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1990 CEQ Annual Report: Chapter Three

Technology for Pollution Prevention

Outline

I. Introduction

America's environmental strategy is undergoing a dramatic transformation. While the National Environmental Policy Act (NEPA) set the goal 21 years ago of creating "a productive harmony" between humans and nature, the nation continues to struggle against pollution and seeks new ways to combat it. The most promising of these new approaches is pollution prevention.

In the early 1970s, the national government adopted a series of pollution control laws aimed at media-specific problems (air, water, land disposal) and a regulatory framework of specific goals, deadlines, and technological controls. Today, while the regulatory framework has accomplished significant pollution reductions, such "command-and-control" measures are often viewed as inadequate and needlessly expensive for each increment of improvement. In retrospect we know, relatively speaking, that the easiest and least costly objectives have been accomplished.

Continued progress requires a broader way of thinking about environmental policy, one which encompasses concerns about economic development and global competitiveness, technological innovation, and a wider variety of environmental risks. That new way of thinking is pollution prevention. Stated simply, pollution prevention means to reduce or eliminate the amount and toxicity of pollutants generated by society at their source. It contrasts with end-of-pipe treatment of wastes already generated.

The preventive concept is not new; on the contrary, a 1966 report of the House Subcommittee on Science, Research, and Development stated that "the concept of...maximum waste prevention in the first place, and salvage of used materials, is an objective which would decrease the need for cleaning up the environment later on."[1] Nonetheless, the Congress was eager to get on with environmental cleanup, and determined that "the obvious and obnoxious cases of pollution should be eliminated as soon as time and money required for construction of abatement facilities will permit."[2] It was toward that end that the current regulatory framework was built and large quantities of technology and management expertise were applied. Pollution prevention remains to this day a relatively new way of thinking for those accustomed to pollution control.

Regardless of which environmental strategy is employed, progress relies on effective use of the nation's managerial and technological resources. Fortunately, the technology for pollution prevention is not necessarily <u>new</u>. Likewise, the <u>systems approach</u>--a holistic, life-cycle approach to problems which defines the problem, establishes objectives, generates options, analyzes and selects solutions, and then continually assesses results--has been in use for decades. What <u>is</u> new in recent years is that such forces as economic competition, regulatory costs, and public concern, in concert with the systems approach, are driving institutional change toward pollution prevention strategies.

A. The Logic of Pollution Prevention

Pollution prevention places priority on source reduction in a "hierarchy" of options for addressing pollutant wastes: first, source reduction; second, recycling and reuse; third, treatment; and fourth, disposal.[3] All of these options are important; indeed, the current state of economic and environmental understanding supports using a mix of these pollution policy options. Nonetheless, source reduction remains the preferred approach for the protection of environmental quality for a variety of reasons:

- Individual pollutant controls do not always address cross-media impacts; for example, the sludge created by treatment of air or water pollution becomes a land disposal problem;
- Both "nonpoint" pollution sources, such as urban stormwater runoff, and small, dispersed point sources, such as commercial establishments, contribute a significant portion of society's harmful pollutants. However, such sources are difficult to regulate through traditional large-source emission standards;
- Pollution prevention embodies efficiency in resource and energy use and, therefore, in most cases offers a more cost-effective solution than direct regulation. This is particularly relevant at a time when economic competitiveness is a national priority and total pollution

control costs to businesses and public agencies have grown to $120 billion annually.

B. A Broad Look at Pollution

A broad definition of pollution encompasses both harm to the environment and economic waste:

> Pollution is the undesirable change in the physical, chemical or biological characteristics of our air, land, and water that may or will harmfully affect human life or that of other desirable species, our industrial processes, living conditions, or cultural assets; or that may or will waste or deteriorate our raw material resources.[4]

From the perspective of the producer in the total economic system, "a waste is a nonproductive stream of material or energy for which the cost of recovery, collection, and transport...to another use is greater than the value as an input."[5] For society, materials and energy become wastes when it is less costly to discard them into the environment than to put them to other uses. Such wastes are termed <u>residuals</u>.

The society at large does incur costs when residuals are discarded into the environment, although the market frequently does not reflect those costs or the value of reusing residuals. But improved methods of accounting for such costs (see Chapter Two, "Making the Environment Count") are beginning to redress the oversight. For example, regulations imposing pollution control costs on waste generators have created economic incentives to prevent pollution. Likewise, many producers now find they can increase production efficiency and achieve their economic selfinterest more effectively by reducing nonproductive residuals--in other words, by preventing pollution.

Table 3-1 identifies "residuals" from key sectors, while Figure 3-1 charts the flow of wastes in the total economic system. Although all contributors, particularly in the manufacturing sector where modern processes create hundreds of residuals, are not identified, the listings demonstrate the broad spectrum of wastes across society and illustrate the broad target for pollution prevention efforts.

TABLE 3-1, FIGURE 3-1

Some waste is virtually inescapable in the use of materials and energy, so from the ecological perspective, the choice of materials and technologies used in the economic system should attempt to minimize the quantity of residuals harmful to the life-sustaining elements of the natural environment. Indeed, the long-range goal should be to discard only the quantity and quality of residuals that can be sustained by the environment's natural self-cleansing capacity. Useful products can also become wastes over time as they wear out or are discarded, causing pollution problems identical to those of waste residuals.[6]

C. Scope of This Chapter

The 1989 Annual Report of the President's Council on Environmental Quality (published in June 1990) offered a national overview of pollution prevention efforts. The 1989 CEQ

Table 3-1. Partial List of Residuals Generated in the United States, Excluding Spills.

Mining: overburden, tailings, leachate, surface runoff, wind entrained particles

Agricultural operations: crop: sediment, pesticides, and nutrients in runoff, nitrogenous material and pesticides in leachate to ground water, wind-blown sediment, wind transported pesticides, volatilized pesticides, pesticide and fertilizer containers

Silvicultural operations: suspended sediment and pesticides in surface runoff, wind transported pesticides, slash

Transportation: CO, HC, NO_x, particulates, particles from tires deposited on ground surface, oil, liquids discharged from boats, salt/sand from snow "removal", tires, used oil, batteries, obsolete vehicles

Residential: white goods, bulky materials, septage, food wastes, yard wastes, Aluminum (cans, wrap), steel cans, glass, plastic (containers, wrap, trays, utensils), household batteries, UN, UCC, UMOP, junk mail, liquid residuals, CO, NO_x, SO_2, TSP, ash (depending on fuel and heating system)

Energy generation: CO, NO_x, SO_2, TSP, Ash (fly, bottom, scrubber sludge), water treatment chemicals, suspended solids, boiler and cooling system blowdown

Manufacturing: "priority pollutants" (liquid), BOD_5, TSS, Food wastes, yard wastes, metals, wood, UCC, UN, UMOP, glass, plastic, Aluminum cans, various solid wastes peculiar to manufacturing process/product combinations, e.g., carpet trimmings, cuttings from sheeting in manufacture of mobile homes, gaseous residuals from heating/air-conditioning/process steam/electricity generation, water treatment sludge, wastewater treatment sludge, scrubber sludge

Commercial: food wastes, yard wastes, glass, plastic, Al cans, UCC, UMOP, UN, bulky goods, gaseous residuals from heating/air-conditioning, liquid residuals such as BOD_5, TSS

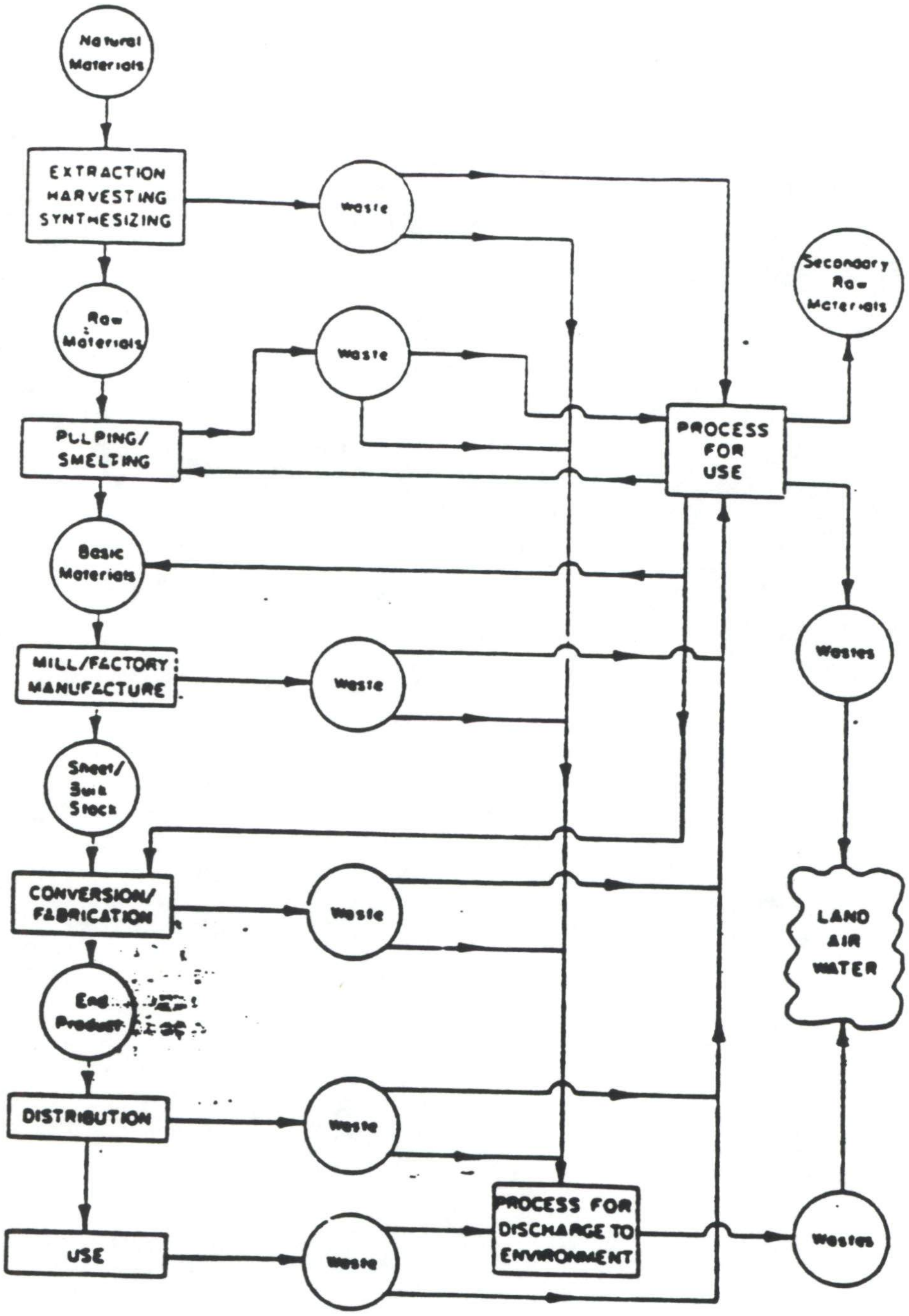
Institutional: same as commercial plus those peculiar to activities, e.g., infectious wastes from hospitals/nursing homes, low level radioactive materials from hospitals/ research labs

Municipal: street sweepings, sediment from debris basins, dead animals, grass clippings/brush and tree trimming from public parks/streets/public building areas, water treatment sludge, wastewater treatment sludge, septage

Construction: wood (lumber + tree segments), bricks, dirt, stamps, fixtures, metals, plastic, food wastes and food containers

Source: Bower, B.T., "Economic, engineering, and policy options for waste reduction," page 4 in Committee on Opportunities in Applied Environmental Research and Development of the National Research Council, Waste Reduction: Research Needs in Applied Social Sciences--A Workshop Report, (Washington, DC: National Academy Press, 1990).

Figure 3-1. Current Sources of Waste in the United States.



Source: Bower, page 2.

Report developed the concept in historical perspective as a long-underused supplement to pollution control. Further, the Report described prevention strategies in manufacturing, energy, transportation, agriculture, and households, and discussed nascent federal, state, and local programs designed to prevent pollution.

This year's Report updates the subject from a pragmatic perspective. Technology, defined as the application of science to specific objectives, especially industrial or commercial objectives, includes both hardware and organizational factors. Hence, "Technology for Pollution Prevention" explores the many ways that scientists, engineers, federal policymakers, and corporate managers are applying new methods and hardware to integrate environmental objectives into their traditional missions. Conceptually, pollution prevention technology is all technology, designed and operated to "make the environment count" in the design and operation of complex production systems. And since technology includes methods as well as equipment, this study emphasizes the systems approach taken by managers who prevent pollution.

For purposes of limiting this study to manageable scope and examining areas of greatest current activity, this chapter focuses on industrial activities in the private and public sectors. The private sector section is primarily concerned with pollution prevention in manufacturing and electric power production. The public sector discussion focuses on two federal agencies with substantial industrial activities: the Departments of Energy and Defense, as well as prevention initiatives of the U.S. Environmental Protection Agency (EPA) and other federal agencies. There is also a broad-ranging discussion of programs in other institutional settings -- legislatures, state agencies, and academia.

In addition to the 1989 CEQ Report and numerous works cited throughout this chapter, the reader may also wish to consult the U.S. Environmental Protection Agency's Pollution Prevention Strategy, released in January 1991, which discusses the prevention concept in several broad social sectors:[7]

- Manufacturing and Chemicals (including changes in production processes, raw material inputs, and outputs);
- Agriculture (including low-input farming methods and soil conservation); and,
- Energy and Transportation (increasing efficiency in production and end-use, and increasing reliance on inherently "clean" energy sources).

The EPA document also provides direction within the Agency to reorient existing programs, and targets specific chemicals from the manufacturing sector for prevention strategies, with a goal of reducing national emissions 33 percent by the end of 1992, and at least 50 percent by the end of 1995.

II. Technology Update

As this section looks broadly across technology developments, three major themes emerge:

- **Current focus: industrial toxics.** Although the opportunities for pollution prevention range across many economic sectors, current efforts are particularly focused on toxic industrial wastes, those substances defined as extremely hazardous under government regulations.
- **Energy efficiency.** Energy is a major component of the economy, and there is a correlation between the efficiency with which the nation uses energy and energy-related pollution. In short, to improve energy efficiency is to prevent pollution. Although the nation's energy efficiency has already improved by about a third since 1973, spurred by energy price changes and use of new technologies,[8] efficiency gains to date are less than what is achievable.
- **Systemic approach.** Pollution prevention technology must be employed as part of a systemic approach which focuses not just on the parts but on the workings of an internally consistent whole. The systems mindset also recognizes the challenge of global economic competitiveness, and of incorporating both existing and emerging technologies. In the energy sector, a particularly important aspect of the systems outlook is utility emphasis on energy efficiency as a management strategy.

A. Measuring the Problem: the Toxics Release Inventory (TRI)

As already noted, while the nation's many pollution problems can be addressed by prevention efforts, much of the emphasis to date has been reduction of industrial toxics. Currently, the best information on this subject is the Toxics Release Inventory (TRI), published by EPA. Title III of the 1986 Superfund Amendments, also known as "The Emergency Planning and Community Right-to-Know Act," requires the inventory. In 1990, EPA published the TRI for the second time, covering 1988 releases of all manufacturing facilities in the United States that produced imported, or processed 50,000 pounds or more of any of 302 individual toxic chemicals and 20 categories of chemicals listed for reporting by EPA, or used in any other manner 10,000 pounds or more of these 322 TRI individual or categories of chemicals. Such chemicals vary widely in toxicity and in the frequency, amounts, and industrial processes in which they are used.[9]

Table 3-2 and the accompanying Figure 3-2 present toxic releases by industry and by discharge medium. Nearly 20,000 facilities reported over six billion pounds of chemical wastes released to the environment or transferred off-site.

TABLE 3-2 ,FIGURE 3-2

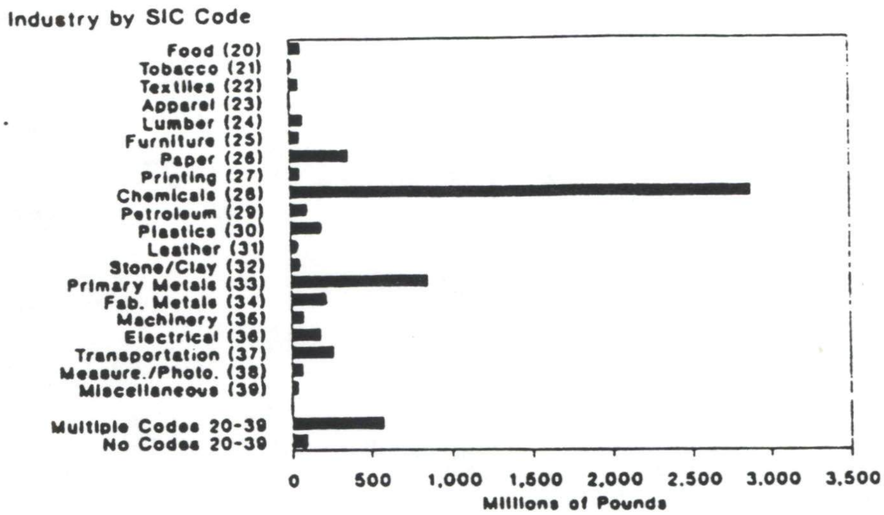
The TRI continues to evolve as an important indicator of waste generation. It is cited frequently as a focus for pollution prevention efforts. TRI data includes releases to all

Table 3-2. Toxics Release Inventory (TRI) Facilities and Forms, by Industry, 1988.

TRI TOTAL RANK	INDUSTRY	SIC CODE	FACILITIES	FORMS	AIR	SURFACE WATER	LAND	UNDERGROUND	PUBLIC SEWAGE	OFF-SITE TOTAL	TOTAL RELEASES AND TRANSFERS	
			Number	Number	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Percent
11	Food	20	1,452	2,649	13,716,106	3,633,426	12,454,502	1,017,909	39,117,332	2,962,616	72,901,891	1.17
21	Tobacco	21	19	62	13,820,462	118,812	14,751	0	791,940	312,982	15,058,947	0.24
15	Textiles	22	401	890	35,617,602	4,693,758	191,896	0	15,274,101	3,547,714	59,325,071	0.95
22	Apparel	23	29	49	1,019,201	250	40,599	0	692,897	166,748	1,919,695	0.03
19	Lumber	24	616	1,719	27,813,245	101,014	198,009	0	952,592	4,303,183	33,368,043	0.53
13	Furniture	25	397	1,556	56,894,704	1,850	56,511	0	390,551	5,451,673	62,795,289	1.01
4	Paper	26	587	2,328	202,210,446	86,518,400	9,925,423	0	39,743,943	31,944,839	370,343,051	5.93
14	Printing	27	313	623	50,423,807	35,150	316	40,000	3,460,704	6,581,949	60,541,926	0.97
1	Chemicals	28	3,838	20,332	754,922,471	228,105,753	164,564,318	973,706,836	323,874,071	438,305,845	2,883,479,294	46.20
9	Petroleum	29	364	3,053	54,989,933	3,471,886	3,153,767	19,846,879	13,060,813	9,713,429	104,236,707	1.67
7	Plastics	30	1,293	3,213	158,832,600	733,598	155,662	3,004	4,957,837	24,443,360	189,126,061	3.03
17	Leather	31	132	372	14,255,347	680,505	353,215	0	20,340,615	2,176,552	37,806,234	0.61
16	Stone/Clay	32	559	1,315	23,283,963	874,242	2,029,808	6,580,250	1,294,091	21,120,356	55,182,710	0.88
2	Primary Metals	33	1,380	5,446	232,958,571	18,987,700	277,003,090	41,020,432	19,088,232	268,808,482	857,866,507	13.75
6	Fabricated Metals	34	2,579	7,860	117,524,318	1,518,379	4,742,417	286,120	18,342,883	72,698,383	215,112,500	3.45
10	Machinery	35	870	2,315	51,754,691	548,021	257,368	52,800	2,993,295	19,725,887	75,332,062	1.21
8	Electrical	36	1,578	5,047	115,198,789	714,367	1,454,389	43,720	18,711,626	46,261,903	182,384,794	2.92
5	Transportation	37	1,054	4,447	201,297,144	331,889	1,256,795	21,384	7,502,020	50,770,863	261,180,095	4.18
12	Measure./Photo.	38	344	1,000	45,076,520	685,863	490,993	250	5,415,110	12,698,912	64,367,648	1.03
8	Miscellaneous	39	372	946	26,171,054	54,173	304,149	0	452,222	9,061,758	36,043,356	0.58
3	Mult. codes 20-39		1,303	5,133	217,850,529	8,547,184	80,320,516	172,724,324	30,813,971	69,259,997	579,516,521	9.29
20	No codes 20-39		282	776	11,938,600	1,238,018	2,588,388	0	3,280,462	4,096,876	23,142,344	0.37
	TOTAL		19,762	71,131	2,427,570,103	361,594,238	561,556,882	1,215,343,908	570,551,308	1,104,414,307	6,241,030,746	100.00

Source: U.S. Environmental Protection Agency, Toxics in the Community, (Washington, DC: U.S. Government Printing Office, September 1990), Pages 56-57.

Figure 3-2. Toxics Release Inventory (TRI) Releases and Transfers, 1988.



Source: EPA, Toxics in the Community, page 146.

environmental media -- air, water, and land -- in contrast to most previous single-media data collection efforts, and it was designed from the outset to be publicly accessible by computer modem.

However, the TRI has limitations. It describes only the emissions of manufacturers, which are a fraction of the total emissions of a broad range of small, dispersed sources such as motor vehicles, solid waste facilities, and small businesses which use solvents, paints and chemicals, or pesticides. It describes only toxic emissions, which are a fraction of the broader pollution problem summarized in Table 3-1. The TRI is limited to those toxic chemicals listed by EPA. Perhaps most significantly, the TRI shows emissions or transfers after treatment, rather than the pollution generation data needed for prevention analysis. On the 1988 inventory form, only 10 percent of the respondents completed a voluntary section requesting data on waste minimization.[10] This statistic led Congress to make reporting on waste minimization mandatory in the future under the Pollution Prevention Act of 1990. Such additional data will help refine the nation's evolving effort to prevent industrial toxics pollution.

B. The Role of Corporate Management

Industrial pollution prevention technology must be integrated into a system that includes the organization, operating procedures, and investment dollars. Corporate management plays the key role in development of such a comprehensive program that reaches all levels of a company. The most successful organizations at preventing pollution and minimizing waste overall are those that employ multi-faceted programs with the following elements:[11]

- A formal commitment by management to the pollution prevention ethic, translated by management and employees into a company-wide commitment in all divisions of the organization;
- Explicit program scope and goals;
- Accurate waste and cost accounting to assess costs, benefits and programs (see Chapter 2);
- Periodic pollution prevention opportunity assessments to identify opportunities for improvement and to evaluate progress;
- Periodic self-evaluation that keeps programs on track; and
- Sharing technical information and experience with affiliates, customers, and suppliers, including educational workshops and training materials.

The following company examples are among many that illustrate elements of the comprehensive systems approach for pollution prevention. They also demonstrate the entire hierarchy of options: source reduction, recycling, treatment and disposal as appropriate. Although these programs all represent integrated approaches, each one highlights specific aspects of the essential elements just outlined (accurate waste and cost accounting methods have already been discussed in Chapter 2, and therefore are not repeated here).

Case Study:

Company-wide Commitment Involves the Employees: The 3M Company

Commitment of top management is essential, but so is that of the entire workforce. Effective managers educate not only themselves but also their employees on environmental risks to the community, and they develop a two-way dialogue concerning ideas and progress toward reducing pollution. The 3M Company established a comprehensive Pollution Prevention Pays (3P) program in 1975 to minimize pollution at the source.[12] The program is directed at the company's 5,000 technical employees who are responsible for product formulation, process, design, manufacturing operations, and recycling. The company's employees were asked to implement pollution prevention concepts in the daily activities of their specialty areas and then submit worthwhile accomplishments to the 3P coordinating committee for review. Their efforts are judged for environmental benefit, cost savings, and technical achievement. Superior efforts are recognized in presentations by senior management before fellow employees, awards, and often in private dinners. Such recognition raises employee enthusiasm and participation.

Since 1975, 3M has recognized more than 2,400 3P projects, resulting in cost savings of more than $480 million. The projects have eliminated more than 120,000 tons of air pollutants, 16,000 tons of water pollutants, and 400,000 tons of sludge, including the prevention of 1.6 billion gallons of wastewater.

Case Study:

Company-wide Commitment Across Activities: Dow Chemical Company

Dow Chemical Company, a diversified worldwide manufacturer of more than 2000 products, must have an equally diverse and comprehensive approach to the environment. Dow spent $860 million in the most recent five-year period on environmental, health, and safety improvements. The pollution policy hierarchy is stressed, with pollution prevention the first priority. U.S. operations are conducted under a program called WRAP--Waste Reduction Always Pays.

Dow continues to reduce water emissions by recycling wastewater, developing more efficient water treatment technologies and upgrading spill prevention and containment systems. The company also has reduced total air emissions from its U.S. plants by more than 50 percent since 1985. Direct savings are an additional payoff for pollution prevention. For example, Dow invested $12 million in 47 waste reduction projects in Louisiana in 1988 and 1989; on average they paid for themselves in just 10 months.[13]

The approach extends to other activities. A new chemical plant in Taiwan has been designed for zero process wastewater discharge. Among a range of recycling initiatives, Dow has formed, with seven other manufacturers, the National Polystyrene Recycling Company with a goal of recycling 25 percent - or 250 million pounds - of the polystyrene used in food service and packaging applications in the United States every year. In energy, Dow is the world's largest producer of cogenerated power and claims efficiency of 20 percent greater than conventional fossil fuel plants. Citing waste reduction and top-down commitment to environmental protection, the World Environment Center awarded Dow its 1989 Gold Medal for International Corporate Environmental Achievement.

Case Study:

Explicit Program Scope and Goals: Chevron

Chevron's Save Money and Reduce Toxics (SMART) program, established in 1987, encourages each division to set goals and develop a plan tailored to its individual problems, with an overall goal of 65 percent toxics reduction by 1992. Managers are evaluated on their ability to meet environmental goals. In SMART's first year, hazardous waste disposal was reduced from 135,000 to 76,000 tons, and the company's waste disposal bill dropped almost $4 million.[14]

Case Study:

Pollution Prevention Opportunity Assessment: AMOCO

The first action in determining the technology needed for pollution prevention is to define the problem by performing a pollution prevention assessment. Basic steps include planning the effort, assessing, evaluating results, and implementing the selected options.[15] Such an effort develops detailed knowledge of the system under examination and generates the opportunities for change to prevent pollution.

In 1989, the American Motor Oil Company (AMOCO) proposed a joint project with EPA to study their Yorktown, Virginia, refinery, which began operations in 1956 and has a capacity of 53,000 barrels per day. The joint project attempts to properly inventory emissions, develop prevention options, rank options, and determine impediments to their implementation. AMOCO contributes 70 percent of the $1.8 million budget, with EPA contributing the remainder. Almost one-half of the costs are for data collection.[16] In addition to studying the facility's options, EPA's objective was to assess the feasibility of integrated permits using a cross-media approach.[17]

Designing a comprehensive and accurate emission data measuring system was a technical challenge in a plant not designed to facilitate such assessment. As one AMOCO official associated with the project said, "Pollution prevention is not for the merely enthusiastic."[18] The assessment required air emission modeling with appropriate site sampling to validate model predictions, 19 surface water sampling locations, an extensive network of groundwater wells, 33 solid waste sampling locations, and a survey of public perceptions. Included in the challenge was integrating new sampling technologies with those in place. Throughout the project, the team hopes to track pollutants through the various media and develop true cross-media pollution prevention options, including a procedure for cross-media permitting.[19]

Case Study:

Self-appraisal: Monsanto

The comprehensive waste reduction program initiated by Monsanto in 1982 had achieved 50 percent reductions by 1987. A self-evaluation made in 1988, however, found that achievements were increasingly the result of "down-sizing," the termination or sale of businesses. Aware that this trend would not continue, the company developed a new effort to focus on multi-media emissions. The programs that emerged are intended to reduce hazardous air emissions 90 percent by 1992, and non-hazardous chemicals by 50 to 70 percent over a five-to-eight year time frame.[20]

Case Study:

Technology Transfer: AT&T and the Boeing Company

Sharing knowledge and experience are key to establishing consistent pollution prevention programs in industries across the nation. AT&T's multi-faceted environmental program includes not only employee education and on-site recycling but also program assistance to other industries. Hundreds of companies have sought AT&T's assistance in setting up their own programs.[21] The Boeing Company has an Office of Environmental Affairs which, among other things, arranges technology transfer among companies.

The communication between Boeing divisions, other aerospace companies, and outside interests are an element of the company's success in guiding its own waste minimization program toward fewer hazardous wastes.[22]

Case Study:

Promoting a Wider Commitment: Chemical Manufacturers Association

An increasing number of associations are moving in support of pollution prevention, setting goals and sharing information among their memberships. In 1990, Chemical Manufacturers Association (CMA) adopted a mandatory membership requirement to abide by ten guiding principles for "Responsible Care." Members must adopt a waste management hierarchy that gives priority to source reduction, recycle/reuse second, and treatment last. CMA has also instituted mandatory reporting by member companies of their progress in waste minimization.[23] The association publishes a Waste Minimization Resource Manual which provides guidance on starting and maintaining a waste minimization program, describes how economic incentives work, and outlines other aspects of the program such as tracking and measuring progress. CMA also publishes a newsletter to update members on advances in waste minimization within the chemical industry.

C. The Production Process -- Generic Pollution Prevention Techniques

American industry is a mosaic of thousands of products and production processes. Economic life reflects the decentralized free enterprise system. It follows logically that technical progress toward pollution prevention is also decentralized, is driven by economic considerations, and is frequently specific to one of thousands of different industrial processes. If some generalization is possible, however, it is to characterize current technology directed toward pollution prevention as employing conventional engineering approaches. In fact, it is to be expected that as priority shifts to prevention from treatment and control, engineers will first employ off-the-shelf technology to achieve their objectives. In future years, it would also be expected that designs would become more innovative as research and talent focus on the challenge at hand.

Industrial pollution prevention techniques can be understood by observing the path of material as it passes through an industrial site.[24] Even before materials arrival on site, important decisions can be made to avoid toxic materials when less toxic substitutes exist. When material arrives at a facility, it is handled and stored prior to use; material may also be stored during stages of the production process. At this point, the objective is to prevent spillage, evaporation from containers or conduits, or shelf-life expirations. Better technology might consist of tighter inventory practices, seal-less pumps, welded rather than flanged joints, bellows seal valves, floating roofs on storage tanks, and rolling covers versus hinged covers on openings. These techniques are not exotic, but could run into large replacement costs if a company has many locations where leakage can occur. Conversely, they could provide large economic benefits by reducing the loss of valuable materials.

At the next stage, materials are processed, frequently in the presence of heat, pressure, and/or catalysts, to form products. As materials are reacted, combined, shaped, painted, plated, and polished, excess materials not required for subsequent stages become waste, frequently in combination with toxic solvents used to cleanse the excess from the product. The company disposes of these wastes either by recycling them into productive reuse or by discharging them into the air, water or land. Often costly treatment is required to reduce the toxicity or pollutant impact of the waste discharge before final disposal. These liquid, solid or gaseous residues at each stage of the processes are the source of toxic waste problems. Pollution can be prevented in many ways specific to particular processes, but the following general fixes are applicable to many operations:

- **Process controls.** The precision of temperature and pressure applications as materials are reacted and handled can significantly alter the formation of toxics. Improvements may include: better control mechanisms to meter materials into mixtures; better sensors to measure reactions; more precise methods of applying heat such as lasers; and computer assists to automate the activity.

- **Cleaning processes.** The necessity of cleaning parts, equipment, and storage containers is a significant source of contamination. Toxic deposits are common on equipment walls. The use of solvents to remove such contamination creates two problems: disposal or the contaminants and emissions from the cleaning process itself. Some technical fixes include the use of water-based cleansers versus toxic solvents, non-stick liners on equipment walls, nitrogen blankets to inhibit oxidation-induced corrosion, and such solvent minimizing techniques as high pressure nozzles for water rinse-out. In-plant reclamation of the wastes is facilitated by segregation of dilute and highly contaminated waste streams and by separation techniques such as distillation, membranes, evaporation, filtration, and centrifugation which convert mixed wastes back to their constituent parts.
- **Chemical catalysts.** Catalysts facilitate chemical reactions and are a fruitful area of pollution prevention research. Better catalysts and better ways to replenish or recycle them would induce more complete reactions and less waste. Substitution of feedstock materials that better interact with existing catalysts can accomplish the same objective.
- **Coating and painting.** For this common source of toxic waste, technical improvements include better spray equipment

such as electrostatic systems and robots. There are frequently alternatives to solvents for stripping coats in preparation for new coats; for example, abrasive means such as bead blasting.

- **Segregating and separating wastes.** A drop of sewage in a bowl of soup produces a bowl of pollution in the mind of the diner. Keeping wastes and non-wastes segregated reduces the quantity of waste that must be handled. A number of technical fixes provide more precise and reliable separation of materials unavoidably mixed together in a waste stream by taking advantage of different characteristics of materials, such as boiling or freezing points, density, and solubility. Simple in principle, these processes become high-tech in the precision with which they are applied to facilitate other important options in the hierarchy such as recycling, treatment and disposal.
- **Support activities.** Garages, motor pools, powerhouses, boilers, and laboratories -- all have wastes which must not be overlooked. The techniques to prevent these wastes include those already described, as well as others.

One addition must be made to the above discussion of processes, which did not address materials and product substitution in any detail. The issues involved in substitution are complex and include economics and social preferences as much as technology. Obviously the use of less toxic materials in products is a superior way to prevent pollution that can be comprehensively implemented in a decentralized society. Science and engineering are actively engaged in both the evaluation and measurement of material toxicity, as well as in development of materials and safe disposal techniques. Likewise, the life-cycle approach dictates that products be designed from the raw material stage to final disposal. Some companies are attempting this; an example is the on-going changes in fast food packaging materials with the ensuing technical debate over the environmentally best substitutes for existing packaging. The substantial progress in reducing lead as an air pollutant with the phasing out of lead in gasoline is another successful example.

In summary, manufacturing pollution prevention technology is a combination of efficient operational procedures, product designs that use input materials with minimum waste (and preferably, which create no toxic byproducts), and technical processes that are precisely sensed, monitored, and controlled. Much of the technology to prevent pollution is available now, and frequently it is relatively simple. Among current techniques, those associated with solvent control and coating/painting are the winners for sheer quantity of actions underway. Large savings accrue when capital investments are made, but smaller process and maintenance actions can add significantly to overall savings. Additionally, although the examples above are couched in terms of large facilities, many apply equally to small businesses as well. The challenges of outfitting the smaller businesses are largely those of education of proprietors to technical opportunities and also those of financing first costs, rather than of technology availability.

D. Research Needs

Although there are innumerable research and development possibilities that are specific to individual industries and proprietary processes, it is possible to conceptualize some generic research needs for pollution prevention.[25] A sample provided next complements the foregoing discussion of existing processes.

- **Understanding Key Chemicals.** Research should address the characteristics of key industrial chemicals that also are toxic - to better understand their mechanism for accomplishing their intended purpose and thus to facilitate their replacement with less toxic substitutes. Examples include: understanding chlorofluorocarbons that are superior cleaning agents on silicon and other electronic surfaces as well as organic solvents which are superior cleansers in general; understanding chemical and biological fouling and other surface phenomena in general, which cause cleaning needs in equipment; understanding reaction chains that yield unreacted elements, for example monomers in polymer production processes, or processes which yield undesirable intermediate products such as dioxin; and understanding processing aids such as surface chemicals or lubricants.

- **Revising Product and Process Design to Emphasize Waste Minimization.** This research area examines changing design criteria to minimize waste streams. For example, painting processes could be more efficient; metal bonding and composite processes could be better understood; transfer of dyes to fabrics uses an excessive amount of inorganic salt; the fiber lay-down process in converting fiber from wood to paper is very inefficient; and the role of diluents - air, water and other fluids in processes need study as they are a primary impediment to recovery of materials. Containers and parts design could be examined to reduce residue buildup.
- **Recycling.** Design for recovery of the product. Research aims at the opportunities. Primary manufactured goods could be designed with easily separable components to facilitate recovery; plastics in general are a promising recycling target; filter and exchange media, an example of products made to protect the environment, should be recoverable; and biological processes may be useful in conjunction with thoughtful design to degrade wastes into usable products.
- **Intractable Wastes.** Address the pressing waste treatment problems, potentially finding solutions through prevention. Water in sludge inhibits chemical and energy recovery; find

dewatering techniques. Color as in dyes is becoming increasingly "color-fast;" reexamine product quality objectives.

- **Social, Economic and Health Factors.** A range of unknowns involve reactions of society to pollution prevention initiatives; include the risks associated with literally thousands of materials and products; and involve the uncertainty over costs for any number of the approaches to pollution prevention.
- **High Technology.** The final section in this chapter mentions some emerging technologies that can assist pollution prevention. Automation, electronics for control devices and sensors, biotechnology, electron beams, and a range of advanced materials are a few of the developments that should be considered for use in pollution prevention.

In summary, pollution prevention research needs range from finding ways to apply new high technology to prevent waste, to addressing some tough materials problems that are known but remain unsolved, to looking at old problems through the new lenses of priority to waste stream minimization, to learning more about the human and social elements involved. Science is challenged by the pollution prevention concept, but the incentives to develop new pollution prevention techniques are strong. The alternatives to pollution prevention are increasing economic costs of waste disposal, increased liability and regulation, and increasingly marginal gains toward a quality environment.

E. Energy Technology

Energy is a major component of the economy; its production and use are a major source of pollution. Advancing pollution prevention requires that the nation address the technological and economic issues of a complex, dynamic energy market.

Predictions of the future depend heavily on one's assumptions, but a study of the American people's view of the nation's energy future[26] suggests several facts:

- New electricity generation capacity will be needed in the U.S., even if conservation and efficiency are pursued as aggressively as possible;
- Energy efficiency gains can and should be accelerated;
- Meeting increased demand will require a growing role for renewable energy sources like solar and wind power;
- Natural gas use is likely to grow, and could serve as a "bridge" fuel until more environmentally-acceptable fuels are available;
- Nuclear power may continue to serve as a reliable and cost-competitive source of electricity, if issues of safety, cost, permitting, and waste disposal are successfully resolved; and,

- o Coal is abundant and relatively economical, and is likely to continue to be a major source of power generation.

A long-term view is essential because energy capital investments made today may not produce power for a decade given long lead times for design, permitting and construction. Once in operation, new energy facilities will last well into the 21st century.

Energy technologies pertaining to pollution prevention fall into three categories:

- o Production of energy produces fewer pollutants if the **energy sources are inherently cleaner** -- for example, if they are renewable such as solar or wind or -- if a fossil fuel, contain less sulfur (reducing SO2 formation), produce less combustion residue (ash), or if they produce lower carbon emissions per unit of energy.
- o Combustion of fuel produces fewer harmful emissions if a **new combustion technology is inherently cleaner** -- by reducing the need for pollutant treatment or by improving efficiency, getting more power from fuel and thus creating less emissions per unit of output.
- o Likewise, emissions are held down if **end-use sectors become more efficient**, demanding less energy and thus creating less pollution.

1. Energy Production

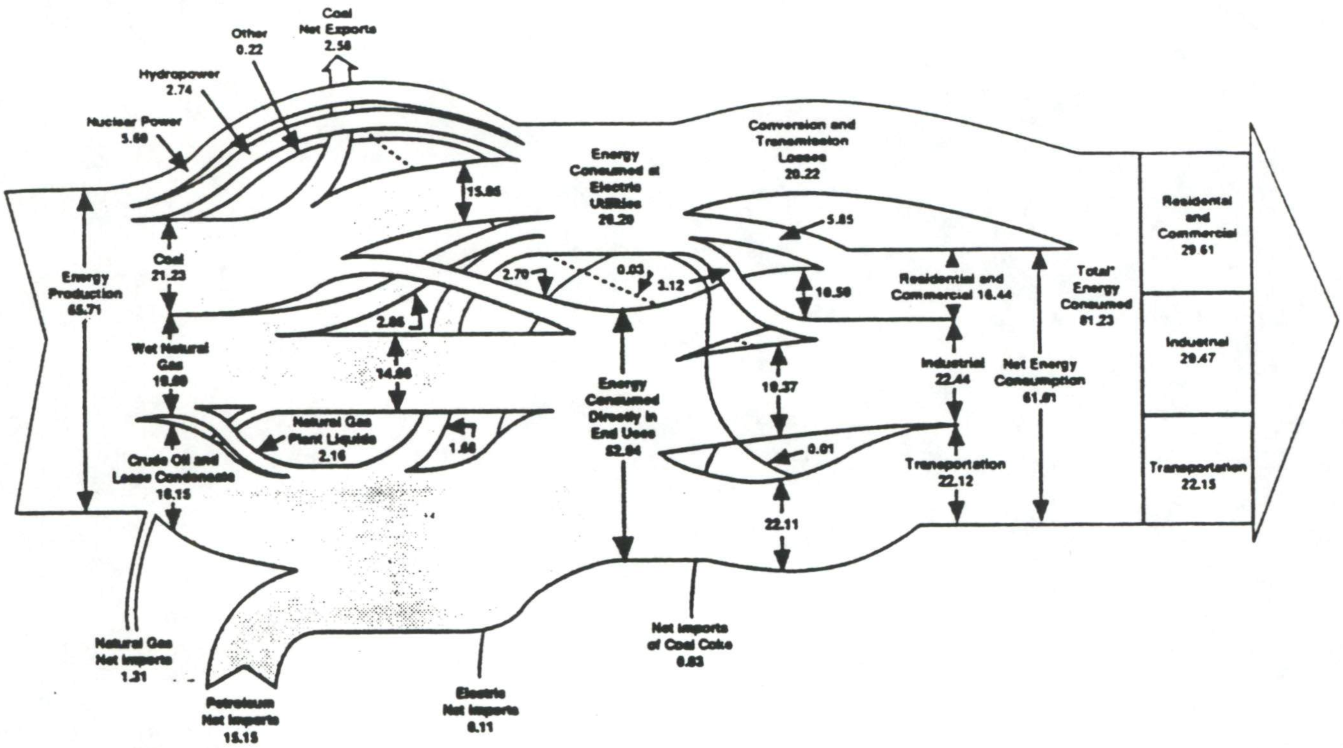
A basic energy flow diagram (Figure 3-3) shows the U.S. relies heavily on fossil fuels.

FIGURE 3-3

Nearly 90 percent of the primary energy the nation consumes is fossil -- petroleum, natural gas, and coal. Fossil fuels are the primary source of sulfur dioxide and nitrogen oxides, two of the "criteria pollutants" targeted by the Clean Air Act, and contributors to various threats to human health and ecosystems. Fossil fuel combustion is also a leading source of emissions of carbon dioxide, of which growing atmospheric concentrations, along with methane, nitrous oxides, chlorofluorocarbons and other gases, are suspected of accelerating the planet's "greenhouse effect."

As the nation seeks a sustainable energy-environmental future, non-fossil fuel sources are attractive options. However, the economics of renewables such as photovoltaics, while favorable in some locations, are unlikely to allow for large substitutions for fossil fuels in the near term. Nor has nuclear technology, another non-fossil alternative, yet overcome serious obstacles. This is despite promising research on advanced light water reactors that incorporates passive safety or even intrinsic safety with modular, standardized design; and despite efforts to develop long term solutions to nuclear waste disposal. Both

Figure 3-~~5~~3. Total U.S. Energy Flow in Quadrillion Btu, 1989.



*Total energy consumed with conversion and transmission losses allocated to end-use sectors in proportion to the sectors' use of electricity.
Note: Data are preliminary.
Note: Sum of components may not equal totals due to independent rounding, the use of preliminary conversion factors; and the exclusion of changes in stocks, miscellaneous supply and disposition, and unaccounted for quantities.

Source: DOE, Annual Energy Review 1989, page 5.

renewable and nuclear alternatives will continue to be priorities for research, development, and incremental additions where justifiable; but in the immediate future, strategies to use fossil fuels as cleanly as possible are needed.

Table 3-3 summarizes fossil fuel technologies being developed for utilities and industry which are inherently more efficient and of less impact to the environment. For comparison, the first category (1a and 1b) displays the average values of existing conventional gas or coal fired steam power plants.

TABLE 3-3

Natural gas, as shown, is inherently cleaner than coal and is currently the most widely used combustion fuel in industry. Technology advances promise to further enhance the efficiency and thus the attractiveness of gas. The combined cycle concept (2a) first combusts gas to drive a turbine, then utilizes the turbine exhaust heat to drive a steam turbine - leading to higher overall efficiency. The concepts of 4a and 5a use the gas turbine exhaust to generate steam, but then route the steam and heat back into the same gas turbine rather than to drive a separate steam turbine. This increases the gas turbine efficiency and lowers nitrous oxides emissions. World natural gas reserves, however, are estimated as less than 60 years at current production rates.[27] Thus gas prices are likely to rise in the years ahead.

As natural gas prices rise, a new breed of clean-coal

Table 3-3. Comparison of U.S. Fossil Fuel Technologies

	Plant Cost[1]	% SO2 Reduced	NOx Emitted[2]	Est Carbon Emitted[3]	Efficiency[4]
1. Conventional (Steam Turbine)					
a. Gas	760	*	180	.14	36
b. Coal w/scrubber	1600	90	300	.25	34
2. Combined Cycle (Steam & Gas)					
a. Gas	520	*	15	.10	47
b. Coal w/Gasification	1700	99	25	.20	42
3. Pressurized Fluidized-Bed Combustion Coal Combined Cycle	1200	90	60	.19	42
4. Steam-Injected Gas Turbine					
a.Gas	410	*	15	.12	40
b.Coal w/Gasification	1300	99	25	.24	36
5. Intercooled Steam-Injected Gas ,Turbine					
a. Gas	400	*	10	.10	47
b. Coal w/Gasification	1030	99	20	.20	42
6. Advanced Fuel Cells					
a. Gas	600-800	*	5-20	.09-.10	50-55
b. Coal w/Gasification	1000-1500	99	10-35	.17-.19	45-52

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[1]Dollars/Kilowatt of Capacity

[2]Milligrams per Million Joules of Electricity

[3]Kilograms of Carbon as CO2/Kilowatt-Hour

[4]Percent Stored Energy Converted to Electricity

*Indicates only trace amounts

SOURCE: Fulkerson, W., R.R. Judkins, and M.K. Sanghvi, "Energy from fossil fuels," Scientific American 263(3):133 (September 1990).

technologies have been developed that become increasingly competitive. These technologies achieve pollution reduction in the generation process rather than with scrubbers and they take advantage of coal reserves that approximate 200 years of world supply at today's extraction rates. Table 3-3 also presents the superior emissions and efficiency characteristics of the pressurized fluidized bed combustor and coal gasification systems. The fluidized bed technologies reduce pollutants during the combustion process; coal mixed with limestone is combusted while suspended on jets of air (fluidized), releasing sulfur which is captured by the limestone. A drawback is that the limestone actually increases the solid waste volumes versus a conventional coal plant.

The alternative is to convert coal to gas, then remove the sulfur - all prior to combustion. The coal gas then is combusted in a variety of options that are conceptually the same as the natural gas systems previously described. (The prototype gasification system that has been tested is the integrated gas combined cycle - IGCC - category 2b in the table.) An additional advantage of coal gasification is that the solid waste is less than half that of a conventional coal plant. Coal gasification also has the interesting potential for multiple uses. The gasifier can accept sewage or hazardous waste, fixing the hazardous elements into the inert glasslike slag that is a byproduct of the gasification process.[28] This material can then be used as a construction material in highways or similar projects. In addition, the gas used to drive the turbine can also be a feedstock for industrial processes, such as for production of methanol, a transportation fuel. This presents the opportunity for an integrated industrial feedstock and energy production facility using resources abundant in the U.S. (there are an estimated 300 years of U.S. coal reserves at current U.S. mining rates).[29]

The coal gasification (IGCC) and fluidized bed technologies have been tested in operation at various sites during the 1980s and are being actively considered by utilities for planned new capacity.[30] The Tennessee Valley Authority also proposes to develop in cooperation with the Electric Power Research Institute an IGCC process that will co-produce electricity and urea for fertilizer. The future leads to even higher efficiencies using the gas in combination with fuel cells - also shown in the table. These concepts are still in research and probably for the 21st century, but would eliminate combustion, deriving energy from an electrochemical process.

In summary, these systems demonstrate the advantages of avoiding pollution by design at the front end of the process, including for better efficiency. They also show economic promise. Globally, the U.S. enjoys a clear competitive lead and is likely to remain the leader in clean coal technology.[31] Other countries with large reserves of coal, such as China and the

USSR, are prime candidates to adopt U.S. clean coal technology.

2. Energy Efficiency

Pollution prevention and energy efficiency are closely related not only in the power plant, but also in end-uses of energy.

From 1970 to 1989, electricity use grew 89 percent, and GNP in constant dollars grew 71 percent, while basic energy consumption in the United States rose only 22 percent -- clear evidence of an increasingly energy efficient economy.[32] Overall the United States is becoming more efficient as it phases in new technology and switches to electricity from direct fuel use at the end-use level. These trends are likely to continue: concern over uncertain fuel prices will drive efficient technologies, while growing electricity use is a product of its inherent flexibility, economy and stability.

Energy efficiency gains have been the target of many recent studies. Trends in end-uses are linked to economics and consumer preferences, which government policy may influence, but cannot control. The results of such studies vary widely depending upon the assumptions used. Nonetheless, most studies agree that overall end-use demand will increase in the future; efficiency gains will restrain demand growth but will likely not reduce demand below current levels.[33]

A useful way to examine efficiency potential is through its relationship to cost. Figure 3-4 demonstrates how differing assumptions can lead to different predictions of potential electricity savings for various costs. The two estimates from Electric Power Research Institute and Rocky Mountain Institute generally agree on those technologies that have greatest potential for cost effective savings (lighting and motors), but disagree on the costs involved.

FIGURE 3-4

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a. Building Sector

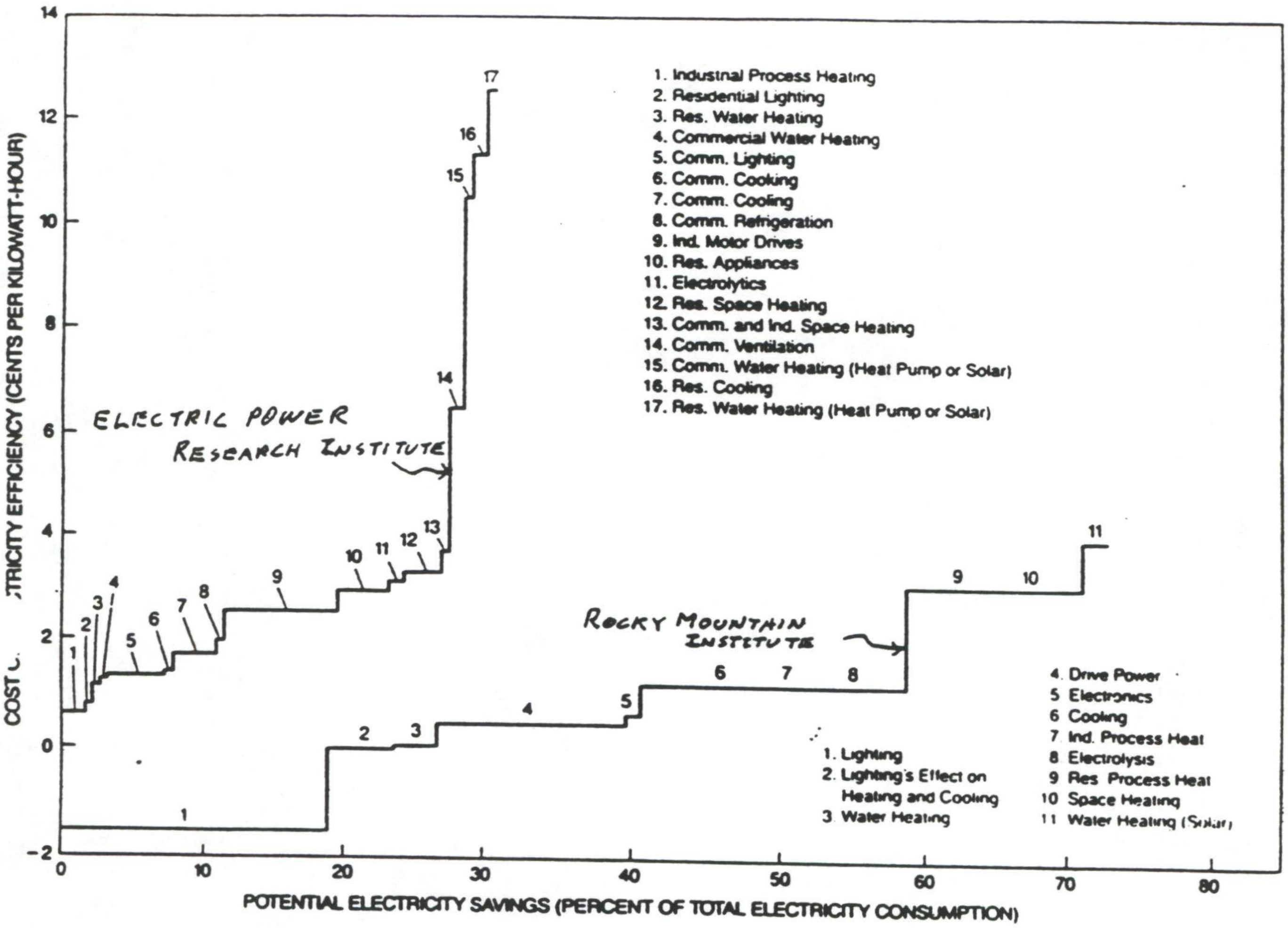
Using models from Department of Energy national laboratories, Table 3-4 divides national energy consumption into a building sector, industrial sector, and transportation sector.

TABLE 3-4

The building sector's consumption is 37 percent of total U.S. energy consumption. By far the largest demand is for space heat, air conditioning and ventilation in both the residential and commercial components of the building sector. Next there is a large "other" category covering numerous appliances, followed by commercial lighting, residential water heat, and refrigerators. These are the logical targets for demand reduction.[34]

Prospects for major building savings are shown in Tables 3-5

Figure 3-6. Estimated Cost and Scale of Potential Electricity Savings, 1990.



Source: Fickett, A.P., C.W. Gellings, and A.B. Lovins, "Efficient Use of Electricity," Scientific American vol(no):pages (September 1990).

Table 3-4. U.S. Fuel Consumption by Sector, 1985-1990.

	1985	1988	1990
	(Quadrillion BTUs)		
INDUSTRIAL SECTOR	27.1	29.1	28.3
TRANSPORTATION SECTOR	20.1	21.9	21.7
BUILDING SECTOR	26.8	29.1	30.3
RESIDENTIAL			
Space Heat	6.5		7.0
Water Heat	2.8		2.9
Refrigerator	1.9		2.0
Air Conditioning	1.1		1.2
Other	3.7		4.1
TOTAL	16.0		17.2
COMMERCIAL			
Space Heat			4.1
Air Conditioning			1.3
Ventilation			1.6
Lighting			3.3
Other			2.8
TOTAL	10.8		13.1
BY FUEL			
Electricity	16.9	18.7	19.3
Oil	2.6	2.7	2.1
Natural Gas	7.1	7.5	8.4
Coal/Other	0.2	0.2	0.5
TOTAL	26.8	29.1	30.3

Source: Data is adapted from the Lawrence Berkeley Laboratory Residential Energy Model and the National Commercial Energy Model maintained by Pacific Northwest Laboratories as reported in Carlsmith, R.S., et al., "Energy Efficiency: How Far Can We Go?"ORNL/TM-11441, (Oak Ridge, TN: Oak Ridge National Laboratory, January 1990).

and 3-6.

TABLES 3-5 and 3-6

Other significant improvements could include:[35]

- **Better building shells.** Many home owners are familiar with the notion of improvements in space heat and cooling if they have considered window coatings and better home insulation. For example, single-glass R-1 windows have poor insulating capability. R-2 double-glazed windows (two panes separated by a quarter-inch of air) are twice as resistant to heat loss. Better insulating windows with ratings as high as R-19 have been created by adding coatings and layers of gas between the panes. "Super" windows cost more than conventional windows but cut monthly energy bills. As insulation is improved, a challenge will be providing adequate ventilation to avoid indoor air pollution.
- **Advanced equipment.** Better controls or new uses for appliances have potential. Sensors can switch lighting or appliances off after a given period of disuse. Hot water heaters may double as furnaces in a super insulated house.
- **Tree planting.** Simply planting shade trees and painting structures lighter colors can save 20-50 percent of a building's cooling wattage on a hot day.

b. Industrial Sector

The government statistics collected on U.S. industrial energy use present a broad picture of economic activity and opportunities for energy efficiency. Table 3-4 shows that the industrial sector consumes approximately 35 percent of the total gross U.S. consumption (which includes transmission and conversion losses by utilities). Table 3-7 breaks out energy consumption by the manufacturing sector in 1985, the last year for which data were available, excluding electrical losses, energy used as feedstock (such as natural gas and petroleum), and several industrial sectors: construction, mining, agriculture, fishing, and forestry.

TABLE 3-7

From these statistics, one sees that the largest industry consumers of energy were, in descending order: chemicals, petroleum and coal, primary metals, and paper, each of which consumed more than 2.0 quads. The next cluster of energy users were food and kindred products, and stone-clay-glass, using just under 1.0 quad each. All other industries listed in Table 10 consume much smaller amounts of energy.

Energy efficiency by manufacturing sector is shown in Table 3-8.

TABLE 3-8

These figures show varying levels of efficiency, calculated

Table 3-7. Manufacturing Sector's Energy Comsumption for Heat and Power by Type of Fuel and Industry Group, 1985.

[In trillions of Btu. Based on the Manufacturing Energy Consumption Survey; therefore subject to sampling variability]

SIC [1] CODE	INDUSTRY	Total consumption	Net electricity [2]	Fuel oil [3]	Natural gas	Coal and coke	Other
(x)	Total	13,747.9	2,286.5	705.2	4,617.7	1,980.3	4,158.2
20	Food and kindred	954.3	165.8	65.1	458.9	131.7	132.9
21	Tobacco products	19.8	4.6	2.3	3.4	9.4	.1
22	Textile mill products	248.1	88.1	21.3	91.2	38.0	9.7
23	Apparel and other textile products	32.4	15.3	2.9	12.5	1.4	.4
24	Lumber and wood products	348.9	55.1	23.4	31.4	(D)	(D)
25	Furniture and fixtures	48.6	15.2	2.7	19.6	2.1	9.1
26	Paper and allied products	2,355.6	183.6	166.9	379.7	322.5	1,302.9
27	Printing and publishing	98.6	52.5	2.4	40.6	(D)	(D)
28	Chemicals and allied products	2,460.5	445.2	100.3	1,180.9	336.4	397.7
29	Petroleum and coal products	2,426.3	120.3	134.9	690.7	7.3	1,472.9
30	Rubber and misc. plastic products	220.8	90.7	15.2	102.0	8.1	4.8
31	Leather and leather products	13.4	4.3	3.3	4.5	.9	.4
32	Stone, clay and glass products	927.6	116.3	33.1	397.0	349.0	32.3
33	Primary metal industries	2,362.2	458.7	53.2	669.2	660.6	520.5
34	Fabricated metal products	296.2	91.2	16.7	171.6	8.7	8.0
35	Machinery, except electrical	277.6	114.2	14.6	113.7	30.6	4.5
36	Electric and electronic equipment	223.7	110.1	10.4	91.4	8.6	3.3
37	Transportation equipment	322.2	115.0	25.7	120.7	43.8	17.0
38	Instruments and related products	79.7	29.2	8.1	23.6	(D)	(D)
39	Miscellaneous manufacturing	31.3	11.4	2.6	15.4	1.3	.7

D Figure withheld to avoid disclosure. X Not applicable. [1] Standard Industrial Classification; see text, section 13. [2] Net electricity is obtained by aggregating purchases, transfers in, and generation from noncombustible renewable resources minus quantities sold and transferred out. [3] Includes distillate and residual.

Source: U.S. Energy Information Administration, Monthly Energy Review, (January 1987) in Department of Commerce, Bureau of the Census, Statistical Abstracts of the United States 1988, (Washington, DC: U.S. Government Printing Office, 1987), page 542.

Table 3-8. Manufacturing Sector Energy Efficiency by Industry Group, 1980 and 1985.

SIC Code	Industry Group	Energy Efficiency Ratios[1] 1980	Energy Efficiency Ratios[1] 1985	Energy Efficiency Change[2] (percent)
20	Food and Kindred Products	3.5	2.7	22.9
21	Tobacco Manufactures	W	W	W
22	Textile Mill Products	5.7	4.8	16.3
23	Apparel and Other Textile Products	NA	NA	NA
24	Lumber and Wood Products	W	W	W
25	Furniture and Fixtures	1.9	1.6	17.4
26	Paper and Allied Products	16.0	13.9	13.0
27	Printing and Publishing	1.1	0.9	15.2
28	Chemicals and Allied Products	15.1	12.4	17.6
29	Petroleum and Coal Products	5.4	4.4	19.8
30	Rubber and Misc. Plastics Products	4.3	3.1	27.8
31	Leather and Leather Products	W	W	W
32	Stone, Clay, and Glass Products	21.6	16.6	23.0
33	Primary Metal Industries	16.4	14.6	11.0
34	Fabricated Metal Products	2.8	2.3	16.4
[illegible]	Machinery, Except Electrical	1.7	0.9	43.6
[illegible]	Electrical and Electronic Equipment	1.7	1.2	26.4
37	Transportation Equipment	1.5	1.1	25.0
38	Instruments and Related Products	1.7	1.2	29.3
39	Misc. Manufacturing Industries	1.8	1.4	23.9
—	All Manufacturing	5.8	4.4	25.1

[1] Thousand Btu per constant (1980) dollar of value of shipments and receipts.
[2] A decrease in the energy efficiency ratio results in an increase in energy efficiency represented by a positive value.
W = Withheld because relative standard error is greater than or equal to 50 percent.
NA = Not available.

Source: U.S. Department of Energy, Annual Energy Review 1989, page 39.

as the ratio of energy use per dollar of value of shipments and receipts. The most energy intensive industries are stone-clay-glass, primary metals, paper, and chemicals, with ratios in the range of 12-16 to 1 -- well above those of other industries. This variation is explained by the fact that the most energy intensive activities are those which convert raw materials into usable form for other industries. Comparing Tables 3-7 and 3-8, one also observes that these basic processing industries are among the top users of petroleum and coal, and thus, they contribute heavily to energy-related pollution. To the extent that industrial energy efficiency can be improved -- gaining greater output from less energy input -- economic and environmental objectives may be achieved simultaneously.

The data in Table 3-8 on changes in efficiency shows a substantial improvement since 1980 in most manufacturing sectors, ranging from 11 percent for primary metals to nearly 44 percent for machinery. Even so, efficiencies remain far below the theoretical maximums imposed by the laws of thermodynamics. For example, one study estimated that the iron and steel industry is at approximately 23 percent of maximum achievable efficiency, aluminum at 13 percent, and petroleum at 9 percent. The pulp and paper industry, which could theoretically use its own lignin wastes for fuel, currently uses as much as three-quarters of a ton of oil to produce one ton of paper.[36]

Despite the diversity of industrial activities in the U.S., there are generic technologies in development, both near and long term, with the potential to improve efficiency and prevent the pollution contribution of many industries. Among these cross-cutting developments are:[37]

- **High efficiency motors.** Motors represent more than half of the nation's industrial uses of electricity. High efficiency models have variable speed drives that adjust up or down with load and may someday use high temperature superconducting materials.
- **New catalysts.** New classes of catalysts are an appropriate target for research to promote lower-energy chemical conversions, as in the production of methanol from methane, or in certain emission control devices.
- **Separation processes.** Less energy-intensive separation processes are needed, to include better membrane materials, better solvent extraction techniques, and advanced heat recovery/utilization in paper and textile processing.
- **Heat recovery/cogeneration.** Using in-house waste heat to drive turbines for energy cuts utility bills. Typical cogeneration in industry turns 10-15 percent of energy to electricity; steam-injected turbines can exceed 40 percent.

Primary metals manufacturing could benefit from several industry-specific efficiency improvements.[38] The amount of energy needed to produce steel in 2010 could be cut 42 percent, an improvement of 2.4 percent per year, through greater penetration of such technologies as: the currently available electric arc furnace, which is more efficient than combustion furnaces and can use virtually 100 percent scrap; near net-shape casting, currently available and well understood; and direct steelmaking, still in development, which combines four smelting processes into one step. A 1.5 percent per year improvement through 2010 would merely bring U.S. steelmakers to the 1990 Japanese level of efficiency.

For other metals, the efficiency of aluminum production could be enhanced up to 36 percent by 2010 with better electrolytic reduction cells, better electrodes, and related advances in research or development. An efficient technique for nonferrous smelting is available - flash smelting, which also attacks the largest single source of industrial process sulfur emissions. By increasing the concentration of sulfur dioxide in the smelter emissions, removal of SO2 by acid plants is improved to 96-99 percent.[39] Greater use is a financial decision.

In the paper industry, 33-40 percent improvements in energy efficiency may be possible by 2010 using such advances as continuous digesters, oxygen bleaching, better evaporators, computer controls, sensors, and better drying techniques. Paper recycling uses only half the energy of the prevalent Kraft production process.[40]

In the chemical, petroleum, and stone-clay-glass industries the generic technology improvements discussed at the start show the greatest promise.

Recycling. It is also important to note the energy-saving potential of greater recycling -- which would reduce not only the nation's quantity of solid waste, but also the pollution associated with energy use. The most energy- and pollution-intensive operations involve the preparation of the virgin materials. Ironically, many companies look for ways to reuse the scrap they create in the factory, but few retrieve their products after they are used by the consumer. Among those industries in which recycling occurs, some experts have estimated that recycled glass consumes 70 percent of the energy needed for new glass, steel approximately 65 percent, plastic 37 percent, and aluminum -- recycling's greatest success story -- 28 percent.[41]

3. Encouraging Energy Efficiency

The pollution prevention ethic, which merges economic and environmental objectives, obviously requires that energy services be provided in the cleanest, most efficient manner possible. How can the nation advance energy efficiency?

A basic reliance on market forces can be expected to provide an incentive for both short-term efficiency improvements and longer-term technological change. This was demonstrated in the last twenty years as the U.S. economy grew much more energy efficient in response to concern over energy supply disruptions, price volatility, and the introduction of new technologies.

Efficiency progress slowed when energy prices eased.

a. Utility Programs

Market forces have had a slower and more limited impact on electric utilities, however; utility prices and practices are regulated by state public utility commissions (PUCs). Traditionally, while utilities in some states were reimbursed for the costs of efficiency measures and environmental controls, the incentives were inadequate to offset the depressed revenues resulting from such programs. Regulatory policies tended to meet growing demand by simply using economic cost comparisons to select the next plant addition.

Recently, coalitions of utilities, environmental groups, and small energy service companies have collaborated with state PUCs to develop profit incentives that enable utilities to earn a return on efficiency investments commensurate with that earned on supply-side investments. Profit incentives are being implemented in Rhode Island, Massachusetts, New York, and California, and related regulatory reforms are proceeding in other states under various labels: demand-side management (DSM), least-cost utility planning (LCUP), integrated value-based planning (IVP), or integrated resource planning (IRP). Twenty-nine states are examining steps to incorporate environmental costs into electric resource decisions. What these reforms all have in common is an attempt to develop mechanisms that allow companies and regulators to evaluate both supply- and demand-side options on a level playing field. In almost every case, energy efficiency investments are being transformed from an afterthought to a profitable priority.[42]

Today, industry leaders such as Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and New England Electric System (NEES) are moving vigorously ahead. PG&E expects to meet three-quarters of its new demand through the year 2000 with efficiency and conservation savings, spending up to $2 billion on the effort.[43] SCE conducts its "Welcome Home" program to foster the building of houses, condominiums, and apartment buildings that are energy efficient. The program also provides homebuyers with energy audits, advice, rebates on the purchase of efficient equipment, and devices to manage energy wisely. The utility set a goal for 1990 of seeing 20,000 new residential units built to program standards.[44] NEES joins forces with the Conservation Law Foundation in an effort to provide $85 million in 1991 to customers for efficient lighting, insulation, and weatherization in 20,000 homes. NEES also purchases and installs efficient motors, lighting, heating and ventilation in the commercial sector. The utility plans total efficiency investments of $420 million over the next six years.[45]

The 1990 amendments to the U.S. Clean Air Act will also promote the campaign for efficiency. Under the acid rain portion of the new law, utilities have the flexibility and the incentive to make the largest reductions possible, at least cost. And in nearly every case, efficiency investments will be a part of the equation. A study sponsored in part by a bipartisan coalition of state governors showed that utilities hardest hit by the acid rain portions of the clean air bill could cut their compliance bill in half through aggressive efficiency and conservation programs.[46] Demand restraint will also help to buy time for improvements in the technology of energy production and emissions control.

Federal leadership can also stimulate the market in "negawatts" by encouraging more efficient housing, buildings and equipment. To achieve energy savings in commercial structures, DOE has developed a set of voluntary standards that will be revised about every five years to stimulate innovation and reflect the current state of technology. Application of these standards in new commercial construction is expected to result in energy savings of 20-25 percent. As for equipment, DOE will soon issue mandatory updated national energy standards for new washing machines, dryers, and dishwashers. Such mandatory standards were issued for refrigerators in 1989. DOE has also begun efforts to update the mandatory efficiency standards for furnaces, air conditioners, heat pumps, and other major residential appliances.

Government can also be a catalyst for change by changing its own energy consumption habits. The DOE building standards just described are mandatory for new federal buildings. Contracts for retrofits of existing buildings to make them more energy efficient are on the rise, as local utilities see inefficient federal buildings as targets of opportunity. In one such program, the General Services Administration, in coordination with the Potomac Electric Power Company (PEPCO) will install lighting retrofits in about 25 of the largest federal buildings in the Washington area. By 1992, the project is expected to save 25 percent of the energy used for lighting them. Overall, the Federal government could save up to 10 percent of its building energy use per square foot by 1995, and 20 percent by 2005, compared to 1985 levels.[47]

b. Barriers

Barriers do exist in the path of energy efficiency progress. The invigorated efficiency movement will require time and effort to penetrate the national scene. As with pollution prevention, a primary challenge is information: only a modest amount of it is available concerning the costs and performance of energy demand-management programs. A concerted effort by the U.S. Department of Energy (DOE), the industry-sponsored Electric Power Research Institute (EPRI), and other organizations to gather more data from actual experience will enable interested parties to design more successful programs. Currently, DOE provides assistance to utilities and state PUCs through its Integrated Resource Management Program (IRP), which helps measure the effectiveness of efficiency programs and operates a national data bank. Funding for this program totaled $1.3 million in fiscal year 1990, and $3 million in 1991.

Energy efficient systems for industry which may be cost effective over their life-cycle, generally have higher first costs. There is evidence that industry requires paybacks of two years or less for cost saving investments, such as for energy efficiency. There is also evidence that industry discriminates toward market share versus cost saving efficiency in allocation of capital funds.[48] A long term capital investment program toward efficiency which would change out or retrofit industrial processes will largely require a change in attitude as much as the correct price signals.

In end-uses of energy, other barriers exist which are not remedied by market forces. Builders tend to be interested in first costs and have not been accountable to owners for energy efficiency. Many renters do not pay their own utility bills, so price signals do not directly affect the consumer.

The source of long-term change in end-use efficiency is research, development, and commercialization of technologies that address both energy and environmental needs. Ultimately, such progress depends on market signals and the initiative of the private sector. Federal funding for energy efficiency R&D will remain a fraction of that for energy production. But as mentioned above, the short capital-recovery requirements by businesses today do not favor long-term energy investment, particularly in small- and medium-sized companies.[49] Federal and state agencies will need to strengthen public-private partnerships such as those authorized by the National Competitiveness Technology Transfer Act of 1989, which directed the national laboratories to help speed the transition of new technologies into the marketplace. Not only will this R&D be focused on better demand-side items such as efficient appliances, windows or building designs, but also cleaner and more productive supply options.

III. Existing Programs

The nation is making considerable efforts to meet the technical challenge of pollution prevention at the federal, state, and local levels. Legislation and government programs can be catalysts for wider adoption of the pollution prevention ethic. But government action by itself, no matter how clear or prescriptive, is insufficient. Other methods such as market incentives and education are also necessary. This section provides snapshots of the key activities and progress in 1990.

A. Federal Agencies

Several federal departments and agencies with antipollution responsibilities moved forward toward pollution prevention in 1990. Among others, the Environmental Protection Agency (EPA) advanced an impressive array of programs, and both CEQ and EPA have developed aggressive outreach and policy development programs. The Department of Agriculture continued to pursue pollution prevention initiatives oriented toward the large nonpoint source challenges of the nation's croplands and Department of Transportation added responsibilities under the Oil Pollution Act of 1990 to the already significant challenges of oversight of the transportation sector.

As a major building landlord, the General Services Administration actively pursued an energy conservation program that has reduced energy consumption 25% between 1973-1975 and an additional 25% 1975-1985, while reducing petroleum 76% during the same period. Other responsibilities included its underground storage tank testing and remediation program, and its hazardous materials spill prevention and control program. GSA emphasizes recycling in its office buildings and is giving priority to building insulation that uses recovered materials.

The Departments of Energy (DOE) and Defense (DOD) incorporated prevention into their large industrial operations and hazardous waste programs. The latter have worked closely with EPA as the requirements for waste management have progressed toward the pollution prevention doctrine. DOE and DOD will contribute to the national environmental effort beyond merely controlling their own operations; they also represent test beds for technologies and techniques of use to the private sector and markets for materials that could be provided from processes using pollution prevention.

The chapter will examine the programs of EPA, DOE, and DOD in more depth in continuing a technology focus that is related to industrial and business types of activities.

1. Environmental Protection Agency

As the nation's primary environmental regulatory agency, EPA has named pollution prevention one of its priorities for the 1990s and beyond. In its report of September 1990, the EPA Science Advisory Board (SAB) recommended an emphasis on pollution prevention as the preferred option for reducing risk.[50]

In 1988, EPA established an Office of Pollution Prevention within its Office of Policy, Planning and Evaluation, and in each of its ten regional offices. Most recently, in January 1991, the Agency released a pollution prevention strategy. It addresses obstacles; expands public participation; emphasizes partnerships, especially with federal agencies; supports state technical assistance programs; promotes outreach and training; integrates pollution prevention concepts in regulations and permits; leverages enforcement; underscores a research strategy; encourages "cleaner" products and technologies; and promotes institutional change at EPA. As described earlier (Section I), it defines pollution prevention in terms of manufacturing and chemical use, agriculture, and energy (including transportation).[51]

The Strategy also reiterates the EPA plan to target certain TRI chemicals. The Agency is identifying 15 to 20 toxics of greatest concern from the Toxics Release Inventory, and proposes a goal of reducing the total releases of these target chemicals by one-third by 1992 and by at least half by 1995 (also see Section IIa). These reductions are to be achieved through voluntary industry action, using cost-effective methods.

Commitments of staff, grants, and contract dollars have helped introduce the pollution prevention ethic to EPA employees and citizens. The Agency has committed nearly $11 million since 1989 to incentive grants for source reduction, recycling, and pollution prevention, which have largely strengthened state technical assistance programs for industry. In 1991 and 1992, EPA offices plan to set aside two percent of contract dollars (approximately $12 million) for innovative pollution prevention projects. The projects will address issues ranging from education to methods for low-input sustainable agriculture (LISA).

EPA also conducts outreach efforts to share innovative technologies and practices with numerous industries. The Agency maintains a Pollution Prevention Information Clearinghouse, which is accessible to the public by means of a telephone "hotline" or by a personal computer. The Clearinghouse provides, among other things, a calendar of events; state, federal, and corporate program summaries; and case study abstracts. The Pollution Prevention Office publishes a monthly newsletter, the "Pollution Prevention News," and through a public-private initiative produced an award-winning videotape.

In 1989, EPA and the University of Cincinnati established the American Institute for Pollution Prevention, comprised of volunteer experts who work in councils to advance pollution prevention technologies and who help provide a new cooperative liaison channel between EPA and industry. Councils on economics, education, implementation, and technology sponsor such projects as: a practical guide to pollution prevention economics; pollution prevention oriented design problems for engineering courses; and analysis of regulatory and legislative barriers to pollution prevention.[52]

EPA devotes a portion of its R&D to pollution prevention. The agency has a cooperative extramural program, jointly executed with outside agencies, industry, and public groups, and an intramural program within EPA. Currently, EPA funds 68 projects under two general headings:[53]

- **Pollution Prevention Research Branch.** This unit is located at the EPA Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio. Projects totalling approximately $3.5 million follow on earlier efforts by the laboratory prior to the establishment of a formal Waste Minimization Branch at RREL and include the: Waste Reduction Innovative Technology

Evaluation (WRITE); Waste Reduction Assessments Program (WRAP); Waste Reduction Evaluations at Federal Sites (WREAFS); and the Waste Reduction Institute for Senior Executives (WRISE), which evolved to the AIPP mentioned previously.[54]

- **Two-percent set-aside program.** A variety of projects from the Agency's contract set-aside program are research and development projects.

In general, pollution prevention research projects are categorized by EPA into six areas:[55]

- **Products.** The products program focuses on preventing pollution throughout the life cycle of a product, especially during its use and disposal. Typical projects include a cooperative venture with University of Tennessee identifying safe product substitutes, a clean products case studies project by INFORM (a private organization), and an industry product design manual being produced by University of Michigan.
- **Process.** WRITE projects in California, Connecticut, Illinois, Minnesota, New Jersey, Washington, and New York focus on evaluating innovative process technologies and techniques that prevent pollution. These cooperative projects range from 18 industry-specific assessment manuals produced in cooperation with the California Department of Health Services, to 30 assessments of small and medium-sized

businesses in New Jersey using university teams. The EPA Cincinnati laboratory developed the Waste Minimization Opportunity Assessment Manual, used widely for environmental audits and determining technology needs.

- **Recycling and reuse.** Among the current recycling projects is reclamation of newsprint using a dry fiberizing process.

- **Socioeconomic and institutional.** Research includes community demonstrations by Tufts University, the University of Pittsburgh, the City of Milwaukee, and a cooperative model communities project with the Department of Defense.
- **Anticipatory research.** EPA-sponsored University Research Centers and Hazardous Substance Research Centers analyze emerging trends and changing needs.
- **Technical transfer and outreach.** Mechanisms include the Pollution Prevention Information Clearinghouse, the American Institute for Pollution Prevention (AIPP), the National Advisory Committee for Environmental Policy and Technology (NACEPT), the EPA Science Advisory Board, and numerous publications, workshops, and conferences.

In summary, EPA leverages its pollution prevention resources to achieve maximum results by cooperating with others. With growing antipollution responsibilities on its agenda -- including implementation of the new Clean Air Act, and upcoming reauthorization of the Clean Water Act and Resource Conservation and Recovery Act (RCRA) -- the EPA is strategically well-poised to integrate prevention into all its activities, and into those of the nation at large.

2. The Department of Defense

The success of the pollution prevention ethic depends in no small part upon commitment by leaders and managers of large organizations. Among the nation's largest organizations, the Defense Department (DOD) made a public commitment in late 1989 to be the leader in federal agency environmental compliance and protection.[56] Integrating the environmental ethic into all facets of DOD will rely on intensive cooperation with the private sector, and on the attitudes and dedication of the nearly four million members of DOD worldwide.[57]

Pollution prevention at the Department of Defense has made significant progress since 1985, when it began to evolve as a priority. In that year, EPA issued regulations to implement the Hazardous and Solid Waste Amendments Act (HSWA) of 1984; seed money for hazardous waste minimization (HAZMIN) within DOD was allocated, managed within the Defense Environmental Restoration Program (DERP), DOD's equivalent to the civilian Superfund program. Under the HAZMIN program, each service -- Army, Navy and Air Force -- established goals in 1987 to cut waste in half by 1992, although the definition of minimization for this prototype program included such non-preventive techniques as delisting and treatment.[58]

In 1989, a new directive on "Hazardous Material Pollution Prevention" provided the focal point for hazardous material management and genuine waste minimization efforts. The new directive requires DOD components and the military services to develop comprehensive guidance and programs to prevent pollution. It emphasizes information exchange and cooperation with other agencies, allied nations, and outside groups.[59] It complements an environmental restoration program budgeted at $600 million in 1990.

Current research and development under the HAZMIN program parallels that of private industry, although defense-specific techniques include recycling off-grade TNT during production. Other familiar priorities are: eliminating, reclaiming, or substituting alternatives for cleaning solvents; employing plastic pellets rather than solvents for paint stripping; and using alternatives to chlorofluorocarbons for electronic and metal cleaning.[60] Because DOD is a large user of CFCs and halons, which damage the Earth's protective ozone layer, a Departmental CFC Advisory Committee is conducting a study on ways to phase out CFCs and halons from procured equipment and supplies.[61]

Most recently, the Defense and the Environment Initiative (D&EI) was launched in 1990 to increase day-to-day environmental sensitivity and prepare environmental strategies. It envisions a long-term, problem-solving effort, employing partnerships in defense-environmental matters. A September 1990 D&EI conference brought together several hundred defense and civilian leaders to review: the near- and long-term DOD environmental strategy, including opportunities for pollution prevention; ways that global strategic policy might encompass environmental issues; and development of an enhanced DOD environmental decision-making structure.[62]

To monitor and evaluate pollution prevention activities, DOD established in September 1989 an intra-agency Hazardous Material Pollution Prevention Committee (HMPP). The committee coordinates the development of a long-term strategy, fosters effective exchange efforts, and serves as a forum to provide DOD guidance on pollution prevention. DOD instituted an effort within the Defense Logistics Agency to reuse hazardous materials to prevent them from becoming hazardous waste.[63]

Examples of DOD's pollution prevention program can be found at various DOD facilities:

- **Philadelphia Naval Shipyard.** An assessment of the shipyard found potential cost savings of $158,000 by controlling waste paint and making changes in cleaning and rinsing aluminum products;[64]
- **Fort Riley, Kansas.** Assessment of the maintenance of trucks, tanks, and armored personnel carriers at the site's motor pools identified recycling options for battery acid

and parts cleansers for an anticipated net savings of $149,400 per year at Fort Riley, with potential for savings at ten similar posts;[65]

- **Tinker Air Force Base.** Solvent testing has shown that waste disposal of halogenated and petroleum-based solvents can be reduced significantly, potentially saving the Air Force $4 million yearly in waste disposal costs.[66]

In another initiative just underway, the DOD and EPA have agreed to a joint demonstration of the model community concept.[67] At three facilities in the Chesapeake Bay area -- Langley Air Force Base, Norfolk Naval Base, and Fort Eustis -- three different services will incorporate pollution prevention into all installation activities. The program, designed to demonstrate multi-media pollution prevention and energy conservation with applicability to other communities, is based on the "total quality management" principle, involving all members of the community. In military terms, DOD's efforts are "a coordinated land-air-water assault on pollution."[68]

3. Department of Energy

In the past two years, the Department of Energy has made a strong commitment to environmental progress. Organizational changes consolidated environmental responsibilities into an Office of Environmental Restoration and Waste Management, and "tiger teams" reviewed environmental procedures in the field.[69]

Part of this new emphasis includes pollution prevention, of obvious value to a department whose estimated bill for corrective remediation of previous waste procedures ranges from $53-$92 billion over the next twenty years.[70] In 1990, DOE issued a waste reduction policy statement which will lead to comprehensive pollution prevention efforts. It establishes a single program to assure that each DOE operating facility organizes a comprehensive waste-minimization program to include goals and schedules, tracking of waste streams, waste minimization methods and technologies, employee training and awareness programs, and compliance with all federal and state regulations.[71]

DOE's pollution prevention program builds on waste minimization efforts launched in 1989. At that time, DOE published a plan to clean up its nuclear-related waste sites and generally bring its aging facilities into compliance with current environmental laws and regulations. That plan identified the need to develop new technologies for problems not now having solutions. Subsequently, a draft Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) Plan was also published in 1989.[72]

These plans were incorporated into an ambitious five-year plan through fiscal year 1996 for Environmental Restoration and Waste Management. The five-year plan explicitly recognizes the need for cultural as well as technical changes throughout the DOE complex, including a "design for minimization" philosophy. The goal is to reduce waste generation in ten years by 50-80 percent in five DOE manufacturing sectors. Such waste reductions could save DOE $10 billion in waste treatment, storage and disposal costs over the next 20 years.[73]

Because radioactive materials present special problems, the nation devotes considerable funds to technology development and remediation at DOE sites. Synergism between remediation teams and pollution prevention engineers could advance the state of the art, using DOE sites as large laboratories for radioactive pollution prevention as well as the hierarchy of protection options.

Site remediation and restoration, especially of radioactive and hazardous waste sites, have been priority projects in recent years, but DOE recognizes the generic advantages of a pollution prevention strategy. Refinements to processes at DOE sites are occurring in much the same way as in industry. Technology development in 1990 saw work in alternative cleaning processes, material substitution, process improvements, and recycling. Production sites conducted assessments for the next iteration of the comprehensive waste minimization plan.[74]

The following are case studies typical of DOE progress at its research, development, and production plants:

- **Rocky Flats.** This DOE site, which produces components for nuclear weapons, established a waste minimization program in January 1988 that focuses on eliminating three hazardous solvents (TCA, carbon tetrachloride, and chlorofluorocarbons) used for cleaning in maintenance and manufacturing throughout the plant. The program has achieved an 80 percent reduction in the use of TCA and CFC's in non-plutonium manufacturing. Through more careful use of solvents in cleaning operations, employees in plutonium manufacturing reduced the use of carbon tetrachloride from 14,000 gallons in 1988 to 10,500 gallons in 1989.[75]

- **Los Alamos National Laboratory.** A program for recycling and reusing of hazardous chemicals has resulted in a number of changes. The laboratory installed an electrolytic silver-recovery system to eliminate disposal of silver-bearing wastes and to provide a financial return to the laboratory. Other techniques replace or recover halogenated solvents, recycle machine coolants, pull mercury out of the waste stream and recycle it, screen lead for reuse, recycle used oil, recycle 75 percent of office paper, and reduce the use of organic solvents through substitution. Every pound of material recycled saves up to $50 plus the cost of replacement materials.[76]
- **Sandia National Laboratory.** A program is in place to reduce and possibly eliminate hazardous liquid wastes resulting from the use of CFCs and chlorinated hydrocarbons in manufacturing cleaning processes. The Sandia project is carried out in conjunction with three other DOE production

facilities and involves hundreds of components; it could have wide applications throughout DOE facilities. Projects to replace chlorinated solvents will use alternatives to remove residues of electronics assembly manufacture and ceramic header fabrication. Alternative manufacturing processes could eliminate the need for solvent cleaning of precision optical components. Ultimately, DOE will eliminate CFC's and chlorinated hydrocarbon solvents from its production cleaning processes altogether.[77]

B. 1990 Legislation

In recent years, Congress and several state legislatures have enacted legislation to advance the pollution prevention ethic. For example, the 1990 Clean Air Act Amendments (CAAA) allow sources of hazardous air pollutants to enjoy a six-year deadline extension of the requirement to install maximum available control technology (MACT) -- if the sources make a voluntary 90 percent reduction of those pollutants below 1987 levels in advance of regulatory action. As this Report is prepared in early 1991, dozens of sites have informed EPA of their intention to make deep voluntary emission reductions.

The Pollution Prevention Act of 1990 garnered far less attention than the clean air legislation. But the Act established a waste management hierarchy with priority given to source reduction, and required EPA to advance industrial pollution prevention by:

- o identifying measurable goals;
- o improving measurement, data collection, and access to data;
- o assessing existing and proposed programs, and identifying barriers;
- o offering grants for state-level technical assistance programs;
- o requiring more data from toxic emitters;
- o identifying opportunities to use federal procurement to encourage source reduction; and
- o establishing awards programs.

Consistent with ongoing activity, the Act emphasizes the reduction of industrial hazardous wastes, and notes that techniques may include: changes in equipment or technology; reformulation or redesign of products; substitution of raw materials; and improvements in housekeeping, maintenance, training, or inventory control.

Legislation providing appropriations for EPA for fiscal 1991 required the Agency to develop and implement a pollution prevention strategy that addresses the full range of environmental problems, including those in agriculture, manufacturing, energy, and federal agency activities.

The Oil Pollution Act of 1990 addresses the wide-ranging problems associated with preventing, responding to and compensating for oil pollution by creating a comprehensive regime for dealing with tanker and facility-caused pollution. It sets new standards for crew licensing and manning; mandates contingency planning; broadens enforcement authority; enhances federal response; and adds new research and development. It also mandates double hulls and includes a number of provisions on liability and compensation for pollution events.

C. State Level Actions

At least 14 states, including Massachusetts, Oregon, Illinois, and New Jersey have passed legislation to limit the use of toxic substances and/or reduce hazardous waste generation. The state laws vary widely in details, but all of them establish technical assistance (TA) programs and information clearinghouses -- another reminder that a key to success in pollution prevention is access to technological "know-how."

The National Roundtable of State Pollution Prevention Programs is one focal point for information exchange among the states. In an effort to strengthen member programs and move beyond information exchange, the Roundtable established four workgroups at its 1990 meeting: information sharing, data collection, program effectiveness, and training.[78]

Most states offer some form of technical assistance to industries interested in reducing waste. Effective state TA programs, like pollution prevention programs generally, have:

- An articulated philosophy or approach;

- o Strategies to engage senior managers and workers at companies;
- o An array of information services including a data base, publications, and training;
- o Capability to conduct on-site audits;
- o Partnerships with key research institutions, universities, and community colleges; and,
- o Positive incentives such as awards.

State TA programs generally have small staffs and limited budgets. Resources are often extended through partnerships with major local universities. Tennessee's program employs retired engineers trained by the University of Tennessee. Rhode Island has a continuing relationship with the University of Rhode Island, which trains undergraduate and graduate engineering for assessment teams. The services of recently-retired or student engineers tends to lower costs, ensure familiarity with emerging technologies, and enhance the pollution prevention ethic in university curricula.

Several states clearly emphasize the economic benefits of pollution prevention. Rhode Island's TA teams offer an on-site audit and assessment to companies who may then adopt or reject the state's recommendations. Since the recommendations might be ignored even if they are technically- and economically-sound, the program emphasizes early development of contacts with the company president or plant manager.[79] The Ohio Technology Transfer

Organization (OTTO), which operates the state's waste reduction TA program, is funded by the Ohio Department of Development. New Jersey, Minnesota, Ohio, Tennessee, and Massachusetts are among the states that offer governor's awards for exemplary corporate approaches to pollution prevention.

D. Education and Training

Because the pollution prevention ethic requires integrating environmental concerns from the outset of any activity, education and proper training are essential. In 1990, environmental education programs were expanded both for children and adults.

Educators generally agree that individuals exposed to good information throughout their pre-school, elementary and high school training are more likely later to incorporate learned values into their behavior. In 1990, the extraordinary celebration of Earth Day's 20th anniversary stimulated thousands of special activities in elementary, middle, and high schools. The National Environmental Education Act of 1990 strengthened learning opportunities for all ages, but focused especially on young students and their teachers. The Act also established an EPA Office of Environmental Education, and a semi-private foundation to leverage private funds for such programs. Under the Act EPA will: work with private organizations to develop environmental education materials and curricula, and train environmental educators; provide grants to local school systems, colleges and universities to develop environmental education programs, including internships; create other national awards in several categories; and create two advisory groups.[80]

As environmental management becomes key to corporate competitiveness, the nation is strengthening programs in higher and continuing education. University business and engineering schools, state technical assistance programs, private consulting firms, trade associations, and government are among the organizations offering seminars, workshops, and courses addressing pollution prevention and clean technology. A sample of these efforts in 1990 were:

- **University of Tennessee Center for Industrial Services.** Interactive teleconference technology was used to present its waste reduction training programs to a national audience. The 1990 teleconference on "Waste Reduction Assessment and Technology Transfer" attracted 1,113 participants at 65 sites in 24 states. The next teleconference will address solvents usage, substitution, and distillation.[81]
- **NACEPT Education and Training Committee.** Tufts University and EPA's National Advisory Committee for Environmental Policy and Technology cosponsored a University Presidents' Roundtable, focusing on environmental management, sustainable development, and university curricula -- at home and abroad. The Committee also supports development of the

Management Institute for Environment and Business, which will fund and utilize research on environmental literacy among corporate employees and graduate business students.[82]

- **Stanford University Graduate School of Business.** Each year, the School's Public Management Program selects a public management initiative, pursuing a topic in "a free marketplace of ideas." The 1990-91 initiative is "Investing in the Environment." Students will focus on problem-solving and will integrate environmental management themes across many disciplines, with a variety of guest speakers, seminars, and projects. Professors tend to integrate what was learned in these initiatives into courses in subsequent years.[83]
- **Tufts Environmental Literacy Institute.** The Institute, funded by grants from EPA, Allied-Signal, Inc., and Union Carbide, arms Tufts faculty with environmental knowledge and skills to use in curricula revision. The program integrates environmental themes into all courses instead of specific electives, since environmental decisions are made by all disciplines: business leaders, attorneys, engineers, economists, scientists, and consumers.[84]

IV. Advancing Pollution Prevention Technology

The goal of the National Environmental Policy Act of 1969, often called the "Magna Carta" of modern environmental policy, was to create a "productive harmony" between humans and nature. That desirable state of harmony would in all likelihood draw nearer if humans found ways to prevent, not just treat, pollution of their natural surroundings. But as the nation has learned from twenty years of environmental policymaking, pollution is not easily prevented. To actually prevent pollution, the nation must continuously design, build, manage, and refine its technology for that purpose in an institutional setting that promotes such efforts.

Traditionally, environmental technology is thought to be control devices or approaches to remediation; environmental engineering is taught as a distinct discipline in universities. That thinking is inadequate at a time in which we demand our technology to be more efficient, and hence more resource- and energy-efficient. Practitioners of pollution prevention will benefit from a broad education in systems integration with some specific knowledge of the biochemistry of pollution, the relation of design to energy use and productivity, and the detailed technical engineering for the process being designed or operated. Environmental engineers will be more effective if they understand people, management, some law and public policy.

Fortuitously, the policies needed to foster pollution prevention technology are those that foster technology in general. The strengths and weaknesses of the United States in global technology competition are the same for pollution prevention technology. A concurrent challenge, for the future and for the world, is to provide clean and energy efficient technology at prices that compete with the dirtier or less efficient alternatives.

A. Barriers to Prevention Technology

The 1990 report from the National Academy of Engineering (NAE) addressing global technology[85] stated that the U.S. basic research enterprise was unsurpassed. The American pool of technical talent is unmatched; the scale of technical creativity is unsurpassed. A review of pollution prevention efforts is consistent with this assessment. Greater prevention is not hindered by a lack of technology; rather, very large gains are possible with what is currently known and available.

The NAE also identified the country's technological weaknesses. These are included below in boldface; CEQ's appraisal of how they relate to pollution prevention are in standard type:

- **Underdeveloped relationships between industry and academia.** There is also evidence that academia could more strongly emphasize pollution prevention in providing graduates with requisite skills for industry.
- **Chronic underinvestment in infrastructure and plant.** This factor could likewise delay capital investment for pollution prevention equipment.

- **Limited technical transfer both inside and outside the firm.** As demonstrated in numerous cases, information transfer is essential to successful pollution prevention efforts.
- **Underdevelopment of the workforce potential.** Inadequate workforce organization, training, and participation hinders prevention ranging from shop floor suggestions to the effective adoption of new techniques.

In general, the NAE found that the U.S. weakness is more a failure to adapt and adopt, not to create the new. This analysis would appear to apply equally to pollution prevention.

The overlap between pollution prevention and technological competitiveness is evident in other ways. A 1990 report by the Department of Commerce[86] on emerging technologies of significant economic potential through the year 2000 included many that CEQ finds relevant to pollution prevention and energy efficiency: advanced materials (important both for corrosion resistance and pollution avoidance in several applications); superconductors (promising for energy efficiency); semiconductors (needed for contaminant controls); computer-integrated manufacturing, better sensors, and artificial intelligence (leading to more efficient manufacturing processes); and biotechnology, which has the potential to replace many chemical and mechanical processes with simpler direct manufacturing techniques. The report also listed existing technologies of growing importance, such as "smart" buildings, chemical catalysis, power generation, and radiation processing.

The Commerce Department report found barriers to U.S. competition in these emerging technologies, such as the high costs of capital and prototype demonstrations. The latter barrier is especially troublesome because the multi-disciplinary nature of emerging technologies is often too expensive for any single firm to bear; the benefits potentially accrue to so many firms that individual firms are unwilling to undertake R&D alone.

Yet another barrier with overlapping impacts on technology generally, and pollution prevention specifically, is the problem of excess regulation. Both the regulated and regulating communities are frustrated by dissonant pollution control laws and complex permitting procedures -- none of which tend to promote innovation or cost-effectiveness, in pollution prevention or any other field.

B. Solutions

1. Measurement and Policy Formulation

Producers want to know the rules of the road before investing in the latest approach to pollution reductions. Regulatory uncertainty only adds to technological and market uncertainties. The concept of pollution prevention is sound, but may not invite investment if laws and regulations provide only for mandatory control technologies, with little flexibility or incentives for voluntary innovation. Several directions for policy solutions are suggested.

A primary challenge is the issue of measurement. The pollution prevention approach aims for decentralized innovation and execution, but also contains an obligation to the public to ensure progress toward a quality environment. Measurement and verification of such prevention is a difficult proposition for all the diverse economic activities conducted in the United States, but clearly more comprehensive data is needed for the design of better programs.

As better measurements are developed, some policymakers may be tempted to impose mandatory pollution cuts based on the latest data, such as the Toxics Release Inventory (TRI), overlooking the technical/economic imperatives of specific industries or processes. Such an approach would mark a retreat from attempts to harness market forces to integrate the environment and economics.

Case-by-case consideration of proposals from industry experts is another approach to pollution prevention, but would place regulators in the position of dictating corporate decisions. Nor is it likely that government can match the technical and financial resources of the private sector for assessment of thousands of productive processes.

A promising solution is greater education, communication, and research among policymakers and the regulated community, to allow a cross-fertilization of ideas and a higher level of mutual understanding. Private sector experts can contribute to formulating cost-effective pollution reduction strategies, and share with regulators and congressional staff the responsibility of setting economic and environmental objectives. An obvious example involves the United States chemical industry, which enjoys a world leadership position, a favorable balance of trade, and a highly respected corps of technical engineers. As one of the nation's leading consumers of energy and producers of toxics, and as one of the national leaders of the prevention movement, the chemical industry has the opportunity to develop programs that are cost- and environmentally-effective--if policymakers provide the proper climate.

2. Technology Promotion

The U.S. Technology Policy issued by the White House Office of Science and Technology Policy (OSTP) in fall 1990[87] is currently the blueprint for United States technology development. The Policy mobilizes the private sector and the public to pursue global economic competitiveness of U.S. firms, given a basic reliance on the free enterprise system. Because pollution prevention depends on developments in all technology, the Policy has special relevance for the prevention movement.

Among other things, the Policy focuses on the need for: a trained quality workforce; a long-term investment climate; better translation of technology into timely, cost-competitive products; efficient technological infrastructure including information transfer; and a legal/regulatory environment that provides stability for innovation and does not pose unnecessary barriers to private investments in R&D and production.

Federal, state, and local governments, industry, and academia all have roles to play. Some specific federal responsibilities include:

- Providing a stable legal and regulatory environment that decreases investment risk; removes unnecessary obstacles to innovation; and promotes industrial competitiveness.
- Supporting basic research and participating with the private sector in pre-competitive research, when uncertainties are too great to permit assessment of commercial potential; and,
- Strengthening science and math education, transfer of federally funded research and development, and cooperation with state-level programs.

Such policies would attack the barriers to U.S. competitiveness generally, and pollution prevention specifically.

C. Conclusion

This chapter has emphasized that pollution prevention is by nature highly process-specific. The concept is easily described, but harder to define. As the nation moves beyond an era of remediating gross sources of pollution, and onward into an era of simultaneous economic and environmental progress, the nation's environmental measurements, regulations, and expectations for policies must be realistic and adaptable to a complex set of problems. Simple prescriptions for environmental objectives are often the wrong prescriptions, or at least, they are rarely the most effective solutions.

America's future can encompass a robust, efficient economy, and a healthy, safe environment if strategies are pursued that recognize not only the individual elements and priorities, but as importantly, the dynamics of a larger system. Pollution prevention's reliance on a decentralized ethic is a reliance on the nation's traditions and strengths. Pollution prevention is a promising strategy, and an exciting technical challenge.

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