventures may have difficulties in obtaining outside financing, or may face higher interest rates and shorter terms. Environmental issues may also hinder small and medium-sized firms in the United States in obtaining financing for any type of activity. A regulated firm subject to high environmental capital and operating costs can be a less attractive financing prospect than another firm not subject to these demands. More importantly, lender liability for environmental claims related to customers' property may reduce lending.

In particular, liability under "Superfund" may make lenders less willing to loan to companies with potentially contaminated sites.[109] While the original statute does exempt lenders,[110] courts have interpreted this narrowly, so that in some cases lenders can be liable for cleanup costs for companies to which they have made loans.111 While it appears that the actual extent of liability asserted against lenders has been insignificant,[112] the uncertainty of the exemption appears to be making lenders more conservative. This issue of lender liability may apply to other types of pollution covered by other statutes, such as RCRA and the Clean Water Act. If these concerns lead lenders to be more cautious in their financing of small and medium-sized manufacturers, either capital availability will suffer or interest rates will increase.113 In addition, firms may choose to not obtain loans if they have to fund expensive tests to determine if their site is contaminated. Either way, U.S. manufacturing competitiveness could be affected.

To address this uncertainty and resulting caution by the lending community, EPA issued a final rule interpreting the security interest exemption in April, 1992. However, this rule has been challenged and as of August, 1993 was still pending.

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108 Organization for Economic Co-Operation and Development, *Economic Instruments for Environmental Protection* (Paris: July, 1989).

109 These are provisions under the Comprehensive Environmental Response, Compensation, and Liabilities Act.

110 The exemption protects from habilit,apq"who, without participating in the management of a ., . facility, holds indicia of ownership primarily to protect [a] security interest in the . . . facility. " (42 U.S.C. 9601 (20)(A).

111 Ibid., pp. 54-55.

112 In the first 10 years of CERCLA's existence, EPA issued more than 18,000 notices to potentially responsible parties. Only 8 were sent to banks and EPA has recovered only $1.5 million in cleanup costs. (Ludwiszewski, p. 63),

113 John M. Campbell, Jr. "~n(jcrL1abi]ity for Environmental Cleanup: Effect on the Financial Services Industry' U.S. *Waste Management Policies: Impact on Economic Growth and Investment Strategies* (Washington, DC: American Council for Capital Formation, May 1992), pp. 45-61.