Developing a Chemical Industry Strategy: State-of-the-Industry Profile

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Executive Summary

As part of its "Industries of the Future" program, the U.S. Department of Energy (DOE) Office of Industrial Technologies (OIT) is developing a strategy to focus its technology development efforts that are relevant to the chemical industry on the highest-priority needs of that industry. Industry involvement is an important part of the strategy development process. To develop the chemical industry strategy, OIT will work with the industry to identify its vision of the industry's future and the technology needs that flow from that vision. An industry-initiated and industry-led effort is currently underway to define a vision and roadmap for change for the chemical industry. This effort, along with additional discussions with industry leaders to identify specific technology needs, will provide OIT with the information it needs to work jointly with industry to develop the strategy. Ultimately, the strategy will help OIT orient its chemical industry-related programs toward those technology needs that are both critical to the industry's future and that are best met through a government/industry partnership.

This report, the first element of the strategy development effort, provides background information on the driving forces affecting the chemical industry, the challenges and opportunities they represent, and how the industry is responding to them. To assess the industry's perspectives on these topics, Pacific Northwest Laboratory (PNL) reviewed a number of industry sources, including the annual reports of 31 major chemical companies. These were supplemented with data from other sources where appropriate.

This review indicates that the driving forces exerting pressure on the chemical industry include economic and competitive conditions, globalization, environmental requirements, and changing customer demands. These can be grouped into two categories: economic/competitiveness trends and environmental trends.

The economic/competitiveness trends affecting the U.S. chemicals industry include (Lenz 1994):

- supply/demand mismatches resulting from slow U.S. and global economic growth and the globalization of supply
- increasing development of domestic chemical industries by other countries, exacerbating global oversupply and shrinking export markets
- decreasing pricing flexibility—prices are now set globally for many chemicals, and the weak economic climate has made customers less willing to accept price increases.

In response to these trends, the industry has cut costs and achieved gains in productivity; focused on customer satisfaction; increased quality; and continued global investment. Employment has fallen at the same time that labor productivity has risen. In addition, firms have moved into the more profitable

specialty chemicals market, and have put less focus on basic, commodity chemicals. One consequence of this movement is a shift of research expenditures from basic chemistry to the technical service that customers demand with specialty chemicals.

Environmental drivers involve regulatory initiatives as well as increased public attention to environmental issues. These two drivers have created strong pressure on the environmental front, which is manifested in two ways:

- as mandates governing chemical industry operations, which are forcing companies to invest in costly environment-related upgrades
- as demands by customers for products that are developed using environmentally benign processes and that help them meet environmental requirements.

Meeting environmental requirements has consumed an increasing share of the industry's capital investment; this trend is likely to continue with the March 1, 1994, issuance of a new Environmental Protection Agency (EPA) rule requiring chemical plants to reduce atmospheric emissions of toxic substances by 88%.

The industry is responding to environmental trends by increasing environmental spending on pollution abatement and control, working to improve the environmental performance of its manufacturing processes, and working with clients to develop new products that conform to new regulations. Industry-wide programs, such as Responsible Care®, have been developed to improve environmental performance and restore public trust.

The industry's pattern of research and development (R&D) expenditures reflects its response to economic/competitive and environmental drivers. Overall, spending for R&D within chemical companies has been gradually decreasing, a trend that is expected to continue until at least the middle of the decade. This decrease is in part a response to the recession that took hold in 1991; R&D investments are not generally viewed as revenue producing and are thus vulnerable when cost-cutting is required (Thayer 1994). In addition, in response to the shift to specialty chemicals, more funding has been allocated to technical service costs and to product extensions or upgrades, leaving less money available for R&D activities in areas such as new chemistry and knowledge building. Finally, the need for increasing investments for environmental needs has also squeezed R&D budgets among chemical firms.

Currently most R&D dollars—67% in 1991—are consumed by technical service costs and product extensions and upgrades, which provide individual companies with competitive edges. Less than 25% of the industry's R&D spending goes into new processes and new chemistry, compared with 50-65% in 1981.

Many companies also are changing how they do R&D, opting to contract to outside organizations and participate in joint R&D ventures with other companies. Firms have also begun to tap into the resources of the federal laboratories, and industry has begun to explore opportunities to partner with the federal government in areas of mutual interest. The OIT's "Industries of the Future" program builds on this movement toward collaboration among firms and with the federal government. The program will advance the state of chemical technology by (DOE 1994):

- catalyzing and facilitating collaborative, integrated planning and implementation of technologies by industry, government, and other participants
- conducting research, development, and deployment (RD&D) through partnerships with industry participants as well as by focusing competencies of the federal laboratories on industry applications
- disseminating technology and information to stimulate broad commercialization of technologies.

As the next steps in the strategy development effort for the chemical industry, OIT will discuss technology needs with industry leaders in the context of the drivers discussed in this report, the vision being developed by industry representatives, and recent input from the industry on technology needs. OIT will hold a public workshop to review these results with stakeholders and seek feedback and additional input. Finally, OIT will use the input from this process to develop a strategy for conducting high-priority RD&D collaboratively with industry and other partners.

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1.0 Introduction

The chemical industry, the largest industrial consumer of energy in the United States, has benefited from U.S. Department of Energy (DOE) efforts to develop technology to improve industrial energy efficiency. Currently, DOE's Office of Industrial Technologies (OIT) is focusing its technology development efforts to be even more effective in helping the industry improve its long-term competitiveness. The Pacific Northwest Laboratory (PNL)^(a) is assisting OIT in developing a chemical industry strategy to focus technology development efforts relevant to the chemical industry on the highest-priority needs of that industry. This report represents an initial effort in developing such a strategy.

This strategy development effort is part of the DOE's "Industries of the Future" program, which is designed to align federal investments in technology research, development, and deployment (RD&D) with the needs of technology users in the private sector (DOE 1994). The industries targeted by the program are developing, with OIT facilitation, visions of their futures that will serve as the basis for shaping a portfolio of RD&D activities focused on high-priority technologies.

The elements of the strategy development effort for the chemical industry are as follows:

- initial characterization of the chemical industry, the forces that are driving it, and the industry's vision of how those forces are shaping its future
- discussions with industry representatives to obtain feedback and input on
 - the driving force analysis
 - the industry's vision of its future
 - the technology-related needs that industry must meet to respond to driving forces and achieve its vision
 - the subset of those needs that might best (or only) be met with government as a partner
 - the issues that must be resolved to increase the effectiveness of government/industry partnership efforts
- identification of detailed technology needs (in cooperation with industry) in high-priority areas
- development of a strategy for working in partnership with the chemical industry on technology-related programs that will achieve those goals common to the chemical industry and the U.S. government.

(a) Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under contract DE-AC06-76RLO 1830.

A key element of the "Industries of the Future" program is the involvement of industry participants throughout the strategy development process. The Chemical Manufacturers Association (CMA), the American Chemical Society (ACS), the American Institute of Chemical Engineers (AIChE), and other groups are currently leading an industry-initiated effort to develop a vision and roadmap for change for the U.S. chemical industry. This effort, which is occurring concurrent with the "Industries of the Future" program for the chemical industry, will provide vital input to the OIT program.^(a) To develop its strategy under this program, OIT will rely on this input as well as additional input obtained from industry representatives.

This report represents the first element of the strategy development effort for the chemical industry. It profiles the driving forces impacting the industry, the challenges and opportunities they present, and how industry is responding to them. Key industry characteristics, such as energy use, environmental constraints, and investment, are described in Section 2.0. Section 3.0 discusses major factors influencing industry actions, such as globalization of markets, increased competitive pressures, and stakeholder pressures. Their influence on industry capital investment and research and development spending are described in Sections 4.0 and 5.0. Section 6.0 presents conclusions, and Section 7.0 addresses next steps in the strategy development process. Appendix A provides supporting tables.

To prepare the report, PNL staff reviewed industry overviews, forecasts, and statistics in trade journals and reports and Department of Commerce publications. This analysis was supplemented with discussions with chemical industry analysts and trade associations and a review of the 1992 annual reports of 31 major chemical companies (see Table A.1) to identify company goals and the strategies they are using to achieve them. To assess the chemical industry's perspectives on these topics, PNL emphasized industry sources in its review, supplementing these with data from other sources where appropriate.

(a) The industry and OIT efforts are closely linked. The leader of the PNL effort to support OIT's strategy development effort for the chemical industry is a participant in the industry group developing the vision and roadmap for change for this industry.

2.0 Industry Characteristics

This section describes characteristics of the chemical industry, including its products, dimensions, energy consumption, environmental mandates, employment, international trade, and stakeholders.

2.1 Products

The chemical industry is extremely diverse. It produces a variety of products that may be viewed as part of three broad categories:

- **basic chemicals**—e.g., acids, alkalies, salts, and organic chemicals
- **chemical products used in further manufacture (intermediates)**—e.g., synthetic fibers, plastic materials, and color pigments
- **finished chemical products used for ultimate consumption**—e.g., drugs, cosmetics, and soaps—or **used as materials in other industries**—e.g., paints, fertilizers, and explosives.

The 4-digit industries in Standard Industrial Classification (SIC) 28 are shown in Table A.2. A broader definition of the industry beyond SIC 28 includes other chemically processed products such as semiconductors, carbon paper, and inked ribbons, which encompass an even more diverse industry. However, this strategy development effort focuses on the chemical sub-industries included in SIC 28 exclusive of pharmaceuticals.^(a) Table A.2 indicates how the companies whose annual reports were reviewed are distributed within SIC 28.

2.2 Dimensions

Statistics on the dimensions of the chemical industry are listed in Table A.3. The chemical industry is among the largest industries in the United States and is a major driving force in the U.S. economy. Total industry revenues exceeded \$316 billion in 1992 (CMA 1993), while shipments exceeded \$295 billion (Chemical Week 1993b). In 1990, the industry accounted for about 1.8% of the U.S. gross domestic product and about 23% of total world chemical production (CMA 1993).

(a) Although industry-wide statistics cited in this report include the pharmaceuticals industry unless stated otherwise, pharmaceuticals are not expected to be a focus of the chemical industry strategy.

In all, U.S. chemical companies produce over 70,000 different chemical products at over 12,000 plants (CMA 1993). United States companies have more than 2,800 facilities abroad, and 1,700 foreign subsidiaries or affiliates operate in the United States.

The chemical industry itself is the largest purchaser of its own chemical production, consuming 24% of the industry's output in 1992 (CMA 1993). The rest of the manufacturing sector purchased 29% of its output, with the remaining output going to non-manufacturing industries and consumers. The high fraction (over 50%) of output used in the manufacturing sector makes chemical industry competitiveness highly dependent on the competitiveness of manufacturing as a whole.

2.3 Energy

The chemical industry is the largest industrial consumer of energy for heat and power purposes in the United States and the second largest consumer of energy feedstocks (after petroleum refining). In 1992, the industry consumed about 5.6 quads of energy for fuel, power, and feedstocks, about 7% of total U.S. energy consumption (CMA 1993). About 52% of this went for fuel and power needs, with 48% for feedstocks. Consumption for heat and power represented about 18% of total manufacturing consumption for this purpose.

Four segments of the chemical industry—inorganic chemicals, plastics, organic chemicals, and agricultural chemicals—dominate industrial energy use. In 1989, these four industry segments consumed almost 87% of the total fuel and electricity purchased by the industry as a whole. In the same year, these industry segments consumed over 90% (in kWh) of the electricity purchased by the chemical industry (DOC 1989).

Over time, feedstocks have grown as a fraction of energy use. In 1970, feedstocks were 39% of the total energy use in the chemical industry; by 1991, this fraction had grown to 48%. This trend reflects increased demand for petrochemicals to create plastics and other materials as well as increased energy efficiency in production processes (CMA 1992). Measured in terms of energy use per unit of output, efficiency in the use of energy for fuel and power has increased by 51% since 1974 (CMA 1992). This increase is due both to improved technology and energy management and to changes in the mix of products toward fine chemicals, whose production is less energy intensive than basic, upstream commodity chemicals.

Energy intensity varies widely among segments of the chemical industry. Some portions of the industry are very energy intensive. For example, the energy needed for fuel and power in the industrial gases industry represents from 40 to 50% of total operating costs. Other parts of the industry are relatively non-energy intensive. For example, energy use in the production of inorganic chemicals amounts to less than 10% of production costs (OTA 1993).

2.4 Environment

The chemical industry is subject to numerous statutes and regulations designed to protect and restore the environment (see Table A.4). These govern discharges to air, water, and land; management of hazardous waste from generation to disposal; cleanup of hazardous waste sites; testing and manufacture of chemical substances and mixtures; and generation, storage, purchase, and shipment of hazardous material. More recent regulatory trends emphasize waste avoidance and pollution prevention over traditional end-of-the-pipe controls.

The chemical industry has been required to make significant capital investments to comply with environmental protection requirements associated with its operations. As a result of these expenditures, the CMA reports that releases of a core list of Toxic Release Inventory chemicals from CMA member companies decreased 35% between 1987 and 1991, an annual decrease of 10.2%. Over the same period, transfers for treatment and disposal decreased 37% and industry production increased 11% (CMA 1993).^(a)

The industry also has spent substantial amounts to clean up inactive hazardous waste sites under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as Superfund. The industry has supported reform of this law to, among other things, replace with a proportional liability scheme the current strict, joint and several liability scheme wherein any party who contributed waste to a Superfund site can be held liable for the total cost of the cleanup, regardless of the amount of waste that party contributed (AIChE 1993).

2.5 Capital Expenditures

The chemical industry is by its nature very capital intensive, requiring heavy investments in equipment, processes, and technology. In 1992, gross capital stocks per employee in the chemical industry were \$197,800, more than twice the amount for U.S. manufacturing as a whole (CMA 1993). New capital expenditures in 1992 totaled \$23 billion (CMA 1993). By and large, aggregate capital spending has increased greatly since the early 1980s, although individual companies' expenditures may fluctuate from year to year, depending on their financial situation, whether they have added any new facilities within the past year, and the company's area of specialty.

2.6 Employment

Over one million people are employed in the chemical industry, though employment has been flat over the past 10 years, matching trends in manufacturing as a whole (CMA 1993). The

(a) CMA member companies account for more than 90% of basic U.S. industrial chemical capacity.

pharmaceuticals sector, in fact, is the only sector showing annual employment increases over that period. The early 1990s saw employment cutbacks of approximately 4% at 21 major chemical companies. Labor productivity (output per labor hour) has increased steadily over the past decade.

2.7 International Trade

The U.S. chemical industry is a substantial contributor to manufacturing exports and has had a trade surplus every year since 1983. In 1993, the industry had exports of almost \$45 billion and imports of about \$29 billion, for a trade surplus of almost \$16 billion (Anderson 1993). However, this surplus has been eroded in recent years by weak overseas economies, which dampened exports, and growing imports (Lenz 1994). (The U.S. economy was less weak than many others, so its imports grew more than its exports.) The chemical trade surplus dropped over 13% in nominal terms from 1991 to 1992 and 3.5% from 1992 to 1993. Also, the composition of exports has been changing. Exports of organics, the largest export category, have fallen slightly while exports of specialty chemicals, such as dyes and coloring materials, essential oils, perfumes, toilet preparations, and cleaning materials, are growing faster than the all-chemical average, though they remain a small fraction of total exports (Anderson 1993). The level and fraction of trade associated with each industry segment are indicated in Table 2.1.

In 1992, the largest single-country market for U.S. chemicals was Canada (16.6%), followed by Japan (10.7%) and Mexico (7.1%). As a bloc, the European Union (EU)^(a) is the U.S. chemical industry's largest single market (27.4%). Exports to Mexico have been growing steadily, doubling over the last five years; the North American Free Trade Agreement is expected to stimulate increased trade with Mexico and Canada.

By region, most exports went to Western Europe (about 30%); East Asia and Latin America received about 17% of exports. Growth in exports to East Asia is slowing as these countries begin to supply parts of their own markets from their own chemical plants (CMA 1993; Anderson 1993).

2.8 Stakeholders

Many groups have a stake in the performance of the chemical industry, including shareholders, employees, customers, retirees, communities/neighbors, suppliers, regulators, industry and trade associations, ultimate consumers, the financial community, the media, joint venture partners, and others. Table A.5 provides examples of these stakeholder groups.

(a) Formerly known as the European Community.

Table 2.1. 1993 U.S. Chemical Trade by Industry Segment (billions of U.S. dollars)

	Exports		Imports		Surplus	
	Level (\$ billions)	Share (%)	Level (\$ billions)	Share (%)	Level (\$ billions)	Share (%)
Organic chemicals	11.0	24.6	9.3	32.0	1.7	10.8
Primary plastics	7.3	16.3	2.7	9.3	4.6	29.3
Pharmaceuticals	5.7	12.8	4.1	14.2	1.6	10.2
Inorganic chemicals	4.1	9.2	3.2	11.1	0.9	5.7
Nonprimary plastics	3.3	7.3	2.1	7.3	1.1	7.3
Oils/perfumes/cleaners	3.0	6.6	1.8	6.0	1.2	7.7
Dyeing/tanning/coloring Materials	2.0	4.4	1.7	5.9	0.3	1.6
Fertilizers	1.8	3.9	1.2	4.0	0.6	3.7
Other	6.7	14.9	3.0	10.2	3.7	23.6
Total	44.9	100	29.2	100	15.7	100

Source: Anderson 1993.

The interests of various stakeholder groups may conflict with one another and with the needs of the industry itself. For example, stringent environmental laws promoted by regulators and public interest groups are aimed at protecting the environment but may damage industrial competitiveness relative to some foreign competitors. Likewise, company shareholders' interests in the short-term profitability of a particular firm may conflict with the local community's interest in the company's long-term success. In spite of such conflicts, shareholder interests often become the most important near-term driver for industry leaders. As much as 75% of a company's common stock may be in the form of institutional holdings. Pressures to ensure near-term profitability through cost reductions have resulted in significant downsizing throughout the industry. At the same time, public and regulatory pressures have motivated the chemical industry to take active steps to reduce the environmental impacts of its operations and to work with community representatives in doing so.

3.0 Industry Drivers and Strategies: Productivity, Globalization, and the Environment Dominate

The driving forces exerting pressure on the chemical industry include economic and competitive conditions, globalization, environmental requirements, and changing customer demands. These forces are interrelated. For example, customer demands have shifted toward more environmentally benign products; increases in spending to meet environmental requirements can affect international competitiveness; and globalization of markets affects the competitive climate in which U.S. companies must operate. The most important aspects of the major driving forces are described in this section in two separate categories, economics/competitiveness and environment, but their interrelationships should be kept in mind. Likewise, industry actions in response to these drivers, discussed in the context of individual drivers, usually are directed at multiple drivers.

3.1 Drivers: Economic and Competitive Pressures are High, Exacerbated by Globalization

Economic forces and competitive pressures have always been major drivers for the chemical industry. They are especially important today in light of the trend toward a global industry, which has been fostered and enhanced by world economic growth, the reduction of trade barriers, and advances in telecommunications and transportation. Competitive pressures increase with globalization of markets and expansion of regional players to foreign markets so that all suppliers compete everywhere.

Several trends are affecting the profitability and competitiveness of the U.S. chemical industry, as described below (Lenz 1994):

- supply/demand mismatches resulting from slow U.S. and global economic growth and the globalization of supply
- increasing development of domestic chemical industries by other countries, exacerbating global oversupply and shrinking export markets
- decreasing pricing flexibility—prices are now set globally for many chemicals, and the weak economic climate has made customers less willing to accept price increases.

Slow growth in the industries served by the chemical industry has affected chemical sales and profits. For example, slowdowns in the aluminum and textile industries have depressed demands for caustic soda from the chlor-alkali industry (SIC 2812) (Chemical Week 1993a). Flat overseas economies have adversely affected export markets for U.S. companies.

In addition to such business cycle effects, however, worldwide overcapacity in some industry segments has led to declining prices and lower profit margins and a trend toward company mergers. For example, low energy prices and worldwide overcapacity in the petrochemical industry are leading to a global consolidation of the refining industry that will ultimately result in fewer and leaner petrochemical companies. This trend is likely to worsen as some overseas markets, most notably in Asia, begin to supply their own petrochemicals and other chemicals, further shrinking export markets for U.S. products. Globally competitive chemical industries are emerging in newly industrializing countries such as Singapore, South Korea, Taiwan, and Thailand, reducing their value as export markets for U.S. companies.

Recent economic conditions and low inflation rates have left industrial customers unwilling to accept price increases for many chemicals, particularly petrochemicals, even in the face of increasing input prices. Also, industrial customers have demanded discounts when feedstock prices have declined, even those customers who purchased chemicals based on other inputs whose prices did not decline. Petrochemical producers typically enjoy only a short period (as short as a week) of improved profitability when feedstock prices fall (Ainsworth 1993).

Prices for many chemicals are set globally, which also has hampered producers' ability to set prices and thus their profitability. As one industry spokesman stated, prices now determine costs. That is, prices are set globally, and companies must make adjustments to input costs (e.g., by laying off workers) to remain profitable (CMA 1994).

Other economic drivers among highly capitalized companies include a need to pay down debt, partly in response to pressure from the financial community. One petrochemical company included in its annual report 11 quotes from various financial analysts highlighting their positive view of the company's efforts to strengthen its profitability (Occidental Petroleum Corporation 1993).

Volatility in product demand, which affects profitability, reflects changing market and economic conditions as well as increased emphasis on nonhazardous products. Changes in worldwide economic conditions can cause significant product demand changes. For example, upheavals in some parts of the world have eliminated the market for certain products. Also, downturns in domestic industries such as the defense and aerospace industries have decreased customers' profit margins and thus their demands. At the same time, significant new markets are opening up in Eastern Europe and Asia that companies feel they must respond to if they are to remain competitive and profitable. In addition, the increased demand for more products that are less hazardous to the environment and to production workers is increasing the market for some chemicals, such as bromide-based water treatment chemicals, and decreasing the markets for others, such as chlorine (see the discussion of environmental strategies). All in all, economic conditions and environmental requirements have created a business that can be characterized as volatile, and this volatility was cited repeatedly in the annual reports as a challenge to the chemical industry.

3.2 Strategies: Companies Emphasize Productivity Gains and Customer Satisfaction

In the 1980s, the chemical industry restructured itself by closing inefficient and obsolete plants, streamlining production processes, reorganizing corporate activities, and placing more emphasis on specialty chemicals with high profit margins (OTA 1993). Yet, as discussed, the 1990s have presented significant economic and competitive challenges that were exacerbated by increasing globalization. Companies responded to economic and competitive drivers by cutting costs and achieving gains in productivity; focusing on customer satisfaction; increasing quality; and continuing global investment. These strategies had important implications for the level and nature of expenditures for capital investment and research and development, as discussed in Sections 4.0 and 5.0.

3.2.1 Strategy: Cost-Cutting and Productivity Gains are Necessary to Improve Profitability

As noted earlier, many companies have found it difficult to raise prices and so have focused on cutting input costs and improving overall productivity to increase profitability. Managing costs and investing in productivity-enhancing equipment were necessary for bottom-line gains in 1993 (Chemical Week 1993b).

Providing value to stockholders and becoming low-cost producers were recurring themes in the annual reports. Many companies had specific goals to achieve percentage returns on shareholder equity that ranged from the mid-teens to 20% (Monsanto 1993; B.F. Goodrich 1993). Sixty-five percent of the companies whose reports were reviewed described planned cost-control measures that included divesting assets to reduce debt, reducing reliance on cyclical products, closing unprofitable or outdated plants, streamlining operations, cutting jobs, encouraging early retirement, and reducing spending on facilities and research.

Restructuring and downsizing in response to economic and competitive pressures have resulted in declines in employment, particularly at 21 large companies where employment decreased 4% in 1992 (C&EN 1993b). At the same time, labor productivity has been increasing steadily for the industry as a whole; the workers left behind after restructuring are being asked to do more. Greater employee productivity is encouraged through means such as financial incentives and awards. Performance-based compensation can put a significant share of an employee's compensation at risk, depending on the profitability of the particular business unit and the corporation as a whole.

Many firms also are focusing on strategic businesses, either by selling non-strategic businesses or acquiring other, complementary businesses.

3.2.2 Strategy: An Increasing Focus on Customer Satisfaction is Critical to Company Success

Companies have responded to economic and competitive pressures by focusing on customer satisfaction as crucial to company success. Providing quality products and services was an implicit or explicit goal for many of the companies whose annual reports PNL reviewed. This was sometimes stated as a goal to maintain product quality in the face of needed cost-cutting.

Underlying product quality goals is a focus on customer satisfaction and becoming the first choice supplier for a company's customers. A related recurring theme was working with customers as partners to solve technical problems and develop products that meet the customers' needs, particularly those related to environmental requirements. Today, product development begins with identifying customer needs. Various companies have implemented cross-functional team strategies that combine expertise from many disciplines—sales, technical service, research, engineering, and logistics—to enable the company to meet customers' product design requirements more easily (ARCO Chemical Company 1993). Being indispensable to customers' success is seen as a high priority. This attitude reflects the situation in Japan, whose model of close, long-term supplier/customer relationships is a crucial element of that country's economic success. In the face of such relationships, customers may be less willing to switch suppliers as prices fluctuate.

In addition, most companies are working to improve on-time delivery and reduce customer complaints by streamlining the supply-chain management process. Customer satisfaction surveys are used by one major enterprise to obtain direct feedback from clients regarding the quality of the company's performance (Nalco Chemical Company 1993). Clients grade both this firm and its competitors on a variety of criteria that they consider important.

The degree of focus on interaction with customers also has been affected by shifts among the types of chemicals sold by the industry. The output of chemical companies is typically divided into two categories: basic or commodity chemicals, which are sold on the basis of price, and specialty chemicals, which are sold on the basis of performance. Compared with commodity chemicals, specialty chemicals are more profitable and less cyclical. In an effort to combat the cyclical nature of the industry, in the 1980s most commodity chemical manufacturers made forays into the downstream specialty chemicals business (Anderson and Ayers 1992). However, the profitability life span of specialty products is shorter than that of commodity chemicals, and customers typically demand closer collaboration and higher levels of technical service with these products (Anderson and Ayers 1992). Also, even the specialty chemicals market is experiencing increased pressure on profit margins. The market as a whole has been becoming more competitive (Anderson and Ayers 1992).

Shifts to specialty chemicals have been reflected in an increasing focus on customer satisfaction and increasing shifts of research expenditures from basic chemistry to technical service (see Section 5.0).

3.2.3 Strategy: Product and Process Quality Help U.S. Companies Compete Internationally

Firms also are responding to economic and competitive pressures by increasing the quality of products and processes. Many of the firms surveyed are seeking certification through the International Organization for Standards (ISO) 9000 program, which was initiated in 1987 as a series of five international standards for quality management and quality assurance (QA). The ISO standards establish a benchmark for QA practices for nearly all phases of the production process, including design, manufacture, installation, packaging, and marketing (see Table A.6). Currently, approximately 35,000 ISO registrations exist in Europe, compared with only 2,000 in the United States, although the number of new registrations grew by 500% in the United States during 1992 (SOCMA 1993). Some major U.S. chemical companies that have achieved ISO certification are listed in Table A.7.

In addition to improving company performance, implementation of ISO standards can help U.S. firms compete more effectively with international chemical companies, since the EU may soon require compliance with ISO 9000 standards for companies that make products in or export goods to EU member countries (Grant Thornton 1992). Companies that are part of ISO 9000 also agree that the program helps them cut costs and boost on-time delivery. A recent survey of 1,679 companies in the United States and Canada having ISO registrations reported an average annual savings of \$179,000 as a consequence of registration, and most companies expected to recoup the costs of registration within 40 months (SOCMA 1993).

3.2.4 Strategy: Global Investment Continues

Companies feel pressure to continue global investment. Regional companies cannot compete in this global market and feel pressure to expand. Expansion in turn requires increased capital expenditures for plants and equipment, for acquisitions, or for both.

In a recent speech to a meeting of the American Institute for Chemical Engineers, a petrochemical industry executive echoed the philosophy underlying most discussion of industry globalization trends:

As a U.S. company, why do we invest outside the United States? . . . We do it because we now know the industry is global . . . We do it to provide flexibility and speed of response. We do it to better serve the diverse needs and values of individual markets and regions. We do it to take advantage of the continuing ebb and flow of feedstock availability and cost. . . . The reward of global investment in the chemical industry is that you get to stay in business—the risk is that if you don't, you won't. It has become an admission fee to get into the game—not an expensive optional choice (Cook 1993).

3.3 Driver: Environmental Requirements Affect Capital Investment and Product Development

As noted previously, the chemical industry is subject to a large number of environmental regulations. Increasing public attention to environmental issues, combined with regulatory initiatives, has created strong pressure for action on the environmental front. These pressures manifest themselves not only as mandates governing chemical industry operations, but also as demands by customers for products that are developed using environmentally benign processes and that help them meet environmental requirements.

Increasing and evolving regulations are seen as a significant challenge by the chemical industry. Such regulations are forcing companies to increase spending on technologies and plant upgrades to comply with new regulations impacting fuel formulation, air and water emissions, and waste handling (see Table 3.1). The Commerce Department reports that capital expenditures for pollution abatement and control in the chemical industry almost tripled between 1985 and 1991 (see Table 3.2).

Further increases in environmental spending are expected. In March 1994, for instance, EPA issued a new rule requiring U.S. chemical plants to cut toxic substances emitted into the air by 88%. As a result, companies will need to install new scrubbers, evaporation barriers, or other forms of pollution prevention technology. These new regulations are estimated to cost firms between \$680 million to \$1 billion a year to comply (Lee 1994).

In many cases, the need to control costs requires producers to pay more attention to waste minimization and process changes that reduce pollutant use and generation as alternatives to end-of-the-pipe controls. At the same time, customers' demands for products that help them meet environmental requirements compel firms to be environmentally focused in their product development. Many customers, for instance, are demanding increased quantities and numbers of solvent-free and water-based products.

Environmental requirements can sometimes have a significant impact on the industry by creating altogether new or expanded market opportunities. For example, the market for hydrogen is expected to surge over the next decade as petroleum refiners upgrade gasoline to meet new Clean Air Act requirements. Methanol markets also are expected to grow with the advent of methyl-tertiary-butyl-ether as an oxygenated fuel additive. Moreover, while the industry is deeply concerned about EPA proposals and public pressure to restrict or ban the use of chlorine in such uses as water disinfection, solvents, plastics, and pulp and paper manufacturing, those companies that have developed alternatives to chlorine in these applications could benefit greatly (Hileman and Hanson 1994).

Future environmental requirements are expected to be increasingly stringent. New developments in chemical processes and technology are viewed as key to the industry's ability to meet these requirements and remain competitive. For example, a chemical company executive, speaking at a January 1994 U.S.-Russia Workshop on Environmental Catalysis, stated that industrial facilities face two major

Table 3.1. Environmental Spending by Company - 1992^(a)

Company	1992 Environmental Spending (millions of U.S. dollars)		Change 1991-1992	
	Capital	Other ^(a)	Capital	Other ^(a)
Air Products	na ^(b)	29	na	12
Allied-Signal	28	69	na	19
BASF	127	651	na	na
Dow Chemical	200	47	-13	-6
Du Pont	300	900 ^(c)	0	0
FMC	20	57	-29	19
General Electric	110	120 ^(d)	-19	0
Henkel	25	134	-25	0
Hoechst	356	910	na	-5
ICI	258	297	28	5
Mobil Oil	572	677	41	6
Monsanto	123	310	76	5
Occidental Chemical	43	80	-17	1
Olin	25	78	0	20
PPG Industries	48	na	167	na
Rhône-Poulenc	113	201	na	na
Rohm & Haas	48	92	-13	-15
Shell Oil	320	1060	-11	17
Texaco	270	403	13	-10
Union Carbide	82	150	26	-18

(a) Includes costs for compliance, remedial activities, and operations. Does not include accruals for environmental liabilities unless indicated.

(b) na = not applicable.

(c) Estimate includes accruals for certain remediation activities.

(d) Remediation costs only.

Source: Thayer 1993b.

Table 3.2. Capital Expenditures for Pollution Abatement in the Chemical Industry
(millions of U.S. dollars)

<u>1980</u>	<u>1982</u>	<u>1984</u>	<u>1986</u>	<u>1988</u>	<u>1990</u>	<u>1991</u>	<u>Average Annual Change</u>		
							<u>1980-91</u>	<u>1980-85</u>	<u>1986-91</u>
781	628	418	624	1,095	1,852	2,066	9.25%	-1.1%	27.1%

Source: Bureau of the Census Data from CMA 1993.

challenges: cleaning up the effects of past manufacturing problems and minimizing the waste from current processing. He noted that, in the future, the industry will have to develop zero-waste processes, minimize the use and transportation of hazardous materials, and develop inherently safer products as well as to satisfy stockholders (Haggin 1994).

3.4 Strategy: More Spending is Required on Environmental Protection

To comply with increasingly stringent environmental regulations, most companies are working on improving the environmental performance of their own internal manufacturing processes and working with clients to develop new products that conform to new regulations.

Chemical companies are making great efforts to reduce both emissions and wastes and are spending more money on environmental protection. Some companies have committed additional funds to upgrading facilities and maximizing the efficiency of their manufacturing processes to comply with environmental regulations. For example, the Commerce Department reports that, in 1991, the chemical industry's capital expenditures for pollution abatement and control reached \$2.1 billion, which represented approximately 10% of the industry's fixed capital investment (CMA 1993). The passage of the Clean Air Act in 1990 may result in the industry's investing up to 25-30% of fixed capital on pollution abatement and control (CMA 1993). According to the U.S. Department of Commerce, more than 90% of pollution control spending is for abatement, including prevention, recycling, and treatment. The remaining 10% is for regulation, monitoring, and R&D (Thayer 1993b).

3.5 Strategy: Industry-Wide Programs Help Ensure Environmental Compliance

Recent years have seen a greater emphasis within the industry on pollution prevention and avoidance as companies develop new ways of preventing the release of hazardous emissions and

wastes. Changes are being made in the areas of materials handling, maintenance, management, and operating practices. When possible, companies may try to substitute less hazardous materials for toxic ones, such as chlorofluorocarbons (CFCs) and methyl chloroform. Many firms have also increased their use of recycling or have begun to purify wastes rather than dispose of them.

This strong trend toward environmental awareness began in the early 1980s. In his speech to industry executives in June 1983, outgoing CMA chairman Bill Simeral said that it was time for the chemical industry to take a look at the industry from the perspective of the American public. Although the chemical industry was actually one of the safest in the country, based on an annual rating by the National Safety Council, most Americans nonetheless associated chemical manufacturers with leaking dump sites and environmental degradation. This was especially true after the Bhopal disaster in 1984. Simeral argued that unless the industry addressed public concerns head on, such images were likely to have a negative impact on the industry as a whole, which could affect everything from sales to recruitment (Rayport and Lodge 1991). Such attitudes provided the impetus for the development of CMA's Responsible Care Program, initiated in 1988. The aim of Responsible Care was to help achieve ongoing reductions in the amount of contaminants released into the air, water, and land from member companies' facilities (Thayer 1993b).

Responsible Care represents an industry-wide effort to improve performance and restore public trust in six key areas. A series of codes identify 106 management practices that members must carry out in these areas: 1) community awareness and emergency response, 2) pollution prevention, 3) process safety, 4) distribution, 5) employee health and safety, and 6) product stewardship (see Table A.8). The members of CMA (about 180 in all) are required to strive to reduce waste generation and pollutants released at each of their plants. Further, they must report annually to the CMA on the volume of substances released at their facilities. To date, the Responsible Care Program has been adopted in more than 20 countries.

Responsible Care receives broad industry-wide support. Smaller, non-CMA-affiliated companies have also begun to adopt the tenets of Responsible Care. Another industry trade group, the Synthetic Organic Chemical Manufacturers Association (SOCMA), whose membership generally is made up of firms with sales less than \$40 million, also promotes members' adherence to the Community Awareness/Emergency Response code of the Responsible Care Program and has begun developing implementation tools for the other five Responsible Care codes (SOCMA 1993).

Although SOCMA members support Responsible Care, they often face implementation challenges that CMA members do not face. These smaller companies do not always have sufficient capital and staff to handle the new demands associated with Responsible Care. Nevertheless, compliance is considered to be very important, because it is becoming increasingly difficult for companies not implementing Responsible Care codes to compete with those that do.

In addition to Responsible Care, various other industry-wide initiatives are aimed at helping companies improve their environmental records and promote public awareness. The Society of the

Plastic Industry sponsors a program called Operation Clean Sweep, which is designed to eliminate the loss of resin pellets from manufacturing facilities and transportation equipment into the environment, where they can be ingested by wildlife. Likewise, the American Plastics Council supports an industry-wide program to promote the responsible use, recovery, and conservation of plastics.

4.0 Effects of Drivers and Strategies on Industry Research and Development

The driving forces discussed in the previous section, and the strategies the chemical industry is using to respond to them, are leading the industry toward a particular future. As discussed in Section 5.0, the industry is in the process of articulating a vision of its desired future. However, at this time some elements of this future are evident and can be stated as follows:

- a lean, cost-conscious, and productive industry
- an industry that achieves high levels of customer satisfaction through product quality and innovation to meet customer requirements, particularly environmental needs
- an industry that competes in the global marketplace, with expansion and joint ventures targeted to meet offshore market needs
- an industry that is a good steward of the environment, using technology and innovation to prevent pollution and avoid waste.

Achieving this future will require development of advanced technologies and processes that will boost efficiency and environmental performance while simultaneously reducing energy and resource use and cutting industry costs (DOE 1994). Such developments will require sustained R&D investments targeted at high-priority areas.

The U.S. chemical industry invests heavily in R&D. In 1992, the industry spent an estimated \$14.1 billion on R&D. The federal government also actively supports chemical research. In 1993, the U.S. government spent about \$950 million on chemical-related R&D (Brennan and Long 1993). A small percentage of this total went to contract research at industrial laboratories; however, most federal funds for chemical R&D supported research at universities and federal laboratories.^(a)

(a) Four agencies provide over 70% of these funds: the U.S. Department of Energy (21%), U.S. Department of Defense (16%), U.S. Department of Health and Human Services—National Institutes of Health (14%), and the National Science Foundation (NSF) (20%) (Brennan and Long 1993). Most NSF funding is directed toward university research. The NSF provides approximately 47% of federal funds for chemical research at universities, while the Departments of Energy, Defense, and Health and Human Services provide the rest (Brennan and Long 1993). In 1992, the academic sector spent approximately \$16 billion on chemical-related research, down slightly from the previous year. The majority of these funds, over 62%, were spent on basic research (Brennan and Long 1993).

However, in spite of the need for R&D to achieve its desired future, overall spending for R&D within chemical companies has been gradually decreasing, a trend that is expected to continue until at least the middle of the decade. A recent survey of 24 major chemical companies revealed that R&D is estimated to fall an average of 1.4% in 1994 (Thayer 1994). Although another survey of the industry as a whole (including both large and small firms) has indicated that R&D spending is still slowly rising, most industry analysts conclude that, on the average, companies are investing less in research and development. Part of this decrease is because of the recession that took hold in 1991. When costs must be reduced, expenses viewed as non-revenue producing get cut first. In such an environment, spending on R&D suffers because it is considered non-revenue producing, especially in the near term (Thayer 1994).

In response, many companies have allocated more money to technical service costs and product extensions or upgrades (see Table 4.1). As mentioned earlier, this is, in part, a consequence of focusing on customer satisfaction and on shifts into specialty chemicals, which require more technical service than do commodity chemicals. This often means that less money is available for R&D activities in areas such as new chemistry and other long-term research (Mullin 1992).

Another reason for the general decline in longer term R&D budgets within the chemical industry is that firms are under greater pressure to comply with increasing environmental regulations, and the costs associated with compliance can be high. For example, in 1991, total U.S. pollution abatement and control spending amounted to about 2.0% of GNP. The EPA estimates that this spending will rise to about 2.8% of GNP by the year 2000, and this does not include the cost of compliance-related R&D, the costs of following and interpreting regulatory changes, legal expenses, and the costs of obtaining permits (CMA 1993).

Table 4.1. R&D Budget Allotments

	Fraction of Total R&D Budget Allotted to Each R&D Category	
	1981	1991
Technical services costs	30%	45%
Product extensions or upgrade	5-10%	22%
Regulatory expenses	<5%	11%
New processes	5-10%	12%
New chemistry	45-55%	10%

Source: Mullin 1992.

At the same time that chemical companies are reducing their overall R&D expenditures, many are also changing the way in which they conduct research. They are increasingly looking to outside sources to help leverage their financial resources. There is a growing trend toward contracting with outside performers, such as universities and independent laboratories, and toward participating in joint R&D ventures with other companies having similar interests. Some firms have also begun to tap into the resources of the federal laboratories. These arrangements help expand companies' technological bases while at the same time reduce R&D costs. Industry experts predict that more and more firms will form alliances in noncompetitive areas to develop technologies that can benefit the entire industry (Thayer 1994). Chemical companies will also have greater incentives to collaborate with the federal government to develop and deploy new technologies.

The OIT's "Industries of the Future" program builds on this movement toward collaboration among firms and with the federal government. The program will advance the state of chemical technology by (DOE 1994):

- catalyzing and facilitating collaborative, integrated planning and implementation of technologies by industry, government, and other participants
- conducting RD&D through partnerships with industry participants as well as by focusing competencies of the federal laboratories on industry applications
- disseminating technology and information to stimulate broad commercialization of technologies.

5.0 Next Steps

As described in Section 1.0, the CMA, the ACS, AIChE, and other groups together are leading an industry-initiated effort to develop a vision and roadmap for change for the U.S. chemical industry. This effort, which is occurring concurrent with the "Industries of the Future" effort for the chemical industry, will provide vital input to the OIT program.

As the next step in the strategy development effort for the chemical industry, OIT will first summarize the results of recent efforts to obtain input from the chemical industry on its technology needs. It will then discuss technology needs with industry leaders, individually and in panels, in the context of the drivers discussed in this report, the vision being developed by industry representatives, and the technology needs summary prepared by OIT. Industry needs related to working successfully with the federal government and federal laboratories will also be discussed. The groups involved in the vision effort will be sponsors and facilitators of this dialogue.

OIT will hold a public workshop to review these results with a broad range of stakeholders and seek feedback and additional input for strategy development and program planning.

Finally, OIT will use the input from these efforts to craft a strategy to focus DOE short-, medium-, and long-term RD&D investments relevant to the chemical industry on the most important needs of the industry and to work collaboratively with industry and other partners to conduct these RD&D activities.

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Appendix A

Tables

Table A.1. Companies Whose 1992 Annual Reports Were Reviewed^(a,b)

Air Products and Chemicals, Inc.	International Flavors and Fragrances
Amoco Corporation	Lubrizol
Atlantic Richfield Company (ARCO)	Mobil Chemical
Ashland Oil	Monsanto
B.F. Goodrich	Morton
Chevron Corporation	Nalco Chemical Co.
Cyanamid	Occidental Petroleum
Dow Chemical	Praxair, Inc.
Du Pont	Proctor and Gamble
Eastman-Kodak	Quantum Chemical Co.
Ethyl Corporation	Rohm and Haas
Exxon Corporation	Shell Oil Company - Chemical Products
General Electric	Texaco, Inc.
Great Lakes Chemical	Union Carbide
Hercules, Inc.	W. R. Grace & Co.
Hoechst Group	

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- (a) With one exception, the review of annual reports was limited to U.S.-based companies, although virtually all these organizations have facilities located in various countries around the world. The one non-U.S.-based corporation, Hoechst Celanese, is headquartered in Germany but has substantial operations in the United States.
- (b) Many of these companies also had significant non-chemical businesses; oil, electronics, aerospace products, and energy systems, to name but a few. However, this review and the strategy development effort are concerned with only the chemicals divisions of U.S. companies.
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Table A.2. Standard Industrial Classifications Major Group 28 - Chemicals and Allied Products^(a)

Industry Segment	SIC Code
• Industrial inorganic chemicals (8 companies)	281
Alkalies and chlorine	2812
Industrial gases	2813
Inorganic pigments	2816
Industrial inorganic chemicals, n.e.c. ^(b)	2819
• Plastics materials and synthetic resins, synthetic rubber, cellulosic and other manmade fibers, except glass (19 companies)	282
Plastics materials, synthetic resins and nonvulcanizable elastomers	2821
Synthetic rubber (vulcanizable elastomers)	2822
Cellulosic manmade fibers	2823
Manmade organic fibers, except cellulosic	2824
• Drugs^(c) (9 companies)	283
Medicinal chemicals and botanical products	2833
Pharmaceutical preparations	2834
In vitro and in vivo diagnostic substances	2835
Biological products, except diagnostic substances	2836
• Soaps, detergents, and cleaning preparations; perfumes, cosmetics, and other toilet preparations (8 companies)	284
Soap and other detergents, except specialty cleaners	2841
Specialty cleaning, polishing and sanitation preparations	2842
Surface active agents, finishing agents, sulfonated oils, and assistants	2843
Perfumes, cosmetics, and other toilet preparations	2844
• Paints, varnishes, lacquers, enamels, and allied products (3 companies)	2851
• Industrial organic chemicals (14 companies)	286
Gum and wood chemicals	2861
Cyclic organic crudes and intermediates, and organic dyes and pigments	2865
Industrial organic chemicals, n.e.c.	2869

Table A.2. (contd)

Industry Segment	SIC Code
• Agricultural chemicals (12 companies)	287
Nitrogenous fertilizers	2873
Phosphatic fertilizers	2874
Fertilizers, mixing only	2875
Pesticides and agricultural chemicals, n.e.c.	2879
• Miscellaneous Chemical Products (7 companies)	289
Adhesives and sealants	2891
Explosives	2892
Printing ink	2893
Carbon black	2895
Chemicals and chemical preparations, n.e.c.	2899

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- (a) Numbers in parentheses indicate the number of companies whose annual reports were reviewed that produced chemicals in each 3-digit SIC category.
- (b) n.e.c. = not elsewhere classified.
- (c) This SIC code was addressed only to the extent that some companies whose reports were reviewed had pharmaceutical operations. For purposes of strategy development, however, the pharmaceuticals industry *per se* will not be examined.
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Table A.3. The Chemicals Industry Today

Dimensions

- Produces 1.8% of U.S. GDP and 10% of all U. S. manufacturing; total shipments reached \$297 billion in 1992
- Includes 12,000 plants producing 70,000 chemicals; 95% produced in 2,000 batch facilities
- Includes 170 U. S. companies with more than 2,800 facilities abroad; 1,700 foreign subsidiaries or affiliates are operating in the U.S.
- Exported \$44 billion and imported \$27 billion in 1992; 29% of international trade is intra-company; over 20% of trade is with Canada and Mexico (\$8.5 billion exported and \$4.8 billion imported)
- Concentrates 63% of production in 10 states: TX, NI, LA, IL, OH, CA, NC, PA, NY, IN; 70% of basic chemicals are produced in the Gulf Coast region
- Invested \$23 billion in 1992 on new plants and equipment, \$6.6 billion by U. S. companies abroad
- Invested \$14 billion in R&D in 1992

Energy

- Total energy needs equivalent to 2.6 million barrels of crude oil per day; crude oil and derivatives, 45%; natural gas, 30%; electricity, 17%; coal, 6%; others, 2%
- Consumed 5.5 quads in 1992 (7% of total U.S. energy consumption); 2.6 quads for feedstocks, 2.9 quads for fuel/power
- Fuel/power costs as a fraction of production costs quite variable: e.g., high for industrial gases (40-50%), lower for industrial organic chemicals (<10%)

Employment

- Employed 1,084,000 in 1992; 1,075,000 in 1982; declines at major companies for third straight year and significant restructuring; only the drugs sector showed growth (3% average annual) over past ten years
- Uses labor less intensively than other manufacturing industries (production workers 53% of total employment vs. 68% for all manufacturing)

Environmental

- Has regulatory costs growing faster than any other component of most capital budgets; 20% of 1992 capital expenditures of \$25 billion was for environmental abatement or compliance
- Has significant emissions: 1991 annual, in millions of metric tons: SO₂, 20.7; NO_x, 18.8; VOC, 16.9; CO, 62.1; particulates, 7.4; lead, 5.0 thousand metric tons; annual rates are declining
- Decreased toxic emissions 35% between 1987-1991 as defined by EPA's Toxic-Release Inventory Reporting Program 35% between 1987-1991, while production rose 11%
- Performs extensive outreach for continuous environmental, health and safety performance improvement through CMA-developed Responsible Care®

Economics

- Values energy costs at only 8% of industry shipments
- Value added \$88 billion in 1990 (1987 \$)
- Experienced declining earnings; profit margins and return on shareholders' equity declined in 1992 for 4th consecutive year

Sources: OTA 1993, C&EN 1993b, C&EN 1993e, CMA 1993.

Table A.4. Major Environmental Statutes Affecting the Chemical Industry

Emergency Planning and Community Right-To-Know Act—Mandates emergency planning and requires reporting of chemicals stored and released to the environment (the Toxic Release Inventory).

Clean Air Act—Prohibits hazardous air pollutant emissions in excess of standards. The 1990 Amendments impose new standards on the chemical industry; regulations announced March 1, 1994, require chemical plants to cut their emissions of toxic substances by 88%.

Toxic Substances Control Act—regulates the testing and manufacture of chemical substances and mixtures.

Resource Conservation and Recovery Act—governs the management of hazardous waste from generation to disposal.

Comprehensive Environmental Response, Liability, and Compensation Act—governs the cleanup of hazardous waste sites. Many chemical companies have been named as Potentially Responsible Parties under the Superfund program.

Clean Water Act—Governs discharges of pollutants into U.S. waters and discharges of pretreated wastewater into sewer systems.

Safe Drinking Water Act—Governs the level of contaminants allowable in drinking water. Its standards are used in setting cleanup standards for contaminated sites.

Source: DOC 1992.

Table A.5. Chemical Industry Stakeholders

Suppliers

Materials, Equipment and Services Suppliers for the Chemical Process Industries, other Producers

Producers

Industrial Inorganic Chemicals; Plastics Materials and Synthetic Resins, Synthetic Rubber, Cellulosic, other Manmade Fibers (except glass); Drugs; Soaps, Detergents, Cleaning Preparations; Perfumes, Cosmetics, Toilet Preparations; Paints, Varnishes, Lacquers, Enamels; Industrial Organic Chemicals; Agricultural Chemicals; Miscellaneous Chemical Products

Customers

Agricultural, Construction, Manufacturing, and Service Industries, Consumers, other Producers

Trade Associations

Chemical Manufacturers Association, Synthetic Organic Chemical Manufacturers Association, Chemical Specialties Manufacturers Association, Council for Chemical Research, Industrial Research Institute, Pharmaceutical Manufacturers Association, Soap and Detergent Association, Chlorine Institute, The Society of the Plastics Industry, others

International Organizations

International Chamber of Commerce, International Organization for Standardization (ISO), others

Academic/Research Institutions

U.S. Colleges and Universities, National Laboratories (Argonne National Laboratory, Idaho National Engineering Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, Battelle Pacific Northwest Laboratory), Research Triangle Institute, Southwest Research Institute, others

Public Interest Groups

Sierra Club, Greenpeace, Environmental Defense Fund, Natural Resources Defense Council, Friends of the Earth, Nature Conservancy, others

Government Agencies

Department of Energy, Department of Commerce, Department of Health and Human Services (FDA), Department of Defense, Department of Labor (OSHA), Department of Agriculture, Environmental Protection Agency, National Science Foundation, NASA

Professional Societies

American Chemical Society, American Institute of Chemical Engineers, American Institute of Plant Engineers, American Academy of Environmental Engineers, others

Shareholders

Individual and Institutional Investors, Financial Services Sector

Table A.6. Elements of ISO 9000

ISO 9001: specifies quality assurance in design, production, installation and servicing a product

ISO 9002: applies to production and installation

ISO 9003: applies to final inspection and testing

ISO 9004: provides quality management and system elements needed to develop and implement a quality system. Also determines the extent to which each system element is applicable.

Seven steps to ISO certification:

1. Compare current procedure to standards 9001-9003.
2. Identify the steps needed to bring them into conformance with the applicable standards.
3. Prepare a quality assurance program.
4. Define, document and implement the new procedures.
5. Prepare the Quality Manual.
6. Arrange a preassessment meeting with the chosen auditor to analyze the Quality Manual.
7. The certification audit.

Source: *Chemical Engineering* 1992

Table A.7. ISO 9000 Certification at U.S. Chemical Companies

Company ^(a)	Registrations		Company ^(a)	Registrations	
	U.S.	Non-U.S.		U.S.	Non-U.S.
Air Products & Chemicals	7 ^(b)	36	Monsanto	2	1
Allied-Signal	2	na	Nalco Chemical	4	18 ^(h)
Arco Chemical	0	5 ^(c)	Occidental Chemical	3 ⁽ⁱ⁾	2 ^(j)
BASF	1	8	Phillips	3	3
Dow Chemical	2 ^(d)	58	PPG Industries	2	2
Du Pont	64 ^(e)	>100	Praxair	3	6
Eastman Chemical	5	1	Rhône-Poulenc	1	32 ^(h)
Engelhard	2	3	Rohm & Haas	4	14
Exxon Chemical	11	60 ^(f)	Solvay Interox	3	1
FMC	5 ^(g)	7	Texaco Chemical	4	3
Hercules	2	2	Union Carbide	21	10
Hoechst Celanese	7	2	Vulcan Chemicals	3	0
ICI	3	>270	Witco	2	1
			W.R. Grace	0	13

(a) Representative listing for late 1992-early 1993. Most certifications are ISO 9002, unless otherwise noted and when available from company data.

(b) Includes one multisite registration involving more than 100 facilities in the United States and Canada.

(c) Includes ISO 9001 registrations for research facilities and headquarters.

(d) Includes facility in joint venture with Exxon Chemical; included in Exxon total.

(e) Includes 11 ISO 9001 registrations.

(f) Company estimate.

(g) One ISO 9001 certification.

(h) Includes several ISO 9001 registrations.

(i) Includes plant in joint venture with Du Pont.

(j) Includes registration for international sales operations in several countries.

na = not available.

Source: Thayer 1993a.

Table A.8. Guiding Principles of *Responsible Care*

- To recognize and respond to community concerns about chemicals and plant operations.
- To develop and produce chemicals that can be manufactured, transported, used, and disposed of safely.
- To make health, safety, and environment considerations a priority in planning for all existing and new products and processes.
- To report promptly to officials, employees, customers, and the public, information on chemical-related health or environmental hazards and to recommend protective measures.
- To counsel customers on the safe use, transportation, and disposal of chemical products.
- To operate plants and facilities in a manner that protects the environment and the health and safety of employees and the public.
- To extend knowledge by conducting or supporting research on the health, safety, and environmental effects of products, processes, and waste materials.
- To work with others to resolve problems created by past handling and disposal of hazardous substances.
- To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace, and environment.
- To promote the principles and practices of Responsible Care by sharing experiences and offering assistance to others who produce, handle, use, transport, or dispose of chemicals.

Source: CMA 1991.

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