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ECONOMIC IMPACT ANALYSIS OF ANTICIPATED HAZARDOUS WASTE REGULATIONS ON THE INDUSTRIAL ORGANIC CHEMICALS, PESTICIDES, AND EXPLOSIVES INDUSTRIES

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CHAPTER ONE

EXECUTIVE SUMMARY

This report has been developed in support of the U.S. Environmental Protection Agency's (EPA) development of an economic impact analysis of anticipated hazardous waste regulations on the combined industrial organic chemicals, pesticides, and explosives industries.

1.1 Regulatory Background

The Resource Conservation and Recovery Act of 1976 (RCRA) (PL 94-580) authorized the EPA to "promulgate regulations establishing such standards, applicable to generators of hazardous waste . . . as may be necessary to protect human health and environment."[1] The EPA is also responsible for developing an assessment of the economic impact resulting from the promulgation of such regulations.

Presently, EPA plans to issue a single regulation that will include standards for all generators of hazardous wastes. Because industrial organic chemicals, pesticides, and explosives industries combined presently generate an estimated 2.3 million metric tons (MT) of hazardous waste annually (13.1 percent of the annual national hazardous waste volume)[2] and because the costs for treatment of hazardous organic wastes are high relative to other hazardous wastes, the EPA has chosen to study the economic impacts of anticipated regulations on these industries.[3] (Henceforth these industries will be referred to as the organic chemicals industry, since the pesticides and explosives within its purview are organic chemicals.)

Minimal effort was devoted to the pesticides and explosives segments, however, because impact potential was small for these segments. The impacts on those pesticides for which data was available appear to be small. Impacts on the private explosives industry also appear small. Larger impacts are expected in the government sector explosives industry, but these products (including munitions) are manufactured at government-owned sites operated by private contractors (GOCO facilities) and the Federal government will bear the burden of additional hazardous waste treatment and disposal efforts.

1.2 Procedures and Results

The analysis of the economic impacts of anticipated hazardous waste regulations on the organic chemicals industry consisted of the following four phases:

1. Development of an analytical methodology.

2. Development of a profile of the industry.

3. Analysis of the costs of compliance.

4. Economic impact analysis.

A chapter in the report has been devoted to each of these phases. Chapter summaries appear below.

1.2.1 Methodology

1.2.1.1 Procedures and Data Sources

The generalized procedure utilized in this report is illustrated in Figure 1-1. The figure shows the development of each phase of the analysis and the relationships among the four phases.

Organic chemicals is a giant industry producing hundreds of products (many are intermediate ones that are not used outside the industry). By volume, 98 percent of this production generates hazardous waste streams.[4] This universe of products subject to regulatory impact is too broad for coverage of each product separately and, therefore, the industry was screened and product lines were isolated for analysis.

Cost estimates developed for EPA indicated that the impacts on the industry as a whole would be small. Therefore, segments were chosen which were expected to be most severely affected. In this way the most serious impacts could be analyzed and that analysis would yield a bottom line of impact on the other segments.[5] The screening procedure utilized three selection criteria in order to identify product lines likely to incur the largest impacts of regulation. The selection criteria used were the following: (1) treatment and disposal cost data must be available for the product, (2) the product must have a high treatment cost as a percentage of price, and (3) the product must be produced in large volume. Cost data had been developed for a 23-segment representative sample of the industry in two previous EPA reports utilized throughout this project. These are:

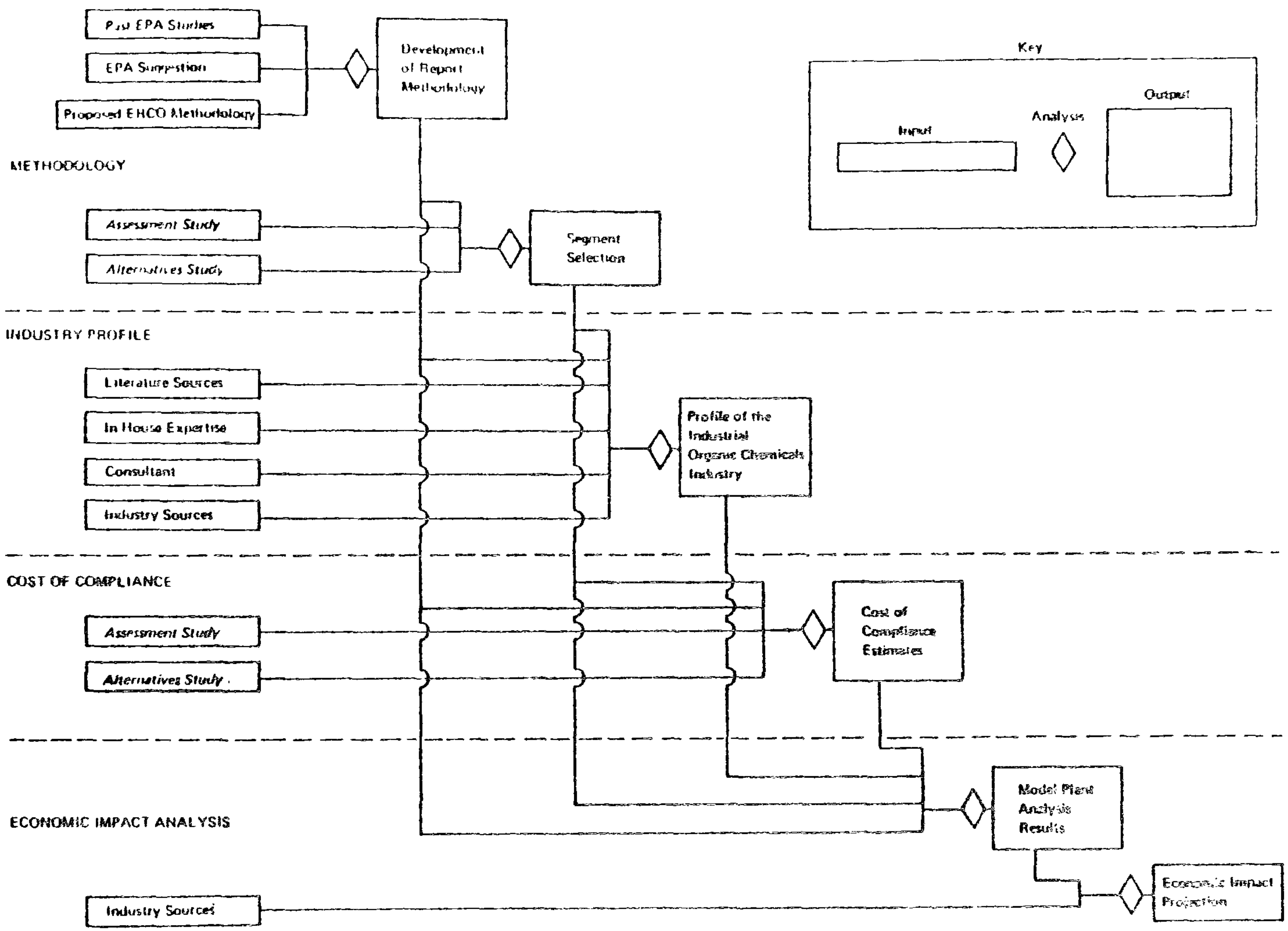

Figure 1–1. Flowchart of generalized procedure for the analysis.

1. Assessment of Industrial Hazardous Waste Practices of the Organic Chemicals, Pesticides and Explosives Industries by TRW, Inc. (referred to here as Assessment Study).

2. Alternatives for Hazardous Waste Management in the Organic Chemicals, Pesticides and Explosives Industries by Processes Research Inc. (referred to as Alternatives Study).[6]

Using these cost data, six segments were identified as highly impacted to be subjected to in-depth analysis. These are:

1. Perchloroethylene.

2. Chloromethanes (methyl chloride, methylene chloride, chloroforms, and carbon tetrachloride.

3. Epichlorohydrin.

4. Vinyl chloride.

5. Acrylonitrile.

6. Furfural.

These six segments represent 5.6 percent of 1973 industry production volume, 8.5 percent of dollar sales, 21 percent of the industry's hazardous waste generation, and 2.7 percent of the national generation of hazardous waste.

A profile for the entire industry was developed, focusing primarily on the six highly impacted segments. These segments tend to represent the industry's diverse economics. The producers, markets, and market forecasts for these products were thoroughly researched and characterized using the available literature and limited contacts with industry personnel. In addition, model plants were developed to characterize the process economics (costs, profit, ROI) for each segment.

The costs of compliance for model plants in each of the highly impacted segments were estimated after a thorough comparative analysis of the engineering cost estimates developed in the Assessment Study and the Alternatives Study. The incineration cost estimates from the Alternatives Study were selected as the data base for developing improved cost estimates. Two sets of estimates were developed. First, a conservative best estimate of cost was developed for each segment. This estimate assumed the model plant was already incurring expenditures for the average level of treatment presently employed in each segment and counted only the incremental increase in costs necessary to comply with anticipated regulations. This set of estimates is believed to overstate costs to the average plant in that they do not recognize economies of scale nor of joint treatment of two or more products.

However, because these estimates are sensitive to this current level of expenditures as well as engineering cost estimation uncertainty, a set of worst-case cost estimates was also developed. These estimates assumed no credit for existing treatment and included a 25 percent allowance for uncertainty. This latter set of estimates is believed to be a bottom-line estimate of the costs that may be incurred by the most severely affected plant in the industry.

Both sets of estimates were incorporated into the economic impact analysis. This analysis utilized a model plant approach for determining impacts on profitability and for calculating the net present value of investing in abatement. The financial position of the firm was limited to the cash flows from the model plant developed in the industry profile. The plant shutdown decision was also analyzed as was the likelihood of full-cost passthrough. The model plant analysis was then validated and refined by a projection of the actual impacts on each segment based on industry responses.

1.2.1.2 Limits of the Analysis

The results of the analysis are sensitive to four areas of input, one area from each of the four phases of the analysis. These are: (1) segment selection, (2) model plant development, (3) cost of compliance estimates, and (4) the economic impact analysis itself.

In selecting the segments, attempts were made to choose those product lines subject to the highest impact. However, the six highly impacted segments were selected from a sample of product lines that included only 23 products of the hundreds produced. Because of the correlation of treatment and disposal costs with hazardous waste volume, production of these products tended to generate a large portion of the hazardous waste in the industry. (The sample represented about 21 percent of the industry's hazardous waste production exclusive of explosives.) However, other segments subject to higher impacts than the six-segment sample may exist.

Financial data for the model plant analysis were developed from the model plant process economics in the industry profile. Cost and profit estimates tended to reasonably approximate present price levels, but a 25 percent uncertainty can be attributed to specifying the mix between costs and profits.

The most serious uncertainty in the analysis stems from the cost of compliance estimates. In the cost analysis, it was found that variations in the estimates between the Assessment Study and the Alternatives Study are often extremely large. In three cases - perchloroethylene, epichlorohydrin, and vinyl chloride - the Assessment Study estimates were 2 to 4 times higher than those of the Alternatives Study. The Alternatives Study estimates were used in the analysis, because they were considered to be more accurate. Little variation was found in the estimates for the other three products.

The economic impact analysis itself incorporates data developed in the preceding three phases and, accordingly, is subject to the variability (which may be additive) in each of them. For this reason, the results of the model plant analysis were compared to data obtained from the industry for the final projection of impact. Results projected by the model plant analysis appeared to be generally comparable to industry responses.

Another limitation of the analysis is imposed by the lack of information regarding the content of the final regulations. It has been assumed that the Assessment Study and the Alternatives Study reasonably represent the technologies and costs represent compliance with the regulations.

1.2.2 Profile of the Industry

The industrial organic chemicals industry is composed of the following five segments:

1. SIC 2861, gum and wood chemicals.

2. SIC 2865, cyclic crudes, cyclic intermediates, dyes, and organic pigments.

3. SIC 2867, industrial organic chemicals not elsewhere classified.

4. SIC 2879, agricultural chemicals not elsewhere classified.

5. SIC 2982, explosives.

1.2.2.1 Composition

Firms in the industry are among the nation's largest, and include highly diversified companies not generally thought of as chemical producers. These firms are often raw materials suppliers or end users of industrial organic chemicals who have entered the industry through vertical integration. Table 1-1 displays financial statistics on the size of firms which domestically produce at least one of the highly impacted chemicals. All 22 firms are ranked within the Fortune 500. General Electric is the largest firm, ranking 9th in sales in the Fortune 500, while Dow-Corning is the smallest, ranking 471st.

1.2.2.2 Market Structure

The industry is composed of hundreds of firms producing hundreds of chemicals, many of which are chemical intermediates that are used as inputs for the manufacture of other chemicals. Few products are manufactured by more than a dozen firms and the resulting small number of firms producing each product tends to give each product market an oligopolistic structure. Prices change when initiated by a price leader, but price increases may be withdrawn if other firms in the industry fail to follow the lead.

Figure 1-2 displays a list of the firms domestically producing the six highly impacted products. Twenty-two firms produce the six product lines. Twelve of these firms produce at least one, chloromethane, while Quaker Oats is the sole producer of furfural. It should be noted that the market power of firms such as Quaker which are subject to minimal direct competition is limited by the large potential for substituting other organic chemicals for their products. Many of the end uses of industrial organic chemicals can be served by a number of different products creating significant indirect competition on any one product.

Throughout the 1960's prices went through an industry-wide decline, and then increased sharply in the mid-1970's. This was due to the strong dependence of the industry on petroleum and natural gas feedstocks as well as industry growth. During the 1960's, the cyclical industry boomed, along with the entire national economy. Regulated natural gas prices

TABLE 1–1

FINANCIAL SIZE OF IMPACTED FIRMS, 1976*

FORTUNE 500 SALES RANK 1976	FORTUNE 500 SALES RANK 1975	FIRM	1976 TOTAL SALES ($ million)	1976 TOTAL ASSETS $ MILLION	1976 TOTAL ASSETS FORTUNE 500 RANK (1976)	NET INCOME $ THOUSAND	NET INCOME FORTUNE 500 RANK (1976)	CHEMICAL SALES ($ million)
82	82	Allied Chemical	2,629.6	2,439.3	60	116,799	95	1,420**
107	106	American Cyanamid	2,093.8	2,002.4	79	135,766	75	607 2
59	51	Borden	3,381.1	1,808.5	93	112,807	98	845 3
17	16	Continental Oil Co.	8,352 9	6,041.5	21	460,000	16	†
25	32	Dow Chemical	5,652.1	6,848.7	18	612,767	13	3,052.1††
471	536	Dow Corning	353.6	384.1	346	42,741	245	n a.
167	178	Diamond Shamrock	1,356.6	1,481.0	122	140,030	71	800.4
16	17	E. I. Dupont de Nemours	8,361.0	7,027.1	17	459,300	17	3,762 5‡
194	195	Ethyl	1,135.4	921.9	194	69,080	163	658 5
97	86	FMC	2,298.4	1,919.6	83	80,157	141	793 5
9	9	General Electric	15,700.0	2,049.7	9	930,000	6	n a
112	107	B. F. Goodrich	1,996.0	1,567 8	113	15,793	404	698 6
26	25	Hooker Chemicals ‡‡ (Occidental)	5,500 0	3,905.0	34	183,721	48	1,500 0§
95	93	Monochem §§ (Uniroyal)	2,314.8	1,633.7	107	20,132	369	n a.
42	46	Monsanto	4,270.2	3,959.1	33	366,300	25	1,046 8‖
100	109	PPG	2,254.8	2,033 2	77	151,500	64	811.7
13	14	Shell	9,309.1	7,836.5	14	706,000	11	1,582.5
204	213	Stauffer	1,100.0	1,268.5	143	113,016	97	484.0‖‖
21	21	Union Carbide	6,345.7	6,621.6	19	441,200	18	1,903 7
73	76	Vistron¶ (Sohio)	2,916.4	6,260.2	20	136,900	72	n.a.
427	433	Vulcan	411.2	376.5	353	37,247	270	131.6
154	151	Quaker Oats	1,473.1	854.9	204	53,093	209	n.a.

* Source: *Fortune*, May 1977; *Moody's Handbook of Common Stocks*, Summer 1977 edition; corporate report data.
** Chemical Division, excluding Energy and Fibers Division.
† About 5 percent of corporate investment is in chemicals.
†† Chemicals and metals sales.
‡ Chemicals and specialty sales; excludes plastics and fibers.
‡‡ A subsidiary of Occidental Petroleum; Occidental statistics presented.
§ Hooker total sales.
§§ A joint venture of Uniroyal and Borden; Uniroyal statistics presented.
‖ Industrial chemicals and polymers and petrochemicals.
‖‖ Industrial and specialty chemicals.
¶ A subsidiary of Standard Oil of Ohio; Sohio statistics presented.

FIRM	HIGHLY IMPACTED CHEMICAL								
						CHLOROMETHANES			
	ACRYLONITRILE	EPICHLOROHYDRIN	VINYL CHLORIDE MONOMER	FURFURAL	PERCHLOROETHYLENE	METHYL CHLORIDE	METHYLENE CHLORIDE	CHLORO-FORM	CARBON TETRACHLORIDE
Allied Chemical			●			●	●	●	●
American Cyanamid	●								
Borden			●						
Conoco			●			●			
Diamond Shamrock					●	●	●	●	
Dow		●	●		●	●	●	●	●
Dow-Corning						●			
DuPont	●				●		●		●
Ethyl			●		●	●			
FMC									●
General Electric						●			
B.F. Goodrich			●						
Monsanto	●								
Occidental					●				
PPG			●		●				
Quaker Oats				●					
Shell		●	●						
Sohio	●								
Stauffer			●		●	●	●	●	●
Union Carbide						●			
Uniroyal			●						
Vulcan					●		●	●	●

Figure 1–2. Distribution of highly impacted chemicals among firms. (*Chemical Marketing Reporter*, "Chemical Profiles.")

caused the real price of these feedstocks to decline while massive industry expansion exploited economies of scale and new technologies to further reduce prices. When oil prices began to soar, costs were driven up and were followed initially by supply shortages. Later, however, demand fell below supply. Plants were forced to operate at low levels of capacity utilization, which resulted in production inefficiencies.

The industry remains highly sensitive to oil and gas prices and has maintained a significant export volume because these price-regulated feedstocks help keep domestic chemical prices below world market prices. Deregulation of the prices of these feedstocks could seriously weaken the industry's position by driving up costs dramatically.

1.2.2.3 Operational Variables

Because of the industry's strong dependence on cheap, reliable sources of feedstocks, it is highly concentrated in the Gulf Coast region of Texas and Louisiana. At least half of the production of the six highly impacted industry segments originates in this region with outlying plants spread about the nation near local oil and gas supplies.

Plant sizes vary significantly for most products produced. Generally, new plants are large, while older plants are small and able to remain competitive only because their capital costs have all been amortized. (The industry generally aims for a 3- to 4-year payback for new investments.)

Plants also vary in the amount of hazardous waste treatment already in place. The industry has made significant efforts - in the absence of regulation - to properly dispose of its hazardous waste; treatment of some kind is performed at most plants. Such actions have been initiated both in order to minimize liability from the dangerous effects of these wastes as well as in anticipation of EPA regulations. It is estimated that existing expenditures for hazardous waste treatment and disposal total $106 million, almost 50 percent of the level of expenditure required for compliance with anticipated regulations.[7]

1.2.2.4 Financial Data

A sample of 10 firms whose business is largely chemical manufacture showed that these firms had higher profitability than the average for all manufacturers. Net income as a percent of sales as well as net income as a percent of equity were each about 2 percent higher for the chemical industry sample than the average for all manufacturers in 1976. Dramatic differences in sales, profits, and financial structure of firms in the industry, due in large part to their diversified operations, preclude much further discussion of the financial position of firms in the industry. For the analysis, heavy reliance was placed on the model plant process economics. These presumed that, in general, firms operate with a 20 to 40 percent gross return to investment. Because investment costs are generally overshadowed by feedstock costs, however, this can create gross profit levels of less than 5 percent of sales for many products.

1.2.3 Costs of Compliance

EPA has not yet proposed treatment and disposal regulations for the generators of hazardous waste. However, the Assessment Study has identified three levels of treatment for the industry. These are:

Level I: Current average practice in the industry.

Level II: Best technology in commerical use at one or more plants.

Level III: Technology necessary to provide adequate environmental protection.

It is the present position of the EPA that the regulations will require compliance with Level III. Technologies have been identified that will achieve this level[8] and cost estimates for several likely treatment and disposal options have been developed in the Assessment Study and the Alternatives Study. The technologies and cost estimates have been reviewed and a set of best estimates has been developed for the six highly impacted segments. These estimates are displayed in Table 1-2 and are based on the costs of incineration developed in the Alternatives Study. These costs are believed to be conservative estimates of the costs incurred by an average plant. The estimates range from 0.1 percent of manufacturing costs for acrylonitrile to 2.1 percent of cost for perchloroethylene.

In order to account for uncertainties in the cost estimates and for site-specific factors that may cause individual plants to incur higher costs, a set of worst-case cost estimates was developed. These estimates are displayed in Table 1-3. They represent an upper bound on costs to be incurred by the most severely affected plant in the industry.

TABLE 1–2

BEST ESTIMATES OF TREATMENT COSTS*

INDUSTRIAL PRODUCT	MODEL PLANT SIZE (MT/yr)	LEVEL III TREATMENT TECHNOLOGY	ASSUMED EXISTING LEVEL I TREATMENT	CAPITAL INVESTMENT COST ($)**	COST PER MT OF PRODUCT ($)	% OF PRODUCT PRICE†
Perchloroethylene	39,000	Controlled Incineration	Landfill	1,178,000	7.69	2.1
Chloromethanes	50,000	Controlled Incineration	Step Landfill	184,000	0.59	0.2
Epichlorohydrin	75,000	Controlled Incineration	Landfill	866,000	2.03	0.2
Vinyl Chloride	136,000	Controlled Incineration	Landfill	860,000	1.22	0.4
Acrylonitrile	181,000	Controlled Incineration	Chemical Landfill	226,570	0.37	0.1
Furfural	18,000	Controlled Incineration	Landfill	1,140,700	1.95	0.2

* Energy Resources Company Inc. estimates based on costs from the *Alternatives Study*.

** Adjusted to a 1976 base year.

† Price sources from the CMR, 1976.

†† Not specified as environmentally adequate in *Assessment Study* because wastes are not detoxified or neutralized.

TABLE 1–3

WORST–CASE ESTIMATES OF TREATMENT COSTS*

INDUSTRIAL PRODUCT	MODEL PLANT SIZE (MT/yr)	COMPLYING TREATMENT TECHNOLOGY	CAPITAL INVESTMENT COST ($)**	COST PER MT OF PRODUCT ($)	% OF PRODUCT PRICE†
Perchloroethylene	39,000	Controlled Incineration	1,472,500	13.46	3.7
Chloromethanes	50,000	Controlled Incineration	230,000	1.70	0.5
Epichlorohydrin	75,000	Controlled Incineration	1,082,500	3.67	0.4
Vinyl Chloride	136,000	Controlled Incineration	1,075,000	1.75	0.6
Acrylonitrile††	181,000	Controlled Incineration	393,109	0.65	0.1
Furfural	18,000	Controlled Incineration	1,425,875	9.88	0.9

* Energy Resources Company Inc. estimates based on costs from the *Alternatives Study.*

** Inflated 25 percent to reflect overall engineering uncertainty.

† Source: *Chemical Marketing Reporter,* October 1976.

†† Original costs from the *Alternatives Study* were adjusted linearly to match the model size, and thus reflect no economies of scale.

These costs range from 0.1 percent for acrylonitrile to 3.7 percent for perchloroethylene.

1.2.4 Economic Impact Analysis

The impacts of anticipated hazardous waste regulations on the industrial organic chemicals industry are summarized in Table 1-4. The incremental costs of compliance for this large industry have been estimated at $137 million, but spread out over the entire industry, this is an average of only 0.6 percent of the 1973 value of shipments. For the nation as a whole, this represents a barely perceptible increase in the Wholesale Price Index for all commodities of 0.011 percent.

Certain individual segments of the industry will be subject to more severe impacts than the industry as a whole. The impacts on the plants producing the six highly impacted product lines are presented in Table 1-5. The table shows that six plants (one a coproducer of perchloroethylene/chloromethane) may be subject to significant impact due to the regulation. All of the six threatened plants are already believed to be marginal operations and hazardous waste regulations will contribute only incrementally to plant closure. Therefore, assuming that no other segments are more highly impacted than the six selected segments, it appears that no plant closures will result directly from the regulations.

TABLE 1–4

THE IMPACTS OF COMPLIANCE FOR THE ORGANIC CHEMICALS, PESTICIDES AND EXPLOSIVES INDUSTRIES

Estimated incremental annual cost ($ million)*	137
Total annual cost ($ million)**	243
Estimated incremental annual cost/value of shipments (1973)†	0.6%
Total annual cost/value of shipments (1973)	1.1%
Increase in wholesale price index for all commodities††	0.011%

* Source: Energy Resources Company Inc. estimates.
** Source: *Assessment Study.*
† Source: U.S. International Tariff Commission.
†† Source: U.S. Bureau of Labor Statistics.

TABLE 1–5

SUMMARY OF IMPACTS ON PLANTS PRODUCING HIGHLY IMPACTED CHEMICALS*

HIGHLY IMPACTED SEGMENTS	NO. OF PLANTS IN SEGMENT	NO. OF PLANTS SUBJECT TO SMALL IMPACT	NO. OF PLANTS SUBJECT TO SIGNIFICANT IMPACT (SHUTDOWN POSSIBLE)
Perchloroethylene	11	8	3
Chloromethanes	19	17	2
Epichlorohydrin	3	3	0
Vinyl Chloride	15	13	2
Acrylonitrile	6	6	0
Furfural	4	4	0
TOTAL OF SIX SEGMENTS	57**	51	6**

* Source: Energy Resources Company estimates.

**Totals are less than the sum of entries because of Stauffer's coproduct perchloroethylene/chloromethanes (carbon tetrachloride) plant, which is counted in both segments. Other coproduct processes are colocated with separate chloromethane plants circumventing double counting.

NOTES TO CHAPTER ONE

1. Resource Conservation and Recovery Act of 1976 (PL 94-580), Section 3002.

2. TRW, Inc., Assessment of industrial hazardous waste practices of the organic chemicals, pesticides and explosives industries, prepared for the U.S. Environmental Protection Agency, 1976, p. 2-23.

3. Four other highly impacted industries are also being studied separately. These are: (1) inorganic chemicals; (2) batteries, specialty machinery and electrical components; (3) leather tanning; and (4) electroplating.

4. TRW, Inc., Assessment study, 1976.

5. TRW, Inc., Assessment study, 1976.

6. Processes Research Inc., Alternatives for hazardous waste management in the organic chemicals, pesticides and explosives industries, Draft report prepared for the U.S. Environmental Protection Agency, 1977.

7. TRW, Inc., Assessment study, 1976, p. 2-23.

8. TRW, Inc., Assessment study, 1976; and Arthur D. Little Co., Analysis of potential application of physical, chemical and biological treatment techniques to hazardous waste management, prepared for the U.S. Environmental Protection Agency, 1976.

CHAPTER TWO

METHODOLOGY

The methodology utilized in assessing the economic impacts of potential hazardous waste regulations on the organic chemicals industry consisted of two phases. First, analytical procedures and data sources for the analysis were specified. Then, a careful review of the limitations of the analysis was undertaken. This review discusses the likelihood of errors which can be attributed to those assumptions to which the analytical conclusions are most sensitive.

2.1 Analytical Procedure and Data Sources

The analytical procedure is separated into the following four phases:

1. Segment selection.

2. Development of an industry profile.

3. Cost of compliance assessment.

4. Economic impact assessment.

A chapter of the report is devoted to each of the last three phases. The methodologies for each are discussed individually below following the presentation of the segment selection.

2.1.1 Segment Selection

The organic chemicals industry manufactures hundreds of products resulting in an estimated 13 percent of the national hazardous waste generated. Trying to analyze the impact on the markets of all of these products is beyond the scope of this project. Instead, an in-depth study has been conducted of selected segments of the industry. It was therefore important to select segments of the industry correctly in order to maximize the usefulness of the analysis.

The industry was first narrowed down by TRW in their Assessment Study.[1] This study analyzed 26 organic chemical processes that produce hazardous waste. Treatment cost data were developed for 23 of these processes in either the Assessment Study or the Alternatives Study.[2] Twenty of the processes (excluding explosives) accounted for 44 percent of the total hazardous waste produced by the organic chemicals chemicals and the technical organic pesticides industries in 1973, and over 6 percent of the total annual hazardous waste generation of the nation.[3] This sample of processes had to be further limited, however, in order to arrive at a sufficiently small group of processes suitable for an in-depth analysis of economic impacts.

Because the impact of hazardous waste regulations on the industry was expected to be small, it was decided that an attempt should be made to analyze in detail the segments most severely impacted. Furthermore, by analyzing the highly impacted segments, a worst-case upper bound could be estimated for the impact on the remaining segments.

In order to determine the highly impacted processes, it was necessary to screen all the processes and rank them by such criteria as volume of product produced (dollars and tons), abatement cost as a percentage of product price for each product, price elasticity of demand for each product, capital availability characterization for each firm, and cash flow associated with each product in each firm. These data were not all available at the outset of the analysis and were, in fact, among the data sought in the in-depth studies. It was, therefore, necessary to use a surrogate measure for economic impact.

It was determined that a useful selection could be made using the following criteria: (1) abatement cost as a percentage of product price and (2) tons of product produced annually. By plotting these two parameters on a graph, the resulting display would highlight the highly impacted processes, which would plot to the upper right. These data were developed from the Assessment Study and the Alternatives Study.

Abatement cost data (in terms of dollars per ton of product) were developed in both reports, although, in general, the cost estimates varied significantly. The Alternatives Study costed out alternatives to the standard treatments examined in the Assessment Study. (The Alternatives Study also costed out the standard treatments, but their assumptions for these appeared to be different from those used by the Assessment Study.) Because alternative treatments have not necessarily been proven, the standard treatment methods could not be eliminated. However, the alternative treatments could not be overlooked because site-specific problems may preclude a plant from using the standard treatments. For these reasons, two points were plotted for each production process: (1) one point using the Assessment Study standard treatment cost for Level III treatment technology, and (2) one point using the Alternatives Study's alternative treatment cost. In several cases, only one of these cost estimates was available so that only one point could be plotted. All cost estimates were adjusted to reflect a 1976 base year.

Data on product prices in 1976 were taken primarily from the Alternatives Study. Defining product prices presented a problem for those processes that created joint products, because the prices for the different products are highly variant. As it happens, however, the lowest priced joint product (the one subject to the highest abatement cost/price ratio) is generally also the product produced in the largest volume. Therefore, the price for the product produced in the largest volume was used. The Alternatives Study used this approach. However, minor discrepancies remained in some of the product prices. In these cases, data published in the Chemical Marketing Reporter (December 27, 1976) were used. (All prices were for fourth quarter, 1976.)

Data on production volumes were taken from the Assessment Study. Although such 1973 data are somewhat out of date, the rankings of the various products using these data are the best available for the purposes of the present study.

The production volume, price, abatement cost, and abatement cost/price ratios for the 23 products studied by the Assessment Study and/or the Alternatives Study are displayed in Table 2-1. The table shows dramatic variation in treatment costs between the Assessment Study process and the Alternatives Study alternative. In some cases, the alternative is more costly; in others it is less costly. In the case of epichlorohydrin, the Alternatives Study reported that waste chemical recycle will return a profit to the waste treatment process. Variation in costs among products for similar technologies are also high, but are roughly proportional to product price so that the abatement cost/price ratios for most products are below 0.01 (1 percent).

The production volumes and cost/price ratios for the products in Table 2-1 are plotted in Figure 2-1. A strong clustering can be detected in the lower left of the graph, indicating minimal expected impact for most products. The outlying points can be segmented easily by the dashed line indicated on the graph.

No price data were available for explosives products precluding their inclusion in this analysis. However, the entire multiproduct private explosives industry segment manufactured only 1,250 thousand metric tons of product. It is therefore assumed that based only on production volume,

TABLE 2–1

CALCULATION OF ABATEMENT COST-TO-PRICE RATIOS (1976 ADJUSTED DATA)

	PRODUCT	1973 U.S. ANNUAL PRODUCTION * (1,000 MT)	PRICE** ($/MT)	LEVEL III COST ($/MT OF PRODUCT)		COST/PRICE RATIO	
				STANDARD TREATMENT*	ALTERNATIVE TREATMENT†	STANDARD TREATMENT	ALTERNATIVE TREATMENT
1	Perchloroethylene	320	364	25.80	6.00	0.0709	0.0165
2	Nitrobenzene	140	510	0.66	3.31	0.0013	0.0065
3	Chloromethane	1,115	320	3.33	1.40	0.0104	0.0044
4	Epichlorohydrin	225	880	16.54	(0.40)	0.0188	(0.0005)
5	Toluene Diisocyanate	230	1,120	6.70	5.55	0.0060	0.0050
6	Vinyl Chloride	2,432	310	5.79	0.25	0.0187	0.0008
7	Methyl Methacrylate	320	840	2.76	6.54††	0.0033	0.0078††
8	Acrylonitrile	614	590	0.57	0.70††	0.0010	0.0012††
9	Maleic Anhydride	128	810	3.40	10.00††	0.0042	0.0123††
10	Lead Alkyls	506	1,440†	14.01	6.33	0.0097	0.0044
11	Ethanolamines	133	860‡	–	2.39 or 5.54	–	0.0028 or 0.0064
12	Furfural	68	1,040	–	38.00	–	0.0365
13	Fluorocarbon	373	1,080†	–	0.56	–	0.0005
14	Chlorotoluene	36.5	660	–	0.17††	–	0.0003††
15	Chlorobenzene	180	570	–	3.50††	–	0.0061††
16	Atrazine‡‡	41	4,295†	18.37	24.20	0.0043	0.0056
17	Trifluralin‡‡	11	12,290†	25.62	50.00	0.0021	0.0041
18	Aldrin‡‡	discontinued	3,021‡	200.66	–	0.0664	–
19	Malathion‡‡	14	2,090	3.37	9.00	0.0016	0.0043
20	Parathion‡‡	62	1,918	2.03	6.00	0.0011	0.0031
21	Explosives (carbon)§	–	–	–	1.43	–	–
22	Explosives (redwater)§	–	–	–	50.50	–	–
23	Explosives (explosives)§	–	–	–	1.98 or 2.94	–	–

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency, 1976.

** Source: *Chemical Marketing Reporter*, October 25, 1976.

† Source: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industry*, prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division; December 1976.

†† No alternative specified. The costs are for the most expensive other treatment.

‡ Source: *Chemical Marketing Reporter*, December 20, 1976.

‡‡ Pesticide.

§ Explosive.

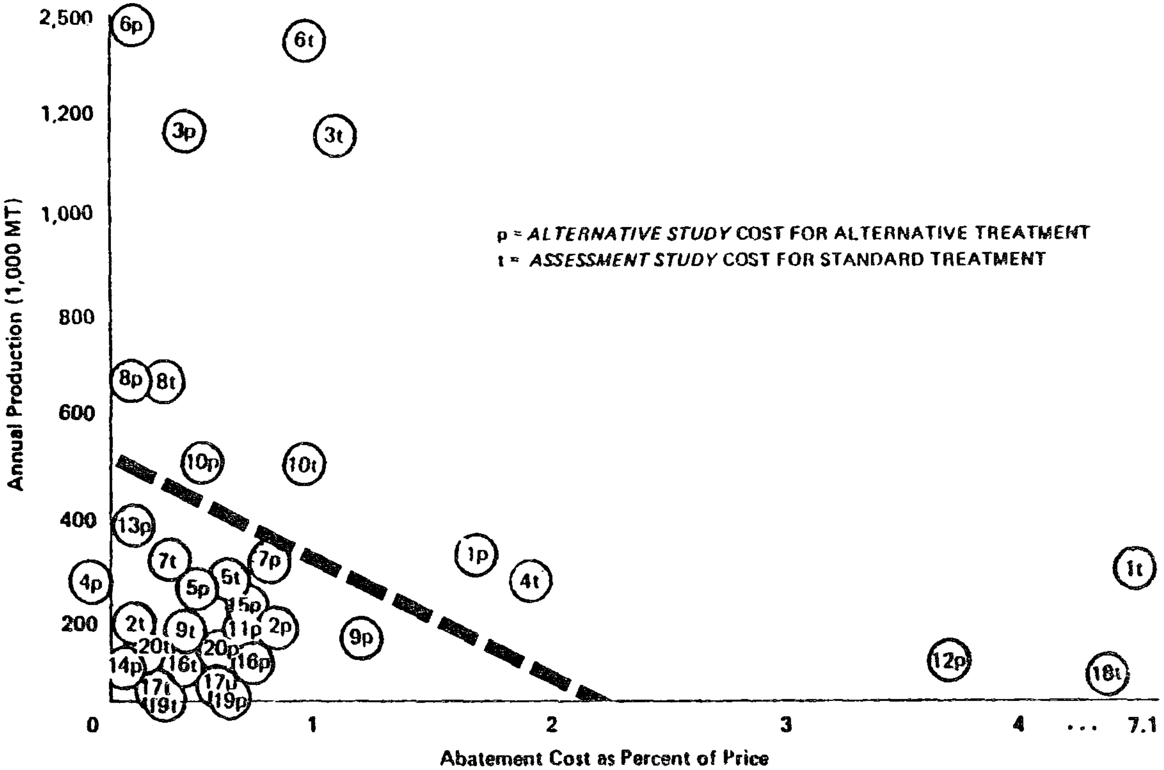

Figure 2—1. Graph of economic importance (1976 prices) annual production vs. cost/price ratio. (Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries,* prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division, December 1976, and TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries,* prepared for U.S. Environmental Protection Agency; 1976.)

impacts would be small. Furthermore, private sector explosives production guarantees only a waste explosives waste stream that can be incinerated. It is therefore assumed that treatment and disposal costs will be small relative to product price. While the Federal explosives production generates other waste streams, the Federal government owns all such facilities and will therefore absorb the burden of Federal hazardous waste regulations.

From Figure 2-1, it can be concluded that eight products appear to be in the highly impacted category.[4] Of these eight, six have been selected as highly impacted products for in-depth study:

1. Perchloroethylene (1).

2. Chloromethane (methyl chloride, methylene chloride, chloroform, carbon tetrachloride) (3).

3. Epichlorohydrin (4).

4. Vinyl chloride (monomer) (6).

5. Acrylonitrile (8).

6. Furfural (12).

Aldrin has not been included because it is no longer produced in this country due to banning by the EPA. Lead alkyls have also been excluded because the EPA limitations of lead in gasoline - the major use for lead alkyls - will diminish their production to 350,000 tons by 1980. At this production level, lead alkyls (with an abatement cost/price ratio of only 0.0044 [0.44 percent]) will fall into the cluster of points below the cutoff line. Also, the Assessment Study and Alternatives Study data used specifically did not include a credit for the lead recovery which is a part of both treatment processes. This credit would substantially reduce the calculated costs for both treatment types.

The relationship of the highly impacted segments to the Assessment Study sample is displayed in Table 2-2 in terms of production volume, sales, total waste, and hazardous waste component. The six highly impacted products represent almost 70 percent of the production volume and almost 60 percent of the hazardous waste volume of the Assessment Study products (exclusive of explosives).

Both samples are then compared to the total industry in Table 2-3. As can be seen in this table, the highly impacted category represents only 5.6 percent of the total national

TABLE 2–2

RELATIONSHIP OF HIGHLY IMPACTED PRODUCTS TO *ASSESSMENT STUDY* SAMPLE

PRODUCT	U S PRODUCTION * (1,000 MT)	SALES: OCT. 1976 PRICE** ($/MT)	SALES: ESTIMATED SALES VOLUME† ($ million)	WASTE VOLUME: WASTE/PRODUCT* RATIO PREDICTED BY PLANT MODELS	WASTE VOLUME: ESTIMATED HAZARDOUS WASTE VOLUME (1,000 MT)	HAZARDOUS WASTE VOLUME: COMPONENT (% of waste* classified as hazardous)	HAZARDOUS WASTE VOLUME: ESTIMATED HAZARDOUS COMPONENT OF WASTE (1,000 MT)
Perchloroethylene††	320	364	116.5	0.308	98 46	97	95.51
Nitrobenzene	140	510	71.4	0.0025	0.35	100	0.35
Chloromethane††	1,115	320	356.8	0.006	6.69	100	6.69
Epichlorohydrin††	225	880	198.0	0.053	11.925	97	11.62
Toluene Diisocyanate	230	1,120	257.6	0.021	4.92	97	4.79
Vinyl Chloride††	2,432	310	753.9	0.010	25.04	99	25.60
Methyl Methacrylate	320	840	268.8	0.086	27.52	100	27.52
Acrylonitrile††	614	590	362.3	0.0007	0.46	100	0.46
Maleic Anhydride	128	810	103.7	0.030	3.88	100	3.88
Lead Alkyls	506	1,440‡	728.6	0.5	253.00	20	50.6
Ethanolamines	133	860‡‡	114.4	0.08	10.64	100	10.64
Furfural††	68	1,040	70.7	0.565	38.44	89	34 36
Fluorocarbon	373	1,080‡	402 8	0.0002	0.08	100	0.08
Chlorotoluene	36.5	660	24.1	0.001	0.04	100	0.04
Chlorobenzene	180	570	102.6	0.044	7.87	100	7.87
Atrazine	41	4.295‡	176.1	11.23	460.43	1.5	6.89
Trifluralin	11	12,290‡	135.2	0.115	1.26	48	0.60
Aldrin	0	3,021‡‡		64.22			
Malathion	14	2,090	29.3	0.155	2.18	45	0 99
Parathion	62	1,918	118.9	0.115	7.13	100	7.13
Total (11) Products	4,774		1,858.2		181.01		174.4
Total All Products	6,948		4,391.7		960.31		295.42

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosive Industries*, prepared for U.S. Environmental Protection Agency, 1976.

** Source: *Chemical Marketing Reporter*, August 27, 1976.

† Assumed merchant market prices for entire production volume, i.e. prices are not discounted for captive use.

†† Products selected for economic impact analysis.

‡ Source: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries*, prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division; December 1976.

‡‡ Source: *Chemical Marketing Reporter*, December 20, 1976.

TABLE 2–3

RELATIVE IMPORTANCE OF HIGHLY IMPACTED SAMPLE*

	ESTIMATED PRODUCTION		ESTIMATED SALES		ESTIMATED WASTE		ESTIMATED HAZARDOUS WASTE COMPONENT	
	VOLUME (1,000 MT)	SAMPLE AS % OF	VOLUME ($ million)	SAMPLE AS % OF	VOLUME (1,000 MT)	SAMPLE AS % OF	VOLUME (1,000 MT)	SAMPLE AS % OF
Economic Study Chemicals (ERCO)	4,774	100	1,858.2	100	181.01	100	174.04	100
Assessment Study Chemicals**	6,948	69	4,391.7	42	960.31	19	295.42	59
National Totals: Organics & Pesticides Industry**†	85,343	5.6	21,740	8.5	2,180	8.3	828	21

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosive Industries*, prepared for U.S. Environmental Protection Agency; 1976.

** Not including explosives category.

† Represents estimated 90% of total tonnage or organic chemicals and technical organic pesticides.)

organic chemical production volume, but includes 21 percent of the total hazardous waste generated by this vast industry. This result confirms the utility of these highly impacted segments selected for the analysis.

2.1.2 Industry Profile

The industry profile consists of characterizing (1) the manufacturers for each product market (firms, plants, capacities, sales), (2) the market interactions (how prices are set, methods of competition used), and (3) the financial condition of the firms subject to the regulations (sales, net income, cash flow). Each of these elements is discussed separately below.

2.1.2.1 Manufacturer Characterization

A variety of operational and financial data were collected on each manufacturer of highly impacted products and its plants which produced these chemicals. Table 2-4 presents a summary of the data collected and the sources used for each type of information. It was necessary to verify much of the data from more than one source. For instance, the figures on plant capacities sometimes varied between sources and further checking was necessary. Direct contacts were made with all the firms in the highly impacted segments in order to verify that they indeed produce the highly impacted products, and to obtain information about their manufacturing processes and treatment systems.

Financial data on each firm were readily available from a number of sources. There was a considerable overlap in the information provided from the sources listed in Table 2-4. The principal reason for the availability of financial data is the fact that the companies studied are large, publicly held corporations. Therefore, their annual financial statistics are generally reported by the various investment surveys and chemical industry data sources. However, virtually none of the financial data available provided information on the profitability of the highly impacted product lines. Firms do not provide sufficient data to allow an assessment of a specific product line, but prefer to aggregate statistics to the division or firm level. As a result, quantitative analysis of the highly impacted segments was performed on the basis of model plants whose development is discussed in Section 2.1.2.3.

Some financial analysis was made of firm-level statistics in order to determine the overall profitability of the

TABLE 2–4

DATA REQUIREMENTS AND DATA SOURCES FOR THE IDENTIFICATION OF MANUFACTURERS

DATA REQUIRED	SOURCES OF DATA COLLECTED
Operational data	
1. Highly impacted products made by each firm 2. Plant location 3. Plant capacity 4. Processes used 5. Capacity utilization 6. Current hazardous waste treatment method 7. Other products produced at plant	Chemical Week, *Buyer's Guide 1977* Chemical Marketing Reporter, *Buyer's Guide 1976–77* Chemical Marketing Reporter, "Chemical Profiles." *Chemical Economics Handbook*, Stanford Research Institute Communications with firms Corporate Reports
Financial data	
1. Annual sales 2. Annual income 3. Annual cash flow 4. Net worth 5. Rate of return on equity 6. Debt-equity ratio	*Value Line Investment Survey* *Moody's Industrial Manual* Corporate Reports Standard & Poor's *Industry Surveys* Chemical Week, "Annual Survey of Chemical Manufacturers"

impacted firms and to ferret out any failing companies. In addition, several financial factors were analyzed based on a 10-firm sample chosen from the total of 22 producers of highly impacted chemicals. The firms were chosen so as to emphasize ones which are predominantly chemical manufacturers in order to maximize the relevance of the statistics studied. Diversified companies, such as General Electric, were excluded. Once the sample was chosen, an assessment was made of the profitability (and, by extension, the pricing power) of the chemical firms. Particular note was made of these firms' performance during the period 1973-76, when prices rose dramatically in the chemical industry. An examination was also made of the financial strength of the firms as indicated by their debt-equity ratios. This ratio is commonly used to indicate any possible future problems a firm might have in financing its continued operations.

2.1.2.2 Market Characterization

The market characterization was undertaken to describe the workings of the six highly impacted product markets. Information was sought to explain the market mechanisms and performance of the six segments as well as to characterize the operational and financial variables that would dictate the industry's ability to meet Level III regulations at each of its plants.

Information was developed for the characterization in three ways. First, published summary statistics were analyzed to determine industry practices and trends. Analysis of the summary statistics also served to highlight special problems in the industry such as declining sales and overcapacity. Second, reports and papers that describe the industry, ranging from studies of one segment to treatises on the aggregate chemical industry, were studied to explain some of the qualitative workings of the industry. Information on such aspects as market structure and pricing behavior was obtained in this manner. Third, contacts with industry experts ranging from journal editors to plant engineers were developed to obtain plant-specific information as well as to receive feedback on the market models being developed. The response from industry personnel was limited due to OMB guidelines restricting the use of surveys in government contracts and the unwillingness of firms to release proprietary data.[5] For this reason, plant and process level data for each of the segments were modeled for the analysis.

2.1.2.3 Model Plant Development

In order to estimate the impacts of abatement cost on production, a model plant was developed for each of the highly impacted product lines.[6] The plant employed the process technology detailed in the Assessment Study with the exception of perchloroethylene. For this product recent changes in production techniques had dated the Assessment Study process which used acetylene; therefore, the more common ethylene process was selected. Plant size was determined by an analysis of the existing perchloroethylene plants.

Model Plant Size. Selecting the model plant size for use in the economic analysis required consideration of several factors: (1) the model plant size must be representative of the major portion of the industry, (2) the model must be appropriately sized in order to be sensitive to impacts that would potentially affect the smallest and the largest firms in the industry, and (3) the model plant should be compatible with the cost data developed in the Assessment Study.

The distribution of plant size for each highly impacted product is displayed in Table 2-5. Also noted in this table is the model size used to estimate abatement costs in the Assessment Study.

The Assessment Study data are then analyzed in Table 2-6. The table shows that the Assessment Study sizes are generally in the middle of the distribution of actual plant sizes. As can be seen in the table, for four of the chemicals, the model plant size used for the Assessment Study treatment model appears to be a reasonable choice for the economic model plant size. These are perchloroethylene, chloromethanes, epichlorohydrin, and vinyl chloride.

For acrylonitrile and furfural, the table shows that the Assessment Study model plant size falls askew from the median range of the distribution of actual plant sizes. It was, therefore, determined that the sizes chosen for the economic impact plant models would differ from the Assessment Study models. For acrylonitrile, the plant size for the purposes of this study is more than double the size used in the Assessment Study. The treatment cost data were adjusted to reflect the economies of scale benefiting the larger plant in the best estimate of cost. However, such adjustments tend to increase the error of the estimates. Therefore, for the worst-case cost estimates, size adjustments were not made to reflect the economies of scale. In this way, any sizing errors introduced would be conservative (i.e., they would

TABLE 2–5

DISTRIBUTION OF PLANT SIZE FOR SIX HIGHLY IMPACTED ORGANIC CHEMICAL PRODUCTS (1,000 MT/yr)

PRODUCT	PLANT SIZE* NAMEPLATE CAPACITY	MEAN SIZE	MEDIAN SIZE	*ASSESSMENT** STUDY* MODEL SIZE
Perchloroethylene	9, 18, 23, 23, 32, 54, 68, 68 73, 91, 91	50	54	39
Chloromethanes	7, 9, 18, 23, 23, 36, 45, 45, 51, 59, 68, 75, 84, 91, 98, 136, 227, 229, 257,	83	59	50
Epichlorohydrin	27, 63, 113	68	63	75
Vinyl chloride	68, 79, 91, 136, 136, 136, 136, 182, 204, 227, 318, 318, 318, 382, 454	213	182	136
Acrylonitrile	109, 125, 182, 186, 286, 391	213	189	80
Furfural	9, 18, 18, 33	20	18	35

* Source: *Chemical Marketing Reporter,* "Chemical Profiles," various issues and industry sources.

** Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries,* prepared for U.S. Environmental Protection Agency, 1976.

TABLE 2–6

MODEL PLANT SELECTION ANALYSIS*

CHEMICAL	EXISTING PLANT SIZES: (1,000 MT/yr)				*ASSESSMENT STUDY* SELECTION			ERCO MODEL PLANT SELECTION			JUSTIFICATION
	LOW	HIGH	MEAN	MEDIAN	SIZE (1,000 MT/yr)	NO. OF ACTUAL PLANTS BELOW	NO. OF ACTUAL PLANTS ABOVE	SIZE (1,000 MT/yr)	NO. OF ACTUAL PLANTS BELOW	NO. OF ACTUAL PLANTS ABOVE	
Perchloroethylene	9	91	50	54	39	5	6	39	5	6	Treatment cost data will be accurate; model will be sensitive to factors impacting smaller plants; cost analysis will tend to worst case for larger plants.
Chloromethanes	7	257	83	59	50	8	10	50	8	10	Model covers the mid-range of plants sizes; treatment cost data will be accurate; model will be more sensitive to factors impacting smaller plants.
Epichlorohydrin	27	113	68	63	75	2	1	78	2	1	Treatment cost data will be accurate; model reasonably close to mean plant size.
Vinyl Chloride	68	454	213	182	136	7	9	136	7	9	Treatment cost data will be accurate; model will be sensitive to factors impacting smaller plants; four plants reported to be 273 MT/yr.
Acrylonitrile	109	391	213	189	80	0	6	182	2	3	Poor data available; model size is the median size for the reliable data; treatment cost data will tend to be pessimistic.
Furfural	9	33	20	18	35	4	0	18	1	1	Two plants reported to be 36 MT/yr; model will be close to the mean plant size; treatment cost data will have to be scaled down to incorporate the changing economics of scale.

* Source: Table 2–4.

overstate costs), and would, therefore, be in accordance with the general methodology.

For furfural, the model plant size is close to half the size of that used in the Assessment Study. The treatment cost data also had to be adjusted to reflect the change in scale, as unit costs are higher for a smaller plant.

After determining model plant sizes, the next step was specification of the cost assumptions. A 10-year depreciation of plant was used for the model plants. While firms generally amortize their organic chemical plants in 3 to 5 years, depreciation guidelines of the IRS generally require firms to depreciate their facilities over a longer period for tax purposes. Straight-line depreciation was selected (though firms may favor double-declining balance) in order to develop costs that are reasonable throughout the 10-year period. (Double declining balance would yield costs that are constantly in flux due to the continually shrinking depreciation base.)

Capital costs were then developed for each of the model plants using a standard engineering cost estimation approach. The sources used to develop the cost data are listed in Table 2-7. Additionally, the Chemical Marketing Reporter (CMR) (August 15, 1977) was used for raw material and product costs.[6] Capital costs from the literature were updated to June 1977, using the Chemical Engineering Cost Index.

All pertinent cost data that could be identified were included in the cost estimate. When no information was available in the technical literature on a specific process, then estimates were made on the basis of information about analogous processes. In some cases, more detail was available than in others. For example, the cost of utilities either was a single item or was subdivided into fuel, cooling water, electricity, etc., depending on the chemical produced. When possible, the Assessment Study basis was used to make sure that the production cost model corresponded directly with estimated residual outputs. The basis items incorporated were the process used (raw feed starting material), the process yields, and the product mix. Several adjustments away from the Assessment Study process configuration had to be made and these changes are listed in Table 2-8.

The production costs were calculated on an annualized product output basis (per pound of product). Cost items such as capital and labor were calculated on an annual basis and divided by annual production. The amounts of variable cost items, such as feed material and utilities, were calculated on the basis of input units per pound of product.

TABLE 2–7

REFERENCES USED TO DEVELOP MODEL PLANT COST ESTIMATES

MODEL PLANT PROCESS	REFERENCES
Perchloroethylene	*Chemical Engineering,* May 4, 1970, p. 74. Hahn, *The Petrochemical Industry,* McGraw-Hill, New York, 1970, p. 312. Lowenheim, *Faith, Keyes, and Clark's Industrial Chemicals,* 4th ed. John Wiley & Sons, New York, 1975, p. 604.
Chloromethanes	Hahn, *The Petrochemical Industry,* McGraw-Hill , New York, 1970, pp. 96, 180. *Hydrocarbon Processing,* November 1975, p. 127. Lowenheim, *Faith, Keyes, and Clark's Industrial Chemicals,* 4th ed. John Wiley & Sons, New York, 1975, p. 530.
Epichlorohydrin	Hahn, *The Petrochemical Industry,* McGraw-Hill, New York, 1970, pp. 337, 339. Lowenheim, *Faith, Keyes, and Clark's Industrial Chemicals,* 4th ed. John Wiley & Sons, New York, 1975, p. 335.
Acrylonitrile	*Hydrocarbon Processing,* January 1971, p. 110. *Hydrocarbon Processing,* November 1975, pp. 108, 109. Lowenheim, *Faith, Keyes, and Clark's Industrial Chemicals,* 4th ed. John Wiley & Sons, New York, 1975, p. 46.
Vinyl Chloride	*Hydrocarbon Processing,* February 1973, p. 100.
Furfural	*Chemical Engineering Progress, 44* (1948) No. 9, p. 669. Dunlop, *Kirk-Othmer Encyclopedia of Chemical Technology,* 2nd ed., *10,* p. 242. *Industrial and Engineering Chemistry, 47* (1955) No. 7, p. 1408.

TABLE 2–8

CHANGES MADE TO *ASSESSMENT STUDY* MODEL PLANT PROCESSES

CHEMICAL	CHANGES	REASON
Perchloroethylene	Starting material changed from acetylene to ethylene. Product yield is 80 percent perchloroethylene, 20 percent trichloroethylene.	Acetylene process is no longer used, since ethylene is a cheaper feedstock. Trichloroethylene is a customary byproduct.
Chloromethanes	Product mix changed from 13 percent CH_3Cl, 26 percent CH_2Cl_2, 53 percent $CHCl_3$, and 8 percent CCl_4 to 70 percent, 15 percent, 10 percent, and 5 percent respectively.	*Assessment Study* product mix produced an unrealistic gross profit margin of about 170 percent. Other data indicated different product mixes.
Acrylonitrile	Ammonia consumption reduced and product yields changed slightly.	*Assessment Study* data did not accurately reflect literature data available.

The amount of each input needed was estimated from knowledge about the nature of the chemical process or taken from the technical literature on the process. Total costs for these were then obtained by multiplying this amount by a cost per unit. All cost breakdowns supplied give this information for each cost item.

The estimated total production cost per pound was compared to the actual bulk volume sales price reported in the CMR. If the difference between cost and value was more than about 5 percent, the cost model was modified. If a large adjustment was needed, the product mix was reassessed, and necessary changes were made. Other variables that were considered adjustable (within limits) were the capacity utilization factor, gross return, and byproduct credit.

For example, the byproduct credit for HCl in perchloroethylene production was reduced in order to better reflect actual production techniques. In the perchloroethylene process a large volume of HCl is produced and normally some of this byproduct is sold and some is converted (via the Deacon process) into Cl_2 for reuse. Customarily Cl_2 has a lower price than HCl and therefore the HCl credit was reduced to reflect this reuse.

The capacity utilization rates for the cost estimation were set at either 90 or 70 percent. The 70 percent figure was used for those highly impacted segments (perchloroethylene and the chloromethane) where poor market conditions indicate that utilization rates are likely to remain below the normal target rate of 90 percent for some time. Nevertheless, the model plant costs were developed to reflect a normal, healthy rate of return rather than current weak market conditions. The effect of poor market conditions is considered by the economic impact methodology described below in Section 2.1.3.

2.1.3 Cost of Compliance

Development of engineering estimates of the costs of compliance for treatment and disposal of hazardous wastes from organic chemicals production was not included in this effort. Cost data used to perform the economic impact analysis were the incineration costs developed in the Alternatives Study because they appear to most closely reflect the costs which will be faced by industry.

This study, performed under contract to EPA in support of potential hazardous waste regulations, developed model plant cost estimates for the technologies required to meet regulatory levels sufficient to provide for environmental protection. Using the cost data presented, a set of best estimates of the cost for achieving Level III technology was developed emphasizing the standard demonstrated treatment practice for organic chemical wastes-incineration. The best estimates of cost were developed as conservative estimates of the incremental cost of achieving Level III. That is, they presume that the costs of the present industry average technology (Level I) are already being incurred and credit the applicable amount of Level I cost[7] to the cost of achieving Level III from scratch.

In order to determine the most significant potential sources of error in these best estimates, the model costs were investigated for their sensitivity to numerous cost input assumptions including costs for land, fuel, maintenance, and labor. These costs appeared to reflect minor uncertainties which could not be easily reduced, and in general the cost-estimating procedures used provide estimates accurate to within 25 percent (see Section 4.4). However, the best estimates of the costs of compliance were found to be quite sensitive to variations in the extent of existing treatment.

Because of the sensitivity of the cost estimates to uncertainty and to variations in the existing treatment assumed, a set of worst-case cost estimates was derived. These estimates took an even more pessimistic view of the previously developed cost data in order to provide a worst-case limitation to impact. Using these estimates in the analysis yields the most conservative scenario for regulatory impact.

The worst-case cost estimates presumed no existent plant treatment so that the incremental cost borne by each plant will be the full cost of achieving Level III technology with no Level I credit. Additionally, a 25 percent factor was added to the Level III cost estimates to reflect the worst possible error resulting from the uncertainty of the cost estimating procedures.

2.1.4 Economic Impact Analysis

The choice an organic chemical manufacturer faces in the presence of hazardous waste management regulation is simply whether the firm should shoulder the incremental costs of hazardous waste pollution abatement in order to comply with regulations and continue manufacture of impacted chemicals, or whether it should discontinue production of these products. This choice will be based on two basic economic parameters:

1. The capital decision: can the resources needed for the additional investment necessary to comply with regulations be provided given the firm's other capital requirements and capital-raising constraints?

2. The price decision: can a sufficient amount of the incremental product costs attributable to abatement be passed on to the consumer via price increases to allow continued production with an acceptable rate of return?

Analyses of these two components of total profitability of manufacturing an organic chemical, as amended by compliance costs, presumably will be conducted by each firm for each regulated manufacturing process. These analyses will take into account all factors influencing the economic decisions, including the following:

1. The economies of scale and possible spreading of equipment costs among several processes served by the same equipment (e.g., a plant-wide incinerator).

2. The value of captive production of organic chemicals used as intermediates within the company, versus outside purchase.

3. Expectations of future profit opportunities in products subject to significant impact.

Unfortunately, the data needed to simulate this process-by-process analysis for each product line of each manufacturer are not available for this analysis. Many relevant financial data of the process level are regarded as proprietary by chemical manufacturers. Additionally, the information needed to properly account for other complicating factors, such as those noted above, is not obtainable.

A model plant approach was developed specifically to circumvent these problems as much as possible. In addition, restriction of the analysis to highly impacted organic chemicals reduces the scope of the analysis to manageable proportions.

The investigation of the economic impacts of hazardous waste management regulations on the industry was based on analysis of the model plant for each highly impacted segment. The general investigation was then supplemented by an in-depth assessment of the regulatory impact to each firm in the highly impacted segments. Impacts on the industry and nation are discussed in the final section.

2.1.4.1 Model Plant Analysis

The model plant analysis consists of a generalized study of impacts in each of the highly impacted segments. A flow chart showing the interrelationships of the five stages of the analysis is displayed in Figure 2-2. The first two stages consist of the assessment of market conditions. The price elasticity of demand is estimated in order to determine the sensitivity of the market to regulation-induced price increases. The price elasticity is then incorporated into the cost passthrough decision model. The decision model examines the likelihood that firms can pass any increased costs on to consumers, suggesting that their market is sufficiently strong to allow price increases. The next two stages examine first the profitability of the model plant under the various treatment cost scenarios and then the attractiveness of the abatement investment itself. These two sections of the analysis provide the only quantitative analyses utilized in the general impact model.

The results of these preliminary stages, which are effectively summarized by "the likelihood of a full-cost passthrough" conclusion and the net present value of investment, provide needed inputs to the plant shutdown decision analysis. The other inputs to this analysis are plant-specific factors which can influence the shutdown decision, often in nonquantifiable terms. An example of such a factor is the "integration [of the impacted process] with other on-site production processes."

The methodology used for each stage of the analysis is discussed below.

Estimation of the Price Elasticity of Demand. The standard method for estimating the price elasticity of demand (i.e., the relative decline in sales resulting from an increase in price) is to develop a simultaneous equation market model specifying both supply and demand. However, this approach could not be utilized for the six highly impacted product lines because sufficient data were not available to adequately characterize the market. For two of the segments, furfural and epichlorohydrin, little production data of any kind are published.

For all segments, difficulties were expected in the specification of the supply equation. In general, the supply equation is ignored using the rationale that producers always adjust to market demand. But significant shortages were experienced in 1974-75, precluding this rationale, and modeling the limitations on supply could not be accurately

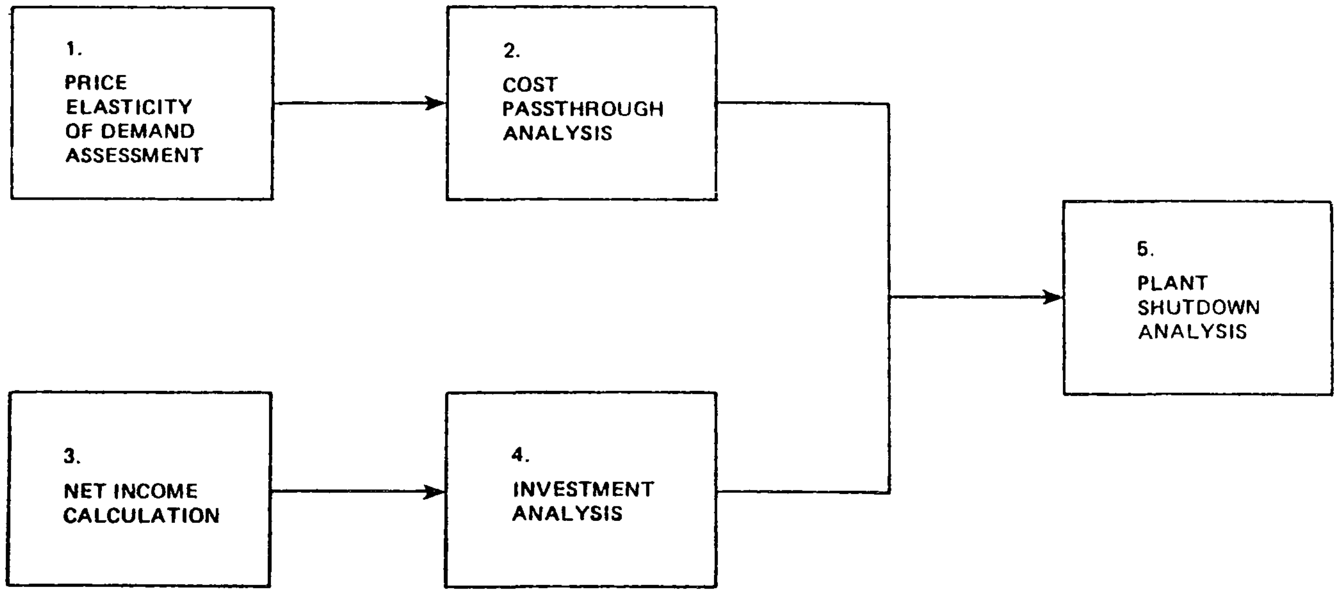

Figure 2–2. Relationship of the elements of the model plant analysis.

performed with the existing data on energy prices, industry capacities, etc.

On the demand side, the extent of captive production and important inventory changes (which could not be isolated) helped to obscure levels of market prices demand volume.

In light of these difficulties, an alternative approach was used for estimating the price elasticity. A number of market demand factors were studied for their qualitative effect on an assumed baseline price elasticity of 1.0 (unitary elasticity: a 1 percent increase in price causes a 1 percent decline in demand). The market demand factors used for this analysis are listed in Table 2-9. The table shows the possible range of influences for each factor and the basis for each estimated influence in terms of market data.

This alternative approach proved to be both a cost-effective and accurate method of estimating the price elasticity. All of the highly impacted product lines could be readily classified as having either a low (0.0 to 0.5), medium (0.5 to 1.0), or high (1.0 to 2.0) price elasticity. Care was taken not to understate the price elasticity of any segment since this could cause an understatement of the overall economic impact of regulation-induced price increases. For example, in order to derive an overall price elasticity for the chloromethane market, it was necessary to combine the price elasticities of the four submarkets in that industry. Three of the submarkets were estimated to have low price elasticities, but the remaining submarket, that of the large-volume chemical, carbon tetrachloride, has a medium price elasticity (0.5 to 1.0). The medium elasticity range was used for the market segment in order to not underestimate possible economic impacts.

The first market factor, as listed in Table 2-9, was the historical and projected demand growth for the industry. Strong demand growth, particularly in a period of price increases, suggests that the price elasticity of demand is low.

The next factor, the level of captive usage, is included in the table as an indicator of the extent to which a chemical product is exposed to merchant market pressures. A high level of captive use (meaning that a firm will use most of its production of a chemical internally) indicates that a chemical is sheltered from market competition. A firm's demand for its own production is likely to be less sensitive to price changes, generally, than open market demand would be. Presumably, the firm has a vested interest in the continued production of the impacted chemical and its derivative end products.

TABLE 2–9

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND

MARKET CHARACTERISTIC	PRESENT DATA	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)
Demand growth	High Low	Decrease Increase
Captive usage	High Low	Decrease Increase
Use as intermediate	High Low	Decrease Increase
Significance of price as basis for competition	High Low	Increase Decrease
Substitutability	High Low	Increase Decrease
Foreign competition	High Low	Increase Decrease

PRICE ELASTICITY ESTIMATE: High (1.0 to 2.0)
Medium (0.5 to 1.0)
Low (0.0 to 0.5)

The extent of use as an intermediate also reveals a significant fact about the nature of demand. The customers of chemical intermediates normally have a stake (in terms of sunk costs in existing processes which require the chemical as an input) in continued purchases of these production inputs and will tend to be less sensitive to price increases.

The "significance of price as a basis for competition" factor presents conclusions about the relative importance of price, effectiveness in use, environmental concerns, and supply stability to market competition. It was often concluded that price was only one of several important types of market competition and, in these cases, the "significance of price" factor was estimated to reduce the price elasticity.

The degree of substitutability was estimated for each highly impacted product on the basis of information about the intermediate and end-use markets of its derivatives. A high degree of substitutability increases the price elasticity.

Lastly, the level of foreign competition was examined. A large volume of imports, for instance, increases the extent to which domestic customers will switch to foreign supplies in the face of domestic product price increases.

Cost Passthrough Analysis. The likelihood that firms will be able to pass on abatement costs through price increases was also studied in terms of the qualitative influences of various market characteristics. The four factors used to assess whether costs can be passed through are listed in Table 2-10. The table also lists the possible data entries for each factor and the direction of their influence on the likelihood of full-cost passthrough. The analysis considers the cost passthrough decision at the industry level and at the plant level, as will become evident below in the discussion of each market characteristic.

The price elasticity of demand is the principal determinant of an industry's ability to pass through costs. A low price elasticity will yield the smallest decline in sales volume for each percent increase in price. Therefore, a minimal decline in profits due to diminished volume will accompany the price increase required to pass on the costs of abatement. If the elasticity is too high, the decline in profit resulting from such increased costs may be more than the loss of profit from absorbing the full cost of abatement so that firms would not be expected to increase their prices.

The size of the required cost increase as a percentage of current unit manufacturing costs (measured from the model plant costs in terms of the manufacturing cost per

TABLE 2–10

COST PASSTHROUGH DECISION MODEL

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL–COST PASSTHROUGH
Price elasticity of demand	High (1.0 to 2.0)	Negative
	Medium (0.5 to 1.0	Neutral
	Low (0.0 to 0.5)	Positive
Variation in abatement costs among firms	High	Negative
	Moderate	Positive
Required cost increase as % of manufacturing cost	Large	Negative
	Small	Positive
Expected capacity utilization	High	Positive
	Medium	Neutral
	Low	Negative

LIKELIHOOD OF FULL–COST PASSTHROUGH: Good likelihood of full-cost passthrough;
Poor likelihood of full-cost passthrough.

metric ton of product) measures the significance of the cost passthrough question. In several of the highly impacted segments, including furfural, acrylonitrile, and chloromethanes, the required cost increase was less than 2 percent of the manufacturing costs for the worst-case cost scenario. Cost increases of this magnitude will certainly not be ignored, nor will they be immediately observable in price increases or changes in operating income. The conclusion drawn in this analysis is the obvious one that firms are more likely to be able to pass through small costs increases.

The two remaining factors concern the competitive balances between firms in a given industry. The variation in abatement costs among firms could mean that firms with above-average treatment costs will not be able to fully recover costs. That is, while the industry price level may rise in response to the regulation, it may not rise enough for all firms to recover costs. The expected capacity utilization rate is included because it affects the willingness of firms to increase prices. It is expected that the lower the industry capacity utilization rate, the more variation will exist among firms. When a firm is running at a low operating level, e.g., 60 percent of capacity, price rises are avoided lest they cause a further decline in the quantity demanded, which will further decrease production efficiency.

A determination regarding the cost passthrough decision was made on the basis of the data presented. The greatest weight was given to the price elasticity factor and to the size of the cost increase due to their basic importance to the question. However, in industry segments where much of the volume of production is used captively, cost passthrough becomes less meaningful. In these segments (e.g., epichlorohydrin) passing on abatement costs is merely an accounting problem because the firm passing on these costs is also the customer bearing the costs. To understand the passthrough decision in this case, it would be necessary to perform another passthrough analysis of the final product sold by the firm, but that is beyond the scope of this study.

Investment Analysis. An assessment was made of the attractiveness of the hazardous waste treatment investment for each of the highly impacted segments. The investment analysis consisted of calculating the expected future cash flows for the model plants in order to measure the continued profitability of operation. Negative results in the cash flow calculation would indicate an unwillingness by firms to make the required investments and suggest important economic impacts and plant shutdowns. The underlying assumptions for this analysis will be discussed below as the basic methodology is laid out. The data requirements for the calculations are (1) the model plant costs and (2) the costs of the hazardous waste treatment investments for the best estimate of cost and the worst-case cost scenarios.

The net income for the model plant was derived prior to the calculation of cash flows. The first step, a fairly important one, was the assumption of the appropriate capacity utilization rate. For most of the segments, a 90 percent utilization rate was used, because that is the normal operating target for the industry. Two of the highly impacted segments, however, currently face considerable uncertainty about future sales. Therefore, the net income calculation for these two segments, perchloroethylene and the chloromethanes, was made on the basis of a 70 percent utilization rate. The 70 percent rate approximates the current operating levels in these industries and allows for the possibility of poor future markets.

Revenue per metric ton of product was then calculated on the basis of current (Chemical Marketing Reporter, August 1977) unit market prices.[8] The use of unit prices will tend to overestimate actual revenues since some customers will normally receive discounts for large-volume purchases and many "sales" are captive transfers within a firm or plant. However, this overstatement is mitigated by the fact that manufacturing costs were also calculated using unit market prices for the necessary chemical feedstocks which comprise most of the costs of production. Manufacturing costs and treatment costs were subtracted from the revenue figure in order to derive gross profit per metric ton. Separate calculations were made for both treatment cost scenarios as well as for a baseline before the addition of treatment costs.

In order to derive the net profit figure, a 50 percent corporate income tax rate was assumed. Finally, the model plant net income was calculated as the product of the net profit per metric ton and the annual production volume. With the net income figure, it was then possible to compare the effect on profitability of the different treatment assumptions.

The investment analysis builds on the calculations made in deriving the model plant net income. The annual cash flow (CF) for any year t was derived in the following manner:

$$CF_t = NI_t + DEP_t - INV_0 - WC_0 + WC_L - SALV_0 + SALV_L$$

where

NI_t = Net income for year t.

DEP_t = Depreciation charges for year t. Depreciation charges are added into the cash-flow figure (after having been subtracted as part of the manufacturer's cost in deriving net profit), because they do not represent an actual expenditure of funds.

INV_0 = Investment costs, considered here to consist of one cash outlay in year 0 when the investment was made. It was assumed that the investment would have zero salvage value at the end of its productive life.

WC_0 = Working capital outlay required in year 0 in order to maintain operation. It is included here as a portion of the opportunity cost of continued operation. Working capital is approximated as one-fourth of the annual manufacturing costs (depreciation charges not included).

WC_L = Working capital remaining at the end of the life of the investment.

$SALV_0$ = Salvage value of the plant at the time of investment. The salvage value of the plant also represents the opportunity cost of not closing the plant.

$SALV_L$ = Salvage value of the plant at the end of the life of the investment.

The net present value of investment was then calculated with appropriate assumptions about the length of the investment life and the correct rate of discounting. A 10-year investment life was used because it is a standard time horizon for cash flow analysis. The discount rate was set at 15 percent, which is indicative of current borrowing conditions in the industry.[9] The net present value of investment was then calculated with the following formula:

$$NPV = \sum_{t=1}^{10} \frac{CF_t}{(1+r)^t}$$

where r = discount rate of 15 percent.

A positive net present value for the discounted cash flow suggests that firms would make the required investment. In theory, it would be desirable to allow for some margin of error in the results. For example, if the net present value is positive but small (small being judged by any responsible criteria), then the investment should be carefully examined. In practice, none of the cash flow analyses performed raised this uncertainty.

The weakness of this approach is that it assumes that the current market conditions will be sustained during the life of the investment. A number of firms may foresee market difficulties which would cause them to use significantly shorter planning horizons, thus reducing the net present value of investments. Such plant-specific conditions are treated later in the analysis in the section on projected impacts.

Plant Shutdown Analysis. The plant shutdown analysis summarizes those factors which are most significant to continued operation for individual plants. The factors considered relevant to the plant shutdown decision are displayed in Table 2-11 along with the effects on the likelihood of plant shutdown resulting from possible values of existing plant data. Each factor is accorded a positive, neutral, or negative influence on the likelihood of plant shutdown, with a conclusion based on their cumulative influence. For example, if all factors are listed as positive influences, then the conclusion would be that plant shutdowns are imminent for the industry.

No a priori assumptions about the likelihood of shutdowns are made for any industry. The current vulnerability of firms in a weak competitive position is taken into account only in the assessment of projected impacts. The plant shutdown analysis covers those influences which can be accurately assessed in terms of a generalized model plant analysis of the industry.

The influence of each factor is estimated on the basis of the most pessimistic industry data. For example, the investment analysis results for the worst-case costs are used for this analysis. Similarly, if any plants in the highly impacted segment are isolated operations, then the degree of integration with other production processes is assumed to be low. It is presumed that a manufacturing operation which can be closed without affecting any other operations is more susceptible to shutdown due to abatement cost increases.

TABLE 2–11

MODEL PLANT SHUTDOWN DECISION FACTORS WITH WORST–CASE TREATMENT COSTS

DECISION FACTOR	PLANT DATA	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN
Net present value of investment	Positive Negative	Decrease Increase
Ratio of investment to net fixed investment	High Low	Increase Decrease
Degree of vertical integration (forward or backward)	High Low	Decrease Increase
Integration with other on-site production processes	High Low	Decrease Increase
Other environmental/ regulatory problems	High Low	Increase Decrease
Likelihood of full-cost passthrough	High Low	Decrease Increase

LIKELIHOOD OF PLANT SHUTDOWN: (segment-specific).

The most significant factors are derived directly, or with a minimum of reworking, from the previous analyses. As mentioned, the investment analysis results from the worst-case cost scenarios were calculated, the cash flow analysis being the most complete quantification possible of the firms' decision-making process. The size of the investment was also calculated as a percentage of the net fixed investment in the model plant. An investment which is large in relation to the existing sunk costs (e.g., 20 percent) is more likely to be foregone than one which constitutes only a small addition (less than 5 percent) to the existing investment. The results of the cost passthrough analysis are also listed. In cases where there was a strong likelihood of a full-cost passthrough, it is thought to be more likely that the regulatory impact on the industry will be small, other factors remaining equal.

The three remaining factors listed cover operational, plant-specific, and firm-specific data. The degree of vertical integration is included because vertical integration complicates the shutdown decision. The firm must then examine a range of its activities. For example, a firm may continue to operate a process that is more costly rather than purchase product from a competitor because the costs of shutting down an inefficient operation may be greater than the cost difference between in-house production and outside purchase.

Similarly, the extent of integration (in technical production terms) with other on-site production processes may affect the likelihood of a shutdown through its effect on plant economics. To illustrate this concern, consider a plant in which two parallel processes use the same raw material inputs. The two processes share the burden of all pollution control systems, but do not supply inputs to each other. Closing down one operation may destroy the viability of the other process. The one remaining profit center must then support all of the plant overhead costs, and the reduced purchase volume of inputs may cause input prices to increase. In general, the closing of any one production process may seriously affect the operations of the entire plant.

Finally, a survey was made of any other environmental or regulatory problems which could affect the future of the highly impacted segments. The possibility of future regulatory bans on sales of a particular chemical, for instance, would radically reduce the commitment of a firm to its continued production. Since it would have been difficult to include such concerns in the investment analysis, this factor was added to the plant shutdown analysis. The three major issues identified: (1) the possibility of a ban on fluorocarbons derived from chloromethanes, (2) the uncertain future of the OSHA emission standards in the vinyl chloride industry, and (3) concerns about the toxicity of perchloroethylene. In each case the factors were accorded a positive influence on the likelihood of plant shutdown.

Conclusions concerning the overall likelihood of plant shutdown were drawn for each highly impacted segment. Since it is unlikely that the influence of each factor would be of equal importance, the conclusions carry implicit judgments about the relative importance of factors. These judgments are made clear in the discussion of the plant shutdown analysis for each highly impacted segment in Chapter Five. In general, the factors given greater weight were: (1) the likelihood of full-cost passthrough, and (2) the results of the investment analysis. The significance of the other factors varied with the industry-specific data.

2.1.4.2 Projected Impact Analysis

The projected impact analysis involved the examination of each highly impacted segment on a plant-by-plant basis. The methodology for this work was relatively informal in that no models were developed. Rather, the analysis involved two definable stages: (1) the gathering of data about current treatment methods and the current competitive position of firms in each industry, and (2) the estimation by ERCO of the regulatory impacts for each plant. Table 2-12 summarizes the information gathered in this portion of the analysis and also the possible entries for each column.

Contacts were made with firms in order to determine their current treatment methods, the interrelationships of their various production processes and any problems they might have complying with potential hazardous waste regulations. Information was also gathered about any firms which appeared to be vulnerable to the competitive pressures of the given industry and the causes of this vulnerability. Vulnerable firms are here defined as being liable to cease production within the foreseeable future because of existing or projected market influences exclusive of hazardous waste regulations. The problems faced by certain firms tend to be common knowledge in the industry, but efforts were made to obtain confirmation from all available sources about the difficulties of the weak firms. The competitive position of all firms was estimated as "good" or "vulnerable." No more refined gradations were possible with the information at hand.

TABLE 2–12

SUMMARY OF PROJECTED IMPACTS

MANUFACTURER	PLANT LOCATION	CURRENT TREATMENT	CURRENT COMPETITIVE POSITION	MANUFACTURER RESPONSE REGARDING IMPACT	PROJECTION OF REGULATORY IMPACT
Plant-specific entries	Plant-specific entries	Plant-specific entries	Good Vulnerable	Negligible Moderate Significant	Small Significant inpact possible

The information provided by industry contacts allowed the estimation of the regulatory impacts. Where firm responses to queries stated that the regulatory impact would be negligible, the information was assumed to be accurate. Further investigation did not suggest that any of the firms which responded in this fashion were misrepresenting their position. In some cases it was found that incineration (a sufficient Level III treatment for all six highly impacted segments) is currently used at a certain plant, even though none of the contacts with the firms produced a definite statement of the impact of regulations. In these cases, the impact was estimated to be small. When information on the current treatment system at a plant was not available, and contacts with the firm did not provide data on the regulatory impact, the impact was assumed to be at the industry average.

A more difficult problem was posed by the estimation of regulatory impacts on vulnerable firms. An investigation was made of the specific reasons for the poor competitive position of each vulnerable firm. In most cases, an investment in hazardous waste treatment equipment was expected to worsen the situation. The vulnerable firms tended to be the smaller firms, which had not yet made an investment in Level III treatment for hazardous wastes. However, it was difficult to separate the incremental effect of potential regulations from effects stemming from their competitive position. Regulation may be the straw that breaks the camel's back, convincing the firm to cease production, or it may merely be a small additional nuisance to a firm with an already weak market position. For the most part, the weak firms' problems are caused by certain established cost disadvantages and the importance of the new regulation was not overemphasized. For the projected impact, vulnerable firms which are not currently undertaking Level III treatment of their hazardous wastes were classified with the phrase, "significant impact possible," leaving a vagueness appropriate to the difficulty of attributing a plant shutdown to any one cause, regulatory or otherwise.

2.1.4.3 Impacts on the Industry and the Nation

The only available data for projecting the impacts of hazardous waste regulations on the organic chemicals industry was an estimate of the aggregate costs for achieving Level III developed in the *Assessment Study*. This figure was an estimate of the total costs for achieving Level III, not the incremental costs. The *Assessment Study* also developed an estimate for the existing Level I expenditures (1973). Subtracting the existing expenditures from the Level III costs yields an estimate of the incremental costs of compliance. This estimate may understate costs because it assumes a full credit for Level I costs which may not be fully applicable to Level III. However, this is believed to be compensated for by the increase in present preregulation expenditures that has occurred since the Assessment Study data were gathered.

The average abatement cost as a percent of price for the industry was developed by comparing the 1973 estimate of incremental costs to the level of industry shipments for 1973. This industry average was estimated from the cost data developed for the sample segments reviewed in the selection of the highly impacted product lines. A comparison of the total Level III abatement costs as a percent of price of the sample to this total developed for the entire industry in the Assessment Study shows that the sample value is 1.0 percent while the industry value is 1.1 percent. (Costs used in the calculation for the sample were Assessment Study standard technology costs except for those products not treated in this report. For these products, the alternative treatment cost from the Alternatives Study was used.)

The effect of the new cost increases on the Wholesale Price Index (WPI) for all commodities was determined by multiplying the incremental cost increase by the weight of the combined industries in the WPI of 0.01849. High and low estimates of the incremental abatement costs as a percent of price were also utilized for comparison.

2.2 Limits of the Analysis

This report was based on application of the methodology described above utilizing the best information available given the constraints of time and cost. Because the analysis is only an approximation of what is likely to happen upon promulgation of hazardous waste regulations, those aspects of the analysis which have the greatest effect on the conclusions warrant further discussion. The sensitivity of results to changes in the four most important portions of the analysis will be discussed individually below. The four areas are: (1) highly impacted segment selection, (2) model plant development, (3) cost of compliance estimation, and (4) economic impact analysis. Additionally, the overriding assumption made throughout this report is that the technologies and costs developed in the Assessment Study and the Alternatives Study reflect compliance with the impending regulations, the content of which has not been finalized.

2.2.1 Highly Impacted Segment Selection

Six products were chosen as those representatives of the organic chemicals industry which would exhibit the highest levels of economic impact. Two distinct selection processes were involved. Both processes were applied to the sample of 20 product lines which had been chosen for treatment cost analysis by the Assessment Study and Alternatives Study contractors.

The first selection process did not specifically utilize a criterion for economic impact. Instead, the criteria used were: (1) national production volume, (2) significance of the products and process waste streams, and (3) industrial importance of the chemical product group represented. There remains, therefore, a distinct possibility that a product which will be severely impacted by the regulations was excluded in this selection and evaded close inspection in the economic analyses.

The second selection process utilized the national production volume and abatement costs as a percent of price. A natural separation of the six highly impacted segments from the rest of the sample which had minimal cost/price ratios as well as low sales volume allows one to assume with a high degree of confidence that the 6 product lines would be subject to the highest impact of the 20 product lines reviewed.

Two factors will mitigate the potential for excluding a highly impacted product line from the economic analysis. First, the consistent use of national production volume as a criterion of selection assures that the six products selected will constitute a significant percentage of total industry production.[10] Because waste volume is related to compliance cost this selection criterion may act as a surrogate for treatment cost and also for impact. Second, since the cost of treatment is generally higher for the more hazardous wastes the use of the selection criterion of waste-stream significance will tend to favor product lines with higher treatment costs. Although this does not necessarily indicate that selected products will always experience higher impacts, it does give some assurance that most of the excluded products will not experience severe impacts. Some uncertainty still remains, however, which cannot be quantitatively specified.

In summary, there exists some likelihood that other highly impacted products may exist that were not subjected to analysis. These products were likely to have been excluded by the selection process used in the Assessment Study.

2.2.2 Cost of Compliance

The costs of compliance had to be estimated for model plants because insufficient data on actual costs were available from manufacturers. The estimates developed relied in large part on the analyses performed and estimates developed in the Assessment Study and the Alternatives Study, and thus incorporate any errors made in these reports. Whenever assumptions were required in order to use or analyze these data, they were made to overstate costs so as not to understate potential impact. Hence, if the results of the economic analysis are in error, they will tend to overestimate the actual impacts of the future regulations on the industry because of overstating actual costs of compliance.

The best estimates of compliance costs reflect this conservative approach. Based as they are on the previous work in the Assessment Study and the Alternatives Study, they cannot be relied on to be precise, particularly if applied to one particular facility. The cost estimates used are accurate to within only 25 percent (see Section 4.4), and do not account for savings resulting from economies of scale for joint treatment facilities at multiproduct plants. In addition, the methodological approach to current existing treatment technology and a number of other factors introduce a conservative bias into the estimates.

The worst-case estimates are predicated on the assumptions that the facility currently has no hazardous waste treatment and that the maximum cost-estimating error of 25 percent has been made. These estimates thereby reflect the worst conceivable possibility and provide an upper bound on the impacts of the future regulations which a firm may experience.

2.2.3 Model Plant Development

A model plant analysis is limited by the fact that real-world conditions can never be represented perfectly. Many, if not most, plants will have characteristics quite different from the model, but this is not necessarily a liability of the model. The principle of using the model is that although data for all actual plants are not available, calculations based on the model will reflect average conditions for the industry. Thus, the calculations cannot be used to predict conditions for a particular facility, but only to indicate what the average conditions are most likely to be. For this study, the plant models were designed to reflect as closely as possible the average conditions in the industry.

Errors in developing model plants can arise from two areas: (1) technical specifications of the model plant and (2) the cost analysis. Each of these is discussed below.

2.2.3.1 Technical Specification

The model plants used in the economic analysis were based on the process descriptions presented in the Assessment Study. In general, data developed in the industry profile agreed with the specifications presented in this study for the hypothetical typical plants. Model plant size, process used, and product mix were adjusted for some cases in order to update the specifications to more closely reflect present practice.

2.2.3.2 Cost Analysis

Insuring that the model plant cost analysis also reflects average industry conditions proved to be somewhat more difficult. Cost and profit data were considerably more difficult to obtain from the manufacturers, and the analysis correspondingly utilizes more guesswork in determining the technical specifications for the model plant.

Although standard cost-estimating procedures were used, they cannot be relied upon to be more accurate than ±25 percent (see Section 4.4). In addition to the potential errors from the cost estimation, however, significant potential for error in the financial analysis exists because of uncertainties in accounting procedures, plant factors, and gross returns to the firm's profit centers. These data are not available, and thus estimates must be based simply on reasonableness and consistency. For this study, price estimates developed for the model plants were compared with published merchant market prices in the literature. If the prices did not correspond to within 5 percent, the assumptions were altered slightly to reflect more likely conditions. In this way, although certain components in the cost analysis might be somewhat inaccurate, the overall analysis should be consistent with the existing price data.

In the cases of perchloroethylene and the chloromethanes, this adjustment process proved quite difficult, and generally the model firm's profits appeared to be unreasonable. In these cases, it was determined that the product yields and product mixes did not reflect current industry practice.

These parameters were adjusted in a technically consistent manner to reflect somewhat more realistic profits. These changes, although not based on any concrete data, still appeared consistent with the average characteristics of the industry.

2.2.4 Economic Impact Analysis

For the purpose of discussing limits to the economic impact analysis, the procedure used is best separated into two distinct phases: (1) analysis of impacts on the highly impacted segments and (2) analysis of the impacts on the industry and the nation. The limitations of each phase are discussed below.

2.2.4.1 Highly Impacted Segments

The highly impacted portion of the economic impact analysis dealt with the predicting of (1) price elasticity of demand, (2) the likelihood of full-cost passthrough, (3) the return of the abatement investment, and (4) the likelihood of plant shutdown. The inputs for these analyses are the model plant data and cost of compliance estimates discussed above and estimates of the contractor based upon knowledge of the industry. As discussed, these data appear to be reasonable, conservative approximations of industry practice. Therefore, it is presumed that the investment analyses are also reasonable, but conservative, representations of the industry's position. Feedback from members of the industry tended to corroborate the analysis. The conservative nature of the analysis was borne out by the responses from many of the firms producing highly impacted products, which noted that the regulations would have negligible impact on them even in cases when the model plant analysis indicated moderate impact. By including available firm- and plant-specific data in the projected impact assessment for each segment, divergence of the model plant analysis from reality was significantly reduced. However, such information could not be obtained for several plants and therefore certain critical plant-specific factors may have escaped inclusion in the analysis.

A review of the sensitivity of the results to variations in the data and assumptions used showed that the variability was dominated by the potential error in the cost of compliance estimates. For example, using the Assessment Study cost estimates for incineration in place of those from the Alternatives Study would have doubled the costs for perchloroethylene (already subject to the most severe impact) and quadrupled the costs for epichlorohydrin and vinyl chloride (shifting these products to potentially large impact).

2.2.4.2 Industry and the Nation

The only quantitative estimates utilized in assessing the magnitude of impact on the industry and the nation was the Assessment Study estimates of existing Level I expenditures (1973) and the total costs of Level III. An estimate of incremental costs was obtained by crediting all Level I expenditures to Level III. This assumption ignores capital investment in Level I technologies which may not be applicable to Level III, thereby understating incremental costs. This is counterbalanced by the new Level I investment since 1973. Both of these factors, however, may be negligible compared to the error in the Assessment Study cost of compliance estimates. As has been discussed above, the Alternatives Study costs have been used in this report, and Assessment Study cost estimates for some products are more than 4 times higher. Furthermore, the large degree of aggregation and averaging used in the Assessment Study to develop their estimate is admittedly subject to large error.[11] A forthcoming report developed for EPA will update this estimate.[12]

NOTES TO CHAPTER TWO

1. TRW, Inc., Assessment of industrial hazardous waste practices of the organic chemicals, pesticides and explosives industries, prepared for the U.S. Environmental Protection Agency, 1976.

2. Processes Research, Inc., Alternatives for hazardous waste management in the organic chemicals, pesticides and explosives industries, Draft Report prepared for the U.S. Environmental Protection Agency, 1977.

3. TRW, Inc., Assessment study, 1976, p. 2-8; and Foster D. Snell, Inc., Potential for capacity creation in the hazardous waste management service industry, prepared for the U.S. Environmental Protection Agency, August 1976.

4. From Figure 2-1, it can be concluded that eight products appear to be in the highly impacted category. These are: (1) perchloroethylene, (3) chloromethane (methyl cloride, methylene chloride, chloroform, carbon tetrachloride), (4) epichlorohydrin, (6) vinyl chloride (monomer), (8) acrylonitrile, (10) lead alkyls (tetraethyllead, tetramethyllead, tetramethylethyllead), (12) furfural, and (18) aldrin.

5. The guidelines enforced by the Office of Management and Budget require that no more than nine contacts be made for any type of data sought without clearance from OMB.

6. One plant was developed to produce the four chloromethanes.

7. Costs for Level I were developed in the Assessment Study.

8. Chemical Marketing Reporter prices tend to be "merchant market" prices which overstate costs to captive users and long-term contract customers. However, this source is the most comprehensive one available for pricing purposes, and using merchant market prices for inputs as well as outputs should keep other cost factors (those of interest) in line.

9. Personal communication, Shaw Bridges of Smith, Barney & Co., a financial analyst specializing in the chemical industry, to John Eyraud, ERCO, September 20, 1977.

10. This percentage is approximately 5.6 percent as presented in Table 2-3.

11. Personal communication, Dr. Gerald Gruber, TRW, Inc., to Jeffery Stollman, ERCO, October 21, 1977.

12. Battelle Columbus Laboratories Draft Report, Cost of complying with hazardous waste management regulations, prepared for the U.S. Environmental Protection Agency, October 12, 1977.

CHAPTER THREE

PROFILE OF THE INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

3.1 The Chemical Industry

The chemical industry taken as a whole comprises nearly 2 percent of the national income and over 7 percent of all manufacturing.[1] Table 3-1 displays the relative contributions to national income of the chemical and other major industries. This $20+ billion industry provides a range of products that serve every segment of the economy. The industry designated by SIC code 28 consists of the following eight segments: (1) 281, industrial chemicals; (2) 282, plastic materials and synthetics; (3) 283, drugs and pharmaceuticals; (4) 284, soap, cleansers and toilet goods; (5) 285, paints and allied products; (6) 286, industrial organic chemicals; (7) 287, agricultural chemicals; and (8) 289, miscellaneous chemical products not elsewhere classified.

This report is concerned with the impact of regulations on the industrial organic chemicals segment of the industry (SIC 286) and includes pesticides and explosives manufacture. This segment, which produces hundreds of products for both intermediate and end use, consists of the following five subsegments:

1. 2861, gum and wood chemicals.

2. 2865, cyclic crudes, cyclic intermediates, dyes, and organic pigments.

3. 2869, industrial organic chemicals not elsewhere classified.

4. 2879, agricultural chemicals not elsewhere classified.

5. 2982, explosives.

3.1.1 Industrial Organic Chemicals Industry

By volume, most organic chemical production consists of chemical "intermediates" in the sense that they form a bridge between basic raw materials (primarily crude oil, natural gas, and coal tars) and finished manufactured products. Industry performance is thus tied to raw materials market conditions and to end-use product demand for organic intermediates.

TABLE 3–1

NATIONAL INCOME WITHOUT CAPITAL CONSUMPTION ADJUSTMENTS BY INDUSTRIAL ORIGIN, 1950–75

($ billion)*

INDUSTRY	1950	1955	1960	1965	1970	1971	1972	1973	1974	1975
Agriculture, forestry, and fisheries	18.3	16.1	17.5	20.4	24.5	25.7	30.6	47.8	43.8	44.7
Mining	5.3	5.9	5.6	6.0	7.8	7.4	8.7	10.4	13.6	16.4
Contract construction	12.0	18.8	21.0	29.8	43.8	47.8	52.3	58.3	61.1	57.9
Manufacturing	76.3	108.0	125.4	170.4	215.4	224.7	251.8	281.6	294.2	303.1
Chemicals and allied products	4.9	7.4	9.1	12.4	16.0	16.8	18.3	20.1	21.6	(NA)
Transportation	13.4	16.0	18.1	23.1	30.3	33.0	36.5	41.6	45.1	44.4
Communications	3.3	5.7	8.2	11.5	17.6	18.3	20.3	21.8	23.8	25.6
Electric, gas, and sanitary services	3.9	6.2	8.9	11.4	14.9	16.3	17.6	18.8	20.0	24.6
Wholesale and retail trade	41.0	52.3	64.7	84.7	122.2	132.9	144.6	162.6	178.5	201.1
Finance, insurance, and real estate	22.8	35.3	48.6	64.0	92.6	103.1	112.5	121.2	130.3	139.0
Services	21.7	31.1	44.6	64.1	103.3	111.2	122.3	136.9	152.7	167.3
Government and government enterprises	23.6	38.1	52.7	75.4	127.4	139.0	152.5	165.8	180.0	197.1
Rest of the world	1.3	2.0	2.5	4.7	4.6	6.6	7.0	9.0	14.4	10.5

* Sources: U.S. Bureau of Economic Analysis, *The National Income and Product Accounts of the United States, 1929–1974,* and *Survey of Current Business,* April 1976.

The intermediate nature of much of the industry has induced participation of firms initially engaged in production of chemical inputs or end use of products. For example, many firms primarily engaged in the oil, natural gas, or coal business have integrated forward and become organic chemical manufacturers. Additionally, manufacturers of end products utilizing organic chemical inputs have integrated backward to join chemical companies in the industry.

3.1.1.1 Highly Impacted Segment

As is discussed above in Section 2.1.1.1, the processes most severely impacted by hazardous waste regulation were segregated for in-depth study, on the basis of abatement cost/price ratios and annual chemical production (see Figure 2-1).

The six market segments to be profiled in detail below are, in order of presentation, (1) perchloroethylene, (2) chloromethanes, (3) epichlorohydrin, (4) vinyl chloride, (5) acrylonitrile, and (6) furfural. The characteristics of the firms manufacturing these highly impacted chemicals will be examined, as well as the entry and exit of firms from this group. The market dynamics for these segments will then be discussed, examining the relations between market structure, pricing behavior, market size, and product uses. Plant-specific data will then be presented for these segments, characterizing the operation of currently active plants in as much detail as possible. Finally, inferences will be drawn as to the profitability of organic chemical manufacture from the firm level financial data that are publicly available.

3.1.1.2 Other Segments

The organic chemicals industry includes hundreds of chemical products. The highly impacted segments (as shown in Table 2-3 above) account for only about 6 percent of production, 9 percent of sales, and 21 percent of hazardous wastes. Nonetheless, many of the market characteristics of the highly impacted segment discussed below apply to organic chemical markets in general. For instance, many of the firms profiled below manufacture numerous organic chemicals in addition to the six highly impacted chemicals. The analysis of the profitability of these products applies to the entire organic chemicals industry. Similarly, the oligopolistic structures and accompanying price behavior outlined for the six highly impacted chemicals typify the industry. Thus, the characterization of the highly impacted segments is generally representative of the entire organic chemicals industry.

3.2 Characterization of the Highly Impacted Segments

3.2.1 Composition

3.2.1.1 Manufacturer Identification

Twenty-two firms have been identified as domestic manufacturers of one or more of the six highly impacted organic chemicals selected for study. These firms, which will therefore be examined in detail, are listed in Table 3-2. As can be seen from this table, several firms which do not directly produce chemicals are included. Uniroyal is considered a member of the industry because of its interest in Monochem Inc., a joint venture with Borden. Monochem is a nonprofit chemical conversion center which does not even own its raw materials. Its financial performance is reflected in the profits of Uniroyal and Borden, while Dow-Corning, though jointly owned by Dow Chemical and Corning Glass, is an independent corporation. Both Occidental Petroleum and Standard Oil of Ohio own subsidiaries (Hooker Chemical and Vistron) that conduct the firms' chemical operations. Not included on this list are Tenneco, which, as of this writing, had placed its plant at Houston, Texas on standby and Atlantic Richfield, which recently withdrew from a joint venture with Stauffer (American Chemical Co.) that had manufactured impacted products in the past.

3.2.1.2 Type of Firm

The firms in the organic chemicals industry are often firms whose public reputations are in industrial sections other than organic chemicals. Unlike the auto and steel industries where the major manufacturers have established reputations as auto or steel producers, the organic chemicals industry includes firms whose reputations have been established as oil companies, food manufacturers, agricultural products manufacturers, and machinery producers. Figure 3-1 displays the major product lines of the 22 firms that manufacture at least one of the six selected chemical lines. This figure shows that all of the firms are highly diversified enterprises, with none of the firms relying solely on organic chemicals for revenues. Over half of the firms are also engaged in the manufacture of plastics and fibers and nearly half are involved in the agricultural/ fertilizers and consumer products markets. Four of the

TABLE 3–2

DOMESTIC MANUFACTURERS OF HIGHLY IMPACTED CHEMICALS

Allied Chemical	B.F. Goodrich
American Cyanamid	Monsanto
Borden	Occidental Petroleum (Occidental)
Conoco	PPG Industries (PPG)
Diamond Shamrock	Quaker Oats
Dow Chemical	Shell Oil
Dow-Corning	Standard Oil of Ohio (Sohio)
E.I. DuPont de Nemours (DuPont)	Stauffer Chemical (Stauffer)
Ethyl	Union Carbide
FMC	Uniroyal
General Electric	Vulcan Materials (Vulcan)

FIRM	MAJOR PRODUCT LINE: CHEMICALS	FIBERS AND PLASTICS	MEDICAL/ DRUGS	AGRICULTURE/ FERTILIZERS	FOODS	OIL AND GAS	METALS	ELECTRICAL EQUIPMENT AND MACHINERY	CONSTRUCTION MATERIALS	CONSUMER PRODUCTS	RUBBERS	TEXTILES
Allied Chemical	●	●		●		●			●	●		
American Cyanimid	●		●	●					●	●		
Borden	●			●	●							
Conoco	●					●	●					
Diamond Shamrock	●	●				●		●				
Dow	●	●	●	●			●			●		
Dow-Corning	●											
DuPont	●	●	●	●				●	●	●		
Ethyl	●	●		●		●	●					
FMC	●			●				●				
General Electric	●	●	●					●		●		
B.F. Goodrich	●	●								●	●	
Monsanto	●	●	●	●				●		●		●
Occidental	●	●		●		●						
PPG	●	●							●			
Quaker Oats	●				●					●		
Shell	●					●						
Sohio	●					●						
Stauffer	●	●		●	●							
Union Carbide	●	●					●		●	●		
Uniroyal	●	●							●		●	
Vulcan	●						●		●			

Figure 3—1. Major product lines of highly impacted firms. (*Moody's Handbook of Common Stocks,* Summer 1977 Edition.)

firms are primarily active in the petroleum production and refining industry and several of the firms manufacture highly impacted chemicals only for use by another division or department of the parent company. Several of the recognized leaders in the industrial chemical industry are also present.

3.2.1.3 Size of Firm

The 22 highly impacted firms studied are among the largest firms in the world. Table 3-3 displays the distribution of these firms by 1976 sales, assets, and net income. Where possible, an estimate of the magnitude of chemical sales is also provided. As can be seen in the table, all of the 22 firms appeared in *Fortune*'s list of the 500 largest domestic corporations by sales. As the table shows, the firms range in size from General Electric, the 9th largest domestic corporation, to Dow-Corning, ranked 471st in 1976. The table also shows that these 22 firms are among the nation's largest with respect to income and assets. With the exceptions of B.F. Goodrich and Uniroyal (companies whose recent financial performance has been poor due to the rubber industry slump), all of the firms rank among the top 300 companies with respect to net income.

For purposes of comparison, impacted firms are grouped by sales volume in Figure 3-2 and by assets in Figure 3-3. It can be seen that Dow-Corning and Vulcan Materials are significantly smaller than the other 20 firms in both categories, and that General Electric is significantly larger than the others. The remaining 19 firms bridge the remaining range of sales and assets, suggesting no groupings that yield further insight into the financial structure of these firms.

3.2.1.4 Age of Firm

The distribution of firms by age is displayed in Figure 3-4. The "years in existence" figure is measured from the date of incorporation. It should be noted, however, that some of the older firms have only recently become active in the organic chemicals industry. In fact, all of the firms in existence for more than 75 years began their activities in markets other than industrial chemicals and ventured into the chemical industry in the course of diversification. There seems to be no consistent correlation between the size of a firm and the number of years in operation.

TABLE 3–3

FINANCIAL SIZE OF IMPACTED FIRMS, 1976*

FORTUNE 500 SALES RANK 1976	FORTUNE 500 SALES RANK 1975	FIRM	1976 TOTAL SALES ($ million)	1976 TOTAL ASSETS $ MILLION	1976 TOTAL ASSETS FORTUNE 500 RANK (1976)	NET INCOME $ THOUSAND	NET INCOME FORTUNE 500 RANK (1976)	CHEMICAL SALES ($ million)
82	82	Allied Chemical	2,629.6	2,439.3	60	116,799	95	1,420**
107	106	American Cyanamid	2,093.8	2,002.4	79	135,766	75	607.2
59	51	Borden	3,381.1	1,808.5	93	112,807	08	845.3
17	16	Continental Oil Co.	8,352.9	6,041.5	21	460,000	16	†
25	32	Dow Chemical	5,652.1	6,848.7	18	612,767	13	3,052.1††
471	536	Dow Corning	353.6	384.1	346	42,741	245	n.a.
167	178	Diamond Shamrock	1,356.6	1,481.0	122	140,030	71	800.4
16	17	E. I. Dupont de Nemours	8,361.0	7,027.1	17	459,300	17	3,762.5‡
194	195	Ethyl	1,135.4	921.9	194	69,080	163	658.5
07	86	FMC	2,298.4	1,919.6	83	80,157	141	793.5
9	9	General Electric	15,700.0	2,049.7	9	930,000	6	n.a.
112	107	B. F. Goodrich	1,996.0	1,567.8	113	15,793	404	698.6
26	26	Hooker Chemicals ‡‡ (Occidental)	5,500.0	3,905.0	34	183,721	48	1,500.0§
95	93	Monochem §§ (Uniroyal)	2,314.8	1,633.7	107	20,132	369	n.a.
42	46	Monsanto	4,270.2	3,959.1	33	366,300	25	1,046.8‖
100	109	PPG	2,254.8	2,033.2	77	151,500	64	811.7
13	14	Shell	9,309.1	7,836.5	14	706,000	11	1,682.5
204	213	Stauffer	1,100.0	1,268.5	143	113,016	97	484.0‖‖
21	21	Union Carbide	6,345.7	6,621.6	19	441,200	18	1,903.7
73	76	Vistron¶ (Sohio)	2,916.4	6,260.2	20	136,900	72	n.a.
427	433	Vulcan	411.2	376.5	353	37,247	270	131.6
154	151	Quaker Oats	1,473.1	854.9	204	53,093	209	n.a.

* Source: *Fortune,* May 1977; *Moody's Handbook of Common Stocks,* Summer 1977 edition; corporate report data.

** Chemical Division, excluding Energy and Fibers Division.

† About 5 percent of corporate investment is in chemicals.

†† Chemicals and metals sales.

‡ Chemicals and specialty sales; excludes plastics and fibers.

‡‡ A subsidiary of Occidental Petroleum; Occidental statistics presented.

§ Hooker total sales.

§§ A joint venture of Uniroyal and Borden; Uniroyal statistics presented.

‖ Industrial chemicals and polymers and petrochemicals.

‖‖ Industrial and specialty chemicals.

¶ A subsidiary of Standard Oil of Ohio; Sohio statistics presented.

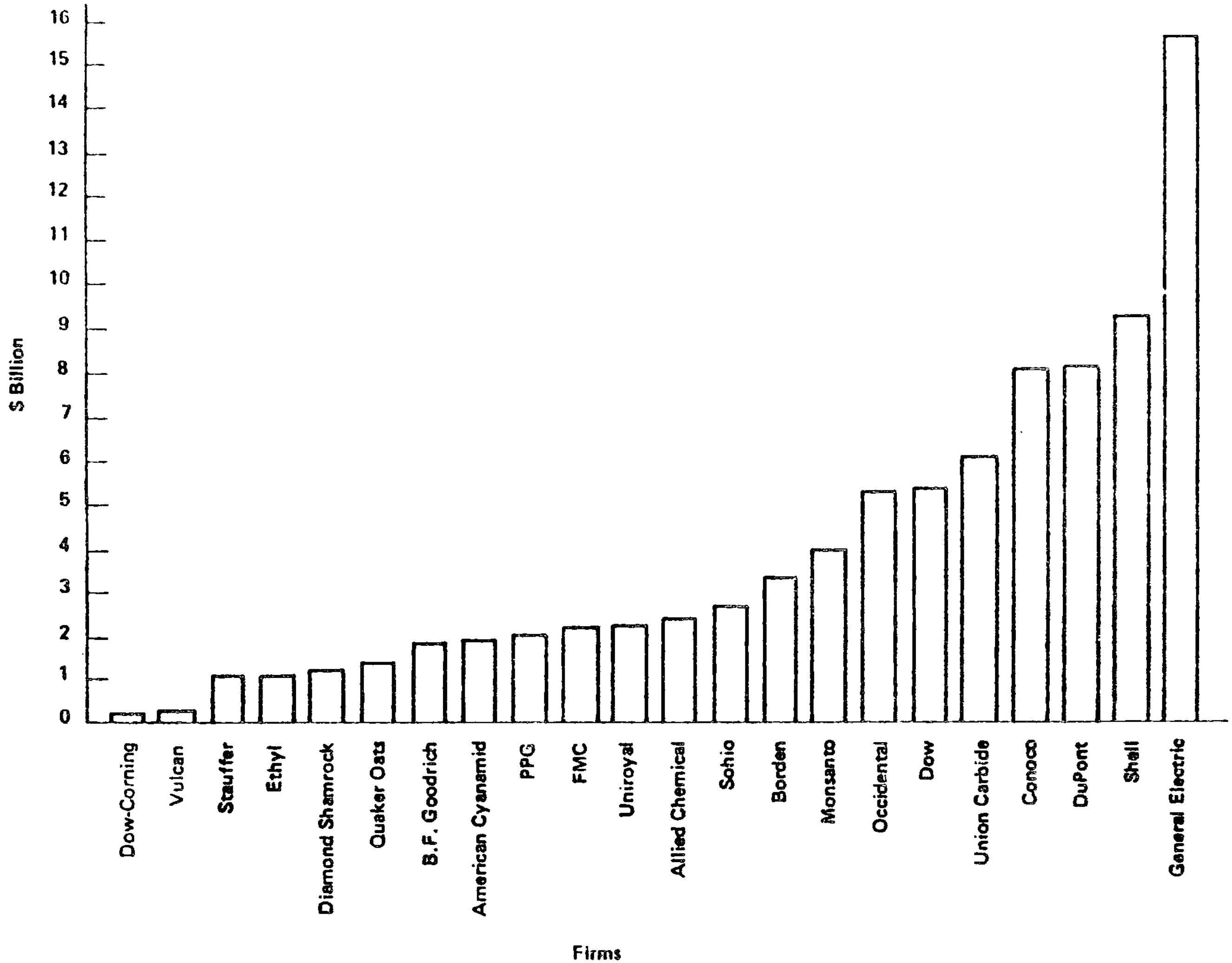

Figure 3–2. Sales of highly impacted firms. (Table 3–3.)

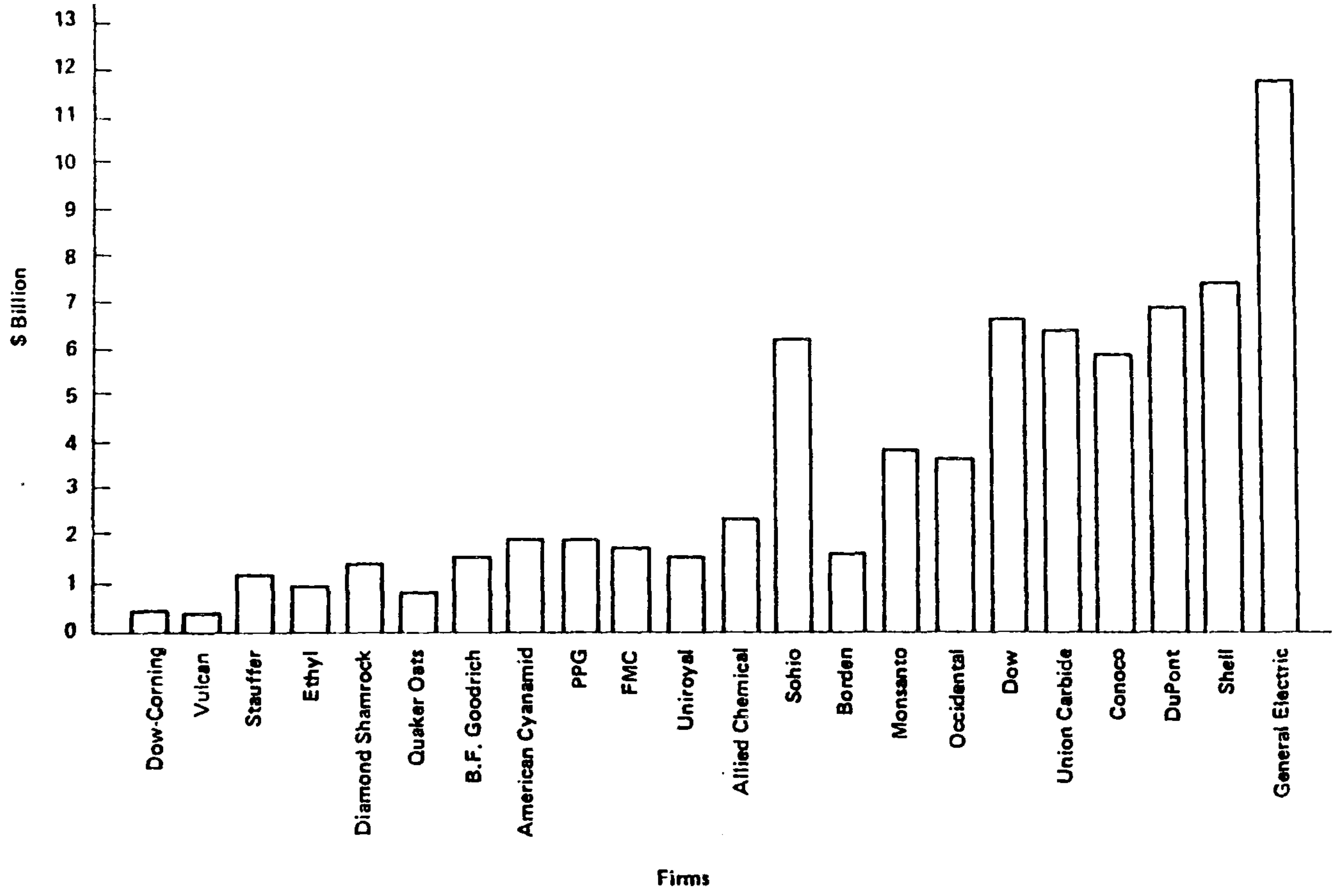

Figure 3–3. Assets of highly impacted firms. (Table 3–3.)

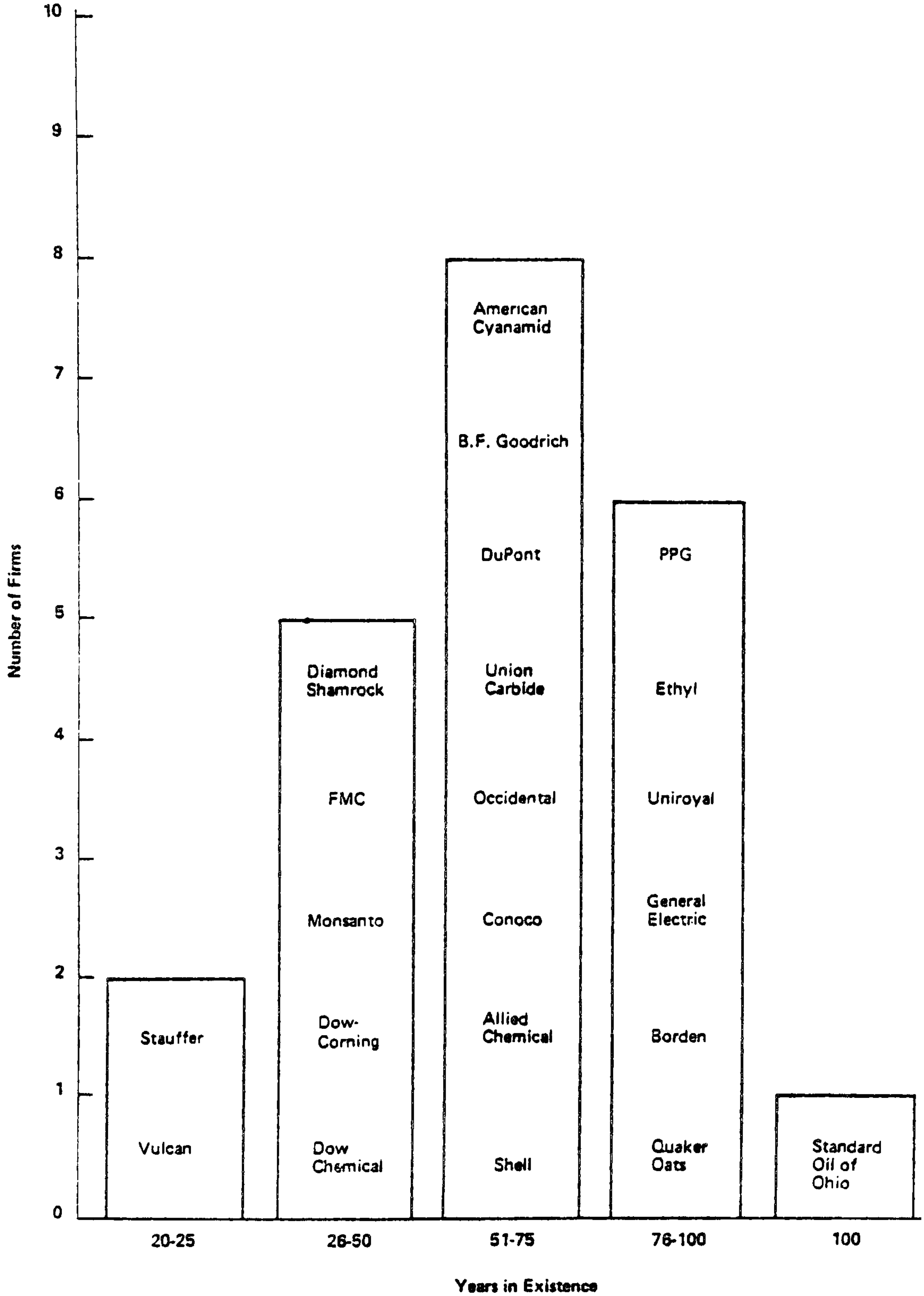

Figure 3-4. Age of highly impacted firms. (Corporate annual reports.)

3.2.1.5 Products Produced

As stated above, each of the 22 firms manufactures at least one of the six highly impacted product lines. Figure 3-5 shows the distribution of production of these chemicals among the manufacturing firms. As is shown in the figure, 12 of the 22 firms manufacture only one of the chemicals, while 3 firms produce only two product lines. Of the remaining seven firms, Dow Chemical manufactures all but two products while Stauffer makes all but three chemicals.

It should be noted that the figure is consistent with the expectation that a firm which produces any of the chloromethane solvents is likely to produce other chloromethanes and perchloroethylene, given the possible common or interrelated production processes. By building a joint treatment facility, impact could presumably be spread over the related chemicals manufactured from single or related basic processes, lessening the impact on each product taken separately.

3.2.1.6 Entries and Exits

Firms enter the organic chemicals industry in two ways, via construction of a new facility or via purchase of an existing operation. In the first case, the market is expanded by an addition to capacity. In an outright purchase, however, the only change is in the name. Industry capacity remains unchanged. Similarly, the exit of a firm may be caused by a plant shutdown - decreasing industry capacity - or sale of the facility to another firm. Statistics separating these two types of entries and exits are not available, but inferences about the entry and exit of firms from the various highly impacted chemical markets can be made based on the U.S. International Trade Commission's lists of chemical manufacturers. Table 3-4 displays the Commission's lists of reporting producers from 1960, 1967, and 1974. The firms identified as current producers are also included for comparison.

As the table shows, vinyl chloride monomer appears to be the most volatile market. Five of the 11 firms reported as 1960 manufacturers had abandoned the market by 1974, while a major producer (Borden) has entered the market only recently. In the chloromethane segment, methyl chloride producers also show significant variation between 1960 and 1977, with four of the nine current producers absent from the 1960 list. The list of producers, however, seems to have undergone a major revision between 1960 and 1967 and has been relatively stable since then. In the methylene chloride market and the furfural market as well, there

FIRM	HIGHLY IMPACTED CHEMICAL								
	ACRYLONITRILE	EPICHLOROHYDRIN	VINYL CHLORIDE MONOMER	FURFURAL	PERCHLOROETHYLENE	CHLOROMETHANES			
						METHYL CHLORIDE	METHYLENE CHLORIDE	CHLORO-FORM	CARBON TETRACHLORIDE
Allied Chemical			●			●	●	●	●
American Cyanamid	●								
Borden			●						
Conoco			●			●			
Diamond Shamrock					●	●	●	●	
Dow		●	●		●	●	●	●	●
Dow-Corning						●			
DuPont	●				●		●		●
Ethyl			●		●	●			
FMC									●
General Electric						●			
B.F. Goodrich			●						
Monsanto	●								
Occidental					●				
PPG			●		●				
Quaker Oats				●					
Shell		●	●						
Sohio	●								
Stauffer			●		●	●	●	●	●
Union Carbide						●			
Uniroyal			●						
Vulcan					●		●	●	●

Figure 3–5. Distribution of highly impacted chemicals among firms. (*Chemical Marketing Reporter,* "Chemical Profiles.")

TABLE 3–4a

PARTICIPATING FIRMS IN THE PERCHLOROETHYLENE INDUSTRY
BY YEAR

1960	1967	1974	1977
Diamond Shamrock	Diamond Shamrock	Diamond Shamrock	Diamond Shamrock
Dow	Dow	Dow	Dow
DuPont	DuPont		DuPont
Hooker	Hooker	Hooker	Hooker
PPG	PPG	PPG	PPG
Stauffer	Stauffer	Stauffer	Stauffer
Detrex	Detrex		
Vulcan	Vulcan	Vulcan	Vulcan
	Ethyl	Ethyl	Ethyl

*Source: 1960, 1967, and 1974: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1977: Energy Resources Company Inc. data.

TABLE 3–4b

PARTICIPATING FIRMS IN THE CHLOROMETHANE INDUSTRY BY YEAR

CHLOROMETHANE PRODUCT	1960	1967	1974	1977
Methyl Chloride	Ansol Chemicila			
	Allied Chemical	Allied Chemical	Allied Chemical	Allied Chemical
	Dow-Corning	Dow-Corning	Dow-Corning	Dow-Corning
	Diamond Shamrock			Diamond Shamrock
	Dow	Dow	Dow	Dow
	DuPont	DuPont	DuPont	
	General Electric			General Electric
		Ancom Chemical		
		Conoco	Conoco	Conoco
		Vulcan	Vulcan	
		Ethyl	Ethyl	Ethyl
		Union Carbide	Union Carbide	Union Carbide
				Stauffer
Methylene Chloride	Allied Chemical	Allied Chemical	Allied Chemical	Allied Chemical
	Diamond Shamrock	Diamond Shamrock	Diamond Shamrock	Diamond Shamrock
	Dow	Dow	Dow	Dow
	DuPont	DuPont	DuPont	DuPont
	Stauffer	Stauffer	Stauffer	Stauffer
	Vulcan	Vulcan	Vulcan	Vulcan
Chloroform	Allied Chemical	Allied Chemical	Allied Chemical	Allied Chemical
	Brown			
	Diamond Shamrock	Diamond Shamrock	Diamond Shamrock	Diamond Shamrock
	Dow	Dow	Dow	Dow
	DuPont	DuPont	DuPont	
	Stauffer	Stauffer	Stauffer	Stauffer
	Vulcan	Vulcan	Vulcan	Vulcan
			Aldrich	
Carbon Tetrachloride	Allied Chemical	Allied Chemical	Allied Chemical	Allied Chemical
	Diamond Shamrock	Diamond Shamrock	Diamond Shamrock	
	Dow	Dow	Dow	Dow
	Food Machinery and Chemical			
	Vulcan	Vulcan	Vulcan	Vulcan
	Mallinckrodt			
	PPG	PPG		
	Stauffer	Stauffer	Stauffer	Stauffer
		FMC	FMC	FMC
			DuPont	DuPont

* Source: 1960, 1967, and 1974. U.S. Tariff Commission, *Synthetic Organic Chemicals*; 1977: Energy Resources Company Inc. data.

TABLE 3–4c

PARTICIPATING FIRMS IN THE EPICHLOROHYDRIN INDUSTRY BY YEAR

1960	1967	1974	1977
Dow	Dow	Dow	Dow
Shell	Shell	Shell	Shell
Union Carbide			

*Source: 1960, 1967, and 1974: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1977: Energy Resources Company Inc. data.

TABLE 3–4d

PARTICIPATING FIRMS IN THE VINYL CHLORIDE MONOMER INDUSTRY BY YEAR

1960	1967	1974	1977
Allied Chemical	Allied Chemical	Allied Chemical	Allied Chemical
American Chemical	American Chemical	American Chemical	Stauffer
B.F Goodrich	B.F. Goodrich	B.F. Goodrich	B.F. Goodrich
Diamond Shamrock	Diamond Shamrock		
Dow	Dow	Dow	Dow
General Tire	General Tire		
Goodyear	Goodyear		
Monsanto	Monsanto		
Ethyl	Ethyl	Ethyl	Ethyl
Union Carbide	Union Carbide		
Uniroyal		Uniroyal	Monochem
	Air Reduction		
	Monochem	Monochem	Monochem
	Tenneco	Tenneco	
	PPG	PPG	PPG
		Conoco	
		Georgia-Pacific	
		Shell	Shell
			Borden

*Source: 1960, 1967, and 1974: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1977: Energy Resources Company Inc. data.

TABLE 3–4e

PARTICIPATING FIRMS IN THE ACRYLONITRILE INDUSTRY BY YEAR

1960	1967	1974	1977
American Cyanamid	American Cyanamid	American Cyanamid	American Cyanamid
B.F. Goodrich	B.F Goodrich		
DuPont	DuPont	DuPont	DuPont
Monsanto	Monsanto	Monsanto	Monsanto
Union Carbide			
	Vistron	Vistron	Vistron

*Source: 1960, 1967, and 1974: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1977: Energy Resources Company Inc. data.

TABLE 3–4f

PARTICIPATING FIRMS IN THE FURFURAL INDUSTRY BY YEAR

1960	1967	1974	1977
Quaker Oats	Quaker Oats	Quaker Oats	Quaker Oats

*Source: 1960, 1967, and 1974: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1977: Energy Resources Company Inc. data.

appears to have been no entry or exit through the 1960's and 1970's while the remaining markets show only minor fluctuations.

The table also shows that entries and exits in the highly impacted markets often involve the same group of large chemical producers. Many of the 22 firms currently producing at least one of the highly impacted chemicals were active in additional highly impacted markets in the 1960's. It is also interesting to note that in several instances a firm chose to abandon a market temporarily and then strategically to re-enter the market when conditions had changed.

3.2.2 Industry Structure and Performance

3.2.2.1 Market Structure

The individual product markets for organic chemicals, like those for most chemical products, tend to be dominated by relatively few firms. While many firms manufacture a number of chemicals, the variety of chemical products is so great that few products are made by more than a dozen firms.

Participation in product markets is further reduced by the extent of vertical integration and captive production in the chemical industry. Many firms use all of their production of any given chemical, particularly those in the industrial organics classification, captively, as an input to other production processes. For example, vinyl chloride monomer is used in the production of polyvinyl chloride. Thus if a dozen firms manufacture a chemical, no more than five or six firms are likely to sell substantial quantities of it on the open, or merchant, market. In fact, some of the producing firms may not be able to supply their own demand for the chemical, and enter the merchant market as buyers rather than sellers.

Because the number of manufacturers competing in any single chemical market is small, an oligopolistic market structure (a market in which all participating firms are likely to recognize the interdependence of their business decisions) has evolved. In this section, two principal characteristics of this oligopolistic market structure will be examined: (1) the high concentration in product markets and (2) the significant barriers to entry.

Concentration. The large number of separate product markets in the chemical industry makes the compilation of meaningful concentration figures a problem. As a first indication of industry structure, the Census of Manufacturers four-firm and eight-firm concentration ratios for various chemical industry segments are presented in Table 3-5 as the percentage of industry sales attributable to the four or eight largest firms. The Census figures are based on the dollar value of factory shipments for the calendar year. The organic chemicals covered by this study fall mostly into the first three subcategories displayed in the table. The four-firm and eight-firm concentration ratios for these groups in 1972 range from 34 to 43 percent and 52 to 57 percent respectively. These figures suggest some concentration; however, the broad classification used fails to capture the structural characteristics of individual product markets.

The concentration ratios for the six highly impacted chemical markets are presented in Table 3-6. The figures are based on current production capacity estimates and are calculated for two-firm and four-firm ratios. The two-firm figures are useful due to the small number of firms in most markets. The four-firm concentration ratios are all above 65 percent. The markets with the largest number of suppliers, vinyl chloride monomer and the chloromethanes, still show significant concentration due to the influence of several large plants. Because producers of chloromethanes do not necessarily market all four products, the individual submarkets within the chloromethane category are even more concentrated. It should be noted that the figures presented indicate only apparent market concentration. The data presented characterize estimated capacity as a surrogate for unavailable production data.

The large amount of captive product use in the industrial organic chemical industry represents another significant feature of market structure. The extent of captive use reduces the amount of product sold between firms which makes it easier for a single large-volume seller to dominate the merchant market. On the other hand, even highly concentrated product markets are subject to competition from other substitutable products. The principal substitutes for each chemical are listed in Table 3-7. Several of the product markets, particularly those of epichlorohydrin and furfural, are affected by the existence of substitutes which can fill the same intermediate uses. In addition, transportable products such as perchloroethylene and furfural face pressure from import prices. Domestic perchloroethylene producers are presently facing a serious challenge from imports of surplus European perchloroethylene while furfural, which can be made from almost any agricultural waste, must be priced low enough to resist competition from Carribean production from sugar cane or other wastes.

TABLE 3–5

1972 CENSUS OF MANUFACTURERS CONCENTRATION RATIOS FOR CHEMICAL INDUSTRY SUBCATEGORIES

CODE	CHEMICAL GROUP	PERCENTAGE OF INDUSTRY SALES MADE BY LARGEST	
		4 FIRMS	8 FIRMS
2869	Industrial Organic Chemicals n.e.c.	43	57
2812	Alkalines and Chlorine	72	91
2813	Industrial Gases	65	81
2819	Industrial Inorganic Chemicals n.e.c.	34	52
2865	Cyclic Crudes and Intermediates	34	52
2879	Agricultural Chemicals	39	57

TABLE 3–6

CONCENTRATION RATIOS FOR HIGHLY IMPACTED PRODUCT MARKETS (BASED ON PRODUCTION CAPACITY)*

CHEMICAL	NO. OF FIRMS	CONCENTRATION RATIO (%) 2 FIRM	4 FIRM
Perchloroethylene	8	40.5	73.6
Chloromethanes:	13	45.6	66.7
Methyl Chloride	9	51.6	75.8
Methylene Chloride	6	66.7	88.0
Chloroform	5	66.4	93.0
Carbon Tetrachloride	7	52.6	90.6
Epichlorohydrin	2	100.0	–
Vinyl Chloride Monomer	10	41.2	68.3
Acrylonitrile	4	70.7	100.0
Furfural	1	100.0	–

* Source: *Chemical Marketing Reporter,* "Chemical Profiles," various issues, and Energy Resources Company Inc. estimates.

TABLE 3–7

PRINCIPAL SUBSTITUTES FOR HIGHLY IMPACTED PRODUCTS

HIGHLY IMPACTED CHEMICALS	PRINCIPAL SUBSTITUTES FOR HIGHLY IMPACTED CHEMICALS FOR DERIVED PRODUCTS
Perchloroethylene	Trichloroethylene
Chloromethanes:	
Methyl Chloride	None
Methylene Chloride	None
Chloroform	Non-fluorocarbon aerosol propellants
Carbon Tetrachloride	Non-fluorocarbon aerosol propellants
Epichlorohydrin	Acrolein and propylene oxide
Vinyl Chloride Monomer	No major substitutes
Acrylonitrile	Wool and other synthetic fibers
Furfural	Phenol based products

Barriers to Entry. The existing market structure of the highly impacted chemical markets is supported by the presence of significant barriers to entry. The chemical industry has seen construction of increasingly larger plants over the years that exploit important economies of scale. Economies can be realized in production, raw material acquisition, research and development, and pollution abatement. As plant sizes have grown, unit costs have fallen and individual new plants are able to supply a significant share of the entire market. For new firms to enter the market and compete with the same unit costs, they must be able to achieve the same production scale. It is, therefore, necessary for the entrant both (1) to possess the resources to finance a large-scale facility and (2) to capture a substantial share of the market. Table 3-8 illustrates this point by presenting the capacities of the largest plants in each highly impacted segment as a percentage of the total industry capacity. In all cases, except vinyl chloride, the largest plant supplies at least one-sixth of total industry capacity. While vinyl chloride plants are among the largest plants in the industry, dramatic growth in this market has allowed for entry of such large-scale facilities. Entry difficulties are exacerbated by captive use. Because captive suppliers can be expected to buy their own intermediates until their demand exceeds their supply capability (except for a limited amount of outside purchase to assure an alternate supply source), the available market to which an entering supply firm can potentially sell is limited.

Despite the importance of economies of scale, there are smaller plants which are operating effectively in the organic chemical markets. These small plants tend to be old facilities and most of the capital costs for the plants have been fully amortized. Also, many small plants supply chemicals for captive firm use. Given the importance of assured routes of supply in the chemical industry, most firms would be reluctant to shut down an internal source of supply to gain a favorable but small cost differential.

Entry of new firms is not uncommon, however. A principal path of entry into a chemical market is through vertical integration. Generally firms will begin to produce industrial organics in order to supply their own production requirements. Typical of this route of entry is a firm such as Borden, which recently built a VCM plant in order to supply its polyvinyl chloride (PVC) production operation. When firms integrate backward toward their required sources of supply, they are assured of a market for their new production line.

Another principal route of entry is through technological change, which may grant a new firm an immediate cost advantage.

TABLE 3–8

CAPACITIES OF LARGEST PLANTS IN SIX HIGHLY IMPACTED PRODUCT MARKETS*

MARKET	FIRM	PLANT LOCATION	CAPACITY (million lb/yr)	CAPACITY AS A % OF INDUSTRY CAPACITY
Perchloroethylene	Diamond Shamrock	Deer Park, Texas	200	16.5
	PPG	Lake Charles, Louisiana	200	16.5
Chloromethanes	Dow	Plaquemine, Louisiana	565	18.2
Epichlorohydrin	Dow	Freeport, Texas	250	55.6
Vinyl Chloride Monomer	B.F. Goodrich	Calvert City, Kentucky	1,000	12.6
Acrylonitrile	Monsanto	Alvin, Texas	860	39.4
Furfural	Quaker Oats Co.	Belle Glade, Florida	72	41.9

*Source: *Chemical Marketing Reporter*, "Chemical Profiles," various issues.

Major technological developments of this nature, however, have been uncommon in recent years.

3.2.2.2 Market Conduct and Pricing Behavior

The oligopolistic structure of the chemical industry is reflected in the behavior of the participating firms. The most visible aspect of firm behavior, pricing policy, is discussed below.

Price is typically one of the key variables in competition. For the chemical industry in general, most prices are set by simple percentage markups over costs, or in terms of target rates of return. Several factors tend to reduce the importance of price competition for the industry. These factors are: (1) joint product cost accounting, (2) price inelastic product demand, and (3) the customer's interest in an uninterrupted supply.

Chemical manufacturers often find it difficult to assign costs to any one product due to the nature of chemical processes. The typical chemical plant houses a number of interrelated processes, each of which produces a number of products. If it is possible to assign raw material costs and labor costs to each individual product, there is still the question of recouping the large capital investment in equipment. Furthermore, the overhead rates in the industry are high due to the rapid deterioration of equipment and the high rate of technological obsolescence. Thus there is a large gap between variable costs and total unit costs. The price of any one product can, therefore, become nearly arbitrary as long as the combined prices of joint products produce the desired return. In general, firms look at return on invested capital (ROI) as the key element in pricing. A desired ROI usually between 25 to 40 percent is selected and a unit price is then calculated by dividing the costs and expected return by the estimated production volume. Subject to existing price constraints, new investments are then ranked by their expected ROI. Because investment is only a small portion of total cost, this strategy yields a return on total cost (gross margin) that appears in general to average between 6 and 9 percent.[2]

The relative price inelasticity of demand also affects price policy. The absence of substitutes precludes the customer's option to switch to another product. Polyvinyl chloride, for example, which is made from vinyl chloride monomer, does not compete with other substances in many applications. Total product demand is therefore insensitive to price increases. In those cases where substitutes are available, they tend to be imperfect substitutes, given the specific properties of each chemical. For example, perchloroethylene competes with two chemicals for the metal cleaning (vapor degreasing) market, trichloroethylene and 1,1,1 trichloroethane. However, each of these three chemicals has qualities which make it desirable for certain applications and thus reduce the importance of price. Perchloroethylene's higher boiling point makes it the preferred chemical for cleaning operations which require high temperatures.

Import price pressure can also affect pricing for those products which are easily transportable. Of the six highly impacted products, only perchloroethylene and furfural are subject to strong import price pressure. Interruption of supply is a factor to which chemical customers are generally more sensitive than they are to price increases. The importance of uninterrupted supply is evident in certain industry practices. Most chemicals are sold under long-term contracts so that the customer may be assured of a steady supply. The contracts may extend far enough into the future to allow the customer time to undertake various options to provide for a new supply source if the present source is considering cessation of production. The customer may require sufficient lead time to build his own plant should the current supplier announce plans for ceasing production. In periods of actual shortages, most suppliers give preferential allocations to their most steady, long-term customers. This policy discourages customers from switching suppliers because of small price differentials.

3.2.2.3 Market and Price Stability

In order to characterize the strong tendencies toward market stability in the chemical industry, it is necessary to consider the behavior of firms across markets and the behavior of firms within a market.

The largest chemical manufacturing firms make a wide range of chemical products, and thus are likely to compete in many separate markets. For firms such as Dow and DuPont, the number of competing markets are many and, accordingly, the incentive to maintain friendly relations is great. While this fact will not result in explicitly collusive behavior, there are some suggestions of cooperation. For example, in areas of common interest, firms are likely to form joint ventures in order to reduce the risk of strong competition. Two such joint ventures are: (1) the creation of Dow-Corning by Dow Chemical and Corning Glass and (2) the creation of Monochem by Borden and Uniroyal.

Kinked Demand Curve. The tendency toward stability within a market can be explained by a theoretical construct of economic theory called the kinked demand curve. Consider the kinked demand curve, DAD' in Figure 3-6. This curve is intended to represent the situation of an individual firm in light of reciprocating price behavior by other firms, not a specific market demand curve. In a period of price stability, such as one in which all firms have set the same price, each individual firm would find itself at the kink in the demand curve (with price at P_x and quantity sold at Q_x). If a firm wished to increase its price, say to P_y, it is assumed that other firms will not increase their prices. The relevant portion of the demand curve is elastic and the firm would gradually lose sales to its competitors (quantity sold falls from Q_x to Q_y), causing income for the firm to decrease. (Total income before the price increase is represented by the area of the rectangle OP_xAQ_x. After the price increase, total income has fallen to OP_yBQ_y.)

Conversely, if a firm lowers its price to Pz, it is assumed that other firms will lower their prices in order to avoid a loss of sales. The original price-cutting firm will enjoy only a momentary competitive advantage and the resulting increase in sales is small (from Q_x to Q_z). The relevant portion of the demand curve is inelastic and the firm again suffers a decrease in total income. (The total income rectangle OP_zCQ_z is smaller than the original OP_xAQ_x rectangle.) Thus the firms in the oligopolistic industry have limited incentive to change prices.

The kinked demand curve scenario must be modified for a period of rising costs. If increasing costs have made it difficult for firms to maintain the desired operating margin, then a firm may successfully increase prices. The price increase will hold if other firms are also willing to increase prices, in contrast to the assumption which creates the kinked demand curve. The industry achieves a new equilibrium at price, P_y, with the kinked demand curve now represented by demand curve D'''ED'.

The price leading firm may be the largest firm in the industry, or the firm least able to withstand rising costs. Occasionally the judgment of the price leading firm may be wrong and one or more firms will fail to raise prices as much, if at all. In such a case, the leader will generally rescind his price increase and the price will return to the lower level. An example of this process may have recently occurred in the acrylonitrile market. The price for acrylonitrile had followed a steady upward trend since 1973. Early in 1977, a new round of price increases was instituted. However, one firm, American Cyanamid, has not yet increased

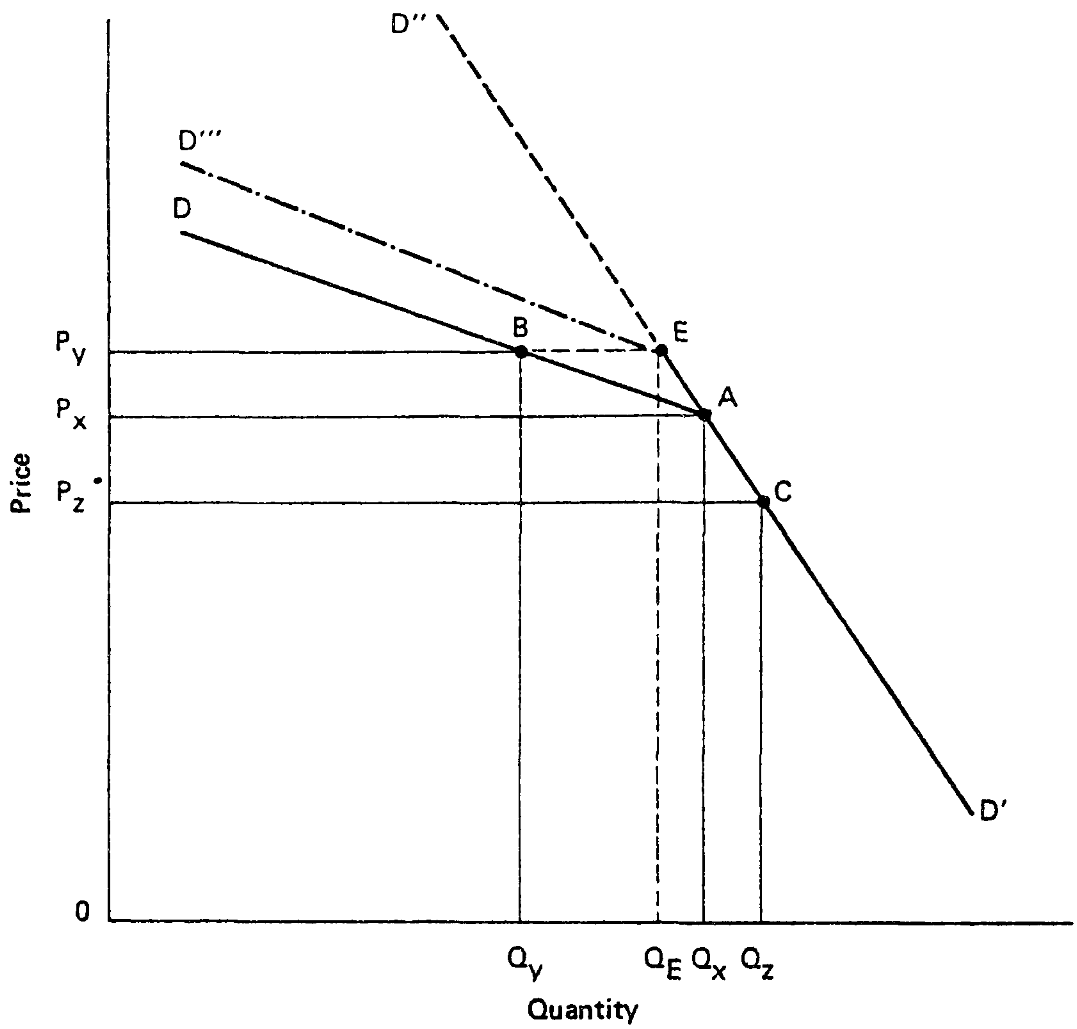

Figure 3 6. A generalized kinked demand curve.

its price to the new higher level. The resulting differential may cause the other firms to return to the price level of 1976.

3.2.2.4 Industry Performance, 1967-72

The oligopolistic influences outlined in previous sections were not sufficient to maintain price levels for the period 1967-72. Several basic price and production trends for the industrial chemical industry are shown in Table 3-9 and illustrated in Figure 3-7. As indicated, the Industrial Chemical Price Index did not increase significantly from 1967 to 1972. The price performances for the highly impacted chemical segments are listed in Table 3-10, in terms of their respective price declines over a longer time period, 1960 to 1972. The longer time period was used for this display in order to capture the long price decline in the individual chemical prices. In all cases except that of furfural (no data were available on epichlorohydrin), substantial price declines were registered during this period. The table also shows that during this period the Wholesale Price Index (WPI) for industrial chemicals remained relatively unchanged while the WPI for all commodities increased 26 percent. Therefore, the decrease in highly impacted chemical prices is even more dramatic relative to wholesale prices in general.

There are two reasons for the fall in chemical prices: (1) the declining real cost of natural gas feedstocks, which have their prices regulated, and (2) the influence of economies of scale on production costs. During the 1960's, the markets for most chemical products were expanding in concert with the general economic growth. Chemical firms responded by building new larger production plants which allowed the realization of economies of scale in production. Each firm hoped to gain production cost advantages and to obtain a permanently larger share of the product markets. However, since each firm wished to maintain its market share, the result of their combined decisions was a competitive pricing war. The situation was essentially that described above in Section 3.2.2.3.

The next section will examine the price performance of the industry since 1972. In recent years, firms have been better able to push prices upward. The reduction in the competitive struggle appears to have come about as firms recognized that price-cutting behavior was not effective in increasing their market share.[3] Furthermore, the economies to be gained by increasing size appeared to have been fully realized by the end of the 1960's. The situation of chemical firms in which increasing the scale of production does not

TABLE 3–9

NOMINAL AND REAL OPERATIONS LEVEL* FOR THE 10 LARGEST IMPACTED CHEMICAL FIRMS ($ Thousand)**

	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
Net Sales	35,107,765	31,061,205	29,580,373	22,445,871	18,405,367	16,631,426	15,860,114	15,683,170	14,765,619	12,762,400
Net Income	2,578,271	2,238,197	2,456,764	1,823,926	1,283,616	1,040,652	978,853	1,113,649	1,078,304	971,200
Income/Sales	7.3	7.2	8.3	8.1	7.0	6.3	6.2	7.1	7.3	7.6
Industrial Chemical Price Index (1967 = 100)	219.0	206.9	151.7	103.4	101.2	102.0	100.9	100.3	101.0	100.0
Sales/Price	160,309	150,127	194,993	217,078	181,871	163,053	157,186	156,363	146,194	127,624
Income/Price	11,773	10,818	16,195	17,640	12,684	10,202	9,701	11,103	10,676	97,120
FRB Production Index, Basic Organic Chemicals	131.8	114.8	122.9	143.9	129.3	119.0	118.5	122.2	111.5	100.0

* Based on the 10 largest impacted chemical companies.
** Source: *Chemical and Engineering News*, Corporate Records, FRB Industrial Production, Bureau of Labor Statistics.

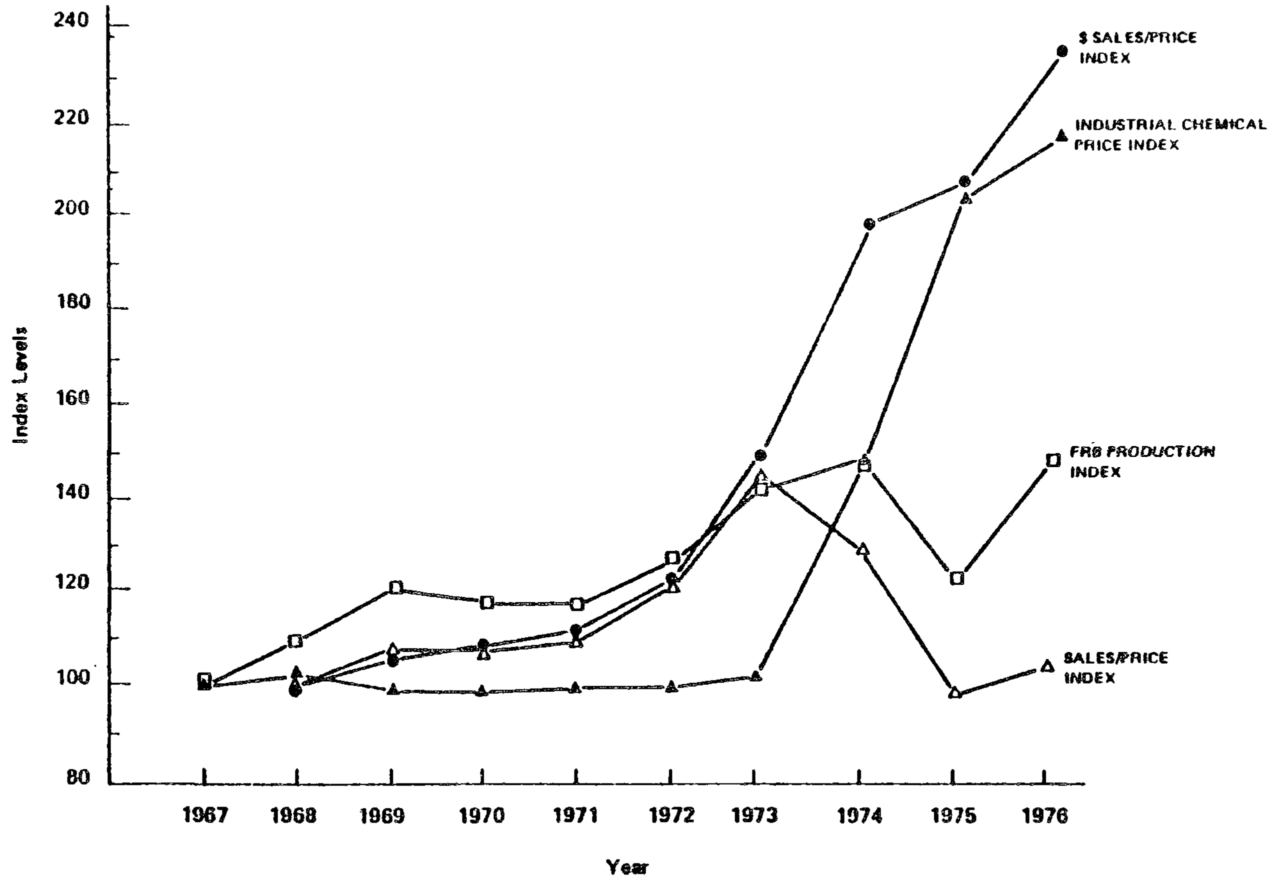

Figure 3–7. Basic price and production trends for the industrial organic chemicals industry. (*Chemical and Engineering News,* Corporate Records, FRB Industrial Production, Bureau of Labor Statistics.)

TABLE 3–10

PRICE DECLINES IN HIGHLY IMPACTED SEGMENTS, 1967–72*

CHEMICAL	1960 PRICE/LB	1972 PRICE/LB	% PRICE DECLINE
Perchloroethylene	$0.10	$0.06	40
Chloromethanes:			
Methyl Chloride	0.12	0.05	42
Methylene Chloride	0.11	0.07	36
Chloroform	0.10	0.07	30
Carbon Tetrachloride	0.08	0.06	25
Epichlorohydrin	n.a.	n.a.	–
Vinyl Chloride Monomes	0.10	0.04	60
Acrylonitrile	0.22	0.11	50
Furfural	0.12	0.175	(46) (Increase)
Wholesale Price Index Industrial Chemicals**	103.2	101.2	2
Wholesale Price Index All Commodities**	94.9	119.1	(26) (Increase)

* Source: 1960 and 1972 U.S. Tariff Commission, *Synthetic Organic Chemicals.*

** Source: U.S. Bureau of Labor Statistics: *Wholesale Prices and Price Indices for Selected Commodities, Annual.*

reduce unit costs is pictured by the unit cost curve in Figure 3-8. It is theorized that production costs eventually reach an irreducible minimum set by raw material costs and the given state of technology.

3.2.2.5 Industry Performance, 1973-76

Prices in the chemical industry since 1973 have been in a strong upward trend. As can be seen in Figure 3-7, the industrial chemicals price index doubled between 1973 and 1975. This price increase took place despite the weak recessionary markets of the period, but during a time when prices for the chief inputs - oil and natural gas - began to soar. The real sales volume (the dollar value of yearly sales divided by the price index) of the period turned down in 1973 and then dropped sharply in 1975. The 1975 real sales volume was 23 percent below that of 1974. The uncorrected figures on sales volume (based on the sales of a sample of the 10 largest chemical firms) did not decrease during the period due to the buoying influence of the price increases.

Figure 3-7 and Table 3-9 also provide an indication of the extent of market power in the industry. In particular, it is clear that through price increases, firms were able to maintain a healthy rate of return despite a temporary market decline and rising costs.

The real net income series shows large increases in real net income for 1973 and 1974 and a steady level ($10 to $12 million for the sample of firms) for all other years. Firms apparently garnered large profits during 1973-74. The raw material shortages of 1973 and 1974 prevented further growth in production, and prices rose as anxious customers competed for the available supply. In 1975 the drop in sales eliminated the temporary bulge in net income, but firms were nevertheless able to raise prices by more than one-third. Net income was a healthy 7.2 percent of sales for 1975.

The beginning of a recovery of real sales in 1976 suggests that the demand for chemical products was not greatly reduced by the large increase in prices. This supports the notion that demand for chemical products tends to be price inelastic. However, little can be inferred from the first year of the recovery.

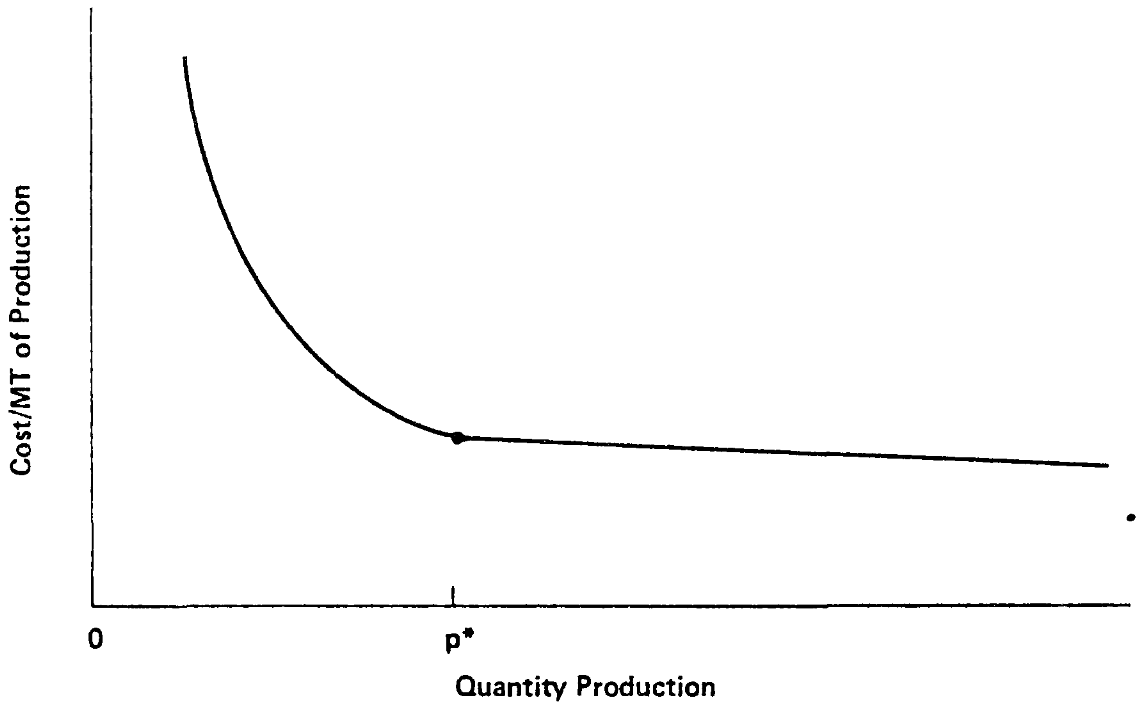

Figure 3–8. Hypothetical cost curve for the chemical industry. Beyond p* further increases in plant size do not result in a decrease in unit costs.

3.2.3 Highly Impacted Chemical Markets

This section details the specific market conditions for each of the six highly impacted segments. For each segment the following subjects are addressed: (1) product uses, (2) product substitutes, (3) current production, and (4) competition and pricing behavior.

3.2.3.1 Perchloroethylene

Product Uses. The dry cleaning industry is the largest customer of perchloroethylene, purchasing an estimated 63 percent of U.S. production for use as dry cleaning solvent. This and other primary uses of perchloroethylene are listed in Table 3-11.

Perchloroethylene has numerous desirable properties as a dry cleaning agent, including its characteristics of viscosity, stability, high solvent power, and nonflammability. It can also be easily recovered for reuse. In metal cleaning, perchloroethylene is used primarily for vapor degreasing. It has been used in areas (1) where use of the preferred substitute, trichloroethylene, has been restricted due to its contribution to air pollution and (2) where the specific properties of perchloroethylene, particularly its higher boiling point than tricloroethylene's, make it the preferred cleanser.

Perchloroethylene is also used in the synthesis of several fluorocarbons. These products are listed in Table 3-12, along with their uses.

Product Substitutes. Perchloroethylene is the preferred cleaning agent of the dry cleaning industry but substitute products do exist. Stoddard solvent, which is a petroleum product, is used in the oil-producing Gulf states. For other markets, however, Stoddard solvent's handling characteristics, particularly its flammability, restrict its market penetration.

As discussed, trichloroethylene is often preferred to perchloroethylene for industrial metal cleaning. Trichloroethylene, which is often produced in the same process as perchloroethylene as a joint product, is cheaper and has preferred handling characteristics; however,in some areas, most notably Los Angeles, use of trichloroethylene is restricted by air pollution regulations. Perchloroethylene competes with 1,1,1 trichloroethane in the Los Angeles market. Use of this special form of trichloroethylene usually requires significant retooling costs for the customer, however.

TABLE 3–11

PERCHLOROETHYLENE PRODUCT
MARKETS AND SUBSTITUTES*

PERCHLOROETHYLENE MARKET	% SHARE PERCHLOROETHYLENE MARKET	SUBSTITUTE	DEGREE OF SUBSTITUTABILITY
Dry cleaning solvent	63	Stoddard	Moderate
Industrial metal cleaning	14	Trichloroethylene 1, 1, 1 trichloroethane	High Moderate
Chemical intermediate (Flourocarbons)	13	n.a.	–
Export and miscellaneous	10	n.a.	–

* Source: *Chemical Marketing Reporter,* "Chemical Profile–Perchloroethylene," August 9, 1976.

TABLE 3–12

CHEMICAL INTERMEDIATE USES OF PERCHLOROETHYLENE

DERIVED PRODUCTS	PRINCIPAL USES
Fluorocarbon 113	Solvent
Fluorocarbon 114	Solvent, refrigerant
Fluorocarbon 115	Food propellant
Fluorocarbon 116	Dielectric gas

An estimation of the degree of substitutibility in each of the perchloroethylene markets is shown in Table 3-11.

Current Production. The market for perchloroethylene has ceased to grow in recent years. The annual production data for the chemical, presented in Table 3-13, show that production has fluctuated around 320,000 metric tons per year since 1970. During this period, demand for domestic perchloroethylene was influenced by (1) reduced demand for dry cleaning due to the increased use of wash and wear clothing and synthetic knit fabrics and (2) substantial volumes of imports. In 1976, imports are believed to have grown to an even larger role in the domestic market.[4] The growth in imports is the result of dramatic increases in European caustic soda production. Chlorine is a byproduct of caustic soda production and European demand for chlorine is low. Therefore, the additional chlorine is transformed into perchloroethylene, ethylene dichloride (EDC), and trichloroethylene, which are the most economically transportable forms of this surplus chlorine, and exported. Perchloroethylene imports from Europe are expected to continue to be problematic until European demand for chlorine in vinyl production catches up with the present surplus chlorine supply. Export statistics for perchloroethylene are not available, but exports are not believed to be a large market factor.

Captive production (that portion of output used internally by the firm and not sold) is not important in the end-use oriented perchloroethylene market. The captive production statistics displayed in Table 3-13 also capture the effect of changing inventories. Although this effect cannot be accurately quantified, the increase in the extent of captive production in 1975 can safely be attributed to unplanned additions to inventory as a result of the market decline of that year. Because of its limited use as a chemical intermediate, the demands of captive production are lower for perchloroethylene than for all of the other highly impacted segments.

Competition and Pricing Behavior. The perchloroethylene market is the most competitive of the six highly impacted market segments studied here. The following factors contribute to this unusual competitiveness:

1. There is little captive production of perchloroethylene, with 90 percent of production or more being sold on the merchant market.

2. Because perchloroethylene is a final product, rather than a chemical intermediate, purchase

TABLE 3–13

PRODUCTION, SALES, AND FOREIGN TRADE OF PERCHLOROETHYLENE, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	308	333	320	333	320	321	288	289	242	210	195	166	147	145	102	95
Sales* (1,000 MT/yr)	267	322	333	328	297	290	277	228	213	193	175	152	126	140	102	85
Apparent Captive Production** (%)	13.2	3.5	0.0	1.5	7.2	9.4	3.7	21.0	12.1	8.2	10.3	8.2	14.4	4.0	0.0	10.16
Imports† (1,000 MT/yr)	17	11	20	12	20	18	16	20	22							
Imports/Production (%)	5.5	3.3	6.3	3.6	6.3	5.6	5.6	6.9	8.7							
Exports†† (1,000 MT/yr)	23.9	13.1	36.2	48.8	N‡	N	N	N	N							
Exports/Production (%)	7.8	3.9	11.3	14.7	–	–	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals,* (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Sources: 1972–75: U.S. Bureau of Census; *U.S. Imports: Consumption and General SIC-Based Products by World Areas (FT 210);* 1971–71: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: SIC Based Products (FT 210);* 1967–69: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: Commodity by Country.*

†† Source: 1972–75: U.S. Bureau of Census; *U.S. Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610).*

‡ Not available.

price is a more important factor in demand, overshadowing other considerations, such as the certainty of continued supply.

3. There are a relatively large number of producers (eight).

4. Most perchloroethylene is sold under short-term contracts, in contrast to most other chemical markets.

These competitive forces result in a market with low customer loyalty and there is little resemblance to the oligopolistic structure that comprises many other chemical markets. Nevertheless, unit values for perchloroethylene, displayed in Table 3-14, show the pattern common to other chemical markets. Dow Chemical and PPG Industries tend to be the most important price setters in this industry, although, for the reasons stated, their power is limited. In 1977 there has been no upward movement of prices due to the declining market and the resulting accumulation of large inventories.

3.2.3.2 Chloromethane Markets

There are four chlorinated solvents which comprise the chloromethane market: methyl chloride (CH_3Cl), methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$), and carbon tetrachloride (CCl_4). All four chemicals can be synthesized from the same basic manufacturing processes. Methyl chloride is produced by the chlorination of methanol or methane which yields coproducts of methylene chloride, chloroform, and carbon tetrachloride. The mix of output chloromethanes from this process can be adjusted as a function of reaction conditions. In other production techniques, one of the chloromethanes can serve as an input into the synthesis of the more highly chlorinated methanes through further chlorination. Thus, annual production capacity estimates for any one of the chloromethanes should be regarded as flexible, with producers possessing the ability to shift output among them. The total chloromethane production in 1975 is displayed in Table 3-15. The table shows that carbon tetrachloride accounted for almost half of total chloromethane production (46.3 percent).

Product Uses. The uses of chloromethanes vary with each specific product. Table 3-16 summarizes the major uses of each of the four chloromethanes.

Methyl chloride finds its largest use (40 percent of 1976 production) as an intermediate in the silicone industry.

TABLE 3–14

PERCHLOROETHYLENE PRICE STATISTICS*

YEAR	UNIT VALUE PER POUND
1975	0.14
1974	0.10
1973	0.06
1972	0.06
1971	0.07
1970	0.07
1969	0.07
1968	0.07
1967	0.08
1966	0.08
1965	0.08
1964	0.09
1963	0.10
1962	0.10
1961	0.10
1960	0.10

* Sources: 1960-74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals,* (preliminary).

TABLE 3–15

PRODUCTION VOLUME OF FOUR CHLOROMETHANES

PRODUCT	1975 PRODUCTION VOLUME (1,000 MT)	% OF TOTAL PRODUCTIONS
Carbon Tetrachloride	411.1	46.3
Methylene Chloride	225.4	24.8
Methyl Chloride	166.2	15.5
Chloroform	118.7	13.4
Total	921.4	100.0

TABLE 3–16

CHLOROMETHANE SOLVENT PRODUCT USES

CHLOROMETHANE SOLVENT	USES	% OF PARTICULAR MARKET
Methyl chloride	Silicones intermediate	40
	Tetramethyllead intermediate	35
	Butyl rubber (catalyst solvent)	4
	Methyl cellulose	4
	Herbicides	4
	Quarternary amines	4
	Miscellaneous	9
	Total	100
Methylene chloride	Paint removers	30
	Aerosols	20
	Export	20
	Chemical processes (mainly solvent degreasing)	10
	Plastics	5
	Miscellaneous	15
	Total	100
Chloroform	Fluorocarbon refrigerants and propellants	60
	Fluorocarbon plastics	30
	Export and miscellaneous	10
	Total	100
Carbon tetrachloride	Fluorocarbon 11	28
	Fluorocarbon 12	52
	Other	20
	Total	100

* Sources: *Chemical Marketing Reporter,* March 29, 1976, September 20, 1976, September 27, 1976, and *Faith, Keyes and Clark's Industrial Chemicals.*

The second largest use - an intermediate in the production of tetramethyllead (TML) - has been declining along with the TML market as a result of the reduction of lead in automobile fuel.

Methylene chloride has been found to have desirable handling and performance characteristics in the product use areas listed in Table 3-16. It is low priced relative to its substitutes, is nonflammable, and has not yet been found to have health-related problems. It is used in cases where a strong solvent is required to remove paint or lacquer. Methylene chloride is also used in aerosol development and its aerosol products do not cause ozone damage. Several additional uses which have significant growth potential include: (1) use as a blowing agent for urethane foam and (2) use in a single-operation phosphatizing process.

Chloroform is used in the manufacture of fluorocarbons for refrigerants, aerosol propellants, and resins. While the aerosol-propellant market has been declining due to environmental problems, the fluorocarbon-refrigerant market in which chloroform is used should not be affected by the ozone controversy because the product is used primarily in closed refrigerant systems which do not allow the chemical to escape into the atmosphere.

Carbon tetrachloride is suffering from the decline in the aerosols market. The largest-volume chloromethane product, carbon tetrachloride, is used in the manufacture of fluorocarbons 11 and 12. The largest outlet for these fluorocarbons has been the aerosols market, which has accounted for more than 60 percent of their use. Due to the fluorocarbon-ozone controversy, aerosol spray cans, which allow the fluorocarbon blowing agent to escape into the atmosphere, are being replaced by mechanical spray cans or cans with nonfluorocarbon blowing agents. Carbon tetrachloride also finds use as a reacting agent in a number of chemical processes.

The summary table of product uses, Table 3-16, indicates the relative diversity of end uses for each chloromethane solvent. A discussion of these end-use markets follows.

Product Substitutes. The chloromethane solvents as a group could not be easily replaced. For the principal uses of the chloromethanes, as listed in Table 3-17, there are few good substitutes. For example, the silicone industry requires methyl chloride as an input for the majority of its products; no other chemical compounds can serve the same purpose. Methylene chloride can be replaced as a paint

TABLE 3–17

PRODUCT SUBSTITUTES FOR CHLOROMETHANE SOLVENTS

CHLOROMETHANE	USE	SUBSTITUTE	DEGREE OF SUBSTITUTABILITY
Methyl chloride	Silicone	None	–
	Tetramethyllead	Other gasoline additives	Poor
Methylene chloride	Paint remover	Alkali emulsions with naptha	Poor
		Methyl chloride	Poor
	Aerosol sprays	Carbon tetrachloride	Fair
		Methyl chloride	Fair
		Compressed methane and water	Fair
		Mechanical spray cans	Fair
	Solvent degreasing	Perchloroethylene	Fair
		Trichloroethylene	Good
Chloroform	Refrigerants	Non-fluorocarbon refrigerants	Poor
	Chlorofluorocarbons	Carbon tetrachloride	Fair
Carbon tetrachloride	Aerosol sprays	Methylene chloride	Good
		Methyl chloride	Fair
		Compressed methane and gas	Good
		Mechanical spray cans	Fair

* Source: Discussions with industry personnel (Tom Robinson of Vulcan Materials Co. to Jeff Stollman of ERCO; Rich Moeller of General Electric to Doug Geoga and John Eyraud of ERCO, Hank Sauer of MCA to John Eyraud of ERCO).

purpose. Methylene chloride can be replaced as a paint remover, but its substitutes, alkali emulsions with naphtha and methyl chloride, have less desirable performance characteristics. Chloroform-derived refrigerants are the most efficient refrigerant liquids. Carbon tetrachloride is being phased out as the blowing agent for aerosol spray cans. However, another chloromethane, methylene chloride, is currently viewed as the best replacement. Mechanical spray cans have absorbed part of the aerosol market, but these cans are less desirable in the marketplace.

Current Production. Methyl chloride production has shown a relatively slow rate of growth, largely due to the sharp decline since 1973 in the tetramethyllead market. Table 3-18 displays annual production and sales from 1960 to 1975. For the period 1965 to 1975, the annual rate of growth was 5.3 percent per year, substantially lower than the 10 to 15 percent averaged by the other chloromethane solvents. The extent of captive production has remained steady at approximately 55 to 60 percent of the total market. Numerous firms, including General Electric, Dow-Corning, and Union Carbide, produce methyl chloride for internal use, in the production of silicone products, and do not produce the other chloromethanes. The silicone industry accounts for the majority of the captive use of these chemicals.

Methylene chloride production trends have closely paralleled those of the chemical industry as a whole. Table 3-19 displays annual production and sales. As can be seen from the table, the production of methylene chloride grew at a rate of 13 percent per annum for the period 1965-75 despite the large production drop in 1975. Captive production for methylene chloride is relatively unimportant, accounting for less than 15 percent of the market in recent years.

The chloroform market is small relative to the other chloromethane products. Annual production and sales are displayed in Table 3-20. The table shows that annual production is less than one-half of the physical production volume of methylene chloride and only one-third that of carbon tetrachloride production. However, the rate of growth for chloroform, 9.2 percent for the period 1965-75, is only slightly less than that for the other chloromethanes. Roughly one-fifth of the annual production volume is used captively by firms. In recent years, the statistics on captive production have fluctuated erratically due to significant changes in inventories, also reflected in these statistics.

TABLE 3–18

PRODUCTION, SALES, AND FOREIGN TRADE OF METHYL CHLORIDE, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	166.2	233.6	246.7	205.7	198.4	191.7	182.7	138.4	124.7	107.0	81.6	60.8	51.7	48.8	47.7	38.2
Sales* (1,000 MT/yr)	65.6	97.4	125.8	94.3	87.6	79.8	75.3	63.2	53.5	47.3	43.0	30.5	24.8	21.0	20.6	19.7
Apparent Captive Production** (%)	60.5	56.5	35.2	54.1	55.9	58.4	58.8	54.4	57.2	56.0	49.5	49.9	52.0	57.1	56.8	48.4
Imports (1,000 MT/yr)	N†	N	N	N	N	N	N	N	N							
Imports of Production (%)	–	–	–	–	–	–	–	–								
Exports† (1,000 MT/yr)	N	N	N	N	N	N	N	N	N							
Exports/Production (%)	–	–	–	–	–	–	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals*, (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Not available.

TABLE 3–19

PRODUCTION, SALES, AND FOREIGN TRADE OF METHYLENE CHLORIDE, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	225.4	276.1	235.9	213.7	181.9	182.4	166.0	137.2	118.9	121.2	95.6	81.4	67.1	65.2	52.5	51.3
Sales* (1,000 MT/yr)	197.1	239.2	214.9	201.1	166.0	162.4	153.3	130.7	102.9	102.4	88.2	71.1	60.4	58.2	51.9	43.6
Apparent Captive Production** (%)	12.6	13.4	8.9	5.9	8.8	10.9	7.6	4.8	13.5	15.5	7.7	12.8	9.9	10.5	1.2	14.9
Imports† (1,000 MT/yr)	5.7	5.6	19.2	5.1	3.5	4.3	3.5	6.6	4.6							
Imports/Production (%)	2.5	2.0	8.1	2.4	1.9	2.4	2.1	4.8	3.9							
Exports†† (1,000 MT/yr)	44.1	46.1	51.9	47.1	39.5	38.9	N‡	N	N							
Exports/Production (%)	19.6	16.7	22.0	22.0	21.7	21.3	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Sources: 1972–75: U.S. Bureau of Census; *U.S. Imports: Consumption and General SIC-Based Products by World Areas (FT 210);* 1970–71: *U.S. Bureau of the Census, U.S. Foreign Trade, Imports: SIC Based Products (FT 210);* 1967–69: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: Commodity by Country.*

†† Sources: 1972–75: U.S. Bureau of Census; *U.S. Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610);* 1970–71: *U.S. Bureau of the Census, U.S. Foreign Trade, Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610).*

‡ Not available.

TABLE 3–20

PRODUCTION, SALES, AND FOREIGN TRADE OF CHLOROFORM, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	118.7	136.9	114.6	110.5	104.7	108.8	98.0	82.2	82.0	81.2	69.2	54.1	47.8	44.5	35.1	34.7
Sales* (1,000 MT/yr)	87.1	114.4	110.6	92.0	83.1	79.3	78.1	63.6	61.6	65.1	55.9	44.5	35.1	36.0	24.8	25.4
Apparent Captive Production** (%)	26.6	16.4	3.5	16.8	20.6	27.1	20.4	22.6	24.9	19.8	19.1	17.7	26.5	17.0	29.2	26.7
Imports† (1,000 MT/yr)	2.5	0.7	N††	N	0.1	0.1	N	N	N							
Imports/Production (%)	12.1	0.5	–	–	0.1	0.1	–	–	–							
Exports‡ (1,000 MT/yr)	5.4	5.4	N	N	N	N	N	N	N							
Exports/Production (%)	4.5	3.9	–	–	–	–	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Sources: 1972–75: U.S. Bureau of Census; *U.S. Imports: Consumption and General SIC-Based Products by World Areas (FT 210);* 1970–71: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: SIC Based Products (FT 210);* 1967–69: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: Commodity by Country.*

†† Not available.

‡ Source: 1974–75: U.S. Bureau of Census, *U.S. Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610).*

Carbon tetrachloride has the largest production volume of the chloromethane solvents. As can be seen from the production and sales data displayed in Table 3-21, production peaked in 1974 at 411,100 metric tons for the year. However, the market dropped off sharply in 1975 due to the combined effect of the recession and the fluorocarbon-ozone controversy. The latter is expected to remain a problem for the carbon tetrachloride market. Captive production has not been particularly significant for carbon tetrachloride, with the annual rate normally below 20 percent. The drop in sales, however, has caused the accumulation of large inventories. In 1975, the extent of captive production rose to close to 50 percent.

Foreign trade, as displayed in Tables 3-18 through 3-21, is not believed to be a significant factor in the chloromethane markets, but imports are believed to surpass exports.

Competition and Pricing Behavior. The chloromethane market should be considered in terms of the four submarkets for the individual solvent products. Two of the submarkets, chloroform and methylene chloride, have a small number of competitors, with five and six firms respectively. The markets for these products have not been affected by environmental concerns. Industry spokesmen indicate that prices are "firm," that is, there is little fear of future price decreases.

Methyl chloride is manufactured by nine firms, but several of these use the product internally for silicone plastics manufacturing. The industry has been weakened by the decline in the tetramethyllead market.

The carbon tetrachloride market is the "weakest" of the chloromethane solvents due to the uncertainty in the future for the derived fluorocarbons. The largest seller of carbon tetrachloride, DuPont, tends to be a price leader for this industry. However, price leadership is of little concern in the current situation as firms attempt to maintain a profitable rate of capacity utilization.

The price series for each chloromethane in terms of unit price per pound is presented in Table 3-22. The prices of all the chemicals increased at least 100 percent between 1973 and 1975, in keeping with the price performance of the industry through this period.

TABLE 3–21

PRODUCTION, SALES, AND FOREIGN TRADE OF CARBON TETRACHLORIDE, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	411.1	527.3	475.0	452.0	457.7	458.6	400.3	346.2	323.6	293.9	269.2	243.0	235.4	219.3	174.1	168.8
Sales* (1,000 MT/yr)	219.5	355.6	448.7	421.9	361.4	381.5	356.4	293.8	274.6	279.1	231.0	210.7	191.0	183.5	152.1	151.2
Apparent Captive Production** (%)	46.6	32.6	5.5	6.7	21.0	16.8	11.0	15.2	15.1	5.0	14.2	13.3	18.9	16.3	12.6	10.4
Imports† (1,000 MT/yr)	7.4	7.6	3.4	5.3	<0.1	<0.1	0.1	1.9	2.3							
Imports/Production (%)	1.8	1.4	0.7	1.2	<0.1	<0.1	<0.1	0.5	0.7							
Exports†† (1,000 MT/yr)	12.4	N‡	N	N	N	N	N	N	N							
Exports/Production (%)	0.3	–	–	–	–	–	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals,* (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Sources: 1972–75: U.S. Bureau of Census; *U.S. Imports: Consumption and General SIC=Based Products by World Areas (FT 210);* 1970–71: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: SIC Based Products (FT 210);* 1967–69: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: Commodity by Country.*

†† Source: U.S. Bureau of Census; *U.S. Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610), 1975.*

‡ Not available.

TABLE 3–22

CHLOROMETHANE PRICE STATISTICS:
UNIT PRICE PER POUND, 1960-75 *

YEAR	METHYL CHLORIDE	METHYLENE CHLORIDE	CHLOROFORM	CARBON TETRACHLORIDE
1975	$0.14	$0.16	$0.16	$0.14
1974	0.09	0.13	0.11	0.10
1973	0.06	0.08	0.07	0.06
1972	0.05	0.07	0.07	0.06
1971	0.06	0.07	0.06	0.05
1970	0.06	0.08	0.06	0.05
1969	0.05	0.08	0.06	0.05
1968	0.06	0.08	0.07	0.06
1967	0.07	0.09	0.07	0.06
1966	0.07	0.10	0.08	0.07
1965	0.07	0.09	0.08	0.07
1964	0.08	0.09	0.08	0.07
1963	0.09	0.09	0.09	0.08
1962	0.10	0.09	0.09	0.08
1961	0.11	0.09	0.10	0.07
1960	0.12	0.11	0.10	0.08

* Sources: 1960-74: U.S. Tariff Commission, *Synthetic Organic Chemicals*, and 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary).

3.2.3.3 Epichlorohydrin

Product Uses. The largest use of epichlorohydrin is in the manufacture of synthetic glycerin. The amount of epichlorohydrin required for this use has been declining due to a lack of market growth and due to the substitution of other raw materials. The relative importance of the epichlorohydrin uses is displayed in Table 3-23. As can be seen from the table, the other principal use is in the manufacture of epoxy resins.

Product Substitutes. The end-use markets for epichlorohydrin are well established although there are some competing substitutes in its intermediate uses. Acrolein and propylene oxide can be substituted for epichlorohydrin in the manufacture of synthetic glycerin. The use of these alternate raw materials has been increasing in recent years, due to cost advantages. However, synthetic glycerin manufacturers will continue to use epichlorohydrin widely. Estimates of the degree of substitutability are presented in Table 3-23.

Epoxy resins made with epichlorohydrin have a large number of uses in chemical processes. As such, there are many substitutes depending upon the specific process use of epoxy resins. An analysis of these numerous substitutes is beyond the scope of this investigation.

Current Production. The U.S. International Trade Commission (formerly the U.S. Tariff Commission) does not publish annual production and sales figures for epichlorohydrin. However, estimates of production have been made based on the production of derived end products. The estimates are presented in Table 3-24 along with available foreign trade statistics. The striking lack of data on this chemical allows no conclusions to be drawn. However, imports are presumed negligible due to the high captive production rates in the industry. Most epichlorohydrin is captively used, which helps account for the shortage of production statistics and lends credence to the estimates.

Competition and Pricing Behavior. The epichlorohydrin market is quite stable, with only two producers of the chemical. The producing firms, Shell Oil Company and Dow Chemical, use the bulk of their production internally. As a result, there is very little competition on the merchant market for sales. In the merchant market, the profit margin is likely to be large given (1) the small contribution that the cost of epichlorohydrin makes to total cost of end-use products and (2) the limited buying power of users. Entry

TABLE 3–23

EPICHLOROHYDRIN
PRODUCT USES AND SUBSTITUTES*

INTERMEDIATE USES	% OF MARKET SHARE	SUBSTITUTE	DEGREE OF SUBSTITUTABILITY
Synthetic Glycerin Manufacturing	55	Acrolein Propylene Oxide	Moderate Moderate
Epoxy Resins	40	Numerous Chemicals	n.a.
Miscellaneous	5	n.a.	n.a.

* Source: Energy Resources Company estimates, and *Faith, Keyes and Clark's Industrial Chemicals.*

TABLE 3–24

PRODUCTION, SALES, AND FOREIGN TRADE OF EPICHLOROHYDRIN, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	N**	N	81.6	N	N	N	39.0	N	N	N	N	38.5	N	31.2	N	N
Sales* (1,000 MT/yr)	N	N	43.1	N	N	N	34.0	N	N	N	N	14.5	N	8.8	8.1	13.3
Apparent Captive Production†	N	N	47.2	N	N	N	12.8	N	N	N	N	62.3	N	71.8	N	N
Imports†† (1,000 MT/yr)	N	N	N	N	0.1	0.1	N	N	N							
Imports/Production (%)	–	–	–	–	–	–	–	–	–							
Exports (1,000 MT/yr)	N	N	N	N	N	N	N	N	N							
Exports/Production (%)	–	–	–	–	–	–	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary).

** Not available.

† The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

†† Source: 1970–71: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: SIC-Based Products (FT 210).*

into the market is unlikely because the demand for synthetic glycerin is mature, with only slow future growth expected.

3.2.3.4 Vinyl Chloride Monomer (VCM)

Product Uses. The dominant use of vinyl chloride monomer is as an intermediate in the production of polyvinyl chloride (PVC). As indicated in Table 3-25, PVC production accounts for 91 percent of VCM production, with the bulk of the remainder going to exports for PVC production outside the United States.

Anticipated market growth for PVC is displayed in Table 3-26. The table shows that the largest use for polyvinyl chloride is for conduit, pipe, and fittings, according to the statistics compiled in Table 3-26. The figures, provided by B.F. Goodrich, show that the growth of consumption of PVC between 1970 and 1975 was largely due to the increase of the conduit and pipe segment. Other market segments registered little growth throughout this period.

Product Substitutes. Since polyvinyl chloride cannot be made without vinyl chloride monomer, there is no need to examine the substitutability of VCM in its intermediate use. Only the end markets for polyvinyl chloride are relevant to a discussion of product substitutes.

A compilation of the possible product substitutes for PVC is presented in Table 3-27. Obviously the degree of substitutability will vary from market to market, but several general comments can be made. Most of the substitutes listed are more expensive and not as suitable to the particular use as PVC. Those substitutes which existed prior to the broad market penetration of PVC, such as steel, rubber, wood, and glass, have already been found to be less desirable. In other cases, such as that of the pipe and conduit market, alternate supplies of the substitute ABS will not be available in sufficient quantity to infringe significantly on the market within the next decade.[5] In the past, consumers of PVC have made only limited substitutions away from PVC.[6] Thus the overall substitution possibilities for PVC are small.

Current Production. VCM is a large volume industrial organic chemical with 1976 production estimated at over 2.7 million metric tons.[7] Annual production and sales figures for the period 1960-75 are presented in Table 3-28. The table shows that the market sagged sharply in 1975, with a 25 percent drop in production. The market drop was the combined result of a recessionary economy and of concern over the effect of OSHA regulations on PVC plants. The

TABLE 3–25

VINYL CHLORIDE MONOMER PRODUCT USES*

USE	% OF TOTAL MARKET **
Polyvinyl Chloride	91
Suspension Holopolymer Resins	
Suspension Copolymer Resins	
Dispersion Resins	
Exports	7
Miscellaneous	3

* Source: *Chemical Marketing Reporter,* "Chemical Profile—Vinyl Chloride Monomer," July 14, 1975 and Energy Resources Company estimates.

** Total does not add up to 100 percent due to rounding.

TABLE 3–26

ANTICIPATED MARKET GROWTH FOR PVC BY INDUSTRY
(1,000 MT)*

INDUSTRY	1970	1975	1980
Apparel	81.6	81.6	127.0
Conduit, pipe and fittings	217.7	449.0	997.7
Flooring	145.1	131.5	254.0
Siding, other construction applications	90.7	122.4	322.0
Home furnishing	231.3	195.0	322.0
Wire and cable	190.5	127.0	226.8
Packaging	122.4	131.5	190.5
Records	63.5	59.0	99.8
Transportation	99.8	72.6	163.3
Other	108.8	258.5	517.0
Total	1,351.4	1,628.1	3,219.9

* Source: B.F. Goodrich Chemical Company, *Chemical Week*, September 15, 1976.

TABLE 3–27

POSSIBLE PVC SUBSTITUTES *

MARKET	PVC RESIN USAGE (1,000 MT) 1973	1974	POSSIBLE SUBSTITUTES
Apparel			
Baby pants	12	12	Rubber
Footwear	66	63	Rubber
Outerwear	31	30	Other synthetic fibers
Building and construction			
Extruded foam moldings	26	22	Wood
Flooring	202	166	Wood
Lighting	5	6	Glass, styrene
Panels and siding	39	44	Wood, polyester
Pipe and conduit	520	505	Steel, ABS, polyethelene
Pipe fittings	41	44	Steel, ABS, polyethelene
Rainwater systems	16	15	Wood, aluminum
Swimming pool liners	18	19	Rubber
Weatherstripping	16	16	Rubber, urethane
Window, other profiles	26	24	Wood, steel, aluminum
Electrical			
Wire and cable	188	161	Rubber, polyethylene
Home Furnishing			
Appliances	20	21	Other plastics in some applications
Furniture	145	144	Wood, melamine
Garden hose	18	17	Rubber, nylon
Housewares	51	n.a.	Styrene, rubber
Wall coverings and wood surfacing film	54	58	Paper, melamine
Packaging			
Blow molded bottles	39	34	Glass, cans
Closure liners and gaskets	9	10	Rubber
Coatings	9	9	None
Film	59	57	Acrylics, styrene
Sheet	35	37	Polyethylene, nylon,polyester
Recreation			
Records	66	65	None
Sporting goods	25	28	Rubber, leather
Toys	38	37	None
Transportation			
Auto mats	18	19	Rubber
Auto tops	15	13	Steel
Upholstery and seat covers	83	84	Nylon polyesters
Miscellaneous			
Agriculture (including pipe)	66	72	Aluminum, polyethylene
Credit cards	8	10	None
Laminates	23	24	None
Medical tubing	23	23	None
Novelties	7	8	None
Stationery supplies	18	20	Polyester
Tools and hardware	8	10	None
Export	66	145	None
Other	42	119	None
Total	2,180	2,151	

* Source: U.S. Environmental Protection Agency, *Standard Support and Environmental Impact Statement: Emission Standard for Vinyl Chloride.*

TABLE 3–28

PRODUCTION, SALES, AND FOREIGN TRADE OF VINYL CHLORIDE, 1960–76

	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	2,494.3	1,903.0	2,549.2	2,427.6	2,307.6	1,966.3	1,832.2	1,694.2	1,346.4	1,099.1	1,133.5	907.0	731.9	650.9	594.8	473.4	470.3
Sales* (1,000 MT/yr)		1,018.0	1,415.8	1,611.9	1,516.1	1,362.2	1,233.6	1,069.7	663.5	431.6	379.2	311.9	270.8	227.1	233.8	192.4	159.8
Apparent Captive Production** (%)		46.5	44.5	33.6	34.3	30.7	32.7	36.9	50.7	60.7	66.5	65.6	63.0	65.1	60.7	59.4	66.0
Imports† (1,000 MT/yr)		1.5	1.2	0.8	<0.1	–	0.1	0.1	0.1	0.6							
Imports/ Production (%)		<0.1	<0.1	<0.1	<0.1	–	<0.1	<0.1	<0.1	<0.1							
Exports†† (1,000 MT/yr)		188.4	187.4	191.0	282.2	281.6	302.0	N‡	N	N							
Exports/ Production (%)		9.9	7.4	7.9	12.2	14.3	16.5	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Sources: 1972–75: U.S. Bureau of Census; *U.S. Imports: Consumption and General SIC-Based Products by World Areas (FT 210);* 1970–71: *U.S. Bureau of the Census; U.S. Foreign Trade: Imports; SIC Based Products (FT 210);* 1967–69: *U.S. Bureau of Census; U.S. Foreign Trade: Imports; Commodity by Country.*

†† Sources: 1972–75: U.S. Bureau of Census; *U.S. Exports: Domestic Merchandise, SIC-Based products by World Areas (FT 610);* 1970–71: *U.S. Bureau of the Census, U.S. Foreign Trade, Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610).*

‡ Not available.

recovery of the market in 1976, however, suggests continued growth for the industry. One manufacturer anticipates a 7 to 9 percent annual growth rate.[8]

Foreign trade does not appear to be of significance in this huge-volume market, perhaps due to the inability of obtaining a sufficiently large supply via tankers to service PVC production needs and the significance of captive production. Slightly under one-half of the domestic VCM production is used captively by its producers. The share going to captive production reached a low in 1971 of 30 percent, but has since grown as existing PVC manufacturers have built new facilities in order to supply their own VCM intermediate.

Competition and Pricing Behavior. Two factors have helped to stimulate competition in the vinyl chloride monomer market: (1) the number of competing firms is large, 10, and (2) the large growing market for the end product, PVC, has encouraged firms to scramble for increased shares of the market. The growth of production capacity has led to expectations of a glut of VCM in the near future. However, the adaptability of PVC to many applications suggests strong future growth for the industry. One firm's expectation of future growth has been presented in Table 3-26.

Discussions with industry personnel, however, indicate that competitive influences are not sufficiently strong to negate the price leadership models discussed above (see Section 3.2.2). The largest sellers in the industry, Shell and Dow, tend to be price leaders. Smaller firms meet the established price in order to stay competitive and maintain their market share. Unit values for vinyl chloride monomers from 1960 to 1975 are displayed in Table 3-29. The price series shows the sharp upward movement typical of the industry after 1973. There is also no substantial discounting off list price for preferred customers in today's market, indicating a firmness of prices.

3.2.3.5 Acrylonitrile

Product Uses. Acrylonitrile is an intermediate that enjoys widespread use in synthetic fibers manufacture. The largest market for acrylonitrile is as an intermediate in the production of acrylic and modacrylic fibers. Acrylic fibers are used in apparel manufacturing where it is the most wool-like of the synthetic fibers. Carpeting is the second largest market for acrylic and modacrylic fibers. Other markets for the fibers include draperies, upholstery, and blankets. A breakdown of uses of acrylonitrile is presented in Table 3-30.

TABLE 3–29

VINYL CHLORIDE PRICE STATISTICS *

YEAR	UNIT VALUE PER POUND
1976	0.10
1975	0.08
1974	0.04
1973	0.04
1972	0.04
1971	0.04
1970	0.04
1969	0.04
1968	0.05
1967	0.05
1966	0.06
1965	0.06
1964	0.06
1963	0.07
1962	0.07
1961	0.08
1960	0.10

* Sources: 1960-74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary); 1976: *Chemical Week,* September 15, 1976.

TABLE 3–30

ACRYLONITRILE PRODUCT USES AND SUBSTITUTES*

USE	% OF TOTAL MARKET	SUBSTITUTE	DEGREE OF SUBSTITUTABILITY
Acrylic and modacrylic fibers	50	Wool	Moderate
Acrylonitrile-butadiene-styrene (ABS) and styrene-acrylonitrile (SAN) resins	20	PVC Steel Polyethelene	Moderate Low Low
Adiponitrile	10	n.a.	–
Nitrile rubber	5	PVC Glass Cans	Moderate Low Low
Miscellaneous	5	n.a.	–
Exports	10	–	–

* Source: *Chemical Marketing Reporter,* "Chemical Profile, Acrylonitrile," January 10, 1977, and Energy Resources Company Inc. estimates.

The manufacture of ABS and SAN resins from acrylonitrile has provided a rapidly increasing outlet for acrylonitrile. The ABS resins are used in pipe, conduit, and pipe fittings. Other supply routes include the manufacturing of components for automotive use, and of linings for refrigerator doors. SAN resins find applications in the manufacture of housewares, automotive components, and instrument lenses.

Nitrile rubber is used in hosing, gaskets, or linings in the petroleum, automotive, and home appliance industries because it is oil resistant, hydrocarbon solvent resistant, and grease resistant. Adiponitrile is used as an intermediate in the production of nylon.

Product Substitutes. The substitutes for acrylonitrile vary with the end-use market being considered. A listing of the markets and the principal substitutes is provided in Table 3-29. In the large synthetic fiber market, wool is a principal competitor. Acrylic and wool fibers have similar appearance and texture. In the plastic resins and nitrile rubber markets, ABS and SAN resins compete with other plastic products such as polyvinyl chloride and other packaging materials such as steel, glass, or cans. The degree of substitutability in these markets is a function of the desired strength, flexibility, and chemical-resistant properties for the product. The acrylonitrile-based products tend to have good chemical-resistant properties but limited flexibility.

Current Production. Historical production and sales data for acrylonitrile are presented in Table 3-31. The production series peaks in 1974 at 1.4 billion pounds per year, with a decline to 1.2 billion in 1975. The growth rate of production for the decade 1965-75 was 11 percent. Recently, imports have grown to be a large portion of the market but their share is likely to decline as new domestic plants cause on-line expansion of domestic capacity. The requirements of captive production have accounted for 50 to 60 percent of total production in recent years.

Competition and Pricing Behavior. There are four domestic acrylonitrile producers. Of the participating firms, American Cyanamid and Monsanto produce largely for captive uses. DuPont sells substantial quantities on the merchant market and also supplies internal demand. Vistron specializes in sales to the smaller consumers of acrylonitrile, specifically those customers who do not have the resources to build their own acrylonitrile capacity.

The price series for acrylonitrile, presented in Table 3-32, shows a pattern typical of that in the chemical

TABLE 3–31

PRODUCTION, SALES, AND FOREIGN TRADE OF ACRYLONITRILE, 1960–75

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Production* (1,000 MT/yr)	550.8	640.2	614.1	505.5	443.9	471.3	524.5	463.0	304.2	324.7	349.9	269.5	206.5	163.3	113.2	104.0
Sales* (1,000 MT/yr)	237.5	232.1	218.0	208.6	194.6	248.1	254.7	n.a.	122.7	144.3	137.6	141.1	96.3	92.1	71.4	83.3
Apparent Captive Production** (%)	56.9	63.8	64.5	58.7	56.2	47.4	51.4	n.a.	59.7	55.6	60.7	47.6	53.4	43.5	36.9	19.9
Imports† (1,000 MT/yr)	16.9	10.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1							
Imports of Production (%)	3.1	1.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1							
Exports†† (1,000 MT/yr)	88.9	70.1	47.8	23.5	N‡	N	N	N	N							
Exports/Production (%)	16.3	10.9	7.8	4.7	–	–	–	–	–							

* Sources: 1960–74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals,* (preliminary).

** The statistics on captive production represent the difference between yearly production and sales figures. Inventory changes are not accounted for.

† Sources: 1972–75: U.S. Bureau of Census; *U.S. Imports: Consumption and General SIC-Based Products by World Areas (FT 210);* 1970–71: *U.S. Bureau of the Census, U.S. Foreign Trade, Imports: SIC Based Products (FT 210);* 1967–69: *U.S. Bureau of Census, U.S. Foreign Trade, Imports: Commodity by Country.*

†† Source: 1972–75: U.S. Bureau of Census; *U.S. Exports: Domestic Merchandise, SIC-Based Products by World Areas (FT 610);*

‡ Not available.

TABLE 3–32

ACRYLONITRILE PRICE STATISTICS*

YEAR	UNIT VALUE
1975	0.23
1974	0.19
1973	0.11
1972	0.11
1971	0.10
1970	0.11
1969	0.12
1968	
1967	0.12
1966	0.13
1965	0.16
1964	0.16
1963	0.14
1962	0.15
1961	0.18
1960	0.22

* Sources: 1960-74: U.S. Tariff Commission, *Synthetic Organic Chemicals;* 1975: U.S. International Trade Commission, *Synthetic Organic Chemicals* (preliminary).

industry, although the size of the price increase in 1974 and 1975 was unusually large. Prices rose by over 70 percent in 1974 alone. In general, prices set by the four firms tend to cluster in the manner described above (see Section 3.2.2.3). There is currently a price discrepancy between firms in the industry, the result of one firm's not acquiescing in a round of price increases in late 1976. If the reluctant firm continues to resist the price increase, the price rise may be rescinded by other firms. This experience is likely to cause the industry to be more cautious concerning price increases.

3.2.3.6 Furfural

Product Uses. Furfural is used as an intermediate in the manufacture of furfuryl alcohol, which, in turn, is used to make furan resins. A breakdown of the uses of furfural and their respective market shares is presented in Table 3-33. The furfural-derived furan resins are used in foundry binders. The large export market consists of shipments by the only domestic producer, Quaker Oats Company, to European subsidiaries and other companies. The bulk of the exported furfural is also used in the manufacture of furfuryl alcohol.

Furfural is also used as a solvent in the refining of lubricating oils and in the extraction of butadiene from C_4 process streams.

Product Substitutes. There are a number of resins which can be used as substitutes for furan resins, thus eliminating the need for furfuryl alcohol and furfural. One group of these substitutes is phenol-based resins, particularly phenolic-polymeric isocyanate. Table 3-33 presents a list of the other principal substitutes in the no-bake binder market, the principal outlet for furan resins.

Tetrahydrofuran can be produced with acetylene and formaldehyde in the Reppe process, thus eliminating the need for furfural. In its use as a solvent in the refining of lubricating oils, the most widely used solvent for the same processes is phenol.[9]

Competition and Pricing Behavior. The only domestic supplier of furfural, the Quaker Oats Company, is currently enjoying few of the benefits which usually accrue to a monopolist. In particular, a number of substitute products (see Table 3-33) have acquired some of the market for furfural-derived products, particularly furfuryl alcohol. Unit sales for 1977 of the Chemical Division of Quaker

TABLE 3–33

FURFURAL PRODUCT USES AND SUBSTITUTES*

FURFURAL USE	% OF FURFURAL MARKET	SUBSTITUTES	DEGREE OF SUBSTITUTABILITY
Chemical intermediate uses:			
Furfuryl alcohol (For furan resin production)	33.0	Furan resin substitutes: alkyd polymeric-isocyanate, phenolic-polymeric isocyanate and silicate foundry binders	High
Tetrahydroforan	9.1	Alternative processes	Moderate
Solvent uses:			
Lube oils	8.5	Phenol	Moderate
Butadiene extraction	7.2	Alternative process	High
Export	39	n.a.	–
Miscellaneous	3	n.a.	–

*Source: *Chemical Marketing Reporter*, "Furfural Market Charted," July 21, 1975, p. 7, and Energy Resources Company Inc. estimates.

Oats (which produces only furfural and furfural-derived products) dropped 7 percent below the 1976 figure. Quaker Oats' problems in this market stem from the period 1974-75 when it enjoyed strong market power. At this time, a temporary shortage of furfural caused sharp increases in prices. The net income for the diversion in 1975 was 260 percent of the 1974 net income figure and 380 percent of the 1973 figure. Customers responded to the shortage by turning to alternative products, particularly to other chemical binders. As a result, the effective monopoly power of the Quaker Oats Company is limited and the firm currently finds itself in a rather competitive market situation. The historical price series for the industry, presented in Table 3-34, shows a consistent upward trend. The period of tight supply is suggested by the large price increase in 1974.

Current Production. The U.S. International Trade Commission does not publish statistics on furfural production or levels of imports and exports in order to avoid revealing the production of the only domestic producer, the Quaker Oats Company. The total production capacity of this company is believed to have climbed to 172 million pounds in early 1975.[10] Assuming 90 percent capacity utilization, domestic production is estimated at approximately 155 million pounds per year.

3.2.4 Manufacturing Plants - Operational Data

3.2.4.1 Plant Locations

The 22 firms that have been identified as domestic producers of at least one of the highly impacted chemicals maintain 43 plants involved in that production within the continental United States and one impacted plant in Puerto Rico. The geographical distribution of these 44 plants is displayed in Figure 3-9. As can be seen from this figure, approximately one-half of the plants are clustered on the Gulf Coast in Louisiana and Texas. The industry has clustered here near reliable and inexpensive sources of natural gas, because gas is an important raw material in organic chemical manufacture. In general, proximity to desirable raw material feedstocks (which comprise 60 to 70 percent of the production costs) is the most important factor governing location decisions for organic chemical manufacturing plants. Other factors influencing plant location include proximity to other plants that use the product as an intermediate, and proximity to rail and water transportation.

This geographical distribution actually understates the relative importance of the Gulf Coast plants because

TABLE 3–34

FURFURAL PRICE STATISTICS, 1960–74

YEAR	FURFURAL PRICE ($0.01/lb)
1974	28.00
1973	18.75
1972	17.50
1971	16.50
1970	16.00
1969	16.00
1968	14.50
1967	14.50
1966	13.50
1965	12.50
1964	11.50
1963	11.50
1962	11.50
1961	11.50
1960	12.00

* Source: *Chemical Marketing Reporter.*

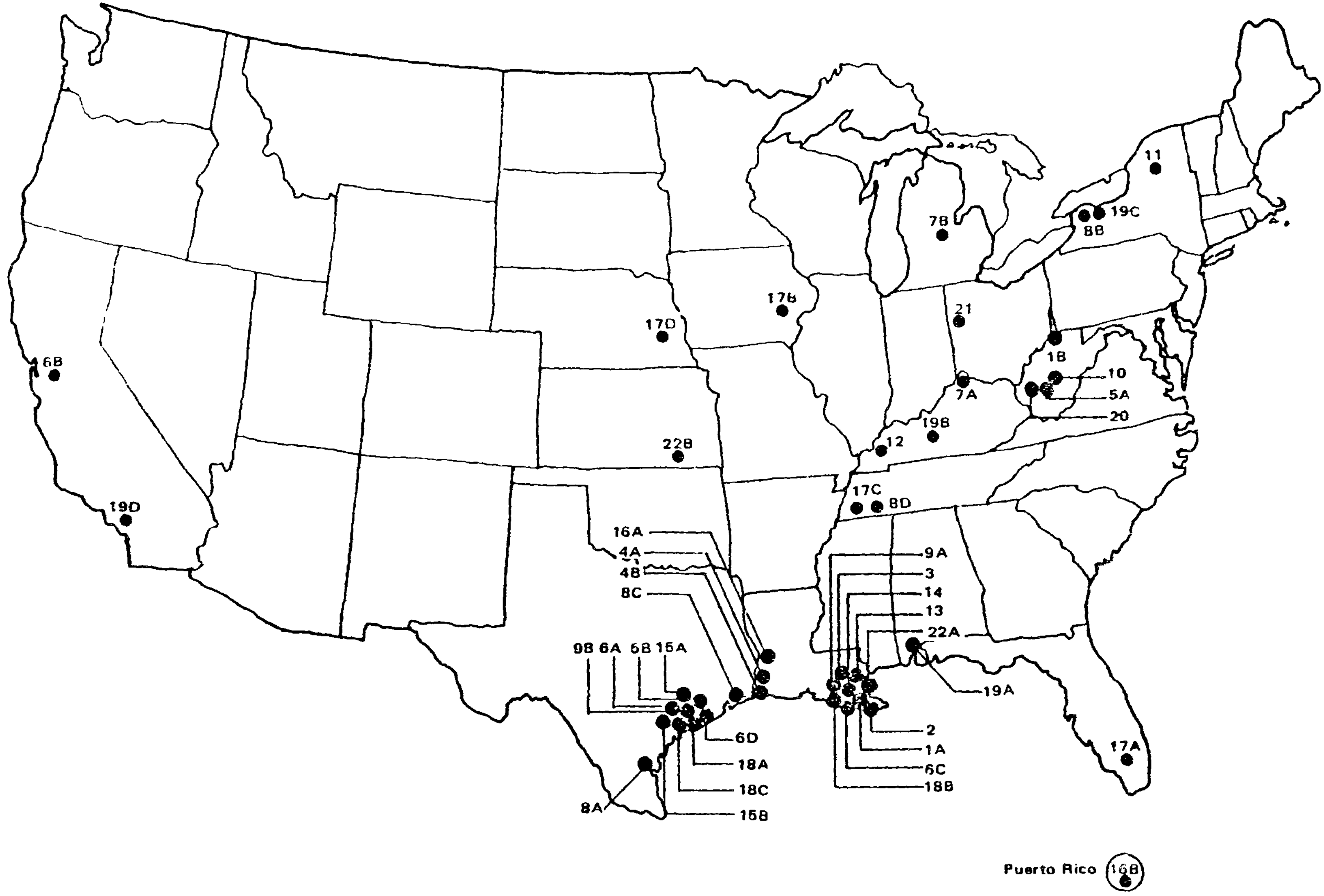

Figure 3–9. Geographical distribution of highly impacted plants.

FIRM	PLANT LOCATION	PLANT CODE	HIGHLY IMPACTED PRODUCTS PRODUCED					
			Perchloroethylene	Chloromethanes	Epichlorohydrin	Vinyl Chloride	Acrylonitrile	Furfural
Allied Chemical	Baton Rouge, La.	1A				V		
Allied Chemical	Moundsville, W.Va.	1B		C				
American Cyanamid	Fortier, La.	2					A	
Borden	Geismar, La.	3				V		
Conoco	Westlake, La.	4A		C				
Conoco	Lake Chares, La.	4B				V		
Diamond Shamrock	Belle, W.Va.	5A		C				
Diamond Shamrock	Deer Park, Tex.	5B	P					
Dow	Freeport, Tex.	6A	P	C	E	V		
Dow	Pittsburg, Calif.	6B	P	C				
Dow	Plaquemine, La.	6C	P	C		V		
Dow	Oyster Creek, Tex.	6D				V		
Dow-Corning	Carrollton, Ky.	7A		C				
Dow-Corning	Midland, Mich.	7B		C				
DuPont	Corpus Christi, Tex.	8A	P	C				
DuPont	Niagara Falls, N.Y.	8B		C				
DuPont	Beaumont, Tex.	8C					A	
DuPont	Memphis, Tenn.	8D					A	
Ethyl	Baton Rouge, La.	9A	P	C		V		
Ethyl	Houston, Tex.	9B				V		
FMC	South Charleston, W.Va.	10		C				
General Electric	Waterford, N.Y.	11		C				
B.F. Goodrich	Calvert City, Ky.	12				V		
Hooker	Taft, La	13	P					
Monochem	Geismar, La.	14				V		
Monsanto	Alvin, Tex.	15A					A	
Monsanto	Texas City, Tex	15B					A	
PPG	Lake Charles, La.	16A	P			V		
PPG	Guayanilla, P.R.	16B				V		
Quaker Oats	Belle Glade, Fla.	17A						F
Quaker Oats	Cedar Rapids, Iowa	17B						F
Quaker Oats	Memphis, Tenn.	17C						F
Quaker Oats	Omaha, Nebr.	17D						F
Shell	Deer Park, Tex.	18A				V		
Shell	Norco, La.	18B			E	V		
Shell	Houston, Tex.	18C			E			
Stauffer	LeMoyne, Ala.	19A		C				
Stauffer	Louisville, Ky.	19B	P	C				
Stauffer	Niagara Falls, N.Y	19C		C				
Stauffer	Long Beach, Calif.	19D				V		
Union Carbide	Institute, W.Va.	20		C				
Vistron	Lima, Ohio	21					A	
Vulcan	Geismar, La.	22A	P	C				
Vulcan	Wichita, Kans.	22B	P	C				

Key for Figure 3–9.

it does not show relative capacities of manufacturing plants. Table 3-35 shows the percentage of identified capacity located in either Texas or Louisiana. As is shown, with the exception of furfural, all of the chemicals have more than half of their productive capacities located on the Gulf Coast, and four of the six have more than 75 percent of their capacity located there. Furfural is presently produced by Quaker using graham processing wastes and, therefore, proximity to gas supplies is not important.

The map key to Figure 3-9 also indicates which highly impacted chemicals each plant produces. As can be seen from the key, only 10 plants produce more than one highly impacted product line with the remaining 34 plants producing only one highly impacted product. Figure 3-10 shows the distribution of firms by the number of plants producing highly impacted products. Only 5 of the 22 firms have more than two such plants.

3.2.4.2 Production Processes Used

Basic production process data for each of the six chemical products being analyzed in depth in this study are provided by the Assessment Study,[11] as explained above in Section 2.1.1.1. Most organic chemicals, including the six selected, can be manufactured by more than one production process. It was, therefore, necessary to determine the appropriateness of the process selected for analysis in the Assessment Study by identifying the process actual manufacturers currently employ. This information is not always made available by manufacturers. The data that were obtained are presented in Table 3-36. This table includes all six highly impacted organic chemicals. As can be seen, the process chosen by the Assessment Study seems to be the one most widely used by manufacturers of all the organic chemicals, with the exception of perchloroethylene production. It is believed that very few manufacturers use the chlorine/acetylene-based process described in the Assessment Study. In that study (based on 1973 data), it was noted: "About 20 percent of the perchloroethylene manufactured uses chlorine and acetylene as starting materials."[12] Since that time this process has probably become even less widely used. Instead, an ethylene-based process is used.

3.2.4.3 Products

The magnitude of the economic impact of hazardous waste regulation at the plant level depends in part on the mix of products manufactured at the plant. In addition to products

TABLE 3–35

GULF COAST PRODUCTION CAPACITY OF HIGHLY IMPACTED CHEMICALS (TEXAS AND LOUISIANA)*

CHEMICAL	% OF PRODUCTION LOCATED ON THE GULF COAST
Chloromethanes	54
Carbon Tetrachloride	45
Methylene Chloride	63
Chloroform	57
Methyl Chloride	68
Perchloroethylene	88
Acrylonitrile	76
Epichlorohydrin	100
Vinyl Chloride Monomer	76
Furfural	0

* Source: See Table 3–38.

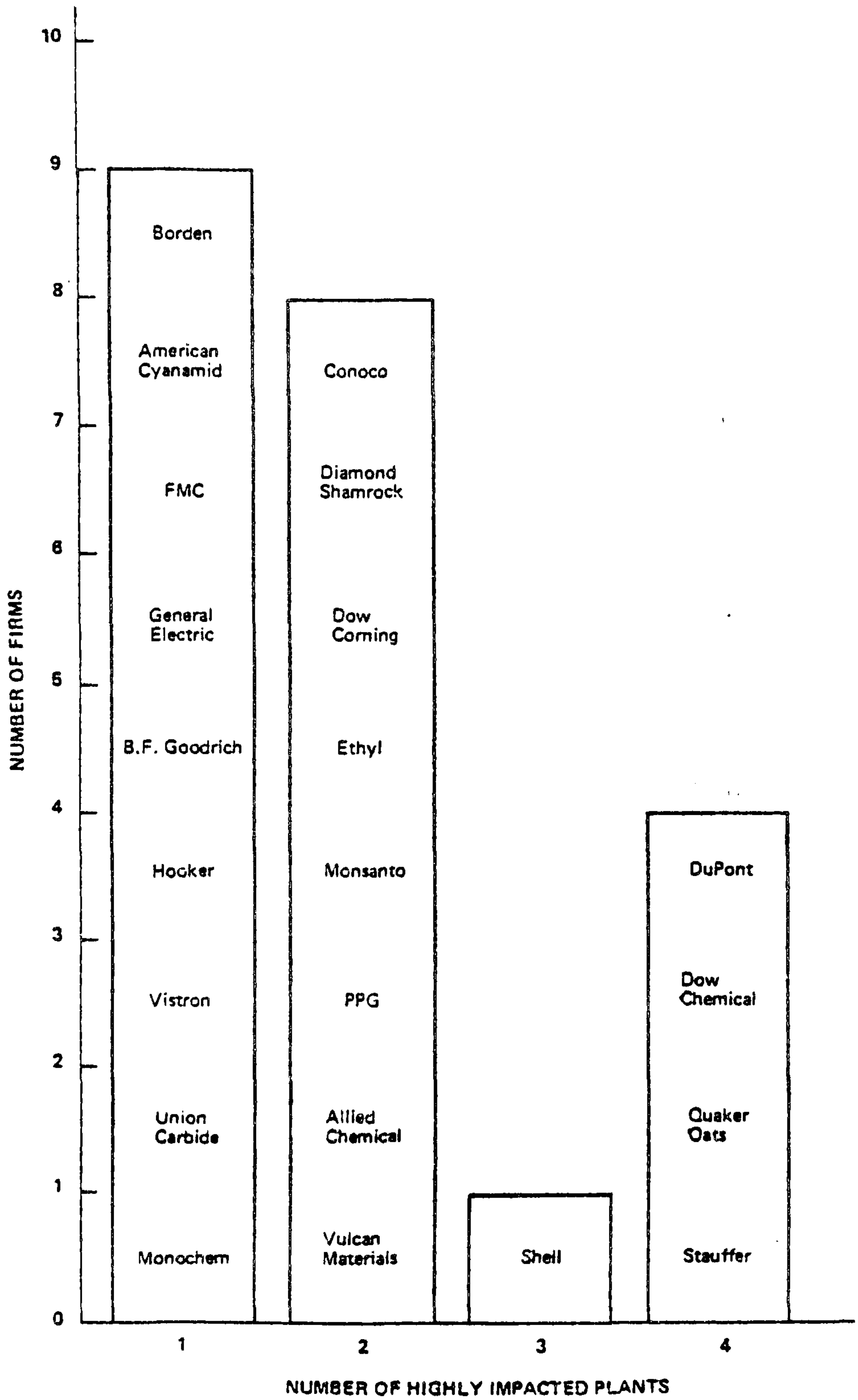

Figure 3—10. Distribution of firms by the number of plants manufacturing selected highly impacted chemicals. (From Figure 3—9 Key.)

TABLE 3–36

PROCESSES USED IN HIGHLY IMPACTED CHEMICAL PRODUCTION*

HIGHLY IMPACTED SEGMENT	FIRM	PLANT	PROCESS	AGREEMENT W/ *ASSESSMENT STUDY*
Perchloroethylene	Diamond Shamrock	Deer Park, Tex.	From EDC	No
	Dow	Freeport, Tex.		
		Pittsburg, Calif.		
		Plaquemine, La.		
	DuPont	Corpus Christi, Tex.		
	Ethyl	Baton Rouge, La.	From EDC	No
	Hooker	Taft, La.	From acetylene	Yes
	PPG	Lake Charles, La		
	Stauffer	Louisville, Ky.	From propylene	No
	Vulcan	Geismar, La.		
		Wichita, Kans.		
Chloromethanes	Allied Chemical	Moundsville, W.Va.	Chlorinate methanol	Yes
	Conoco	Westlake, La.	Chlorinate methanol(?)	Yes
	Diamond Shamrock	Belle, W.Va.	Chlorinate methanol	Yes
	Dow	Freeport, Tex.		
		Pittsburg, Calif.		
		Plaquemine, La.		
	Dow Corning	Carrollton, Ky.	Chlorinate methanol	Yes
		Midland, Mich.	Chlorinate methanol	Yes
	DuPont	Corpus Christi, Tex.		
		Niagara Falls, N.Y.		
	Ethyl	Baton Rouge, La.		
	FMC	S. Charleston, W.Va.		
	General Electric	Waterford, N.Y.	Chlorinate methanol	Yes
	Stauffer	LeMoyne, Ala.	From CS_2 and chlorine	No
		Louisville, Ky.	From propylene	No
		Niagara Falls, N.Y.		
	Union Carbide	Institute, W.Va.	Chlorinate methanol	Yes
	Vulcan	Geismar, La.		
		Wichita, Kans.		
Epichlorohydrin	Dow	Freeport, Tex.		
	Shell	Norco, La.	From allyl chloride	Yes
		Houston, Tex.		
Acrylonitrile	American Cyanamid	Fortier, La.	Sohio	Yes
	DuPont	Beaumont, Tex.	Sohio	
		Memphis, Tenn.	Sohio	
	Monsanto	Chocolate Bayou, Tex.	Sohio	
		Texas City, Tex.	Sohio	
	Vistron	Lima, Ohio	Sohio	Yes
Vinyl Chloride	Allied	Baton Rouge, La.	EDC based	Yes
	Borden	Geismar, La.	EDC based	Yes
	Conoco	Lake Charles, La.	EDC based	Yes
	Dow	Freeport, Tex.	EDC based	
		Oyster Creek, Tex.	EDC based	
		Plaquemine, La.	EDC based	
	Ethyl	Baton Rouge, La.	EDC based(?)	Yes(?)
		Houston, Tex.	EDC based	
	B.F. Goodrich	Calvert City Ky.	EDC based	Yes
	Monochem	Geismar, La.	Acetylene based	No
	PPG	Lake Charles, La.	EDC based	
		Guayanilla, P.R.	EDC based	
	Shell	Deer Park, Tex.	EDC based	
		Norco, La.	EDC based	
	Stauffer	Long Beach, Calif.	EDC based	
Furfural	Quaker Oats	Memphis, Tenn.	Acid digestion (steam distillation)	Yes
		Belle Glade, Fla.	Acid digestion	Yes
		Cedar Rapids, Iowa	Acid digestion	Yes
		Omaha, Nebr.	Acid digestion	Yes

* Source: Telephone interviews with industry contacts, corporate data.

directly affected by regulations, the manufacture of related products not directly influenced by regulations may be affected because of upstream or downstream price increases for the directly impacted products. It is important to distinguish between products that are completely independent and products that are related to impacted products because the production of one can provide a source material for the other, or one can be produced as a byproduct of the manufacture of the other. Thus, if an impacted product line were to be discontinued, another product for which its production provided a raw material might also be discontinued or be redesigned to utilize a new input chemical. On the other hand, the presence of related production processes that allow the sharing of abatement costs might reduce the impact of regulation on a particular manufacturing operation at the plant level. Table 3-37 presents the available information on the products produced at the 44 plants manufacturing at least one of the six highly impacted products. While the available information is sketchy, it is clear from the table that completely independent chemical production processes under the same roof are relatively rare. It is generally economical to locate processes that can generate source material for each other within the same facility to avoid transportation and storage costs, and to make the best possible use of all production byproducts. For example, the Diamond Shamrock facility at Belle, West Virginia manufactures chloromethanes. As a byproduct of this process, hydrochloric acid is produced, which is sold as muriatic acid.

3.2.4.4 Plant Sizes

Due to the significant economies of scale involved in organic chemicals production, plant size can be an important factor affecting the plant-level impacts of hazardous waste regulation. It is possible that relatively small plants (with higher unit costs) might be more severely impacted than larger plants which can spread fixed costs of abatement equipment over a larger volume. It is also true, however, that many of the smaller plants are fully depreciated because they are relatively old, adding to their profitability.

The distribution of plant sizes is discussed in Section 2.1.1.3. Table 3-38 shows the capacities of highly impacted plants by firm for each of the six chemicals selected for study. As the table illustrates, the 22 firms vary significantly in the amount of highly impacted capacity, with Dow Chemical having the largest total capacity for highly impacted chemicals.

TABLE 3–37

PRODUCTS PRODUCED AT HIGHLY IMPACTED PLANTS*

FIRM	PLANT LOCATION	Perchloroethylene	Chloromethanes	Epichlorohydrin	Vinyl Chloride	Acrylonitrile	Furfural	OTHER PRODUCTS PRODUCED
		HIGHLY IMPACTED PRODUCTS PRODUCED						
Allied	Baton Rouge, La				V			Chlorine caustic soda
Allied	Moundsville, W.Va.		C					Chlorine, caustic soda, TD'
American Cyanamid	Fortier, La.					A		Ammonia, sulphuric acid, YP soda, Assorted polymers
Borden	Geismar, La.				V			NA
Conoco	Westlake, La.		C					NA
Conoco	Lake Chares, La.				V			EDC
Diamond Shamrock	Belle, W.Va.		C					Myoleric acid
Diamond Shamrock	Deer Park, Tex.	P						Trichloroethylene, ethylene dichlorite
Dow	Freeport, Tex.	P	C	E	V			Petrochemical complex, EPI, UCM
Dow	Pittsburg, Calif.	P	C					NA
Dow	Plaquemine, La.	P	C		V			
Dow	Oyster Creek, Tex.				V			NA
Dow-Corning	Carrollton, Ky.		C					Silicone probably
Dow-Corning	Midland, Mich.		C					NA
DuPont	Corpus Christi, Tex.	P	C					NA
DuPont	Niagara Falls, N.Y.		C					NA
DuPont	Beaumont, Tex.					A		NA
DuPont	Memphis, Tenn.					A		NA
Ethyl	Baton Rouge, La.	P	C		V			Sodium, EDC, anti-knock compounds
Ethyl	Houston, Tex.				V			NA
FMC	South Charleston, W.Va.		C					NA
General Electric	Waterford, N.Y		C					Elastorus, fluids, resins
B F Goodrich	Calvert City, Ky				V			Other products
Hooker	Taft, La.	P						Chlorine, caustic soda and a solvent section
Monochem	Geismar, La				V			Adeylene
Monsanto	Alvin, Tex					A		NA
Monsanto	Texas City, Tex.					A		NA
PPG	Lake Charles, La.	P			V			NA
PPG	Guayanilla, P.R.				V			NA
Quaker Oats	Belle Glade, Fla.						F	NA
Quaker Oats	Cedar Rapids, Iowa						F	Oatmeal
Quaker Oats	Memphis, Tenn.						F	Furfuryl alcohol, tetrachyoren, furan chemicals
Quaker Oats	Omaha, Nebr.						F	Furfuryl alcohol
Shell	Deer Park, Tex.				V			NA
Shell	Norco, La.			E	V			Ethylene, glycerin
Shell	Houston, Tex.			E				Benzene, ethyl alcohol, epoxy resins, ethylene
Stauffer	LeMoyne, Ala.		C					NA
Stauffer	Louisville, Ky.	P	C					Sulphuric acid
Stauffer	Niagara Falls, N.Y.		C					NA
Stauffer	Long Beach, Calif				V			Glycerin, ethyl lead, PVC
Union Carbide	Institute, W Va.		C					Silicone
Vistron	Lima, Ohio					A		Ammonia, resin producing facility
Vulcan	Geismar, La	P	C					NA
Vulcan	Wichita, Kans	P	C					Chlorine, caustic soda, EDC

* Source: Telephone interviews with industry contacts.

TABLE 3–38

CAPACITIES OF HIGHLY IMPACTED PLANTS*

HIGHLY IMPACTED PRODUCT	FIRM	PLANT	CAPACITY (1,000 MT/yr)
Perchloroethylene	Diamond Shamrock	Deer Park, Tex.	91
	Dow	Freeport, Tex.	54
		Pittsburg, Calif.	9
		Plaquemine, La.	68
	DuPont	Corpus Christi, Tex.	73
	Ethyl	Baton Rouge, La.	23
	Hooker	Taft, La.	18
	PPG	Lake Charles, La.	91
	Stauffer	Louisville, Ky.	32
	Vulcan	Geismar, La.	68
		Wichita, Kans.	23
Chloromethanes			
Methyl Chloride	Allied Chemical	Moundsville, W.Va.	11
	Conoco	Westlake, La.	45
	Diamond Shamrock	Belle, W.Va.	11
	Dow	Plaquemine, La.	68
		Freeport, Tex.	32
	Dow-Corning	Carrollton, Ky.	9
		Midland, Mich.	7
	Ethyl	Baton Rouge, La.	45
	General Electric	Waterfor, N.Y.	23
	Stauffer	Louisville, Ky.	7
	Union Carbide	Institute, W.Va.	23
Methylene Chloride	Allied Chemical	Moundsville, W.Va.	23
	Diamond Shamrock	Belle, W.Va.	45
	Dow	Freeport, Tex.	90
		Plaquemine, La.	
	DuPont	Niagara Falls, N.Y.	18
	Stauffer	Louisville, Ky.	27
	Vulcan	Geismar, La.	36
		Wichita, Kans.	14
Chloroform	Allied Chemical	Moundsville, W.Va.	14
	Diamond Shamrock	Belle, W.Va.	18
	Dow	Freeport, Tex.	45
		Plaquemine, La.	45
	Stauffer	Louisville, Ky.	34
	Vulcan	Geismar, La.	21
		Wichita, Kans.	18

*Sources: Stanford Research Institute, *Chemical Economics Handbook; Chemical Marketing Reporter,* "Chemical Profiles", telephone communications with industry personnel; corporate reports.

TABLE 3–38 (CONTINUED)

HIGHLY IMPACTED PRODUCT	FIRM	PLANT	CAPACITY (1,000 MT/yr)
Carbon tetrachloride	Allied Chemical	Moundsville, W.Va.	4
	Dow	Freeport, Tex.	61
		Pittsburg, Calif.	36
		Plaquemine, La.	56
	DuPont	Corpus Christi, Tex.	225
	FMC	South Charleston, W.Va.	135
	Stauffer	LeMoyne, Ala.	90
		Louisville, Ky.	16
		Niagara Falls, N.Y.	68
	Vulcan	Geismar, La.	41
		Wichita, Kans.	27
Epichlorohydrin	Dow	Freeport, Tex.	113
	Shell	Houston, Tex.	63
		Norco, La.	27
Acrylonitrile	American Cyanamid	Fortier, La.	109
	DuPont	Beaumont, Tex.	186
		Memphis, Tenn.	125
	Monsanto	Chocolate Bayou, Tex.	391
		Texas City, Tex.	286
	Vistron	Lima, Ohio	182
Vinyl Chloride	Allied Chemical	Baton Rouge, La.	
	Borden	Geismar, La.	
	Conoco	Lake Charles, La	
	Dow	Freeport, Tex.	
		Oyster Creek, Tex.	
		Plaquemine, La.	
	Ethyl	Baton Rouge, La.	136
		Houston, Tex.	
	B.F. Goodrich	Calvert City, Ky.	
	Monochem	Geismar, La.	136
	PPG	Lake Charles, La.	182
		Guayanilla, P.R.	227
	Shell	Deer Park, Tex.	
		Norco, La.	
	Stauffer	Long Beach, Calif.	
Furfural	Quaker Oats	Memphis, Tenn.	n.a.
		Belle Glade, Fla.	n.a.
		Cedar Rapids, Iowa	n.a.
		Omaha, Nebr.	n.a.

3.2.4.5 Capacity Utilization

In an industry such as the organic chemicals industry, where significant economies of scale exist, the ability to maintain equipment utilization rates is the key to efficient production. Capital equipment is designed for maximum efficiency near the full utilization level with unit costs rising dramatically when capital is under-employed. Industry experts contacted agreed that capacity utilization rates in the range of 80 to 90 percent of nameplate design capacity are a reasonable goal for organic chemical producers in general, and for the producers of highly impacted chemicals in particular.[13]

Data are not readily available for a calculation of historical capacity utilization rates for highly impacted chemicals. Nonetheless, some indication of the level and variability of capacity utilization rates can be obtained by comparing the U.S. International Trade Commission's production figures with current capacity estimates under the assumption that capacity has remained substantially the same over the last 3 years. The capacity utilization rates generated in this way are presented below in Table 3-39. Even though these estimates may be subject to some bias (probably downward since earlier capacity totals are likely to be overstated), the table does show that utilization rates in the neighborhood of 80 percent are not uncommon during nonrecessionary times. In addition, it can be seen that these rates can fall off sharply during times of decreased demand, often to the neighborhood of 50 percent. Thus, unit costs can rise during a period of declining demand due to capital under-utilization.

3.2.4.6 Employment

Employment statistics for the organic chemicals industry are not available because of joint production. Firms involved in the production of organic chemicals also manufacture other products, and the organic chemicals component of plant employment is difficult to isolate. It is likely, however, that industrial organic chemicals industry employment closely parallels industry-wide chemical employment trends, for which statistics are available.

Table 3-40 presents recent employment and earnings statistics for the industrial chemicals industry. The effects of the 1975 recession may be discernable in the slight reduction of the number of production workers and of the length of the workweek in that year, and in the near-zero growth of total employees. However, employment

TABLE 3–39

CAPACITY UTILIZATION RATES
(1,000 MT/yr)*

CHEMICAL	CAPACITY	1975 PRODUCTION	1974 PRODUCTION	1975 UTILIZATION RATE (%)	1974 UTILIZATION RATE (%)
Perchloroethylene	550	309	334	56	61
Chloromethanes					
Methyl Chloride	282	166	224	59	80
Methylene Chloride	341	226	227	66	81
Chloroform	196	119	137	61	70
Carbon Tetrachloride	767	412	529	53	69
Epichlorohydrin	205	n.a.	n.a.	n.a.	n.a.
Acrylonitrile	1,280	552	1,542	43	50
Vinyl Chloride Monomer	3,189	1,907	2,555	60	80
Furfural	n.a.	n.a.	n.a.	n.a.	n.a.

* Source: *Chemical Marketing Reporter,* Chemical Profiles, U.S. Tariff Commission.

TABLE 3–40

INDUSTRIAL CHEMICAL EMPLOYMENT AND EARNINGS*

	1976	1975	1974	1973
Total employees (thousands)	336	324	322	311
Production workers (thousands)	180	171	173	169
Workweek (hours)	42.1	41.4	42.6	42.7
Hourly earnings (S)	6.57	5.93	5.38	4.97
Weekly earnings (S)	276.60	245.50	229.19	212.22

* Sources: U.S. Department of Labor, *Chemical and Engineering News*, June 7, 1976 and June 6, 1977.

in the industrial chemicals industry was not as severely reduced by the recession as it was in the synthetic fibers industry and other chemical product areas. As is shown, recovery was fairly swift for industrial chemicals (unlike other chemical industries) and 1976 employment has more than recouped 1975 losses. In addition, Table 3-40 illustrates the steady growth of nominal wages which has characterized the industrial chemicals industry labor force.

The number of employees that would be forced out of work if a product line were closed down due to hazardous waste regulation would depend primarily on the number of workers at the plant level engaged in the production of that product. However, since most plants produce several chemicals, it is difficult to assess the number of employees required for manufacture of any specific organic chemical. Table 3-41 shows total employment for each of the plants producing a highly impacted chemical. Because organic chemical manufacture is not labor intensive, cutbacks in production levels have little effect on employment. A minimum number of production workers are required to run a production process and this number is relatively insensitive to the volume produced by a particular facility. Employment reductions are likely to occur only if processes are shut down entirely, but the production workers may merely be transferred to production of a substitute for the product shutdown. The fraction of these employees potentially affected depends on (1) the severity of impact on the highly impacted products and the other products produced at that plant (see Section 3.2.4.3) and (2) the ability of firms to substitute other products for discontinued lines.

3.2.4.7 Waste Streams Produced

Actual production processes used by manufacturers of the six highly impacted products closely conform to Assessment Study model processes (with the exception of perchloroethylene production), as noted above in Section 3.2.4.2. The Assessment Study characterizations of process waste streams which are, therefore, likely to be representative of the industry's wastes are displayed in Table 3-42. In the case of perchloroethylene, it is believed that the waste stream described in the Assessment Study, which is based on an acetylene process, is very similar to the waste streams generated by the more common ethylene-based process.

TABLE 3–41

ESTIMATED EMPLOYMENT AT HIGHLY IMPACTED PLANTS*

FIRM	LOCATION	NUMBER OF EMPLOYEES
Allied Chemical	Baton Rouge, La.	1,000
	Moundsville, W.Va.	400 (north and south)
American Cyanamid	Fortier, La.	500
Borden	Geismar, La.	100
Conoco	Westlake, La.	100
	Lake Charles, La.	n.a.
Diamond Shamrock	Belle, W.Va.	n.a.
	Deer Park, Tex.	500
Dow	Freeport, Tex.	2,600
	Pittsburg, Calif.	600
	Plaquemine, La.	1,200
	Oyster Creek, Tex.	200
Dow-Corning	Carrollton, Ky.	100
	Midland, Mich.	2,000
DuPont	Corpus Christi, Tex.	n.a.
	Niagara Falls, N.Y.	n.a.
	Beaumont, Tex.	n.a.
	Memphis, Tenn.	500
Ethyl	Baton Rouge, La.	1,000
	Houston, Tex.	n.a.
FMC	South Charleston, W.Va.	200
General Electric	Waterford, N.Y.	n.a.
B.F. Goodrich	Calvert City, Ky.	600
Hooker	Taft, La.	300
Monochem	Geismar, La.	100
Monsanto	Alvin, Tex. Texas City, Tex.	2,500
PPG	Lake Charles, La.	1,200
	Guayanilla, P.R.	n.a.
Quaker Oats	Belle Glade, Fla.	n.a.
	Cedar Rapids, Iowa	n.a.
	Memphis, Tenn.	200
	Omaha, Nebr.	100
Shell	Houston, Tex.	3,000
	Deer Park, Tex.	n.a.
	Norco, La.	300
Stauffer	LeMoyne, Ala.	100
	Louisville, Ky.	100
	Niagara Falls, N.Y.	n.a.
	Long Beach, Calif.	n.a.
Union Carbide	Institute, W.Va.	1,800
Vistron	Lima, Ohio	300
Vulcan	Geismar, La.	100
	Wichita, Kans.	400

* Source: Marketing Economics Institute, Inc., *Marketing Economics Key Plants, 1975-76 Guide to Industrial Purchasing Power, 4,000 Plants with 100 Employees or More.*

TABLE 3–42

WASTE STREAM CHARACTERIZATION FOR *ASSESSMENT STUDY* PROCESSES*

CHEMICAL	PROCESS BASE	WASTE STREAM CHARACTERIZATION
Perchloroethylene	Acetylene Based	A two-phase sludge from the purification columns, containing hexachlorobutadiene (77%), chlorobenzenes (7%), chloroethanes (3%), chlorobutadiene (3%), tars (7%), and 3% miscellaneous.
Chloromethanes	Methanol Based	Solid tails (bottom) from the distillation column yielding carbon tetrachloride, composed of hexachlorobenzene (45%), hexachlorobutadiene (45%), and tars, etc. (10%)
Epichlorohydrin	Allyl Chloride	Heavy ends from the fractionator, composed of epichlorohydrin (2%), dichlorohydrin (11%), chloroethers (14%), trichloropropane (70%), tars, resins and others (3%).
Acrylonitrile	Propylene (Sohio)	Impurities from the product purification step, consisting of complex nitrile compounds, polymers and tars.
Vinyl Chloride	EDC	The heavy ends from the ethylene dichloride recovery still, composed of 1,2 dichloroethane (23%), 1,1,2 trichloroethane (38%), 1,1,1,2 tetrachloroethane (38%), tars (1%).
Furfural	Digestor/Distillation Dehydration	Still bottoms from the stripping column, composed of polymers and tars (89%), and sulfuric acid (11%), and filter solids from the dehydrating column bottom stream, which is composed of fines and particulates and contains furfural.

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries,* prepared for U.S..Environmental Protection Agency, 1976.

3.2.5 Manufacturing Firms - Financial Data

3.2.5.1 Economics of Abatement

As discussed above in Section 2.1.3, a firm's decision to continue or discontinue impacted operations will be made on a process by process basis and will be based on the profitability of manufacture under regulation. This determination of profitability will take into account marginal unit cost increases due to pollution control as well as the ability to finance the capital investment to comply with hazardous waste regulations. Unfortunately, financial data at the process level necessary to characterize the decision process of firms are not readily available. In most cases, the best financial information available is aggregated to the firm level. The purpose of this section is to examine firm level data on the profitability of operations and on the availability of capital. Section 3.2.5.4 then presents model plant financial data as estimates of the actual process economics that the impacted firms will face. These model plant estimates will be used in the economic impact analysis.

It is assumed that the profitability of firms that are major participants in the organic chemicals industry gives some indication of the general profitability of manufacturing processes. While this approach does not distinguish relative profitabilities of various product lines, it is believed that it can suggest whether organic chemical manufacture is more or less profitable than other manufacturing activities. If organic chemicals manufacture is relatively profitable, it is less likely that operations will be discontinued under regulation.

The capital position of the industry will be examined from the perspective of identifying unusual investment strengths or weaknesses of firms, rather than through a detailed firm by firm financial analysis. The interactions of a firm's major financial variables are explained. The capital flows are then surveyed in an attempt to derive industry level conclusions and to highlight unique situations of particular firms.

3.2.5.2 Profitability

Several market characteristics and pricing policies that are common in the organic chemical markets, as well as in chemical markets in general, suggest that these firms will be more profitable than most manufacturing firms. As discussed above in Section 3.2.2.1, most chemical markets, including the organic chemical markets, are characterized by an oligopolistic structure. In addition to the "nonpredatory" pricing policies common among these firms that recognize their interdependence, this oligopolistic structure implies some ability to price products so as to obtain relatively high rates of return.

Table 3-43 illustrates that greater-than-normal profitability is precisely what is observed for the 10-firm organic chemicals industry sample. The table presents 10-year comparisons of two basic measures of corporate profitability: the ratio of income to sales and the ratio of income to stockholders equity (net worth) for both the organic chemical manufacturers sample and for all domestic manufacturers. As can be seen in the table, the difference between income as a percent of sales for organic chemical producers and all domestic manufacturing firms averages approximately 2.5 percentage points and is never less than 2.0 percentage points. The return on equity for the organic chemicals industry firms, as measured by the income/equity ratio, is greater than the manufacturing return in every year except two, and the differential appears to be widening over time.

The current profitability situation of the 22 manufacturers of at least one of the six chemical groups is described in Table 3-44 by four measures of profitability. The table shows that there is significant variation in profitability among firms, ranging from the poor showing of the rubber companies to the high profitability of Dow and Dow-Corning. However, the table does not allow the inference that any of the producers of highly impacted organic chemicals are in a difficult financial position.

3.2.5.3 Investment Constraints

Capital Flows Within a Firm. In order to appreciate the capital structure and investment position of a firm or industry through an examination of its basic financial statistics, it is necessary to understand basic capital flows within the corporate structure. Figure 3-11 illustrates these simplified flows. As is shown, there are two basic sources of capital: funds generated through the operation of the firm and funds raised from outside sources. Operations sources include income from the sale of the firm's products, the sale of its property, or an increase in the value of its investments as well as factors that diminish the amount that the firms must pay out such as deferred taxes and depreciation.[14] Nonoperations sources include new funds raised through the capital markets.

TABLE 3–43

COMPARATIVE PROFITABILITY OF CHEMICAL INDUSTRY SAMPLE WITH ALL MANUFACTURERS*

PROFITABILITY MEASURE	1976	1975	1974**	1973	1972	1971	1970	1969	1968	1967
Income/ Sales, All Manufacturing (%)	5.3†	4.6	5.5	4.7	4.3	4.1	4.0	4.8	5.1	5.0
Income/Sales, Industry Sample (%)	7.3	7.2	8.3	8.1	7.0	6.3	6.2	7.1	7.3	7.3
Income/Equity, All Manufacturing (%)	13.7†	11.6	14.9	12.8	10.6	9.7	9.3	11.5	12.1	11.7
Income/Equity, Industry Sample (%)	15.5	15.0	18.1	15.3	11.8	10.1	10.0	11.9	12.0	11.3†

*Sources: *Economic Report of the President 1977,* p. 283; *Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations,* Federal Trade Commission.

**Federal Trade Commission data underwent significant procedural changes, making comparisons with earlier years difficult.

† Data for 3rd Quarter 1976 annualized.

TABLE 3–44

PROFITABILITY MEASURES, 1976*

COMPANY	OPERATING PROFIT MARGIN (%)	NET INCOME GROSS REVENUES (%)	EARNINGS SHARE (%)	EARNINGS EQUITY (%)
Allied Chemical	8.8	4.4	4.52	10.5
American Cyanamid	9.7	6.5	2.73	12.2
Borden	6.5	3.3	3.64	12.0
Conoco	13.4	5.8	4.38	17.5
Diamond Shamrock	18.8	10.3	3.90	20.8
Dow	19.2	10.8	3.30	21.4
Dow-Corning	23.1**	12.1	17.10	21.7
DuPont	11.0	5.5	9.30	11.4
Ethyl	12.7	6.0	7.18	14.5
FMC	9.4	3.5	3.43	9.2
G.E.	8.8	5.9	4.12	17.7
B.F.Goodrich	4.8	0.8	0.95	2.1
Monsanto	15.6	8.6	10.05	16.3
Occidental	13.6	3.3	2.76	14.1
PPG	13.1	6.7	4.85	14.8
Quaker Oats	10.4	3.6	2.31	12.3
Shell	16.1	7.6	5.06	15.4
Sohio	8.1	4.7	3.55	8.8
Stauffer	17.0	10.3	5.20	18.9
Union Carbide	12.8	7.0	7.15	14.4
Uniroyal	3.5	0.9	0.57	3.2
Vulcan	11.9	9.1	3.19	18.5

* Sources: *Fortune Magazine*, 1976-77; and *Moody's Handbook of Common Stocks*, Summer 1977 Edition.

** Energy Resources Company estimate.

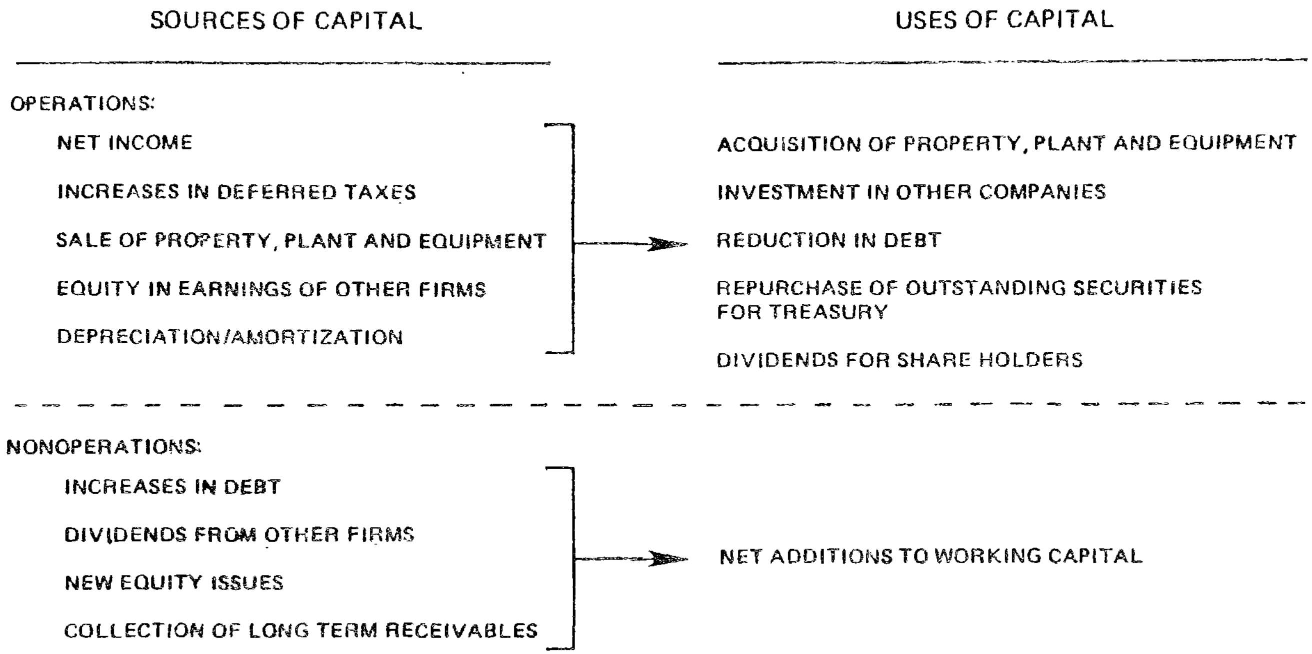

Figure 3–11. Capital flows within a firm.

Working capital can be thought of as a measure of the company's capital needs for running its business.[15] The figure illustrates that in addition to funding changes in this amount, capital can be used for expansion, outside investment, alterations in capital structure, and dividends for corporate shareholders.

Any investment that hazardous waste regulations might require would be included in the category "acquisition of property, plant, and equipment." A firm's ability to generate sufficient capital for such an investment is thus influenced by its ability to raise capital from outside sources at reasonable prices, its ability to maintain satisfactory operating incomes and its ability to divert existing capital funds from other potential uses, as well as by the size of required incremental investment relative to the capital budget.

Operations Profile. As mentioned previously, identifying the firms included in the organic chemicals industry is not a straightforward task as most organic chemical producers are large firms engaged in diverse chemical and nonchemical activities. Similarly, aggregate operations statistics for the 22 firms identified as producers of at least one of the six highly impacted product lines contain much information unrelated to the chemical industry. Since most companies do not disclose data by product line, it is impossible to eliminate unrelated activities.

In order to control this problem as much as possible, financial statistics were calculated based on the 10 largest impacted firms that are recognized as being primarily in the chemical business. While this does not solve the problem, it reduces the amount of nonchemical "noise" in the statistics. The 10 firms selected are the following:

1. Allied Chemical

2. American Cyanamid

3. Diamond Shamrock

4. Dow Chemical

5. DuPont

6. Ethyl

7. Monsanto

8. Stauffer

9. Union Carbide

10. FMC Corp.

Table 3-45 presents operating statistics for this group over the last 10 years. The statistics in Table 3-45 suggest several conclusions. First, the industry is fundamentally cyclical in nature. Profitability, as measured by the ratios of income to (1) sales, (2) assets, and (3) net worth, fell off markedly in response to the recessions of 1970 and 1975, and recovered only slowly in the following year. Similarly, the growth pattern of net income is interrupted in these recession years. Second, the industry has been expanding. Nominal net sales have grown over the period at a rate greater than 15 percent annually. Net income has also more than doubled. Third, the industry is highly capital intensive and this trend is increasing. The entire chemical industry in 1976 accounted for nearly 13 percent of the capital spending of all domestic manufacturers while the industry accounted for only 8.6 percent of manufacturers shipments. Working capital requirements and capital expenditure ratios have significantly exceeded manufacturing averages over the 10-year period.

The organic chemicals segment of the chemical industry is also significantly more capital intensive than manufacturing in general. Capital expenditures as a percentage of assets have averaged 11.5 over the 10-year period, compared with a figure of 4.2 for all manufacturing.[16] The recent trends of the ratios of capital expenditures to (1) assets and (2) sales, as shown in the table, are strongly upward. Capital expenditures have averaged more than 1.6 times greater than net income, suggesting the industry's dependence on nonincome sources of funds.

The cash flow estimates for the 10 firm sample, shown in Table 3-46, are consistent with what would be expected of a rapidly growing capital-intensive industry. The large capital needs of firms have led to a negative net cash flow over the last 10 years, requiring firms to raise capital from outside sources. While the calculations in Table 3-46 are only an approximation to strictly defined cash flows, they do show clearly that funds generated within the industry have been insufficient to fund expenditures, and, thus, the dependence on debt and equity financing is significant.

Capital Structure. The ability of a firm to raise capital and the cost of that capital depend on the existing capital structure of the firm. Two features of that structure

TABLE 3–45

10-YEAR INDUSTRY FINANCIAL STATISTICS*

	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
Net Sales	35,107,765	31,061,205	29,580,373	22,445,871	18,405,367	16,631,426	15,860,114	15,683,170	14,765,619	13,910,500
Net Income	2,578,271	2,238,197	2,456,764	1,823,926	1,283,616	1,040,652	978,853	1,113,649	1,078,304	1,021,900
Total Assets	34,047,193	29,829,787	26,270,907	21,978,177	19,427,172	18,304,704	17,346,195	16,418,392	15,546,023	15,428,383
Net Worth	16,606,025	14,945,216	13,548,689	11,919,645	10,909,471	10,263,818	9,821,462	9,382,370	8,986,336	8,955,979
Capital Expenditures	4,941,235	4,476,911	3,713,742	2,237,765	1,737,533	1,824,200	1,958,409	1,742,891	1,451,842	1,586,651
Income/Sales (%)	7.3	7.2	8.3	8.1	7.0	6.3	6.2	7.1	7.3	7.3
Income/Assets (%)	7.6	7.5	9.4	8.3	6.6	5.7	5.6	6.8	6.9	6.6
Income/Net Worth (%)	15.5	15.0	18.1	15.3	11.8	10.1	10.0	11.9	12.0	11.4
Capital Expenditures/ Total Assets (%)	14.5	15.0	14.1	10.1	8.9	10.0	11.3	10.6	9.3	10.3
Capital Expenditures/ Net Income	1.9	2.0	1.5	1.2	1.4	1.8	2.0	1.6	1.3	1.6
Capital Expenditures/ Net Sales (%)	14.1	14.4	12.6	10.0	9.4	11.0	12.3	11.1	9.8	11.4

* Based on the 10 largest impacted chemical companies. Sources: *Moody's Handbook of Common Stocks,* Summer 1977 Edition; *Chemical and Engineering News,* "Facts and Figures for the Chemical Industry," June 7, 1976, June 5, 1972, June 6, 1977, Investment Survey, and Corporation Reports.

TABLE 3–46

INDUSTRY CASH FLOW APPROXIMATIONS*
($($1,000)d)

CASH FLOW COMPONENT	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
Net income after taxes	2,578,271	2,238,197	2,456,764	1,823,926	1,283,616	1,040,652	978,853	1,113,649	1,078,304	1,021,900
Depreciation	2,024,600	1,787,300	1,627,300	1,444,300	1,398,900	1,332,000	1,294,600	1,233,300	1,181,500	1,146,590
Cash inflow	4,602,871	4,025,497	4,084,064	3,268,226	2,682,516	2,372,652	2,273,453	2,346,949	2,259,804	2,168,490
Dividends**	909,466	791,018	765,022	724,494	685,333	658,979	652,861	662,177	670,785	687,865
Capital expenditures	4,941,235	4,476,911	3,713,742	2,237,765	1,737,533	1,824,200	1,958,409	1,742,891	1,451,842	1,586,751
Cash outflow	5,850,701	5,267,929	4,478,764	2,962,259	2,422,846	2,483,179	2,611,270	2,405,068	2,122,627	2,274,616
Net cash flow	(1,247,830)	(1,242,432)	(394,700)	305,967	259,650	(110,527)	(337,817)	(58,119)	137,177	(106,126)

* Based on 10-firm sample. Sources: *Chemical and Engineering News*, "Facts and Figures for the Chemical Industry," June 5, 1972, June 7, 1976, June 6, 1977, *Value Line Investment Survey*, *Moody's Handbook of Common Stocks*, Summer 1977 Edition, Corporation Reports.

** Number of shares x dividends/share.

are examined below, one dealing with capital from inside sources and one dealing with sources outside the firm.

The structural statistic most widely analyzed is some form of a debt/equity ratio. It is generally true that debt financing is less expensive than new equity issues when the amount of debt is moderate. However, as the amount of debt rises, the interest obligations of the firm also rise. Unlike dividends, these interest payments are a contractual obligation that must be met during bad times as well as good times under pains of bankruptcy and default. Hence, as the interest obligation rises, the risk of bankruptcy or default during income downturns increases. This is particularly important in a cyclical industry such as organic chemicals. Therefore, a firm desires some debt financing to exploit lower capital costs, but not so much as to raise its bankruptcy risk excessively and increase the risk borne by lenders to the firm (a risk ultimately expressed in demands by lenders of a higher interest rate).

Table 3-47 presents a profile of the debt structure of industry firms over the previous 10-year period. The percentages displayed represent the amount of total invested capital accounted for by long-term debt issues. While there is some variance between selected firms, with Dow Chemical relying more heavily and Dupont relying less heavily on debt financing than average, all firms are within a rough rule-of-thumb acceptable range; this is to say, no obvious financial dangers are apparent. It is interesting to note that Dow and Dupont have been approaching the mean levels over the last several years.

Over the 10-year period, no other obvious trend among these firms toward or away from debt financing is apparent. As would be expected, debt financing, which is a substitute for operating income as a source of funds, becomes more important during times of declines in operating income. This is observed in 1975. However, it is not clear that this represents a trend. It is true, however, that debt financing became relatively more important for the chemical industry as a whole during this period. This possible discrepancy between the chemical industry and the organic chemicals segment might be explained by the relatively high profits often returned by organic chemical product lines.

Another statistic which describes part of the capital formulation process is the dividend payout ratio (the percent of earnings paid out to shareholders in the form of dividends). By reducing dividends, a firm can increase the amount of retained earnings available for use in the capital budget. Management, on the other hand, also wishes to

TABLE 3–47

FINANCIAL LEVERAGE (%) OF SELECTED INDUSTRY FIRMS*

FIRM	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
Allied Chemical	32	34	28	30	33	32	32	36	35	36
American Cyanamid	27	21	19	20	20	19	13	14	13	14
Diamond Shamrock	40	36	33	29	30	32	26	28	27	33
Dow Chemical	36	36	37	43	44	45	46	42	39	37
DuPont	23	17	16	6	7	7	5	5	4	4
Monsanto	29	29	25	28	30	31	32	27	27	28
PPG	29	32	28	25	27	28	27	18	19	20
Stauffer	40	31	27	31	31	29	27	24	25	27
Union Carbide	32	30	24	28	29	31	32	33	33	34
Vulcan**	29	29	20	20	20	22	19	19	18	17
Average	28.8	29.5	25.7	26.0	27.1	27.6	25.9	24.6	24.0	25.0

* Long-term debt/total invested capital. Sources: *Chemical and Engineering News*, "Facts and Figures for the Chemical Industry," June 5, 1972, June 7, 1976, June 6, 1977; Corporation Reports.

** Vulcan is used here in place of FMC because of lack of data for FMC.

maintain dividends at a high, steady level to maximize the price of its outstanding equity. Table 3-48 shows the 10-year dividend payout ratio for 10 industry firms. It is readily apparent that the high payout rates of the 1960's and the early 1970's have been drastically reduced, even in times of earnings growth. This represents an attempt on the part of the industry to raise additional funds from within the firm.

The current structural position of all 22 manufacturers of at least one selected highly impacted chemical is summarized in Table 3-49. Included in this chart is the current ratio, the ratio of current assets to current liabilities. This statistic is a measure of the short-run liquidity position of the firm. An unusually low current ratio would suggest a large amount of cash outflow in the near future relative to short-run ability to pay. Generally a current ratio in the neighborhood of 2 to 1 is regarded as satisfactory. However, it must be emphasized that the proper level of the ratio varies significantly between firms and industries and should be regarded only as the first step in a detailed financial analysis. Table 3-49 illustrates that several firms, particularly Dow Chemical and General Electric, have relatively low current ratios, while the majority are well within the standard range.

3.2.5.4 Model Plants

Because data were unavailable on the production costs, profitability and cash flows of the six highly impacted product lines, costs for a model plant were estimated. These model production data will serve to characterize the present condition of the hypothetical typical plant for each product line.

The sizing of the model plants is discussed in Section 2.1.1.5 and the size selected for each model is displayed in Table 2-5. The actual production processes for which costs have been developed are considered the most common processes used in the production of each chemical by the Assessment Study. In the case of perchloroethylene, however, recent shifts in production techniques have caused a change to a process using ethylene instead of the acetylene identified in the Assessment Study.

It should be noted that the production costs for the model plants for each of the six highly impacted product lines are displayed in Tables 3-50 through 3-55. It should also be noted that the cost data presented are for representative plants. Plant size, process used, and the various estimated

TABLE 3–48

DIVIDEND PAYOUT RATIOS (%) OF SELECTED INDUSTRY FIRMS*

FIRM	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
Allied Chemical	40	43	28	37	50	64	77	49	–	76
American Cyanamid	55	49	45	56	58	63	65	62	65	79
Diamond Shamrock	24	23	21	36	59	88	74	92	77	54
Dow Chemical	27	21	16	32	43	52	59	52	52	49
DuPont	56	78	67	48	64	68	73	69	69	74
FMC	29	29	38	37	42	59	48	42		40
Monsanto	27	30	25	28	52	68	83	58	50	53
PPG	28	40	38	36	37	46	93	53	57	61
Stauffer	26	24	27	41	54	73	69	57	58	57
Union Carbide	35	38	25	44	58	79	75	67	77	71
Average	34.7	37.5	33.0	39.5	51.7	66.0	71.6	10.1	60.1	61.4

* Source: *Moody's Handbook of Common Stocks*, Summer 1977 Edition. Dividend payout ratio: dividends paid/net earnings.

TABLE 3–49

CAPITAL STRUCTURE FINANCIAL RATIOS, 1976*

FIRM	DEBT/ CAPITALIZATION**	DEBT/ EQUITY†	CURRENT RATIO††	DIVIDEND PAYOUT RATIO‡
Allied Chemical	0.29	0.47	2.0	0.40
American Cyanamid	0.27	0.38	2.3	0.55
Borden	0.26	0.37	2.2	0.37
Continental Oil Company	0.25	0.40	1.6	0.26
Dow Chemical	0.37	0.66	1.4	0.27
Dow-Corning	0.34	0.55	2.9	
Diamond Shamrock	0.36	0.66	1.9	0.24
E.I. DuPont de Nemours	0.22	0.32	2.4	0.56
Ethyl	0.33	0.55	3.4	0.20
FMC	0.33	0.53	1.8	0.29
General Electric	0.21	0.25	1.40	0.40
B.F. Goodrich	0.33	0.54	2.40	0.85
Occidental (Hooker)	0.39	0.71	1.5	0.36
Monsanto	0.27	0.41	2.9	0.27
PPG	0.29	0.46	2.7	0.28
Quaker Oats	0.24	0.34	2.0	0.37
Shell	0.19	0.26	1.5	0.28
Stauffer	0.37	0.68	3.1	0.26
Union Carbide	0.29	0.52	2.3	0.35
Uniroyal (Monochem)	0.40	0.74	2.3	0.88
Sohio (Vistron)	0.68	2.3	1.6	0.38
Vulcan	0.28	0.46	2.8	0.31

* Sources: *Moody's Handbook of Common Stocks,* Summer 1977 Edition, *Value Line Investment Survey, Chemical and Engineering News,* "Facts and Figures on the Chemical Industry," June 5, 1972, June 7, 1976, June 6, 1977.

** Long term debt/long term debt + preferred stock + deferred taxes + common equity + surplus.

† Long term debt/equity.

†† Current assets/current liabilities.

‡ Dividends paid/net earnings.

TABLE 3–50

MODEL PLANT FOR PRODUCTION OF PERCHLOROETHYLENE*

CAPITAL COST**

Plant	$10,800,000

OPERATING COSTS**

ITEM	BASIS (per lb of product)	$1,000/YR	$/LB
Ethylene	0.178 lb @ $0.0012/lb	1,610	0.0214
Chlorine	1.71 lb @ $0.0675/lb	8,683	0.1154
"Stabilizer"	l lb @ $0.0003/lb	23	0.0003
Steam	4.5 lb @ $0.002/lb	677	0.0090
Cooling Water	36 gal @ $0.05/1,000 gal	135	0.0018
Process Water	3 gal @ $0.30/1,000 gal	68	0.0009
Electricity	0.091 kWh @ $0.02/kWh	135	0.0018
Fuel	572 Btu @ $2.00/$10^6$Btu	83	0.0011
Refrigeration	171 Btu @ $12.50/$10^6$Btu	158	0.0021
Labor and Overhead	6/shift @ $25,000 man yr.	450	0.0060
Maintenance	6% of capital	648	0.0086
Depreciation	9% of capital	972	0.0129
Gross Return	25% of capital	2,700	0.0359
Total		16,342	0.2172

PRESENT MERCHANT MARKET VALUE†

Perchloroethylene	0.80/lb @ $0.1625/lb	9,783	0.1300
Trichloroethylene	0.20/lb @ $0.2075/lb	3,123	0.0415
HCl	0.85/lb @ $0.054/lb	3,454	0.0459
Total		16,360	0.2174

* Based on the following assumptions:
Model plant capacity: 86 million/yr (39,000 MT/yr)
Process: Toaglosei Chemical Company process from ethylene
Capacity utilization factor: 70%
Total annual production: 107.5 million/lb perchloroethylene and trichloroethylene

** Source: Energy Resources Company estimates.

† Source: *Chemical Marketing Reporter*, August 15, 1977.

TABLE 3–51

MODEL PLANT FOR PRODUCTION OF CHLOROMETHANES*

CAPITAL COST **

Plant	$9,800,000

OPERATING COSTS **

ITEM	BASIS (per lb of product)	$1,000/YR	$/LB
Steam	3.6 lb/lb @ $0.002/lb	554	0.0072
Cooling water	36 gal/lb @ $0.05/1,000 gal	139	0.0018
Power	0.16 kWh @ $0.02/kWh	246	0.0032
Chemicals and Supplies	$0.12/lb	92	0.0012
Methanol	0.37 lb @ $0.0637/lb	1,815	0.0236
HCl	0.80 lb @ $0.0775/lb	4,774	0.0620
Oper. Labor & Overhead	$100,000/shift x 3	300	0.0039
Maintenance	6% of capital	588	0.0076
Depreciation	9% of capital	882	0.0114
Gross Return	34% of capital	3,332	0.0433
Total		12,722	0.1652

PRESENT MERCHANT MARKET VALUE†

CH_3Cl	0.70 lb @ $0.15/lb	8,085	0.1050
CH_2Cl_2	0.15 lb @ $0.21/lb	2,425	0.0315
$CHCl_3$	0.10 lb @ $0.21/lb	1,617	0.0210
CCl_4	0.05 lb @ $0.15/lb	577	0.0075
Total		12,704	0.1650

* Based on following assumptions:
Model plant capacity: 400 million lb/yr (181,000 MT/yr)
Process: Chlorination of methane
Capacity utilization factor: 70%

** Source: Energy Resources Company estimates.

† Source: *Chemical Marketing Reporter*, August 15, 1977.

TABLE 3–52

MODEL PLANT FOR PRODUCTION OF EPICHLOROHYDRIN*

CAPITAL COST**

Plant $7,900,000

OPERATING COSTS**

ITEM	BASIS (per lb of product)	$1,000/YR	$/LB
Utilities	$0.024/lb	3,960	0.0240
Lime	1.0 lb/lb @ $0.015/lb	2,475	0.0150
Allyl chloride	1.04 lb/lb @ $0.28/lb	48,048	0.2912
Chlorine	0.90 lb/lb @ $0.0675/lb	10,032	0.0608
Labor and overhead	$0.01/lb	1,650	0.0100
Maintenance	6% of capital	474	0.0032
Depreciation	9% of capital	711	0.0048
Gross return	28% of capital	2,212	0.0134
Total		69,562	0.4224

PRESENT MERCHANT MARKET VALUE†

Epichlorohydrin	$0.44/lb	72,600	0.4400

* Based on following assumptions:
Model plant capacity: 165 million lb/yr (75,000 MT/yr)
Process: From allyl chloride
Capacity utilization factor: 90%
Note that ~69% of cost is due to allyl chloride which is usually made upstream by the same manufacturer.

** Source: Energy Resources Company estimates.

† Source: *Chemical Marketing Reporter*, August 15, 1977.

TABLE 3–53

MODEL PLANT FOR PRODUCTION OF VINYL CHLORIDE*

CAPITAL COST**

Plant	$22,000,000

OPERATING COSTS**

ITEM	BASIS (per lb of product)	$1,000/YR	$/LB
Chlorine	0.63 lb/lb VCM @ $0.1675/lb	11,475	0.0425
Ethylene	0.47 lb/lb VCM @ $0.125/lb	15,876	0.0588
Catalyst	$0.15/lb	405	0.0015
Net steam and fuel	0.0033 MM Btu/lb @ $2.00/MM Btu	1,782	0.0066
Cooling water	31 gal/lb @ $0.05/1,000 gal	432	0.0016
Electricity	0.1 kWh/lb @ $0.02/kWh	540	0.0020
Royalty	2% of capital	440	0.0016
Local taxes, insurance	1.5% of capital	333	0.0012
Oper. labor, supervision	7/shift @ $25,000/yr	525	0.0019
Overhead and admin.	50% of labor and maintenance	922	0.0034
Maintenance	6% of capital	1,320	0.0049
Depreciation	9% of capital	1,980	0.0073
Gross return	20% of capital	4,400	0.0163
Total		44,800	0.1496

PRESENT MERCHANT MARKET VALUE†

Vinyl chloride	1.0 lb @ $0.145 – $0.150/lb	43,500–45,000	0.1450–0.1500

* *Based on the following assumptions:*
Model plant capacity: 40 million lb/yr (18,000 MT/yr)
Process: B.F. Goodrich oxychlorination (Badger process) from ethylene and chlorine (includes EDC step)
Capacity utilization factor: 90%

** Source: *Energy Resources Company estimates.*

† Source: *Chemical Marketing Reporter,* August 15, 1977.

TABLE 3–54

MODEL PLANT FOR PRODUCTION OF ACRYLONITRILE*

CAPITAL COST**

Plant	$53,000,000

OPERATING COSTS**

ITEM	BASIS (per lb of product)	$1,000/YR	$/LB
Propylene	1.18 lb/lb @ $0.10/lb	42,480	0.1180
Ammonia	0.4 lb/lb @ $0.06/lb	8,640	0.0240
Catalyst	$0.0099/lb	3,564	0.0099
Utilities	$0.0264/lb	9,504	0.0264
Labor and overhead	$0.0099/lb	3,564	0.0099
Maintenance	5% of capital	2,650	0.0074
Depreciation	10% of capital	5,300	0.0147
Sales, R&D, admin.	$0.0094/lb	3,384	0.0094
Gross profit†	40% of capital	21,200	0.0589
Subtotal		100,286	0.2786
Acetonitrile credit	0.1 lb @ $0.24/lb	(8,640)	(0.0240)
Total		91,646	0.2546

PRESENT MERCHANT MARKET VALUE††

Acrylonitrile	1.0 lb @ $0.27/lb	108,000	0.2700

* Based on the following assumptions:
Model plant capacity: 400 million lb/yr (181,000 MT/yr)
Process: Sohio process
Capacity utilization factor: 90%

** Source: Energy Resources Company estimates.

† 50% tax rate.

†† Source: *Chemical Marketing Reporter,* August 15, 1977.

TABLE 3–55

MODEL PLANT FOR PRODUCTION OF FURFURAL*

CAPITAL COST**

Plant	$14,000,000

OPERATING COSTS**

ITEM	BASIS (per lb of product)	$1,000/YR	$/LB
Sulphuric acid	1.0 lb/lb @ $0.024/lb	864	0.024
Steam	16 lb/lb @ $0.0020/lb	1,152	0.032
Electricity	2.0 kWh/lb @ $0.02/kWh	1,440	0.040
Raw materials	$75/ton, 20% yield	6,750	0.188
Waste disposal	4 lb/lb @ $0.005/lb	720	0.020
Credits†	$0.045/lb	(1,620)	(0.045)
Operating labor	7/shift @ $24,000 man yr	504	0.014
Maintenance	4% of capital	560	0.016
Depreciation	9% of capital	1,260	0.035
Gross return	35% of capital	4,900	0.136
Total		16,530	0.460

PRESENT MERCHANT MARKET VALUE††

Furfural	1.0 lb/lb @ $0.47/lb	18,800	0.470

* Based on the following assumptions:
Model plant capacity: 40 million lb/yr (18,000 MT/yr)
Process: Hydrolysis of pentosans
Capacity utilization factor: 90%

** Source: Energy Resources Company estimates.

† From methanol and firing some of the waste under boilers.

†† Source: *Chemical Marketing Reporter*, August 15, 1977.

cost components will vary from plant to plant. However, assuming that all producers remain competitive, the model plants presented are believed to represent a reasonable basis for the development of process economics cost data to be used in the economic impact analysis.

NOTES TO CHAPTER THREE

1. Statistical Abstract of the U.S. 1976, Table 640, National income without capital consumption adjustments by industrial origin 1950-1975.

2. Moody's Industrial Manual, 1976.

3. Personal communication, Regis Schultis, Smith, Barney and Co., to John Eyraud, ERCO, September 1977.

4. Personal telephone communication, Tom Holcomb, Vulcan Materials, to Jeffery Stollman, ERCO, September 12, 1977.

5. ABS resins are manufactured from acrylonitrile, and currently represent only a small portion of the acrylonitrile end-use market. Within the limits provided by current capacities, a large increase in ABS resin production would require some decrease in the other uses of acrylonitrile.

6. Personal communication, Merlin Kennigy, Ethyl Corporation, to John Eyraud, ERCO, August 1977.

7. Chemical Marketing Reporter, September 19, 1977.

8. Chemical Marketing Reporter, September 19, 1977.

9. Personal communication, Diane Hamburger, Quaker Oats Company, to John Eyraud, ERCO, August 1977.

10. Furfural market charted. Chemical Marketing Reporter, July 21, 1975.

11. TRW, Inc., Assessment of industrial hazardous waste practices of the organic chemicals, pesticides and explosives industries, prepared for the U.S. Environmental Protection Agency, 1976.

12. TRW, Inc., Assessment study, 1976, p. 5-3.

13. Mr. Jim French, American Cyanamid; Mr. Jack Devoe, Allied Chemical; Mr. Web Fox, Diamond Shamrock; Mr. Rich Moeller, General Electric; Mr. Stan Paist, ERCO consultant.

14. Depreciation is subtracted from income before tax liability is calculated but it involves no cash outflow. Hence, it provides capital by reducing tax liability.

15. The technical definition of working capital is the difference between current assets and current liabilities.

16. U.S. Bureau of Census, Annual survey of manufacturers, 1968-77. Note that capital expenditure data were not available yet for 1975 and 1976. Accordingly, the average for all manufacturing contains data only for the 8-year period 1967-74.

15. The technical definition of working capital is the difference between current assets and current liabilities.

16. U.S. Bureau of Census, Annual survey of manufacturers, 1968-77. Note that capital expenditure data were not available yet for 1975 and 1976. Accordingly, the average for all manufacturing contains data only for the 8-year period 1967-74.

CHAPTER FOUR

THE COSTS OF COMPLIANCE

This chapter deals with the development of estimates for the costs to be incurred by producers of highly impacted chemicals in complying with expected hazardous waste regulations. The chapter consists of four sections.

Section 4.1 presents the estimates that will be used in the economic impact analysis presented in Chapter Five. Two sets of estimates were developed, a best estimate and a worst-case estimate. The best estimate of cost was derived for treating the waste streams of each product according to the use of proven current technology. In addition, a worst-case estimate of cost was also developed to account for unusual circumstances that could result in higher than average costs.

Section 4.2 presents the results of the technology assessments of potential hazardous waste treatment processes provided in the previous studies performed for EPA. A discussion is included of the comparability of these studies and of the choice of treatment to be used in the economic impact analysis. The cost estimates from these studies of implementing the hazardous waste treatment technologies are presented and analyzed in Section 4.3. In addition, the sensitivity of these estimates to the assumptions is reviewed, and the methodology used to generate the estimates of Section 4.1 is discussed. This chapter concludes with a short discussion in Section 4.4 of costs for hazardous waste treatment to be incurred by very small plants not included in available data sources.

4.1 Cost Estimates

In its evaluation of hazardous waste practices, the Assessment Study,[1] discussed in detail in Section 4.2, identified the following three levels of treatment and disposal technology:

Level I: Current average practice in the industry.

Level II: Best technology in commercial use at one or more plants.

Level III: Technology necessary to provide adequate environmental protection.

In certain cases, the technologies for two or all of these levels may be identical. In performing the economic analysis, Level III was assumed to represent compliance with the regulations addressed in this project. The costs of compliance are therefore the incremental costs incurred by each facility which has a hazardous waste stream to upgrade their existing waste treatment practice to Level III.

The Assessment Study and the Alternatives Study,[2] which are discussed in detail in Section 4.2, developed estimates of the costs of hazardous waste treatment for a number of significant production processes in the organic chemicals, pesticides, and explosives industries. These estimates were then subjected to review and comparative analysis in order to develop a best estimate of compliance cost for model plants producing each of the six highly impacted product lines. These best estimates are presumed to represent the most likely capital costs and total treatment costs per unit of product applicable to all plants in the industry. The estimates are the net costs of upgrading the hazardous waste treatment system from Level I (average current practice) to Level III (adequate for environmental protection).

The best estimates of compliance cost are presented in Table 4-1. The table shows that unit treatment cost ranges from less than $0.40/MT of acrylonitrile to over $7/MT of perchloroethylene. The table also shows these incremental costs as a percentage of merchant market price for each product line. Perchloroethylene appears to be hardest hit by treatment with abatement costs equal to 2.1 percent of price.

A sensitivity analysis revealed that the cost estimates presented in Table 4-1 were highly sensitive to a 25 percent uncertainty in the cost estimation procedure as well as site-specific factors, in particular the actual level of existing waste treatment at each plant. Accordingly, a second set of cost estimates was developed to yield an estimate of compliance costs for those plants potentially subject to a worst-case cost situation. The worst-case cost estimates presume that no waste treatment is currently practiced at the plant and that the full 25 percent cost uncertainty will be incurred in facility installation and operation.

The worst-case estimates of compliance costs are presented in Table 4-2. As can be seen from this table perchloroethylene remains the hardest hit product with

TABLE 4–1

BEST ESTIMATES OF TREATMENT COSTS*

INDUSTRIAL PRODUCT	MODEL PLANT SIZE (MT/yr)	LEVEL III TREATMENT TECHNOLOGY	ASSUMED EXISTING LEVEL I TREATMENT	CAPITAL INVESTMENT COST ($)**	COST PER MT OF PRODUCT ($)	% OF PRODUCT PRICE†
Perchloroethylene	39,000	Controlled Incineration	Landfill	1,178,000	7.69	2.1
Chloromethanes	50,000	Controlled Incineration	Chemical Landfill ††	184,000	0.59	0.2
Epichlorohydrin	75,000	Controlled Incineration	Landfill	866,000	2.03	0.2
Vinyl Chloride	136,000	Controlled Incineration	Landfill	860,000	1.22	0.4
Acrylonitrile	181,000	Controlled Incineration	Chemical Landfill ††	226,570	0.37	0.1
Furfural	18,000	Controlled Incineration	Landfill	1,140,700	1.95	0.2

* Energy Resources Company Inc. estimates based on costs from the *Alternatives Study*.

** Adjusted to a 1976 base year.

† Price sources from the CMR, 1976.

†† Not specified as environmentally adequate in *Assessment Study* because wastes are not detoxified or neutralized.

TABLE 4–2

WORST–CASE ESTIMATES OF TREATMENT COSTS*

INDUSTRIAL PRODUCT	MODEL PLANT SIZE (MT/yr)	COMPLYING TREATMENT TECHNOLOGY	CAPITAL INVESTMENT COST ($)**	COST PER MT OF PRODUCT ($)	% OF PRODUCT PRICE†
Perchloroethylene	39,000	Controlled Incineration	1,472,500	13.46	3.7
Chloromethanes	50,000	Controlled Incineration	230,000	1.70	0.5
Epichlorohydrin	75,000	Controlled Incineration	1,082,500	3.67	0.4
Vinyl Chloride	136,000	Controlled Incineration	1,075,000	1.75	0.6
Acrylonitrile††	181,000	Controlled Incineration	393,109	0.65	0.1
Furfural	18,000	Controlled Incineration	1,425,875	9.88	0.9

* Energy Resources Company Inc. estimates based on costs from the *Alternatives Study*.
** Inflated 25 percent to reflect overall engineering uncertainty.
† Source: *Chemical Marketing Reporter*, October 1976.
†† Original costs from the *Alternatives Study* were adjusted linearly to match the model size, and thus reflect no economies of scale.

abatement costs equal to 3.7 percent of price - nearly twice the best estimate ratio. The ratios for the other products have increased by similar magnitudes.

4.2 Technology Assessment

Three studies have been conducted for EPA to assess the technology applicable to hazardous waste treatment and disposal for the organic chemicals industry. These are:

1. Assessment of Industrial Hazardous Waste Practices of the Organic Chemicals, Pesticides and Explosives Industries by TRW, Inc. (referred to here as Assessment Study).

2. Analysis of Potential Application of Physical, Chemical and Biological Treatment Techniques to Hazardous Waste Management by Arthur D. Little Co. (referred to here as Techniques Study).[3]

3. Alternatives for Hazardous Waste Management in the Organic Chemicals, Pesticides and Explosives Industries by Processes Research Incorporated (referred to as Alternatives Study).

Each of these studies and their contributions to the economic analysis are discussed below. In addition, the Level III technologies chosen as representing compliance with the anticipated regulation are identified.

4.2.1 The Assessment Study

In addition to establishing the technology levels mentioned in Section 4.1, the Assessment Study serves three functions: (1) it provides a technical characterization of the production processes used in the organic chemicals, pesticides, and explosives industries; (2) it analyzes the hazardous waste streams that result from these processes and estimates the volumes produced; and (3) it assesses the applicability of the technologies and their costs for achieving Levels I, II, and III. The waste and process characteristics presented are not only the basis of the technology assessment presented in this report, but are also the basis of the Alternatives Study discussed in Section 4.2.3. A summary of the technology assessment is presented after a brief discussion of the study methodology.

The explosives industry and the pesticide formulation and preparation industry required special attention in the Assessment Study due to the difficulty of obtaining production and financial data. This difficulty has precluded detailed consideration of explosives or pesticide formulation industries in the current study. These industries and the data presented for them in the Assessment Study will not be discussed in this chapter. Technical organic pesticides, which fall under SIC 2869, are, however, included in the purview of this analysis.

The data sources for the Assessment Study included the open literature, prior EPA studies, industry and government sources, and prior TRW studies. The data search was keyed towards estimating production rates, processes used, waste quantities, waste components, waste stream destination, and waste hazard classification for individual components.

The chemicals considered were initially restricted by the following criteria:

1. Individual organic chemical compounds whose production in the United States was 10 million pounds per year or more.

2. Groups of closely related organic compounds for which production data were readily accessible, or for which group production was 10 million pounds per year or more.

3. Organic chemical compounds closely related to the compounds of (1) above.

4. Suspected carcinogens, 14 of which were not included under (1), (2), or (3) above.

5. Technical organic pesticides for which U.S. production was 1 million pounds per year or more.

These criteria limited the study to 899 plant sites and 373 chemicals, estimated to account for 90 percent of the total industry tonnage produced in 1973. For each of the 373 chemicals produced, detailed production process descriptions, including waste characterizations and volume generation factors, were developed and classified into general production process used. From this list, 26 chemical processes were chosen and a hypothetical typical plant was developed for each. This selection was made on the basis of the significance of a product and its waste streams, its national production volume, and the importance of the chemical products group it represented. For each of the 26 processes, a detailed analysis of the process and the wastes produced was performed, based on the hypothetical typical plant models which represented as closely as possible the actual plants in the industry. Wastes were characterized as highly dangerous, moderately dangerous, and other according to specific criteria, and estimates were made of 1973, 1977, and 1983 quantities of waste requiring land disposal.

In the Assessment Study, 15 of the identified processes were selected for analysis of applicable hazardous waste treatment technologies. The processes were chosen on the basis of waste stream volume and hazardous character. Each of the three levels of treatment/disposal technology was examined.

Table 4-3 presents the data on the 15 hypothetical typical processes chosen for technology assessment. These data were used as the basis of the cost estimations discussed in Section 4.3. Table 4-3 shows that Level III technology, with two exceptions (atrizine and trifluralin), is identical to Level II technology. This implies that technologies currently in use in at least one commercial application are sufficient to achieve adequate environmental protection. In particular, this fact applies to the five entries in Table 4-3 which were chosen for the economic analysis. The sixth product chosen, furfural, was not analyzed in depth in the Assessment Study.

It should be noted that the five products in Table 4-3 selected for economic analysis all require controlled incineration at Level III. Although this indicates that the six-product sample for economic analysis does not include a broad range of technologies, there are two good justifications for this selection. First, controlled incineration is by far the dominant Level III technology, as it is well suited to wastes in the organic chemicals industry. Second, controlled incineration is generally a more costly alternative than other potential Level III technologies. Thus, the economic costs are likely to be higher for those products requiring controlled incineration, and the ratio of abatement cost to product price - a surrogate criterion for economic impact - will consequently tend to be greater. By selecting these processes, therefore, attention will be focused on the areas of most significant impact.

A major drawback of the Assessment Study is that it deals with the standard, established technologies for hazardous waste management, primarily incineration and landfilling. However, the identified Level III technology might not be the best treatment option on either economic or environmental

TABLE 4–3

DATA FOR THE FIFTEEN HYPOTHETICAL TYPICAL PLANTS EXAMINED IN THE *ASSESSMENT STUDY**

INDUSTRIAL PRODUCT	SIC	TOTAL 1973 U.S. PRODUCTION (1,000 MT)	ANNUAL PRODUCTION OF THE MODEL PLANT (MT)	WASTE HAZARD	ANNUAL PRODUCTION OF WASTE BY THE MODEL (MT)	CONTROL TECHNOLOGIES		
						LEVEL I	LEVEL II	LEVEL III
Perchloroethylene**	28,692	320	39,000	Liquid Heavy Ends	12,000	Deep Well Injection	Controlled Incineration	Controlled Incineration
Nitrobenzene	28,651	140	20,000	Liquid Heavy Ends	50	On-Site Landfill	Controlled Incineration	Controlled Incineration
Chloromethanes**	28,692	1,115	50,000	Solid Tails	300	Contractor Landfill	Controlled Incineration	Controlled Incineration
Epichlorohydrin**	28,692	225	75,000	Liquid Heavy Ends	3,975	On-Site Storage	Controlled Incineration	Controlled Incineration
Toluene Diisocyanate	28,651	230	27,500	Residue Sludge	588	On Site Landfill	Controlled Incineration	Controlled Incineration
Vinyl Chloride**	28,692	2,432	136,000	Liquid Heavy Ends	1,400	Contractor Incineration	Controlled Incineration	Controlled Incineration
Methyl Methacrylate	28,692	320	55,000	Liquid Heavy Ends	4,730	Uncontrolled Incineration	Controlled Incineration	Controlled Incineration
Acrylonitrile**	28,692	614	80,000	Liquid Heavy Impurities	60	Uncontrolled Incineration	Controlled Incineration	Controlled Incineration
Maleic Anhydride	28,692	128	11,000	Sludge and Residue	333	Landfill	Secured Landfill	Secured Landfill
Lead Alkyls	28,692	506	60,000	Lead Sludge	30,000	Incineration with Lead Recovery	Controlled Incineration and Recovery	Controlled Incineration and Recovery
Atrazine	28,694	41	20,000	Alkali Scrubber Solution	224,600	Deep Well Disposal	Deep Well Disposal	Ozonation and Deep Well Disposal
Trifluralin	28,694	11	10,000	Solid Spent Carbon	1,150	Drum Storage	Trench Storage	Regeneration of Carbon
Aldrin	28,694	0	4,500	Area and Equipment	289,000	Lined Pond	Lined Pond	Lined Pond
Malathion	28,694	14	14,000	Filter Cake	1,826	NaOH Addition and Burial	NaOH Addition and Burial	NaOH Addition and Burial
Parathion	28,694	62	20,000	Sulfur Sludge	2,300	Uncontrolled Incineration	Secured Landfill	Secured Landfill

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency, 1976.
** Selected for the economic analysis.

grounds, if alternative control techniques are considered. The identification of alternative techniques was the goal of the Techniques Study, discussed in the following section. The applicability of these alternatives to the waste streams identified in the Assessment Study is analyzed in the Alternatives Study, which is discussed in Section 4.2.3.

4.2.2 The Techniques Study

The Techniques Study analyzed the potential applicability of 44 physical, chemical, and biological treatment techniques to hazardous waste management. The techniques were characterized according to current and likely future availability and according to the categories of waste for which they would most likely be applicable. Table 4-4 presents a list of the categories of potential availability. Eleven of the 44 techniques were classified as I or II and were not considered in the Alternatives Study as potential alternative hazardous waste treatment techniques for use by the organic chemicals, pesticides, and explosives industries. The 33 remaining techniques and their availability are presented in Table 4-5. The most promising techniques were analyzed in detail, and the data provided included the efficiency and engineering characteristics of the technique, the environmental characteristics, the energy use, and the impact on water use, in addition to its availability. These data were used in the Alternatives Study to determine the applicability and advantages of the techniques for treating hazardous wastes in the organic chemicals, pesticides, and explosives industries.

4.2.3 The Alternatives Study

In the Alternatives Study, a total of 20 waste streams (from 18 production processes)[4] were selected from the Assessment Study and analyzed in conjunction with 33 alternative treatment methods selected from the Techniques Study. The objective of the Alternatives Study was to identify attractive alternative treatments for each of the hazardous waste streams. The treatments were selected on the bases of (1) resource or energy recovery, (2) level of detoxification, (3) technical viability, and (4) economic feasibility. The study emphasizes that the practices of secure landfilling and controlled incineration, although they may be relatively inexpensive and can be made environmentally sound, are not always the best available technology. For each waste stream, the most attractive alternative treatment was chosen and analyzed. Table 4-6 presents the selected alternative treatments.

TABLE 4--4

CATEGORIES OF AVAILABILITY USED IN THE *TECHNIQUES STUDY**

NUMBER	DESCRIPTION	LEVEL OF CHARACTERIZATION IN REPORT
I	Process is not applicable in a useful way to wastes of interest to the OSW/HWMD program.	Category assignment.
II	Process may be available after 5-10 years of research.	Category assignment and a description of technical problems which need to be resolved.
III	Process is available or will soon be available and may provide attractive alternative for hazardous waste management.	Category assignment, description of technical problems, and projections of the applications to industrial wastes.
IV	Process is available and developed but not commonly used for hazardous wastes.	Category assignment, description of technical problems, and projections of the applications to industrial wastes.
V	Process will be common to most industrial waste processing practices.	Description of current applications and potential including costs, environmental effects, energy requirements, etc.

* Source: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries,* prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division, December 1976.

TABLE 4–5

33 ALTERNATIVE TECHNIQUES FROM THE *TECHNIQUES STUDY**

TYPE	TREATMENT	CATEGORY
Physical	Air Stripping	n.s.**
	Carbon Adsorption	n.s.
	Centrifugation	V
	Distillation	IV
	Evaporation	III
	Filtration	V
	Flocculation	n.s.
	Flotation	n.s.
	Ion Exchange	n.s.
	Resin Adsorption	III
	Reverse Osmosis	n.s.
	Sedimentation	V
	Solvent Extraction	III
	Steam Distillation	IV
	Steam Stripping	IV
	Ultrafiltration	II
	Crushing and Grinding	V
Chemical	Calcination or Incineration	V
	Catalysis	III
	Chlorinolysis	III
	Electrolysis	n.s.
	Hydrolysis	III
	Neutralization	V
	Oxidation (includes chlorination)	IV
	Ozonation	III
	Precipitation	n.s.
	Reduction (includes dechlorination)	IV
Biological	Activated Sludge	IV
	Aerated Lagoon	III
	Anaerobic Digestion	IV
	Composting	V
	Trickling Filter	n.s
	Waste Stabilization Pond	n.s.

* Source: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries,* prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division; December 1976.

** Not specified.

TABLE 4–6

MOST ATTRACTIVE ALTERNATIVE HAZARDOUS WASTE TREATMENT TECHNOLOGIES IDENTIFIED IN THE *ALTERNATIVE STUDY**

INDUSTRIAL PRODUCT	WASTE STREAM	ALTERNATIVE TREATMENT PROCESS	BENEFITS DERIVED
Perchloroethylene**	Liquid heavy ends	Distillation	Volume reduction, detoxification and materials recovery
Nitrobenzene	Liquid heavy ends	Steam distillation	Volume reduction, byproduct recovery
Chloromethanes**	Solid tails	Distillation	Volume reduction, byproduct recovery
Epichlorohydrin**	Liquid heavy ends	Solvent extraction	Volume reduction, product recovery
Toluene diisocynate	Residue sludge	Hydrolysis	Detoxification and product recovery
Vinyl chloride**	Liquid heavy ends	Distillation	Volume reduction and materials recovery
Methyl methacrylate	Liquid heavy ends	None	–
Acrylonitrile**	Liquid heavy impurities	None	–
Maleic anhydride	Sludge and residues	None	–
Lead alkyls	Lead sludge	Filtration	Volume reduction, detoxification and materials recovery
Ethanolamines	TEA and tars	Centrifugation or sedimentation	Materials recovery, low energy use, or volume reduction and detoxification
Furfural**	Sulfuric acid, tars and polymers, and fines and particulates	Sedimentation and Distillation	Volume reduction, product and materials recovery
Fluorocarbon	Chlorides and organics	Reduction or distillation	Materials recovery, low energy use, or volume reduction and detoxification
Chlorobenzene	Resins	None	–
Atrozine	Alkali scrubber	Neutralization	Detoxification, materials and byproduct recovery
Trifluralin	Solid spent carbon	Crushing and grinding	Volume reduction, byproduct recovery
Malathion	Filter cake and liquid wastes	Hydrolysis and sedimentation	Volume reduction, detoxification, materials and product recovery
Parathion	Sulfur sludge	Sedimentation	Volume reduction, materials recovery.

* Source: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries,* prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division; December 1976.

** Selected for economic analysis.

Most of the selected techniques involve significant advantages in reducing waste volume and in reclaiming and reusing economically valuable components in the waste stream. These techniques, unlike those characterized in the Assessment Study, have generally not been demonstrated in commercial use for the application suggested. For this reason, there may be some resistance in the industry against instituting the alternatives, especially in the case where no cost advantage over demonstrated Level III technologies exist. However, in those cases where a cost advantage exists, in particular for the industry segments subject to the largest impact, the alternative techniques will provide an opportunity for firms to reduce the impact of meeting environmental goals. In the cases where a significant cost advantage exists for the alternative due to the reclamation of valuable components, the alternative may be adopted throughout the industry. This result will reduce the impact of meeting environmental goals on the industry at the same time as it increases the recovery of valuable resources.

The Alternatives Study also examined the costs of standard treatment technologies such as incineration and landfilling. However, the large variations in costs estimated for similar technologies by this and the Assessment Study, discussed in Section 4.3.2, hint that the technical assumptions used may be quite different. Therefore, the technologies analyzed in the two studies may not be strictly comparable. For example, "controlled incineration" as specified in the Assessment Study is probably not identical to "incineration" as specified in the Alternatives Study. However, both incineration and the alternative treatments in the Alternatives Study are identified as adequate to protect the environment. In this study, they were therefore assumed to be appropriate Level III technologies, and the choice of which of the two studies to use for characterizing Level III technology was based on the choice of which cost estimates to use. These are discussed in Section 4.3.

An exception to this rule is furfural, which has two separate hazardous waste streams. The Alternatives Study presents two possible treatment alternatives which will adequately protect the environment, namely, incineration and a process utilizing sedimentation and distillation. The Assessment Study did not analyze hazardous waste treatments for furfural. Chemical landfilling was not considered to be adequate because it does not provide for detoxification or recovery of hazardous materials. The incineration alternative was chosen as the most likely technique to be adopted because it is an accepted and prevalent method for treating hazardous wastes and is considerably less costly.

The sedimentation and distillation treatment process is considered as an alternative which may be used in certain cases.

4.3 Cost Analysis

In addition to their technical assessment of hazardous waste treatment, the Assessment Study and Alternatives Study present data and estimates of the costs of the treatment technologies they investigated. The cost estimates developed are summarized in Section 4.3.1 and are analyzed in Section 4.3.2. Section 4.3.3 presents the methodology used to develop the best and worst-case estimates of the costs of compliance.

4.3.1 Cost Estimates

The cost estimates for achieving Levels I, II, and III using the standard technologies identified in the Assessment Study are presented in Table 4-7 for the 15 products covered. The corresponding costs estimated for the 23 products considered in the Alternatives Study for Level III technologies were not available in similar detail at the writing of this report. However, summary estimates, expressed as the treatment cost per metric ton of waste on a dry basis, are presented in Table 4-8.

While it can be expected that the Level III Alternatives Study costs for landfill and incineration should be very close to the Level III Assessment Study costs for the same products, this is not the case. The treatment and cost estimates from the two studies are presented in Table 4-9, and a significant divergence among the costs developed in each study is evident. A discussion of the bases for the estimations and an assessment of the comparability of the costs developed in the two reports are therefore required. In addition, an attempt must be made to identify sources of error and of uncertainty. These issues are addressed in the following section.

4.3.2 Comparative Analysis of Costs

Because of the striking differences in costs for similar treatments between the Assessment Study and the Alternatives Study, the bases for cost estimation used in each study were reviewed. Table 4-10 displays the assumptions used in each of the reports for the development of cost estimates. As can be seen from the table, the

TABLE 4–7

HAZARDOUS WASTE TREATMENT COST ESTIMATES IN THE *ASSESSMENT STUDY**

INDUSTRIAL PRODUCT	ANNUAL WASTE** PRODUCTION OF MODEL PLANT (MT)		COST ESTIMATES LEVEL I	LEVEL II	LEVEL III
Perchloroethylene	12,000	Treatment	Deep well injection	Controlled incineration	Controlled incineration
		Investment	$262,000	$7,080,000	Same as Level I
		Annual cost			
		Capital	26,200	108,000	
		Operating	74†,000	430,700	
		Energy	67,600	64,200	
		Total	167,800	602,900	
		Cost/metric ton of waste	16	57	
Nitrobenzene	50	Treatment	On-site landfill	Controlled incineration	Controlled incineration
		Investment	$27,000	$4,900	Same as Level II
		Annual cost			
		Capital	2,700	4,500	
		Operating	9,100	6,600	
		Energy	100	200	
		Contractor	0	0	
		Total	11,900	9,100	
		Cost/metric ton of waste	238	182	
Chloromethane solvents	300	Treatment	Contractor landfill	Controlled incineration	Controlled incineration
		Investment	$ 0	$170,000	Same as Level II
		Annual cost			
		Capital	0	17,000	
		Operations	7,100	95,900	
		Energy	0	1,100	
		Contractor	16,100	0	
		Total	23,200	114,000	
		Cost/metric ton of waste **	77	380	

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency; 1976.

** Based on dry weight .

† No credit for lead recovery.

†† Credit taken for regenerated carbons.

TABLE 4–7 (CONTINUED)*

INDUSTRIAL PRODUCT	ANNUAL WASTE** PRODUCTION OF MODEL PLANT (MT)		COST ESTIMATES		
			LEVEL I	LEVEL II	LEVEL III
Trifluralin	1,150	Treatment	Storage in drums	Storage in trenches	Regeneration of carbon
		Investment	$37,200	$34,400	$2,250,000
		Annual cost			
		Capital	3,700	3,400	225,000
		Operating	331,600	29,500	30,000
		Energy	0	0	0
		Total	335,500	33,900	267,000††
		Cost/metric ton of waste **	192	19	153
Parathion	2,300	Treatment	Uncontrolled incineration	Secured landfill	Secured landfill
		Investment	$130,700	$38,500	Same as Level II
		Annual cost			
		Capital	13,100	3,800	
		Operating	83,300	22,800	
		Energy	2,900	1,200	
		Contractor	0	0	
		Total	99,300	27,800	
		Cost/metric ton of waste **	43	12	
Malathion	1,826	Treatment	NaOH addition and burial	NaOH addition and burial	NaOH addition and burial
		Investment	$34,300	Same as Level I	Same as Level I
		Annual cost			
		Capital	3,400		
		Operating	28,100		
		Energy	800		
		Contractor	0		
		Total	32,300		
		Cost/metric ton of waste **	18		

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries,* prepared for U.S. Environmental Protection Agency; 1976.

** Based on dry weight .

† No credit for lead recovery.

†† Credit taken for regenerated carbon.

TABLE 4–7 (CONTINUED)*

INDUSTRIAL PRODUCT	ANNUAL WASTE** PRODUCTION OF MODEL PLANT (MT)		COST ESTIMATES		
			LEVEL I	LEVEL II	LEVEL III
Methyl methacrylate	4,730	Treatment	Uncontrolled incineration	Controlled incineration	Controlled incineration
		Investment	$114,500	$134,800	Same as Level II
		Annual cost			
		Capital	11,400	13,500	
		Operating	81,100	84,500	
		Energy	5,700	5,900	
		Contractor	0	0	
		Total	98,300	103,900	
		Cost/metric ton of waste**	21	22	
Acrylonitrile	60	Treatment	Uncontrolled incineration	Controlled incineration	Controlled incineration
		Investment	$4,100	$4,600	Same as Level II
		Annual cost			
		Capital	4,400	5,600	
		Operating	14,800	24,500	
		Energy	200	300	
		Contractor	19,400	31,400	
		Total	38,800	61,800	
		Cost/metric ton of waste	323	523	
Maleic anhydride	333	Treatment	Landfill	Secured landfill	Secured landfill
		Investment	$23,000	$30,700	Same as Level II
		Annual cost			
		Capital	2,300	$3,100	
		Operating	15,900	22,100	
		Energy	400	400	
		Contractor	0	0	
		Total	18,600	25,600	
		Cost/metric ton of waste	56	77	

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency; 1976.

** Based on dry weight

† No credit for lead recovery.

†† Credit taken for regenerated carbons.

TABLE 4–7 (CONTINUED)*

INDUSTRIAL PRODUCT	ANNUAL WASTE** PRODUCTION OF MODEL PLANT (MT)		COST ESTIMATES LEVEL I	LEVEL II	LEVEL III
Epichlorohydrin	3,975	Treatment	On-site storage	Controlled incineration	Controlled incineration
		Investment	$984,000	$934,000	Same as Level II
		Annual cost			
		Capital	98,400	93,400	
		Operating	102,900	753,900	
		Energy	100	2,400	
		Contractor	0	0	
		Total	201,400	849,700	
		Cost/metric ton of waste**	51	214	
Toluene diisocyanate	588	Treatment	On-site landfill	Controlled incineration	Controlled incineration
		Investment	$28,500	$349,000	Same as Level II
		Annual cost			
		Capital	2,900	34,900	
		Operating	35,600	90,100	
		Energy	100	2,400	
		Contractor	0	0	
		Total	38,600	129,400	
		Cost/metric ton of waste**	66	215	
Vinyl chloride	1,400	Treatment	Contractor incineration	Controlled incineration	Controlled incineration
		Investment	$ 0	$473,000	Same as Level II
		Annual cost			
		Capital	0	47,300	
		Operating	0	738,700	
		Energy	0	1,600	
		Contractor	266,500	0	
		Total	266,500	787,600	
		Cost/metric ton of waste	190	563	

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency; 1976.

** Based on dry weight .

† No credit for lead recovery.

†† Credit taken for regenerated carbons.

TABLE 4–7 (CONTINUED)*

INDUSTRIAL PRODUCT	ANNUAL WASTE** PRODUCTION OF MODEL PLANT (MT)		COST ESTIMATES		
			LEVEL I	LEVEL II	LEVEL III
Lead alkyls	30,000	Treatment	Incineration, Lead recovery	Controlled incineration Lead recovery	Controlled incineration Lead recovery
		Investment	$513,100	$613,900	Same as Level II
		Annual cost			
		Capital	51,300	61,400	
		Operating	269,300	285,400	
		Energy	228,500	228,800	
		Contractor	0	0	
		Total	549,100†	575,600†	
		Cost/metric ton of waste **	18†	19†	
Aldrin	289,000	Treatment	Lined pond	Lined pond	Lined pond
		Investment	$3,614,000	Same as Level I	Same as Level I
		Annual Cost			
		Capital	361,400		
		Operating	256,100		
		Energy	200		
		Contractor	0		
		Total	617,700		
		Cost/metric ton of waste **	2		
Atrazine	224,600	Treatment	Deep well disposal	Deep well disposal	Ozonation and Deep well disposal
		Investment	$235,200	Same as Level I	$779,200
		Annual cost			
		Capital	42,500		77,900
		Operating	75,800		139,200
		Energy	8,600		34,300
		Contractor	0		0
		Total	126,900		252,400
		Cost/metric ton of waste **	1		1

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency; 1976.

** Based on dry weight .

† No credit for lead recovery.

†† Credit taken for regenerated carbons.

TABLE 4–8

HAZARDOUS WASTE TREATMENT COST ESTIMATES FROM THE *ALTERNATIVES STUDY* *

INDUSTRIAL PRODUCT	ANNUAL WASTE PRODUCTION OF MODEL PLANT (MT)	ALTERNATIVE TREATMENT	TREATMENT COSTS ($/MT of Waste)			
			ALTERNATIVE TREATMENT	SANITARY LANDFILL	CHEMICAL LANDFILL	INCINERATION
Perchloroethylene	12,000	Distillation	20	10	48	35
Nitrobenzene	50	Steam distillation	1,324	98	157	–
Chloromethane	300	Distillation	230	97	128	226** 393†
Epichlorohydrin	3,975	Solvent extraction	(7)††	17	55	55
Toluene diisocyanate	588	Hydrolysis	260	97	156	206
Vinyl chloride	1,400	Distillation	24	17	67	136
Methyl methacrylate	4,730	–	–	17	76	22
Acrylonitrile	60	–	–	98	158	260** 148†
Maleic anhydride	333	–	–	98	166	323
Lead alkyls	30,000	Filtration	27‡	7‡	61‡	–
Ethanolamines	1,120	Centrifugation or sedimentation	69 30	18	77	102
Furfural	19,600	Sedimentation	68	8	70	9
Furfural	350	Distillation				136
Fluorocarbon	18	Reduction or distillation	2,500 (670)††	98	117	–
Chlorotoluene	15	–	–	73	156	–
Chlorobenzene	1,400	–	–	17	70	82
Atrazine	224,600	Neutralization	2	6	69	–
Trifluralin	1,150	Crushing and grinding	437	18	326	104
Aldrin	289,000	–	–	–		–
Malathion	1,826	Hydrolysis	72	18	326	73
Malathion	350 (solids)	Sedimentation	(12)††	18	76	167
Parathion	2,300	Sedimentation	51	17	70	58
Explosives	200 (solids)	Solvent extraction	667	–	–	1,120
Explosives	15,000	Incineration and selide recovery	101	–	–	183
Explosives	250	Crushing and grinding, wet oxidation or reduction	992 1,470	–	–	895

* Source: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries*, prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Division December 1976.

** Assuming one shift

† Assuming two shifts

†† Figures in parentheses indicate credits.

‡ No credit for lead recovered

TABLE 4–9

COMPARISON OF COST ESTIMATES FOR SIMILAR TREATMENTS FROM THE *ASSESSMENT STUDY* AND THE *ALTERNATIVES STUDY* *

	INCINERATION** COST (\$/MT of waste)		LANDFILL† COST (\$/MT of waste)	
PRODUCT	*ASSESSMENT STUDY*	*ALTERNATIVES STUDY*	*ASSESSMENT STUDY*	*ALTERNATIVES STUDY*
Perchloroethylene	57	35	–	48
Nitrobenzene	182	–	238	157
Chloromethanes	380	393	77	128
Epichlorohydrin	214	55	–	55
Toluene diisocyanate	215	206	66	156
Vinyl chloride	563	136	–	67
Methyl methacrylate	22	22	–	76
Acrilonytrile	523	260	–	158
Maleic anhydride	–	323	77	166
Parathion	–	57	12	70

* Source: Tables 4–7 and 4–8.
** Assumed to be controlled.
† Assumed to be chemical landfill (secured).

TABLE 4–10

COMPARISON OF COST–ESTIMATING ASSUMPTIONS FROM THE *ASSESSMENT STUDY* AND THE *ALTERNATIVES STUDY*

ITEM	*ASSESSMENT STUDY* *	*ALTERNATIVES STUDY* **
Base year	1973	1976
Technical specifications of technologies	Defined as Level II	Not defined†
Component cost assumptions		
Cost of capital	10% of capital	10 % of capital
Depreciation	Straight line	Straight line
Estimated lifetime – lagoons	25 yr	10 yr
– mobile equipment	5 yr	10 yr
– all else	10 yr	10 yr
Salvage value considered	Yes	No
Engineering costs	n.s.††	10% of capital
Contingency	n.s.	20% of capital plus engineering
Land	$6,000/acre	$5,000/acre
Taxes and insurance	n.s.	4% of installed capital
Maintenance	6% of investment	4% of installed capital
Labor	$7.50/hr	$9/hr
Supervision	Included in labor	50% of labor
Incineration air use	125% of stoichiometric	n.s.
Sodium hydroxide use in scrubbers	110% of stoichiometric	n.s.
Waste/supplies freight distance	250 mi	n.s.
Unit Costs		
Electricity	$0.02/kWh	$0.03/kWh
Freight	$32/ton	n.s.
Sodium hydroxide	$114/ton	n.s.
Activated carbon	$0.30/lb	n.s.
Fuel oil	$2.04/MBtu	$2.00/MBtu
Utility water	$0.30/1,000 gal	$0.30/1,000 gal
Boiler feed water	n.s.	$0.50/1,000 gal
Institutional air	n.s.	$20/M scf
Steam	n.s.	$4/1,000 lbs
Clay	$8/ton	n.s.
55 gal steel drums	$15 ($7.50 used)	n.s.
Concrete	$20/yd^3	n.s.
Excavation	$0.68/yd^3 (shallow) $1.98/yd^3 (deep)	n.s.
Surface finishing	$0.37/yd^2	n.s.

* Source: TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries,* prepared for U.S. Environmental Protection Agency, 1976.

** Sources: Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries,* prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Programs; December 1976; and conversation, Alexandria Tierney, EPA, with G. Gantz, ERCO, June, 1977.

† Final report not available at this writing.

†† Not specified.

three predominant differences in the cost estimates from the Assessment Study and the Alternatives Study result from (1) different time bases, (2) different definitions of the technical requirements for similar treatments, and (3) different component cost assumptions and costing procedures.

The time bases are not a significant problem, as the cost data can be updated in a reasonably accurate manner using a standard cost index for updating the older Assessment Study costs. However, this tends to introduce further error in the analysis and should be avoided if possible.

The definitions of the technical requirements for similar treatments are not explicitly identified in either of the two studies, but the large cost variability evident in Table 4-9 implies that significant differences are likely. It is beyond the scope of this study to determine which treatments reflect a more accurate interpretation of the requirements for environmental protection. According to the claims made in these two studies, the Level III technologies from the Assessment Study and incineration and the alternative treatments from the Alternatives Study will provide adequate protection of the environment.

Both the Assessment Study and the Alternatives Study used cost estimating procedures which were based on an engineering design analysis of the specified waste treatment technology applied to the hypothetical typical plants. Detailed estimates were derived for capital, operating, and energy costs of the treatment facilities, and were summarized by calculating the cost of the treatment per metric ton of waste on a dry basis. These procedures should yield comparable results if they are based on comparable component cost assumptions.

Although many of these assumptions (displayed in Table 4-10) are the same (e.g., the cost of capital), the two sets of assumptions do exhibit some differences. These differences may be attributable to several different factors. For example, the higher costs assumed for labor in the Alternatives Study may be due to the need for more highly trained personnel. Also, the apparent difference in the equipment lifetime estimates used in the depreciation calculations can be attributed to the fact that the Alternatives Study does not examine lagoons or landfills with the same detail as does the Assessment Study. For all other treatment and disposal methods, the two studies are in accord with equipment lifetimes estimated at 10 years.

Some of the disparity in assumptions reflects fluctuations in contractor and supplier price estimates which resulted from cost changes due to time, location, and individuals contacted. For this reason, an attempt was made to verify the unit cost assumptions used by contacting independent contractors in the hazardous waste management industry. In general, there was close agreement between estimated item costs and quoted prices. However, substantial disagreements between total costs for hazardous waste treatments were prevalent. Table 4-11 presents a comparison of data from two independent sources with the assumptions used in the Alternatives Study and Assessment Study. The wide range and disparity among total treatment costs shown in this table for incineration or landfill are due to the variable requirements for different types of waste. Factors impacting the total cost include (1) whether the wastes are in small batches or bulk, (2) whether flue gas scrubbing and stack monitoring are required, (3) the amount of fuel required for incineration, (4) the requirements for handling and transporting the waste, (5) the methods required to protect the environment, etc. These parameters vary so widely that no significant conclusions can be drawn from the data in Table 4-11.

With respect to the component costs presented in Table 4-10, the most variant cost is for land. In the case of New England, the estimated cost is 3 to 4 times higher than the costs assumed in the two studies. This fact is understandable, however, as land is currently at a premium in New England, particularly for unpopular uses such as landfilling. The New England costs for fuel and water are also higher on average than national costs. But on the whole there is general agreement between the four estimates tabulated in Table 4-11. (Because New England hosts only a small segment of the organic chemicals industry, this regional disparity will have little effect on the industry at large.)

One difference between the two sets of assumptions in Table 4-10 which cannot be explained as being due to variations in contractor estimates or in the technologies being considered is the figure for maintenance costs. The Assessment Study uses 6 percent of installed costs and the Alternatives Study uses 4 percent. Although the difference does not alter the total estimated costs too greatly, the change has raised objections from industry sources.[5]

It can be seen that the hazardous waste treatment cost estimates are based upon varying assumptions and do not necessarily indicate faulty methodologies. The methods used in the Assessment Study and the Alternatives Study are both

TABLE 4–11

COMPARISON OF HAZARDOUS WASTE TREATMENT COSTS

COST COMPONENT	*ASSESSMENT STUDY*	*ALTERNATIVES STUDY*	HAZARDOUS WASTE FACILITY*	HAZARDOUS WASTE FACILITY**
Treatments				
Incineration (controlled)	∿ $200/MT average	∿ $135/MT average	$80/MT (no scrubbers)	$22 to $102/MT
Chemical Landfill	∿ $30/MT average	∿ $90/MT average	$80 to $220/MT	–
Item Cost				
Land	$6,000/acre	$5,000/acre	$20,000/acre	$3,000 to $20,000/acre
Transportation	$35.30/MT (250 m)	–	$31.25/MT (500 m) or $62.50/MT (with return)	–
Electricity	$0.02/kWh	$.03/kWh	$0.03/kWh	$0.03 to $o.035/kWh
Oil (No. 2 Fuel)	$2.04/MBtu	$2.00/MBtu's	$2.86/MBtu	–
55-gal Drums	$15 new, $7.50 used	–	$16 new, $8 used	–
Activated carbon	$0.30/lb	–	–	$0.35 to $0.50/lb
Water	$0.30/1,000 gal	$0.30/1,000 gal	$.50/1,000 gal	–

* Source: Don Corey, Recycling Industries, Inc., Braintree, Massachusetts.
** Source: Ed Ashby, Rollins Environmental Services, Inc., Swedesborough, New Jersey.

standard acceptable methods, but the estimates will still diverge from costs incurred in the development of treatment at actual sites. It is generally accepted that these methods will provide estimates in the reasonable range of costs for actual plants and specific treatments, but that they can be relied upon to be accurate within only 25 percent.[6] This 25 percent uncertainty accounts for uncertainties in engineering design, in details of financing, in site-specific problems, and in cost-estimating assumptions. For the purpose of the present study, 25 percent will be used as the estimated margin of error for the cost estimates developed. A thorough analysis of uncertainty and of the errors in the data is beyond the scope of this study.

On the basis of this analysis, no overriding factors were uncovered which would indicate which set of cost estimates should be used for the economic analysis. The decision was therefore based on three considerations which differentiate between the two studies. First, the Assessment Study estimates were based on a 1973 base year and error would be introduced by updating these to 1976. Second, using cost estimates from one and not both studies would insure that the economic impact study results would be comparable. Third, the Alternatives Study estimates were developed with cognizance of the Assessment Study and this earlier study was reviewed as an input to the Alternatives Study. For these reasons, the cost estimates from the Alternatives Study were chosen for use in developing the costs of compliance estimates.

4.3.3 Cost Estimating Methodology

4.3.3.1 Best Estimates of Cost

The best estimates of treatment costs for the institution of Level III technology for the six highly impacted industry segments must be based on (1) the best choice of treatment and (2) the best estimates of costs for that treatment. The choice of treatment in all six cases must be made between incineration and the alternative technology specified in the Alternatives Study, in accordance with the choice of best cost estimates made in the previous section.

Incineration was chosen as the disposal technique to be employed for the economic analyses because it is standard accepted practice for hazardous waste disposal and will probably be chosen by most firms attempting to achieve Level III environmental protection. Although the alternative treatment technology may eventually be used in many facilities, it has not as yet been proven commercially.

The only major calculation required to generate best estimates of the costs of compliance from the Alternatives Study estimates was to determine the credit for costs currently incurred for waste treatment. That is, the costs of compliance are actually the costs of upgrading the treatment system from current levels to Level III.

For the purpose of crediting existing waste treatment expenditures, it was assumed that all manufacturers currently used Level I technology (Level I is defined as current average industry practice), and that the cost burden of meeting Level III requirements is equal to the incremental cost of going from Level I to Level III. This assumption is justified because most Level I costs are operating charges rather than costs for plant and equipment. Therefore, there are no sunk costs and the present level of labor and other variable expenditures can be applied to the variable portions of Level III costs. Level I technology was assumed to be the existing treatment methods identified in the Alternatives Study. These methods in all six cases were either sanitary or chemical landfill. In two cases, perchloroethylene and epichlorohydrin, the existing method specified was chemical landfill, which was estimated as equal to or more expensive than incineration. In these cases, the conservative choice of sanitary landfill as the Level I technology was made so that an impact of some kind would be estimated for these industry segments.

One factor remains to be considered in developing best estimates of the costs for compliance with Level III requirements. This factor is the relative size of the hypothetical typical plant used in the cost estimations in the Alternatives Study compared to the model plant size chosen for the economic analysis. These sizes are the same for four of the selected industry segments, as discussed in Chapter Two. In the case of acrylonitrile, the hypothetical typical plant is smaller than the model plant and in the case of furfural, it is larger. The treatment cost data should be adjusted to reflect the fact that larger plants benefit from the economies of scale. The standard six-tenths rule was used for adjusting the cost estimates for the change in size. This rule states that a change in plant size will change the annual costs according to the formula:

$$\text{new cost} = \text{old cost} \cdot (\text{new size}/\text{old size})^{0.6}$$

Therefore, the new treatment cost per ton for acrylonitrile is somewhat lower, reflecting the benefits of the larger-sized plant. The new treatment cost per ton for furfural is somewhat higher due to the decrease in plant size.

4.3.3.2 Worst-Case Cost Estimation

The best estimates of costs of compliance for hazardous waste treatment are reasonable, conservative estimates given the constraints discussed in Section 4.3.2. However, the cost estimates cannot be totally relied upon as reflections of the actual costs to be faced by plants on an individual basis. Because it is important to assure that the economic analysis is sensitive to the most severe impacts that may occur in actual practice, the economic analysis will also include an assessment of impact using worst-case costs. It is presumed that using these worst-case costs will serve as an accurate indication of the maximum potential of economic impact on plants that are most strongly affected. This assessment will be based on worst-case cost estimates for Level III treatment technology. In particular, these estimates will be used in the plant closure analysis presented in Chapter Five.

There are several factors which exhibit considerable uncertainty and which must therefore be incorporated into the worst-case cost estimates. One of these factors is the present status of waste treatment at a facility. Not all plants can be expected to be spending at a level equal to the costs of Level I technology. Many plants may have no treatment at all. Therefore, the worst-case cost estimates should presume a zero cost baseline and reflect the full cost of Level III. Another factor to be considered is the uncertainty of the engineering estimates. These estimates are reported to be accurate to within 25 percent; therefore, the best estimate should be inflated by 25 percent to reflect the worst possible case. This adjustment provides a considerable safety margin for the worst-case estimate.

One other factor must be considered that applies only to the acrylonitrile industry. Since the Alternatives Study's hypothetical typical plant is smaller than the economic analysis model plant, the original cost estimates for treatment at this plant would tend to be pessimistic. This is the result of the fact that the industry is actually composed of larger plants which benefit from economies of scale for waste treatment technology. Although the original treatment cost estimates were adjusted to reflect this fact in developing best estimates, the adjustment introduced a potential for error and need not be made for the worst-case cost estimates. By using the original costs (but inflated linearly to match the size of the model plant), an extra margin of error is incorporated at the same time that a potential source of error is avoided. This argument does not apply to furfural, however, as the economic analysis model plant is smaller than the hypothetical typical plant and the diseconomy of a smaller scale must be reflected in the cost estimates. Therefore, the costs were scaled for the worst-case estimate just as they were for the best estimate.

4.4 Small Plant Costs

This report includes data only for those plants producing 1,000 pounds of product annually (0.45 MT/year) or more. As can be surmised from the capacity figures in Table 2-4, the production levels of plants producing highly impacted chemicals are 3 orders of magnitude above this cutoff. It is therefore unlikely that any plants below the 1,000-pound cutoff are producing these products economically, if at all.

It is possible that a small plant whose entire production is captively used may exist, however. Even though economic reasoning would predict that no plants exist in this small range, unique circumstances may exist that keep such a plant operating. These plants are still subject to regulation and will be forced to deal with their hazardous waste streams. It is presumed that all such small plants will deal with their waste streams in the same way - storage of wastes in sealed drums and eventual landfill.

The volume of wastes expected from the largest possible plant in the small-plant category (1,000 lb/year) is displayed in Table 4-12. It can be seen from the table that the annual waste streams from the operations of small plants will require less than two 55-gal drums per year and, for three of the six products, one drum will last a plant lifetime. For the remaining products, drums can be stored at the plant site until a truckload accumulates, whereupon they can be delivered to a chemical landfill. It is estimated that the total annualized cost for this process will range from $1 to $30 annually.

TABLE 4–12

EXPECTED WASTE VOLUME FROM A 1,000 LB/YR PLANT
FOR EACH HIGHLY IMPACTED PRODUCT LINE

PRODUCT	ESTIMATED WASTE (lb) *	ESTIMATED WASTE VOLUME (gal)
Perchloroethylene**	308	37
Chloromethanes**	6	1
Epichlorohydrin**	53	6
Vinyl Chloride**	3	1
Acrylonitrile**	0.75	1
Furfural†	559	66

* Assuming specific gravity of 1.0 for waste.

** TRW, Inc., *Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides and Explosives Industries*, prepared for U.S. Environmental Protection Agency; 1976.

† Processes Research, Inc., *Alternatives for Hazardous Waste Management in the Organic Chemical, Pesticides and Explosives Industries*, prepared for Office of Solid Waste Management Programs, Hazardous Waste Management Programs; December 1976.

NOTES TO CHAPTER FOUR

1. TRW, Inc., Assessment of industial hazardous waste practices of the organic chemicals, pesticidies and explosives industries, prepared for the U.S. Environmental Protection Agency, 1976.

2. Processes Research Inc., Alternatives for hazardous waste management in the organic chemicals, pesticides and explosives industries, Draft Report prepared for the U.S. Environmental Protection Agency, 1977.

3. A.D. Little, Inc., Analysis of potential application of physical, chemical and biological treatment techniques to hazardous waste management, prepared for the U.S. Environmental Protection Agency, 1976.

4. Three additional waste streams from the explosives industry were also selected.

5. Personal communication, Alexandria Tierney, EPA/OSW/HWMD, to George Gantz, ERCO, June 1977.

6. Personal communication, Dr. Gerald Gruber, TRW, Inc., to George Gantz, ERCO, June 1977.

CHAPTER FIVE

ECONOMIC IMPACT ANALYSIS

This chapter presents the analysis of the economic effects on the organic chemicals industry of promulgating hazardous waste regulations. The analysis focuses on the six highly impacted segments, namely (1) perchloroethylene, (2) chloromethanes, (3) epichlorohydrin, (4) vinyl chloride, (5) acrylonitrile, and (6) furfural. The impacts on each of these segments are reviewed in detail using a model plant analysis. The results of this analysis are then supplemented with actual industry data for a final assessment of projected impacts. These analyses are followed by more general analyses of impacts on the industry as a whole. The analyses of the highly impacted segments are believed to provide an upper bound on impacts on the entire organic chemicals industry. The chapter concludes with an assessment of the aggregate impacts on the nation.

The regulations in general will require small expenditures for hazardous waste treatment and disposal relative to the manufacturing costs of organic chemicals and financing these investments should not present a problem. In addition, industry-wide costs will be reduced because some firms have already instituted sufficient treatment and disposal techniques for compliance with potential regulations at many of their plants. These abatement leaders have not suffered noticeable impact from their investment in treatment and disposal facilities. Table 5-1 presents a summary of the total costs of compliance that the industry is expected to incur. The table shows that while the incremental annualized cost of abatement totals $137 million, this represents only 0.6 percent of the value of shipments for the industry. The inflationary effect of this cost increase will be reflected in a barely perceptible (0.01 percent) increase in the Wholesale Price Index for all commodities.

Within the industry, however, costs may range from zero percent of the shipment value to over 10 percent for some plants producing particular chemicals. Table 5-2 displays estimates of the percentage increase in manufacturing costs for the six-product highly impacted sample. The table includes estimates for two scenarios of compliance costs. The best estimate of cost is a conservative estimate of the cost increases to be incurred by an average plant. The worst-case cost estimates represent an upper bound for cost increases incurred by the hardest hit plants in the industry.

TABLE 5–1

THE IMPACTS OF COMPLIANCE FOR THE ORGANIC CHEMICALS, PESTICIDES AND EXPLOSIVES INDUSTRIES

Estimated incremental annual cost (S million)*	137
Total annual cost (S million)**	243
Estimated incremental annual cost/value of shipments (1973)†	0.6%
Total annual cost/value of shipments (1973)	1.1%
Increase in wholesale price index for all commodities††	0.011%

* Source: Energy Resources Company Inc. estimates.
** Source: *Assessment Study.*
† Source: U.S. International Tariff Commission.
†† Source: U.S. Bureau of Labor Statistics.

TABLE 5–2

ESTIMATED PERCENTAGE INCREASE IN MANUFACTURING COST DUE TO COMPLIANCE FOR SIX HIGHLY IMPACTED SEGMENTS*

	TREATMENT COST SCENARIO	
HIGHLY IMPACTED SEGMENT	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
Perchloroethylene	3.1	5.0
Chloromethanes	0.2	0.6
Epichlorohydrin	0.2	0.4
Vinyl chloride	0.4	0.6
Acrylonitrile	0.1	0.2
Furfural	0.3	1.4

*Source: Energy Resources Company Inc. estimates.

As can be seen from the table, the cost increases for five of these six product lines (selected because of their high vulnerability to impact) are not large. Only perchloroethylene, with a best estimate cost increase of 3.1 percent and a worst-case cost increase of 5.0 percent, stands out as highly vulnerable to cost impacts of the regulation.

In-depth analysis of these six segments revealed that plant shutdowns are unlikely to result from hazardous waste regulations except for plants particularly vulnerable to other market pressures. Table 5-3 displays a summary of the vulnerability of plants to shutdown due to regulation. The table shows that three perchloroethylene plants may cease operations with the addition of hazardous waste costs to their already vulnerable market positions. The chloromethane plant that is designated as vulnerable to the regulation is one of the three perchloroethylene plants so designated. This plant utilizes a joint perchloroethylene/carbon tetrachloride production process so that carbon tetrachloride (one of four chloromethanes) production would cease if the perchloroethylene plant closed. The two vinyl chloride plants subject to possible shutdown are faced with marginal competitive positions and hazardous waste regulations will serve only to aggravate their difficulties. The regulations alone should not be sufficient to cause the plants to close, but combined with significant expected market shifts caused by competitors building new larger and more efficient plants, the future of these two facilities is in question.

5.1 Economic Impact Analysis of the Six Highly Impacted Segments

5.1.1 Perchloroethylene

The perchloroethylene market will be the hardest hit of the highly impacted chemical markets. Perchloroethylene has the highest cost/price ratio of the products for which cost data were developed and has the highest estimated price elasticity of demand of the highly impacted products. Additionally, the perchloroethylene market is suffering from strong foreign competition, carcinogenicity concerns, and a slow rate of demand growth.

5.1.1.1 Model Plant Analysis

Price Elasticity of Demand. The market conditions that perchloroethylene is subjected to cause it to have the highest price elasticity of demand of the market

TABLE 5–3

SUMMARY OF IMPACTS ON PLANTS PRODUCING HIGHLY IMPACTED CHEMICALS*

HIGHLY IMPACTED SEGMENTS	NO. OF PLANTS IN SEGMENT	NO. OF PLANTS SUBJECT TO SMALL IMPACT	NO. OF PLANTS SUBJECT TO SIGNIFICANT IMPACT (SHUTDOWN POSSIBLE)
Perchloroethylene	11	8	3
Chloromethanes	19	17	2
Epichlorohydrin	3	3	0
Vinyl chloride	15	13	2
Acrylonitrile	6	6	0
Furfural	4	4	0
TOTAL OF SIX SEGMENTS	57**	51	6**

* Source: Energy Resources Company Inc. estimates.

** Totals are less than the sum of entries because of Stauffer's coproduct perchloroethylene/chloromethanes (carbon tetrachloride) plant, which is counted in both segments. Other coproduct processes are colocated with separate chloromethane plants circumventing double counting.

segments studied. In Table 5-4 the components of the perchloroethylene market are presented with an estimate of their influence on a baseline price elasticity of 1.0. From the table it has been estimated that the price elasticity for perchloroethylene is high (between 1.0 and 2.0). This is due in part to the fact that perchloroethylene is unique among the highly impacted products since it is sold primarily as a final product rather than as an intermediate. Consumers of intermediate chemicals frequently find that they must redesign or retool their process equipment if they switch to another intermediate chemical. However, the consumers of perchloroethylene, principally dry cleaning establishments, would be able to switch to another product without such retooling. There are presently only fair substitutes for perchloroethylene, as noted in Table 5-4, but fears concerning the carcinogenicity of the chemical may serve as an impetus to the development of an adequate replacement. In the short run, the price elasticity of demand facing domestic producers is also increased by the substantial import volumes of the chemical. Imports are an unsteady influence given the tendency for import volumes to fluctuate. But in the near term, imports which utilize surplus chlorine generated in European caustic soda production are expected to apply continued pressure to the domestic market.

Likelihood of Full-Cost Passthrough. The high price elasticity of demand combined with the high cost of hazardous waste treatment make a full-cost passthrough unlikely for this industry. The size of the required cost increase shown in Table 5-5 along with the principal competitive influences which may inhibit a cost passthrough. The estimates of treatment costs, calculated as a percentage of unit manufacturing costs for the model plant, are the largest of the highly impacted segments. Both the best estimate of abatement costs (3.1 percent) and the worst-case cost estimate (5.0 percent) are more than twice that of any other highly impacted chemical. Price increases of this magnitude would result in a significant loss of sales for firms, given the high price elasticity of demand. This decline in demand will reduce production, thereby lowering capacity utilization and further injuring profitability. The relatively low capacity utilization rate is significant because it makes a firm reluctant to be a price leader. Price leadership exposes a firm to the risk of a still greater loss of production volume if other firms do not follow price increases. As described in Section 3.2.2.2 above, if other firms remain at the old price, they may gain some of the price leader's market share. The loss of customers and the resulting lowering of the capacity utilization rate lowers the manufacturer's profit margins. At this writing, perchloroethylene manufacturers were

TABLE 5–4

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR PERCHLOROETHYLENE

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth Historical Projected	Low 1965–75: 6%/yr Through 1980: 3% to 4%/yr	Increase
Captive usage	0% to 15%—Low	Increase
Use as intermediate	Low	Increase
Significance of price as basis for competition	High	Increase
Substitutability	Moderate	Neutral
Foreign competition	Substantial imports	Increase

PRICE ELASTICITY ESTIMATE: High (1.0 to 2.0).**

* Source: Chapter Three.
** Source: Energy Resource Company Inc. estimates.

TABLE 5–5

LIKELIHOOD OF FULL-COST PASSTHROUGH FOR PERCHLOROETHYLENE*

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL COST PASSTHROUGH
Price elasticity of demand	High (1.0 to 2.0)	Decrease
Variation in abatement costs among firms	Moderate	Neutral
Required cost increase as % of manufacturing cost	Large	Decrease
Best estimate	3.1%	
Worst-case	5.0%	
Expected capacity utilization	60% – Low	Decrease

LIKELIHOOD OF FULL-COST PASSTHROUGH: Poor; incomplete cost passthrough for some firms.

* Source: Energy Resources Company Inc. estimates.

already operating with extremely slim profit margins. Any price increase is likely to be limited to that absolutely necessary for firms to avoid operating at a loss.

Net Income and Investment Analysis. The calculation of net income figures indicates that even after abatement cost increases the model plant manufacturers would continue to operate in this industry. The calculations were based on an assumed operating rate of 70 percent of capacity in order to reflect the market uncertainties for the industry. (A 90 percent capacity utilization rate is usually desired.) The model plant achieves profitability in all the cases examined, as presented in Table 5-6. The large treatment costs, however, do cause a fall in net income of 8 percent in the best estimate case and 14 percent in the worst-case scenarios.

The investment analysis, displayed in Table 5-7, indicates that the model plant would make the required treatment investment. Cash flows for the best estimate and worst-case scenarios are nearly the same (both are rounded off to $2.1 million per year, as shown in the table), but the larger size of the worst-case investment causes it to have a lower net present value. Both values are significantly positive, $7.50 million in the best estimate and $6.93 million in the worst-case estimate.[1]

Plant Shutdowns. The model of the plant decision-making process indicates that plant shutdowns are a potential problem. In Table 5-8 the inputs to the decision and their independent effects on the likelihood of plant shutdown are presented. Two factors, the unlikelihood of a full-cost passthrough and the moderately high cost of the treatment investment, operate to increase the likelihood of plant shutdowns. The low degree of vertical integration in the industry also makes closings more likely but is not considered to be as strong an influence. The positive results of the investment analysis and the extensive integration of perchloroethylene manufacturing with other plant processes work to decrease the likelihood of plant shutdowns. Given the mixed influences which affect this important decision the model can only conclude that shutdowns are possible. A firm-by-firm analysis of the industry follows in the next section.

5.1.1.2 Projected Impacts

The future market situation for perchloroethylene indicates an absence of significant growth possibilities. Strong European competition is dramatically undercutting

TABLE 5–6

MODEL PLANT NET INCOME CALCULATION
FOR PERCHLOROETHYLENE*

MODEL PLANT FINANCIAL DATA	TREATMENT COST SCENARIO		
	NO NEW TREATMENT	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
Revenue (S/MT)	358	358	358
Manufacturing cost (S/MT)	259	259	259
Treatment cost (S/MT)	0	8	13
Gross profit (S/MT)	99	91	86
After-tax profit (S/MT)**	50	46	43
Total annual net income (S million)	1.4	1.3	1.2

* Assumes average annual production of 27,300 MT (70% of capacity). Source: Energy Resources Company Inc. estimates.

** Assumes 50% corporate tax rate.

TABLE 5–7

MODEL PLANT INVESTMENT ANALYSIS
FOR PERCHLOROETHYLENE*

MODEL PLANT INVESTMENT MEASURES	TREATMENT COST SCENARIO: BEST ESTIMATE OF COST	TREATMENT COST SCENARIO: WORST-CASE COST ESTIMATE
After-tax profit (S/MT)	46.0	43.0
Depreciation (S/MT)	32.0	33
After-tax cash flow (S/MT)**	78.0	76
Total annual cash flow (S million)	2.1	2.1
Investment outlay (S million)	1.2	1.5
Working capital requirement (S million)†	1.6	1.6
Net present value of investment (S million)††	7.5	6.9

* Source: Energy Resources Company Inc. estimates.
** After tax cash flow = profit + depreciation.
† Working capital requirement = 1/4 (manufacturing cost – depreciation).
†† Assumes a 15% discount rate and an investment life of 10 years.

TABLE 5–8

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR PERCHLOROETHYLENE

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$6.9	Negative
Ratio of investment to met fixed investment	13.9 % – High	Positive
Degree of vertical integration (forward or backward)	Low	Positive
Integration with other on-site production processes	Extensive integration	Negative
Other environmental/ regulatory problems	Significant	Positive
Likelihood of full-cost passthrough	Poor – little chance of full-cost passthrough	Positive

LIKELIHOOD OF PLANT SHUTDOWN: Plant shutdowns are possible **

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

domestic prices. Imported perchloroethylene from Italy and Spain is available at port of entry in New Jersey for \$0.09/lb while domestic product costs \$0.17/lb. This competition has created large domestic inventories and squeezed domestic profit margins making further investment for hazardous waste treatment for perchloroethylene operations unlikely in the short term.[2] Several small firms in the industry presently regard their perchloroethylene operations as marginal and the cessation of production could be a possibility. These firms will want to minimize any additional expenditures in their perchloroethylene operations and the required investments for hazardous waste treatment could therefore hasten their exit from the industry. In order to obtain a more accurate analysis of this issue, it is necessary to examine all the factors which impact competition in the industry.

Table 5-9 displays the likely impacts on the present domestic producers of perchloroethylene. Firm size and production volume appear to be important determinants of profitability in the industry. The largest producers can derive cost advantages both in production and in hazardous waste treatment. The large producers also tend to be the firms which have already invested in the necessary incinerators for perchloroethylene. As can be seen from the table, the firms which are known to be currently incinerating wastes include Dow Chemical, Diamond Shamrock, PPG, and Vulcan Materials Co. DuPont has also stated that regulations will have a negligible impact on their operation.[3] However, even those firms may elect to shift their incineration capacity to more profitable operations forcing closure.

Small firms have less volume over which to spread normal production costs, although economies of scale are not the only consideration in looking at relative size. The small firms tend to be able to run at higher utilization rates during market slumps. They normally require this high capacity utilization factor to stay profitable, and they secure the necessary market share by undercutting the price of the larger firms. Small firms, however, are losing their ability to operate in this fashion, as the long-term slump in the perchloroethylene market causes the larger firms to also become price aggressive. Survival becomes principally a question of producing at the lowest costs.

While the hazardous waste regulations will clearly worsen the cost disadvantages of small firms, several other supply characteristics are thought to be particularly important to the willingness and ability of firms to stay in the industry. These supply characteristics include:

TABLE 5–9

SUMMARY OF PROJECTED IMPACTS FOR PERCHLOROETHYLENE

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION **	MANUFACTURER RESPONSE REGARDING IMPACT *	PROJECTION OF REGULATORY IMPACT **
Diamond Shamrock	Deer Park, Tex	Incineration	Good	–	Small
Dow Chemical	Freeport, Tex.	Incineration	Good	Negligible	Small
	Plaquemine, La.	Incineration	Good	Negligible	Small
	Pittsburg, Calif.	Incineration	Good	Negligible	Small
DuPont	Corpus Christi, Tex.	Incineration	Good	Negligible	Small
Ethyl	Baton Rouge, La	Deep well disposal	Vulnerable	–	Significant impact possible
Hooker	Taft, La.	N.A.	Vulnerable	–	Significant impact possible
PPG	Lake Charles, La.	Incineration	Good	–	Small
Stauffer Chemical	Louisville, Ky.	Contractor used for landfill disposal	Vulnerable	Significant	Significant impact possible
Vulcan Materials	Geismer, La.	Plan to incinerate	Good	Negligible	Small
	Wichita, Kans.	Incineration	Good	Negligible	Small

* Source: Contacts with industry personnel.
** Source: Energy Resources Company Inc. estimates.

1. The need to purchase raw materials outside the firm.

2. Outdated production processes.

3. Integration of the perchloroethylene process with other firm operations.

The plants which are thought to be in the worst competitive position and, therefore, the most threatened by hazardous waste treatment, are listed below:

1. Ethyl, Baton Rouge, Louisiana (capacity 22,700 metric tons). Ethyl runs a combined perchloroethylene-trichloroethylene process which produces a large volume of wastes. The firm currently disposes of the waste through deep-well disposal, and has yet to incur the costs of incineration. Ethyl also must purchase its chlorine inputs, whereas other firms produce their own supplies. The same plant produces tetramethyllead and vinyl chloride monomer (VCM). The former market has declined substantially and, as will be discussed in Section 5.1.4, the Ethyl VCM operation is also not in a strong competitive position.

2. Stauffer Chemical, Louisville, Kentucky (capacity 84,000 metric tons). Stauffer produces its perchloroethylene as a coproduct with carbon tetrachloride, a product whose market is declining significantly (see Section 5.1.2). Faced with two marginal products, Stauffer may see no point in staying in either market. Stauffer is also a net purchaser of chlorine, a factor which tends to correlate with a weak competitive position. The firm views the addition of controlled incineration into their process as quite expensive, and anticipates that a number of technical problems will need to be solved to accomplish this addition.

3. Hooker Chemical, Taft, Louisiana (capacity 18,100 metric tons). Hooker is the only firm which still uses an acetylene-based process. They can currently obtain the necessary acetylene under a long-term contract with a natural gas supplier on the Gulf Coast. It is generally felt in the industry that when their current gas contract expires (the actual expiration date is unknown), Hooker may have to pay substantially higher gas prices. The increased input costs could threaten

the viability of their operation. In these circumstances, a substantial investment in an EPA-required pollution abatement system may not be made if the firm feels that it will have to close its doors shortly in any case.

5.1.2 Chloromethanes

Three of the four chloromethanes should face negligible impact from hazardous waste regulations. Carbon tetrachloride will be subject to limited impact except where it is a joint product with perchloroethylene in a marginal perchloroethylene plant.

5.1.2.1 Model Plant Analysis

Price Elasticity of Demand. A summary of the estimates of the price elasticity of demand for the four chloromethanes is presented below in Table 5-10. Table 5-10 is developed from separate estimations of the price elasticity for each of the chloromethane solvents presented in Tables 5-11 through 5-14. For all of these products, their effectiveness vis-a-vis substitutes is a major factor in price elasticity determination. Carbon tetrachloride is estimated to have a higher price elasticity than the other chloromethanes because there exist numerous substitute products developed to replace carbon tetrachloride-based fluorocarbons in their use as aerosol propellants. Chloroform is subject to similar pressures in its aerosol uses, but it is expected to maintain its advantage over other products in its larger refrigerant market. The other chloromethanes face only moderate substitutability. Methyl chloride is essential as an intermediate to the silicone industry. Methylene chloride is well established in its primary solvent uses and is increasing its share of the aerosol market where it is often used in place of carbon tetrachloride.

The other factors listed in Tables 5-11 through 5-14 are weaker influences than the degree of substitutability. Foreign competition is negligible for all the chloromethane markets.

In order not to understate any possible economic effects, the overall elasticity for the chloromethane solvents will be assumed to be in the 0.5 to 1.0 range (medium).

Likelihood of Full-Cost Passthrough. Table 5-15 displays the cost passthrough analysis. The required cost increase for chloromethane solvents is quite small, at only

TABLE 5–10

SUMMARY OF ELASTICITY ESTIMATES FOR CHLOROMETHANE PRODUCTS

PRODUCT	ELASTICITY ESTIMATE
Methyl chloride	Low (0.0 – 0.5)
Methylene chloride	Low (0.0 – 0.5)
Chloroform	Low (0.0 – 0.5)
Carbon tetrachloride	Medium (0.5 → 1.0)

TABLE 5–11

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR METHYL CHLORIDE

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	Moderate	Increase
Historical	1965–75: 5.3%/yr	
Projected	Through 1980: 6%/yr	
Captive usage	55% to 65% – Moderately high	Decrease
Use as intemediate	High	Decrease
Significance of price as basis for competition	Low	Decrease
Substitutability	Moderate	Neutral
Foreign competition	Negligible	Decrease

PRICE ELASTICITY ESTIMATE: Low (0.0 to 0.5).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–12

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR METHYLENE CHLORIDE

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	High	Decrease
Historical	1965–75: 13%/yr	
Projected	Through 1980: 10% to 12%/yr	
Captive usage	5% to 15% – Low	Increase
Use as intermediate	High	Decrease
Significance of price as basis for competition	Low	Decrease
Substitutability	Moderate	Neutral
Foreign competition	Negligible	Decrease

PRICE ELASTICITY ESTIMATE: Low (0.0 to 0.5).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–13

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR CHLOROFORM

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth Historical Projected	High 1965–75: 9.2%/yr Through 1980: 8% to 10%/yr	Decrease
Captive usage	15% to 25% – Low	Increase
Use as intermediate	High	Decrease
Significance of price as basis for competition	Low	Decrease
Substitutability	Low to moderate	Decrease
Foreign competition	Negligible	Decrease

PRICE ELASTICITY ESTIMATE: Low (0.0 to 0.5).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–14

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND
FOR CARBON TETRACHLORIDE

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	Poor	Increase
Historical	1964–74: 6.8%/yr	
Projected	Through 1979: +3% to (–10%)/yr	
Captive usage	10% to 30% – Low to medium	Neutral
Use as intermediate	High	Decrease
Significance of price as basis for competition	Low	Decrease
Substitutability	High	Increase
Foreign competition	Negligible	Decrease

PRICE ELASTICITY ESTIMATE: Medium (0.5 to 1.0).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–15

LIKELIHOOD OF FULL-COST PASSTHROUGH FOR CHLOROMETHANES*

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL-COST PASSTHROUGH
Price elasticity of demand	Medium (0.5 to 1.0) (Combined estimate)	Neutral
Variation in abatement costs among firms	Moderate	Neutral
Required cost increase as % of manufacturing cost	Small	Positive
Best estimate	0.2%	
Worst-case	0.6%	
Expected capacity utilization	70% to 80% – Medium	Neutral

LIKELIHOOD OF FULL-COST PASSTHROUGH: Poor; incomplete cost passthrough for some firms.

* Source: Energy Resources Company Inc. estimates.

0.6 percent for the worst-case costs scenario. As displayed in the table, this suggests that manufacturers will be able to recover costs. The other influences on the cost passthrough decision are all estimated to have no significant effect. The degree of capacity utilization was high for the industry in 1974 but has since fallen. This decline is due to the uncertain future for carbon tetrachloride, the largest volume chloromethane, the production of which dominates industry capacity. Capacity utilization is estimated to be "medium" to reflect this change. Abatement cost differences are of some note because of the wide range of sizes for operating plants. However, the smallest plants in the industry tend to produce for captive use and, therefore, should still be able to pass on a cost increase.

Investment Analysis. The uncertainties about future market conditions for chloromethane manufacturers were accounted for, in the investment analysis, by lowering the anticipated level of capacity utilization. It was assumed that the model plant would be running at 70 percent of capacity for the expected life of the investment (10 years). The model plant net income calculation is displayed in Table 5-16. The treatment costs have a negligible effect on profitability in the best estimate scenario, and a 6 percent drop in the worst case.

The components of the investment decision are shown in Table 5-17, and one notable statistic is the small size of the required investment, $0.23 million in the worst case. The net present value of the investment was calculated to be roughly $9 million in both cases, which means that firms which are in a situation at least as favorable as that of the model plant under a worst-case cost scenario would probably make the necessary expenditures.

Plant Shutdowns. Hazardous waste treatment expenditures will not seriously affect chloromethane manufacturers, except through their effect on marginal perchloroethylene/carbon tetrachloride coproduct plants. The elements of the plant shutdown decision are presented in Table 5-18. In the table, the only other factor indicating the possibility of a plant shutdown is the environmental problems for carbon tetrachloride. Carbon tetrachloride is the largest-volume chemical of the chloromethane group and a ban on fluorocarbons would bring a number of changes to the industry. The factors relating directly to hazardous waste treatment, such as the size of the required investment, are not sufficient to cause the industry problems.

TABLE 5–16

MODEL PLANT NET INCOME CALCULATION FOR CHLOROMETHANES*

MODEL PLANT FINANCIAL DATA	TREATMENT COST SCENARIO		
	NO NEW TREATMENT	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
Revenue ($/MT)	364	364	364
Manufacturing cost ($/MT)	269	269	269
Treatment cost ($/MT)	0	0.6	1.7
Gross profit ($/MT)	95.0	94.4	93.3
After tax profit ($/MT)**	47.5	47.2	46.7
Total annual net income ($ million)	1.7	1.7	1.6

* Assumes average annual production of 35,000 MT (70% of capacity). Source: Energy Resources Company Inc. estimates.

** Assumes 50% corporate tax rate.

TABLE 5–17

MODEL PLANT INVESTMENT ANALYSIS
FOR CHLOROMETHANES*

MODEL PLANT INVESTMENT MEASURES	TREATMENT COST SCENARIO	
	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
After-tax profit (S/MT)	47.2	46.7
Depreciation (S/MT)	20.1	20.3
After-tax cash flow (S/MT)**	67.3	67.0
Total annual cash flow (S million)	2.4	2.3
Investment outlay (S million)	0.18	0.23
Working capital requirement (S million)†	2.2	2.2
Net present value of investment (S million)††	9.3	9.1

* Source: Energy Resources Company Inc. estimates.
** After-tax cash flow=profit + depreciation.
† Working capital requirement = 1/4 (manufacturing cost – depreciation).
†† Assumes a 15% discount rate and an investment life of 10 years.

TABLE 5–18

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR CHLOROMETHANES

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$9.1 million	Negative
Ratio of investment to net fixed investment	2.3% – small	Negative
Degree of vertical integration (forward or backward)	Moderate	Neutral
Integration with other on-site production processes	Integrated with threatened perchloroethylene processes	Positive
Other environmental/ regulatory problems	Significant	Positive
Likelihood of full-cost passthrough	Good likelihood of full-cost passthrough	Negative

LIKELIHOOD OF PLANT SHUTDOWN: Small chance of plant shutdown.**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

5.1.2.2 Projected Impacts

While the markets for the chloromethanes, particularly the high-volume product carbon tetrachloride, are subject to great uncertainty about future demand, it appears that the small costs of waste treatment for these products will preclude a strong regulatory impact. The projected impact for each manufacturer is displayed in Table 5-19. As can be seen from the table, a significant impact is considered possible for two plants, those of Ethyl Corp. and Stauffer Chemical Co. Ethyl produces methyl chloride at its Baton Rouge plant, where it also produces perchloroethylene and vinyl chloride monomer. Both of these other operations are thought to have a weak competitive position in their respective markets (see Sections 5.1.1 and 5.1.4 for information on the regulatory impact in these markets). Thus, even though there is no indication of a distinct treatment problem for methyl chloride wastes, the operation could be threatened by the possibility that the entire plant would be closed.

The Stauffer plant in Louisville, Kentucky houses a joint perchloroethylene-carbon tetrachloride process. The process generates a relatively large volume of wastes (worst-case estimates may be applicable) and Stauffer has indicated that the addition of controlled incineration would be quite expensive. Therefore, Stauffer would be faced with the decision of whether to make a fairly large investment in order to continue production of the two chemicals, each of which currently faces a weak market. In these circumstances, they may choose to cease production.

Several other chloromethane producers also manufacture perchloroethylene but should not be threatened by hazardous waste treatment regulations. Diamond Shamrock and Vulcan Materials send their chloromethane wastes for treatment to their perchloroethylene plants, where incineration is currently taking place. In the case of Diamond Shamrock, this involves transporting the chloromethane wastes from Belle, West Virginia to Deer Park, Texas.[4] Dupont runs a joint perchloroethylene-carbon tetrachloride process and they have indicated that the regulatory impact will be negligible.[5]

Chloromethane producers who do not also make perchloroethylene have only a small waste disposal problem. Allied Chemical, for instance, uses a contractor to dispose of its hazardous waste. The volume of waste generated would not economically support in-house incineration in this case.[6]

TABLE 5–19

SUMMARY OF PROJECTED IMPACTS FOR CHLOROMETHANES

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION**	MANUFACTURER RESPONSE REGARDING IMPACT *	PROJECTION OF REGULATORY IMPACT**
Allied Chemical	Moundsville, W.Va.	Contractor used for treatment	Good	Negligible	Small
Conoco	Westlake, La.	N.A.	Good	Negligible	Small
Diamond Shamrock	Belle, W.Va.	Wastes shipped to Deer Park, Tex. plant for incineration	Good	Negligible	Small
Dow Chemical	Freeport, Tex.	Incineration	Good	Negligible	Small
	Plaquemine, La.	Incineration	Good	Negligible	Small
	Pittsburg, Calif.	Incineration	Good	Negligible	Small
Dow-Corning	Carrollton, Ken.	N.A.	Good	Negligible	Small
	Midland, Mich.	N.A.	Good	Negligible	Small
DuPont	Corpus Christi, Tex.	Incineration	Good	Negligible	Small
	Niagara Falls, N.Y.	—	Not operating	—	—
Ethyl	Baton Rouge, La.	Deep well disposal	Vulnerable	—	Significant impact possible
FMC	South Charleston, W.Va.	N.A.	—	—	Small
General Electric	Waterford, N.Y.	Incineration	Good	Negligible	Small
Inland Chemical	Manati, Puerto Rico	None	Good	Negligible	Small
Stauffer Chemical	Louisville, Ky.	Contractor used for treatment	Vulnerable	Significant	Significant impact possible
	LeMoyne, Ala.	N.A.	Good	Negligible	Small
Union Carbide	Institute, W.Va.	N.A.	Good	Negligible	Small
Vulcan Materials	Geismer, La.	Plan to incinerate	Good	Negligible	Small
	Wichita, Kans.	Incineration	Good	Negligible	Small

* Source: Contacts with industry personnel.

** Source: Energy Resources Company Inc. estimates.

5.1.3 Epichlorohydrin

The epichlorohydrin market should not be seriously impacted by hazardous waste treatment regulations. The investment in treatment equipment will be fairly expensive, but the additional operating costs should add little to the cost of the product. Only two firms, Shell Oil and Dow Chemical, manufacture epichlorohydrin and both should be able to meet new regulatory requirements with little difficulty. Both presently have incinerators running and their plants are large integrated facilities that allow abatement costs to be spread over many products.

5.1.3.1 Model Plant Analysis

Price Elasticity of Demand. An estimate of the price elasticity of demand for epichlorohydrin was made despite the lack of market sales of the chemical (see Table 5-20). The estimation of market conditions for this chemical, as for the other intermediates studied, is made on the basis of evidence about the continued use of the chemical as an input to other processes. In this case, the analysis focuses on the effect of changes in the epichlorohydrin price on its use in the manufacture of synthetic glycerin and epoxy resins. Both markets are expected to be insensitive to price changes. The extensive captive use of epichlorohydrin effectively reduces the price sensitivity of its market since the existing processes of the two producing firms are dependent upon the continued manufacture of the chemical. In the past, the producer/users of epichlorohydrin have shown some tendency to reduce their use of the chemical by employing alternative processes for the manufacture of synthetic glycerin. However, changes of this type require some retooling costs and therefore indicate moderate but not strong sensitivity to price (or in this case, manufacturing costs). Epichlorohydrin is well established as an intermediate in epoxy resin manufacturing and, while there are possibilities for substitution through alternative manufacturing processes, the degree of substitutability is limited. The influence of substitute products on the baseline price elasticity is, therefore, not strong and is considered to have a neutral impact in terms of the analysis. On the other hand, the influence of high captive use is to decrease the price elasticity. Captive users are likely to favor using their own supplies even if they are more expensive than other producers' because the extra costs for compliance are likely to be less than the increased overhead costs resulting from shutting down the supplying plant. High levels of captive use will therefore lessen users' sensitivity to price.

TABLE 5–20

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR EPICHLOROHYDRIN

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	Low to moderate	Neutral
Historical	n.a.	
Projected	3% to 6%/yr	
Captive usage	High	Decrease
Use as intermediate	High	Decrease
Significance of price as basis for competition	Low	Decrease
Substitutability	Moderate	Neutral
Foreign competition	Negligible	Decrease

PRICE ELASTICITY ESTIMATE: Low (0.0 to 0.5).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

The markets for epichlorohydrin are mature, particularly that of intermediate use in synthetic glycerin manufacturing, and future growth is likely to be slow. Markets with falling growth rates resulting from increasing product substitution may be indicative of a high price elasticity of demand. However, the epichlorohydrin market is not subject to this substitution effect, and slow future growth does not indicate a high price elasticity.

Likelihood of Full-Cost Passthrough. The two manufacturers of epichlorohydrin are the largest consumers of the chemical, allowing them to pass on the increased costs of manufacture to the next level of processing. The data which makes this conclusion possible are summarized in Table 5-21. Most notably, the size of the required cost increase as a percentage of manufacturing cost is small, estimated in the worst case as 0.42 percent. The low price elasticity indicates that the resulting fall in demand should be negligible. Both firms in this industry make epichlorohydrin as one product line in huge petrochemical complexes. As a result, there is no significant difference in the scale of operation and no interfirm differences in the cost of abatement are expected. Expected capacity utilization is projected to be between 65 and 80 percent, buoyed mainly by demand for use in epoxy resins. A healthy level of capacity utilization also eases the passthrough of abatement costs.

Net Income and Investment Analysis. Treatment costs should add only $3 to the $900 cost of manufacturing a metric ton of epichlorohydrin. Table 5-22 presents the net income calculation to determine whether treatment costs can be absorbed while maintaining profitability. Comparing the model plant net income projection with and without treatment costs shows that treatment using the best estimate of costs reduces net income from $3.0 million to $2.9 million. Net income under a worst-case cost scenario is only slightly lower at $2.8 million. These treatment costs represent declines in net income of 3 percent and 7 percent respectively.

The investment required for epichlorohydrin producers would be roughly $1 million. Table 5-23 presents the investment analysis. In terms of the model plant costs, the worst-case investment of $1.1 million is one-eighth of the net fixed investment of $7.9 million. However, the cash flows summarized in the table indicate that the investment would be a profitable one. On the basis of an after-tax cash flow of more than $50/MT, the net present values of the investment are $6.0 million and $5.6 million for the best estimate and worst-case costs respectively. These figures, it can be safely said, are conservative estimates of

TABLE 5–21

LIKELIHOOD OF FULL-COST PASSTHROUGH FOR EPICHLOROHYDRIN*

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL COST PASSTHROUGH
Price elasticity of demand	Low (0.0 to 0.5)	Positive
Variation in abatement costs among firms	Negligible	Positive
Required cost increase as % of manufacturing cost	Small	Positive
Best estimate	0.23%	
Worst-case	0.42%	
Expected capacity utilization	70% to 85% – Medium to high	Positive

LIKELIHOOD OF FULL-COST PASSTHROUGH: Good likelihood of full-cost passthrough.

*Source: Energy Resources Company Inc. estimates.

TABLE 5–22

MODEL PLANT NET INCOME CALCULATION FOR EPICHLOROHYDRIN*

MODEL PLANT FINANCIAL DATA	TREATMENT COST SCENARIO		
	NO NEW TREATMENT	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
Revenue ($/MT)	970	970	970
Manufacturing cost ($/MT)	882	882	882
Treatment cost ($/MT)	0	2.0	3.7
Gross profit ($/MT)	88.0	86.0	84.3
After-tax profit ($/MT)**	44.0	43.0	42.2
Total annual net income ($ million)	3.0	2.9	2.8

* Assumes average annual production of 67,500 MT (90% of capacity). Source: Energy Resources Company Inc. estimates.

** Assumes 50% corporate tax rate.

TABLE 5–23

MODEL PLANT INVESTMENT ANALYSIS
FOR EPICHLOROHYDRIN*

MODEL PLANT INVESTMENT MEASURES	TREATMENT COST SCENARIO	
	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
After-tax profit ($/MT)	43.0	42.0
Depreciation ($/MT)	11.9	12.1
After-tax cash flow ($/MT)**	54.7	54.2
Total annual cash flow ($ million)	3.7	3.7
Investment outlay ($ million)	0.87	1.08
Working capital requirement ($ million)†	14.7	14.7
Net present value of investment ($ million)††	6.0	5.6

* Source: Energy Resources Company Inc. estimates.
** After-tax cash flow = profit + depreciation.
† Working capital requirement = 1/4 (manufacturing cost – depreciation).
†† Assumes a 15% discount rate and an investment life of 10 years.

profitability given the probable market power of the two epichlorohydrin producers, Shell Oil Company and Dow Chemical.

Plant Shutdowns. As suggested by the previous discussion, plant shutdowns are unlikely for epichlorohydrin manufacturers. The various components of the shutdown decision are listed in Table 5-24. The only factor that has a positive effect on the likelihood of a plant shutdown is the large size of the initial treatment investment, calculated here as a percentage of the net fixed investment. However, the net fixed investment figure used for the model plant analysis is only an estimate of the actual requirements for the epichlorohydrin process equipment. In reality, the investment required for a petrochemical complex is many times larger than the model plant figure, but the costs of treating epichlorohydrin wastes will be spread over the manufacturing and treatment costs for a number of chemicals. The burden of the hazardous waste treatment investment on epichlorohydrin is therefore lessened significantly. All of the other factors listed indicate that there should not be serious difficulties for this industry. The most significant factors are the strong likelihood of a full-cost passthrough and the high degree of vertical integration. The latter point suggests that this manufacturing process could not be easily separated from the other plant operations and shutdown.

5.1.3.2 Projected Impacts

Regulations for hazardous waste management should not seriously impact either of the two epichlorohydrin manufacturers, Shell Oil Company or Dow Chemical. A summary of the projected impacts for each of the plants is presented in Table 5-25. Both companies manufacture the chemical in large petrochemical complexes, which allows them to spread the costs of treatment (controlled incineration) over a number of products. The results of the investment analysis presented above are likely, therefore, to overstate the incremental costs of treatment for epichlorohydrin alone.

Communication with the representatives of Shell and Dow during the course of this project indicated that both firms have taken steps to meet the anticipated regulations.[7] Each firm is using, or planning to use, controlled incineration processes which should meet any governmental regulatory standards. To the extent that the firms are moving towards controlled incineration in anticipation of regulation, these regulations will have made their primary economic impact prior to being instituted.

TABLE 5–24

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR EPICHLOROHYDRIN

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$5.6 million	Negative
Ratio of investment to net fixed investment	13.7 % – large	Positive
Degree of vertical integration (forward or backward)	High	Negative
Integration with other on-site production processes	Extensive integration	Negative
Other environmental/ regulatory problems	Moderate	Negative
Likelihood of full-cost passthrough	Good likelihood of full-cost passthrough	Negative

LIKELIHOOD OF PLANT SHUTDOWN: Small chance of plant shutdown.**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–25

SUMMARY OF PROJECTED IMPACTS FOR EPICHLOROHYDRIN

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION**	MANUFACTURER RESPONSE REGARDING IMPACT	PROJECTION OF REGULATORY IMPACT**
Dow Chemical	Freeport, Tex.	Incineration	Good	Negligible	Small
Shell Oil	Houston, Tex.	Incineration	Good	Negligible	Small
	Norco, La.	Incineration	Good	Negligible	Small

* Source: Contacts with industry personnel.
** Source: Energy Resources Company Inc. estimates.

5.1.4 Vinyl Chloride

While the model plant for vinyl chloride has among the highest treatment costs of any plant and worst-case treatment costs are 0.6 percent of production costs, the booming VCM/PVC market should have little trouble absorbing the costs. Two small producers presently suffering from weak positions in the market may be subject to significant impact from the regulation only because of the combination of treatment costs and their vulnerable market positions.

5.1.4.1 Model Plant Analysis

Price Elasticity of Demand. Vinyl chloride is expected to have one of the lowest price elasticities of the highly impacted chemicals. The price elasticity estimation is presented in Table 5-26. While examination of price and sales data over the past 15 years shows significant increases in demand accompanied by dramatic price declines, it is believed that both the demand growth and the price reduction were the results of the boom in the market. The current price elasticity of the market is believed to be better represented by its recent performance. Recently, vinyl chloride has been subject to sharp price increases which have not had sizeable effects on demand. These increases were not sufficient to price PVC (a derivative of vinyl chloride) out of the numerous markets where it has been found to be extremely effective in a broad range of applications.

The limited substitutability for VCM/PVC is believed to exercise the strongest influence on the baseline elasticity. All other determinants are estimated to have a negative effect except the significance of price on competition, which is believed to have a neutral influence. The 4 to 5 percent estimate of future demand growth may well be conservative given the strong sales growth in 1976 and 1977. Furthermore, the industry has planned to increase capacity by over 50 percent by 1980. The continued sales growth is seen as a sign of price firmness and the effect of the expansion of capacity on prices is likely to swamp any increase in price due to hazardous waste treatment.

Substitutability and foreign competition are not significant at this time and high, increasing rates of captive use will minimize the effects of cost increases. If the National Energy Plan is enacted, however, then the price of the necessary feedstocks for VCM production will increase substantially. The price rise could eliminate the export market for VCM and PCV and stimulate importing of these chemicals.

TABLE 5–26

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR VINYL CHLORIDE

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	Moderate	Decrease
Historical	1964–74: 13.2%/yr	
Projected	Through 1979: 4% to 5%/yr†	
Captive usage	40% to 50% – Moderately high	Decrease
Use as intermediate	High	Decrease
Significance of price as basis for competition	Moderate	Neutral
Substitutability	Low	Decrease
Foreign competition	Negligible	Decrease

PRICE ELASTICITY ESTIMATE: Low (0.0 to 0.5).**

* Source: Chapter Three.

** Source: Energy Resources Company Inc. estimates.

† Dow Chemical Company projects 7% growth into the 1980's. (Source: *Chemical Marketing Reporter*, October 24, 1977.)

Likelihood of Full-Cost Passthrough. The required cost increase and other elements of the cost passthrough decision are presented in Table 5-27 and the results suggest an easy passthrough of costs. Treatment costs are quite low, 0.4 percent of total manufacturing costs for the best estimate scenario and 0.6 percent for the worst-case costs. Also, the low price elasticity will encourage producers to pass through abatement costs.

There are, however, some mildly restraining influences on price increases. Expected capacity utilization has been projected conservatively at between 65 and 80 percent in order to account for the possibility of a glut in the VCM market. As will be discussed below in Section 5.1.4.2 (Projected Impact), a number of new plants will be coming on stream by 1980 and this will increase competitive pressures in the industry. Firms in a weak competitive position or those with worst-case costs may not be able to fully recover the cost increase through price increases.

Net Income and Investment Analysis. The analysis of revenues and costs indicates continued profitability for the model plant in this industry. Net income figures are displayed for the plant with and without treatment costs in Table 5-28. The substantial difference in best estimate and worst-case costs is noteworthy. The model plant net income figure falls 5.1 percent with the best estimate treatment costs and 9.8 percent with the worst-case costs.

Another view of the effect of regulations on the model plant is presented by the investment analysis in Table 5-29. For the investment analysis, the difference between the best estimate and worst-case costs is relatively unimportant. The annual cash flow for the worst case, $3.01 million, is only 9 percent below that of the best estimate case. The net present value of the investments in each case is significantly positive.

Plant Shutdowns. Hazardous waste management regulations should not have a strong impact on the vinyl chloride industry. The regulations might help precipitate some plant shutdowns, but the current vulnerability of certain firms is caused largely by general market and production conditions. Table 5-30 presents the relevant plant shutdown decision factors and their estimated effects under a worst-case cost scenario. OSHA regulations are considered significant in increasing the likelihood of plant shutdown even though most firms have met or will be able to successfully meet these other regulations. Because of the possibility that some plants may not be able to fully recover costs (although the industry as a whole should have

TABLE 5–27

LIKELIHOOD OF FULL-COST PASSTHROUGH FOR VINYL CHLORIDE*

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL COST PASSTHROUGH
Price elasticity of demand	Low (0.0 to 0.5)	Positive
Variation in abatement costs among firms	High	Negative
Required cost increase as % of manufacturing cost	Small	Positive
Best estimate	0.4%	
Worst-case	0.6%	
Expected capacity utilization	65% to 80% – Medium to high	Neutral

LIKELIHOOD OF FULL-COST PASSTHROUGH: Strong likelihood of full-cost passthrough. Plants with worst-case costs may not fully recover costs.

* Source: Energy Resources Company Inc. estimates.

TABLE 5–28

MODEL PLANT NET INCOME CALCULATION FOR VINYL CHLORIDE*

MODEL PLANT FINANCIAL DATA	TREATMENT COST SCENARIO: NO NEW TREATMENT	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
Revenue ($/MT)	320	320	320
Manufacturing cost ($/MT)	294	294	294
Treatment cost ($/MT)	0	1.2	1.8
Gross profit ($/MT)	26.0	24.8	24.2
After-tax profit ($/MT)**	13.0	12.4	12.1
Total annual net income ($ million)	1.6	1.5	1.5

* Assumes average annual production of 122,400 MT (90% of capacity). Source: Energy Resources Company Inc. estimates.

** Assumes 50% corporate tax rate.

TABLE 5–29

MODEL PLANT INVESTMENT ANALYSIS FOR VINYL CHLORIDE*

MODEL PLANT INVESTMENT MEASURES	TREATMENT COST SCENARIO	
	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
After-tax profit ($/MT)	12.4	12.1
Depreciation ($/MT)	16.9	17.1
After-tax cash flow ($/MT)**	29.3	29.2
Total annual cash flow ($ million)	3.6	3.6
Investment outlay ($ million)	0.9	1.1
Working capital requirement ($ million)†	8.5	8.5
Net present value of investment ($ million)††	9.1	8.8

* Source: Energy Resources Company Inc. estimates.
** After-tax cash flow = profit + depreciation.
† Working capital requirement = 1/4 (manufacturing cost – depreciation).
†† Assumes a 15% discount rate and an investment life of 10 years.

TABLE 5–30

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR VINYL CHLORIDE

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$8.8 million	Negative
Ratio of investment to net fixed investment	4.9% – small	Negative
Degree of vertical integration (forward or backward)	Medium	Neutral
Integration with other on-site production processes	Low – isolated plant	Positive
Other environmental/ regulatory problems	Substantial – OSHA regulations	Positive
Likelihood of full-cost passthrough	Fair likelihood of full-cost passthrough; small plants may not recover costs fully	Neutral
LIKELIHOOD OF PLANT SHUTDOWN:	Some likelihood of plant shutdown. Small plants are most vulnerable.**	

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

no trouble), the cost passthrough factor is accorded a neutral influence. The investment analysis, as discussed above, indicated that firms are likely to make the necessary investment. However, struggling enterprises may see only a limited future for themselves in the industry and in such a case, almost any investment may be considered wasteful. Plant shutdowns are, therefore, possible as the combined result of environmental regulations and the weakening competitive position of small producers in the industry.

5.1.4.2 Projected Impacts

Expectations of a continuation of the rapid growth of the VCM/PVC market in recent years and the attractive profitability of 1974 have encouraged firms to expand or enter the industry. As of this writing, four firms have announced plans for the construction of new plants or expansion of existing plants scheduled to come on line within a few years. In each case the expansions amounted to an additional 455,000 metric tons per year (1 billion pounds per year) of VCM capacity. The four firms and their respective capacity increases are listed in Table 5-31.

Sales growth for the industry has been impressive, with a yearly growth of 13.2 percent from 1964 to 1974 and new peaks of production in 1976 and again in 1977 (projected). However, the four new plants constitute an increase in capacity of over 50 percent. As a result, there is some expectation of a glut in vinyl chloride production and this will increase the competitive pressures within the industry. It has been noted that economies of scale are very significant for VCM producers. The capacity of the new plants suggests that 455,000 metric tons is recognized as an optimum plant size.

A summary of the projected impacts of hazardous waste regulations on the vinyl chloride producers is developed in Table 5-32. The existing smaller and often older plants are thought to be at a cost disadvantage in comparison to the new giants. The one exception is the new Borden VCM plant which, although built for a capacity of only 136,000 metric tons per year, should be adaptable (1) to environmental controls and (2) to expansions. Also, Borden's VCM production will be used internally for PVC production and should, therefore, be less vulnerable to competitive pressures.

Several plants will be particularly vulnerable to the new competitive pressures and to the impact of hazardous waste management regulations. These are described below:

TABLE 5–31

PLANNED EXPANSIONS IN VCM CAPACITY

FIRM	PRIOR EXPERIENCE IN VCM	CAPACITY (1,000 MT)
Georgia Pacific	New entrant	455 (1979)
Diamond Shamrock	New entrant	455 (1978)
PPG	Currently VCM producer	455 (1980)
Dow	Currently VCM producer	273 (1977) 182 (1980)

TABLE 5–32

SUMMARY OF PROJECTED IMPACTS FOR VINYL CHLORIDE

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION**	MANUFACTURER RESPONSE REGARDING IMPACT*	PROJECTION OF REGULATORY IMPACT**
Allied Chemical	Baton Rouge, La.	N.A.	Vulnerable	–	Significant impact possible
Borden	Geismer, La.	N.A.	Good	–	Small
Conoco	Lake Charles, La.	Plan to incinerate	Good	Moderate	Small
Dow Chemical	Freeport, Tex.	Incineration	Good	Negligible	Small
	Plaquemine, La.	Incineration	Good	Negligible	Small
	Oyster Creek, Tex.	Incineration	Good	Negligible	Small
Ethyl	Baton Rouge, La.	Deep well disposal	Vulnerable	–	Significant impact possible
	Houston, Tex.	–	Not operating	–	–
B.F. Goodrich	Calvert City, Ky.	N.A.	Good	–	Small
Monochem	Geismer, La.	Incineration	Vulnerable	Negligible	Small
PPG	Lake Charles, La.	Incineration	Good	–	Small
	Guayanilla, P.R.	N.A.	Good	–	Small
Shell Oil	Deer Park, Tex.	Incineration	Good	Negligible	Small
	Norco, La.	Incineration	Good	Negligible	Small
Stauffer Chemical	Long Beach, Calif.	N.A.	N.A.	–	Small

* Source: Contacts with industry personnel.

** Source: Energy Resources Company Inc. estimates.

1. Allied Chemical, Baton Rouge, Louisisana (capacity 136,000 metric tons). Allied has announced that it will sell or expand its VCM plant, suggesting strongly that the firm cannot run its operation profitably at its current level. With 136,000 metric tons of capacity per year, it is among the smaller VCM manufacturers in the industry. It is also known that Allied has had considerable problems in meeting the OSHA standard for emissions. (The OSHA regulations presented a serious problem for the industry, but the obstacle has largely been overcome by most firms.)

2. Ethyl Corporation, Baton Rouge, Louisiana (capacity 136,000 metric tons). This same Ethyl Corp. plant has been described in Section 5.1.1.2 on perchloroethylene as one which is vulnerable to competitive pressures in that industry. The firm's problems in VCM manufacturing stem most likely from similar sources, namely, the cost disadvantages of this particular plant. However, there are several indications of specific difficulties in the VCM market where Ethyl is a "swing supplier" (i.e., they sell to captive producers during periods when their customers' demand outprices their in-house supply) absorbing most of the customers' risk of incremental changes in demand. Ethyl has already closed one VCM plant, in Houston, Texas. At their Baton Rouge plant, Ethyl makes ethylene dichloride (EDC), some of which is used in VCM manufacturing and some of which is sold to B.F. Goodrich for use in their VCM plant in Calvert City, Kentucky. The latter customer, however, is expected to cease its purchases from Ethyl as soon as it develops its own EDC production capability. The loss of this major customer could result in a lower utilization rate for the EDC facility and this, in turn, may accentuate VCM production cost problems. Like the Allied plant, Ethyl's plant is small for the industry, creating further cost disadvantage.

5.1.5 Acrylonitrile

The acrylonitrile industry will not be hard hit by hazardous waste regulations. Both the required investments and the increases in manufacturing costs will be small. The impact that is felt by the industry should be distributed fairly evenly among firms because all firms use the same process and are currently disposing of wastes by similar techniques.

5.1.5.1 Model Plant Analysis

Price Elasticity of Demand. There is little indication from the market history of acrylonitrile that demand is sensitive to price increases. Table 5-33 presents the estimate of price elasticity. All of the principal determinants of price elasticity, such as the characteristics of competition as delineated in the table, suggest a low price elasticity. There is no direct substitute for acrylonitrile, which is used to produce acrylic fibers, although wool and other fabrics can be substituted in some clothing products and the majority of production is used captively by firms, thus further reducing the sensitivity of customers to price changes. Also, demand growth for the next half decade should continue to be strong. Demand growth represents an outward shifting of the demand curve but is also used here as an indication of the tightness of supply. Where demand is strong, there can be some possibility of shortages and customers are known to be considerably less concerned about price changes than about interruption in supplies.

Likelihood of Full-Cost Passthrough. The small size of the cost increase required by hazardous waste treatment for acrylonitrile means that a full-cost passthrough should take place. The elements of the cost passthrough decision are presented in Table 5-34. The cost increase is only 0.2 percent of the manufacturing costs using the worst-case cost estimates and represents the smallest cost increase among the highly impacted segments. The cost increase is so small that other factors are of only secondary importance. The low price elasticity for the chemical suggests there will be ample leeway for the required price rise. Abatement cost differences between firms are not of particular importance since it is expected that most firms will be required to make similar adjustments for hazardous waste treatment. Economies of scale as they affect treatment costs will exist, but none of the plants in the industry is exceptionally small. The current high level of capacity utilization is expected to be sustained so that firms are not likely to be reticent about initiating a small price rise.

Net Income and Investment Analysis. The analysis of net income for the model plant is presented in Table 5-35. The table indicates continued profitability despite hazardous waste treatment. The net profit earned per metric ton of product (over $80) is quite high for the industry. The profit level reflects the need to provide an adequate return on the large investment required for acrylonitrile manufacturing. The estimated capital costs for the model

TABLE 5–33

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR ACRYLONITRILE

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	High	Decrease
Historical	1965–75: 11%/yr	
Projected	Through 1981: 8% to 10%/yr	
Captive usage	55% to 65% – Moderately high	Decrease
Use as intermediate	High	Decrease
Significance of price as basis for competition	Moderate	Neutral
Substitutability	Low	Decrease
Foreign competition	Minimal	Decrease

PRICE ELASTICITY ESTIMATE: Low (0.0 to 0.5).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–34

LIKELIHOOD OF FULL-COST PASSTHROUGH FOR ACRYLONITRILE*

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL-COST PASSTHROUGH
Price elasticity of demand	Low (0.0 to 0.5)	Positive
Variation in abatement costs among firms	Moderate	Neutral
Required cost increase as % of manufacturing cost	Small	Positive
Best estimate	0.1%	
Worst-case	0.2%	
Expected capacity utilization	70% to 80% – Medium	Neutral

LIKELIHOOD OF FULL-COST PASSTHROUGH: Good likelihood of full-cost passthrough.

* Source: Energy Resources Company Inc. estimates.

TABLE 5–35

MODEL PLANT NET INCOME CALCULATION FOR ACRYLONITRILE*

MODEL PLANT FINANCIAL DATA	TREATMENT COST SCENARIO		
	NO NEW TREATMENT	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
Revenue (S/MT)	595	595	595
Manufacturing cost (S/MT)	431	431	431
Treatment cost (S/MT)	0	0.4	0.7
Gross profit (S/MT)	164	163.6	163.3
After-tax profit (S/MT)**	82.0	81.8	81.7
Total annual net income (S million)	13.4	13.3	13.3

* Assumes average annual production of 163,000 MT (90% of capacity). Source: Energy Resources Company Inc. estimates.

** Assumes 50% corporate tax rate.

plant are $53 million. Net income per annum is likewise quite high, with the treatment costs having a negligible impact.

The figures used in deriving the net present value of investment are presented in Table 5-36. The required treatment investments are small. The worst-case estimate of the investment is under $0.5 million. The net present value of investment is, as a result, quite large and positive for acrylonitrile producers.

Plant Shutdowns. The impact of hazardous waste treatment regulations should not cause any plant shutdowns in the acrylonitrile industry. The plant-specific data most relevant to the shutdown decision are listed in Table 5-37, and none of the influences suggest serious difficulties. The profitable results of the investment analysis and small size of the required investment both indicate strongly that firms will incur the additional costs. The fact that the largest firms use their production captively and that all acrylonitrile plants are tied into refineries makes it clear that the closing of any acrylonitrile operations would complicate the other production activities for the firms. The industry will soon become subject to OSHA regulations regarding the exposure of employees to chemical emulsions. The possibility of problems with OSHA regulations is accorded only a neutral influence because it is not clear that these will seriously impact the industry. Regarding the treatment costs of hazardous wastes, a full-cost passthrough is expected. To conclude, there is a remote chance of plant shutdowns in this industry.

5.1.5.2 Projected Impacts

Unlike several other highly impacted segments, the distribution of the impact will be more or less evenly distributed among firms in this industry. None of the plants are extremely small so cost differences should not be pronounced. A summary of the projected impacts is presented in Table 5-38. Most of the plants are currently discharging their wastes through deep well disposal and will therefore require some future outlay for the treatment investment.[8] The small size of the treatment costs precludes the need for further analysis.

5.1.6 Furfural

The Quaker Oats Company with its four plants is the sole producer of furfural and is therefore the focus of the economic impact analysis. The monopoly power of the company

TABLE 5–36

MODEL PLANT INVESTMENT ANALYSIS FOR ACRYLONITRILE*

MODEL PLANT INVESTMENT MEASURES	TREATMENT COST SCENARIO	
	BEST ESTIMATE OF COST	WORST-CASE COST ESTIMATE
After-tax profit ($/MT)	81.8	81.7
Depreciation ($/MT)	32.6	32.7
After-tax cash flow ($/MT)**	114.4	114.4
Total annual cash flow ($ million)	18.6	18.6
Investment outlay ($ million)	0.23	0.39
Working capital requirement ($ million)†	16.3	16.3
Net present value of investment ($ million)††	77.0	76.8

* Source: Energy Resources Company Inc. estimates.
** After-tax cash flow = profit + depreciation.
† Working capital requirement = 1/4 (manufacturing cost – depreciation).
†† Assumes a 15% discount rate and an investment life of 10 years.

TABLE 5–37

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR ACRYLONITRILE

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$76.8 million	Negative
Ratio of investment to net fixed investment	Less than 1% – very small	Negative
Degree of vertical integration (forward or backward)	Medium to high	Negative
Integration with other on-site production processes	Extensive integration	Negative
Other environmental/ regulatory problems	OSHA regulations	Neutral
Likelihood of full-cost passthrough	Good likelihood of full-cost passthrough	Negative

LIKELIHOOD OF PLANT SHUTDOWN: Remote chance of plant shutdown.**

* Source: Chapter Three.
** Source: Energy Resources Company inc. estimates.

TABLE 5–38

SUMMARY OF PROJECTED IMPACTS FOR ACRYLONITRILE

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION**	MANUFACTURER RESPONSE REGARDING IMPACT*	PROJECTION OF REGULATORY IMPACT**
American Cyanamid	Fortier, La.	Deep well disposal	Good	–	Small
DuPont	Beaumont, Tex.	Incineration	Good	Negligible	Small
	Memphis, Tenn.	Incineration	Good	Negligible	Small
Monsanto	Chocolate Bayou, Tex.	Deep well disposal	Good	–	Small
	Texas City, Tex.	Deep well disposal	Good	–	Small
Vistron	Lima, Ohio	Deep well disposal and and biological treatment	Good	–	Small

* Source: Contacts with industry personnel.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–37

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR ACRYLONITRILE

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$76.8 million	Negative
Ratio of investment to net fixed investment	Less than 1% – very small	Negative
Degree of vertical integration (forward or backward)	Medium to high	Negative
Integration with other on-site production processes	Extensive integration	Negative
Other environmental/ regulatory problems	OSHA regulations	Neutral
Likelihood of full-cost passthrough	Good likelihood of full-cost passthrough	Negative

LIKELIHOOD OF PLANT SHUTDOWN: Remote chance of plant shutdown.**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–38

SUMMARY OF PROJECTED IMPACTS FOR ACRYLONITRILE

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION**	MANUFACTURER RESPONSE REGARDING IMPACT*	PROJECTION OF REGULATORY IMPACT**
American Cyanamid	Fortier, La.	Deep well disposal	Good	–	Small
DuPont	Beaumont, Tex.	Incineration	Good	Negligible	Small
	Memphis, Tenn.	Incineration	Good	Negligible	Small
Monsanto	Chocolate Bayou, Tex.	Deep well disposal	Good	–	Small
	Texas City, Tex.	Deep well disposal	Good	–	Small
Vistron	Lima, Ohio	Deep well disposal and and biological treatment	Good	–	Small

* Source: Contacts with industry personnel.
** Source: Energy Resources Company Inc. estimates.

has been sharply reduced in recent years by the market surge of other chemical binders in the foundry industry - the principal end-use market for furfural-derived products. Overcapacity will be the principal cause of any future plant shutdowns, although hazardous waste management regulations may help precipitate the exit.

5.1.6.1 Model Plant Analysis

Price Elasticity of Demand. The price elasticity estimate for furfural is presented in Table 5-39. Market data on furfural, as is the case for epichlorohydrin, is scarce, making the estimation of the price elasticity slightly more difficult. However, the two countervailing forces from among those listed in the table appear to be the principal market influences. One influence which operated to decrease price elasticity was a supply shortage, as the output of the Quaker Oats Company, the sole producer, lagged behind demand. Shortages, actual or anticipated, tend to put customers at a very inelastic point on their demand curve and reduce the importance of prices on sales. On the other hand, past supply shortages have forced customers to consider alternative inputs (particularly for furan resins in the adhesive-binder market) so that some end-use markets have become fairly competitive and price sensitive.

The other influences in the baseline price elasticity are weaker. The extent of captive usage is high, because most furfural is used by Quaker Oats to make furfuryl alcohol. However, furfuryl alcohol is then sold to furan resin producers. The degree of captive usage is, therefore, misleading in this market, and has been accorded a neutral influence on the price elasticity estimate. Foreign competition is significant in this industry because it is estimated that 40 percent of domestic furfural production is exported. Quaker Oats competes with foreign producers for international customers although there are no data on the level of imports of furfural to the United States.

Likelihood of Full-Cost Passthrough. The costs of hazardous waste treatment are likely to be passed through. Table 5-40 displays the cost passthrough analysis. The required cost increase should represent, at worst, 1.4 percent of costs. The high rate of capacity utilization, estimated here as 90 percent, makes it relatively easy for the Quaker Oats Company to increase costs despite the presence of competing products. Abatement cost differences between firms are obviously not relevant because there is only one firm producing the product.

TABLE 5–39

ESTIMATION OF THE PRICE ELASTICITY OF DEMAND FOR FURFURAL

MARKET CHARACTERISTIC	PRESENT DATA*	INFLUENCE ON BASELINE PRICE ELASTICITY (1.0)**
Demand growth	Low	Increase
Historical	1970–76: 6%/yr	
Projected	3%/yr	
Captive usage	High	Neutral
Use as intermediate	High	Decrease
Significance of price as basis for competition	Low	Decrease
Substitutability	High	Increase
Foreign competition	Significant competition for foreign markets	Neutral

PRICE ELASTICITY ESTIMATE: Medium (0.5 to 1.0).**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

TABLE 5–40

LIKELIHOOD OF FULL-COST PASSTHROUGH FOR FURFURAL*

COST PASSTHROUGH FACTOR	PRESENT DATA	EFFECT ON LIKELIHOOD OF FULL COST PASSTHROUGH
Price elasticity of demand	Medium (0.5 to 1.0)	Neutral
Variation in abatement costs among firms	None	Positive
Required cost increase as % of manufacturing cost	Small	Positive
Best estimate	0.3%	
Worst-case	1.4%	
Expected capacity utilization	90% – High	Positive

LIKELIHOOD OF FULL-COST PASSTHROUGH: Good likelihood of full-cost passthrough.

* Source: Energy Resources Company estimates.

Net Income and Investment Analysis. The net income calculations for the model plant are shown in Table 5-41. The table indicates that treatment costs will have only a small effect on the profitability of the model plant. The after-tax profit rate is large in each case, with the difference between the best estimate and worst-case treatment costs being moderated by the effect of the 50 percent corporate income tax rate. The reduction in estimated net income due to the addition of treatment costs is negligible.

In order to derive the model plant cash flow figures, the after-tax profit per metric ton is added to the depreciation charges. The cash flow figures and the investment analysis calculations are presented in Table 5-42. The depreciation charges are substantial because the capital cost per metric ton of furfural is quite high. The required investments are large, $1.1 million for the best estimate of cost and $1.4 million for the worst-case cost estimate. Nevertheless, the net present value of the investment is significantly positive at $15.82 and $15.32 million respectively.

Plant Shutdowns. The requirement of an investment in hazardous waste treatment could help precipitate a plant shutdown; however, it should not be the actual cause of the shutdown. The costs of incineration are not sufficient to cause the elimination of an otherwise profitable operation. The results of the worst-case investment analysis and plant-specific data which may influence the shutdown decision are presented in Table 5-43. The highly profitable results of the investment analysis, as were discussed above, indicate a minimal impact of regulation on this market. The only factor which increases the likelihood of a plant shutdown is the fact that the Quaker Oats plants tend to be isolated manufacturing operations. Furfural production is not tied into other manufacturing processes which would then be adversely affected by the shutting down of the furfural operations. The issue of other environmental or regulatory problems is accorded a neutral influence due to the possibility that recent startup difficulties with the new Bayport plant may be related to environmental problems. Such concerns are not sufficiently important to deter the conclusion that there is a small chance of plant shutdowns.

5.1.6.2 Projected Impacts

The Chemical Division of the Quaker Oats Company has recently suffered a period of poor performance and is, therefore, somewhat vulnerable to environmental regulations. In fiscal 1977, the division showed an operating loss of

TABLE 5–41

MODEL PLANT NET INCOME CALCULATION FOR FURFURAL*

MODEL PLANT FINANCIAL DATA	TREATMENT COST SCENARIO: NO NEW TREATMENT	TREATMENT COST SCENARIO: BEST ESTIMATE OF COST	TREATMENT COST SCENARIO: WORST-CASE COST ESTIMATE
Revenue (S/MT)	1,036	1,036	1,036
Manufacturing cost (S/MT)	714	714	714
Treatment cost (S/MT)	0	2.0	9.9
Gross profit (S/MT)	322	320	312
After tax profit (S/MT)**	161	160	156
Total annual net income (S million)	2.6	2.6	2.5

* Assumes average annual production of 16,200 MT (90% of capacity). Source: Energy Resources Company Inc. estimates.

** Assumes 50% corporate tax rate.

TABLE 5–42

MODEL PLANT INVESTMENT ANALYSIS
FOR FURFURAL*

MODEL PLANT INVESTMENT MEASURES	TREATMENT COST SCENARIO: BEST ESTIMATE OF COST	TREATMENT COST SCENARIO: WORST-CASE COST ESTIMATE
After-tax profit (S/MT)	160	156
Depreciation (S/MT)	85.8	86.6
After-tax cash flow (S/MT)**	245	243
Total annual cash flow (S million)	4.0	3.9
Investment outlay (S million)	1.1	1.4
Working capital requirement (S million)†	2.6	2.6
Net present value of investment (S million)††	15.8	15.3

* Source: Energy Resources Company Inc. estimates.
** After-tax cash flow = profit + depreciation.
† Working capital requirement = 1/4 (manufacturing cost – depreciation).
†† Assumes a 15% discount rate and an investment life of 10 years.

TABLE 5–43

MODEL PLANT SHUTDOWN DECISION FACTORS USING WORST–CASE TREATMENT COST FOR FURFURAL

DECISION FACTOR	PLANT DATA*	EFFECT ON LIKELIHOOD OF PLANT SHUTDOWN**
Net present value of investment	$15.0 million	Negative
Ratio of investment to net fixed investment	2.6% – small	Negative
Degree of vertical integration (forward or backward)	Medium to high	Negative
Integration with other on-site production processes	Low – isolated plants	Positive
Other environmental/ regulatory problems	Moderate	Neutral
Likelihood of full-cost passthrough	Good likelihood of full-cost passthrough	Negative

LIKELIHOOD OF PLANT SHUTDOWN: Small chance of plant shutdown.**

* Source: Chapter Three.
** Source: Energy Resources Company Inc. estimates.

$8.8 million, compared with an operating income of $11.8 during the previous year. The company's annual report states that operating costs were up, due to expenses at the new Bayport, Texas furfural plant. The plant had been scheduled to come on line in 1977 but production runs revealed serious operating problems, and the reopening has been delayed until 1978.

Further problems for the division stem from the depressed state of the furfural market. Unit sales declined by 7 percent in fiscal 1977, and the annual report lists three reasons for the decline:

1. Reduced production in the foundry industry, which is the principal market for furfuryl alcohol.

2. The working off of large product inventories by customers built up during a previous furfural shortage.

3. Increased competition from other chemical binders and from foreign furfural producers.

Given the decline in sales and the additional new capacity to be available shortly, there is some prospect for underutilization in the older plants. A list of the Quaker Oats plants and a summary of the regulatory impact at the firm level is presented in Table 5-44. At the Belle Glade, Florida plant, adjustments have already been made to improve the operating efficiency by changing production schedules to more closely coincide with the seasonal inputs of raw materials (byproducts from sugar cane grinding). However, concern about underutilization may be premature given the temporary nature of some of the furfural market difficulties, particularly the running down of excess inventories.

5.2 Aggregate Impacts on the Industry

Because of the diverse nature of the organic chemicals industry, the six highly impacted segments that are expected to suffer the strongest impacts due to the proposed hazardous waste regulation have been studied. This detailed study presents an upper bound for impacts on the remaining segments of the industry. These remaining segments are expected to be less affected than the highly impacted segments; however, the aggregate effect of the regulation on the industry warrants further discussion. This section will treat three topics significant to the regulation's effect on the industry as a whole. These are: (1) prices and profits, (2) capital availability, and (3) competition.

TABLE 5–44

SUMMARY OF PROJECTED IMPACTS FOR FURFURAL

MANUFACTURER	PLANT LOCATIONS	CURRENT TREATMENT*	CURRENT COMPETITIVE POSITION**	MANUFACTURER RESPONSE REGARDING IMPACT*	PROJECTION OF REGULATORY IMPACT**
Quaker Oats Co.	Memphis, Tenn.; Belle Glade, Fla.; Cedar Rapids, Iowa; Omaha, Nebr.; and Bayport, Tex. (on-line, 1978)	(No plant-specific information available)	Vulnerable	–	Small

* Source: Contacts with industry personnel.
** Source: Energy Resources Company Inc. estimates.

5.2.1 Prices and Profits

By volume, 98 percent of the organic chemicals produced have a hazardous waste stream.[9] Therefore, it can be expected that most organic chemicals produced have hazardous waste streams and their manufacturers are likely to incur new costs for compliance with hazardous waste regulations, unless existing treatment is sufficient for compliance. The only available estimates of anticipated compliance costs for the entire industry were developed in the Assessment Study and are displayed in Table 5-45. The table displays the incremental annual cost of compliance with Level III along with an estimate of the value of production for the industry (both values are in 1973 dollars). It is assumed in the table that the full costs of Level I are credited to Level III. While it is likely that some present abatement expenditure will not be applicable to Level III processes, this is believed to be compensated for by the increases in treatment that have occurred since 1973. As can be seen from the table, the average incremental cost increase necessary to cover the additional costs incurred due to compliance with the regulation will be less than 1 percent for the industry as a whole. This figure includes the costs to the six highly impacted product lines discussed in Section 5.1. In fact, it is expected that incremental treatment costs as a percentage of price will exceed 1 percent for only a few chemicals. This is predicated on reviewing the sample data in Figure 2-1. While these data represent the total costs for achieving Level III (not just the incremental costs), they are good surrogates for the relative magnitude of incremental cost. This figure does not contain data for all organic chemicals but is believed to be representative of the industry as a whole.[10] The average incremental increase in cost of 0.6 percent is so small that, even under high price elasticities, it should not cause a significant change in either product prices or industry profits. It is expected, therefore, that these costs will be borne by the industry until price increases are instituted for other reasons. When price increases are initiated, they are expected to contain the incremental cost of compliance. In general, compliance costs alone are not sufficient to warrant price increases.

Due to a large variability in the actual abatement costs incurred by each plant, the actual passthrough of costs will vary from firm to firm. Some firms may react to high abatement costs (relative to other firms) by suffering a small reduction in profitability in order to keep their price at the market equilibrium. Other firms may be able to raise their profit margins if their abatement

TABLE 5–45

THE COSTS OF COMPLIANCE FOR THE ORGANIC CHEMICALS, PESTICIDES AND EXPLOSIVES INDUSTRY, 1973*

	TREATMENT LEVEL		
COST CATEGORY	LEVEL I	LEVEL III	ESTIMATED INCREMENTAL COST**
Total annual cost ($ million)	106	243	137
Value of shipments 1973 ($ million)	21,740	21,740	21,740
Total annual cost/value of shipments (%)	0.5	1.1	0.6

* Source: *Assessment Study* (1973 data).
** Energy Resources Company Inc. estimates.

costs are relatively low and the market price reflects the higher cost incurred by competitors.

5.2.2 Capital Availability

As has been discussed in the case of the highly impacted segments, the capital costs required for compliance with hazardous waste regulations are expected to be sufficiently low so as not to impose a large burden on organic chemical manufacturers. In fact, the magnitude of capital costs discussed in the analysis of the highly impacted segments is likely to overstate the impacts on large multiproduct facilities in which manufacturers will be able to exploit economies of scale in joint treatment facilities. Unfortunately, no data on the total capital costs of the regulation have yet to be developed to bear this out. However, should any individual firms be particularly severely affected by the capital costs of abatement, the opportunity exists to contract out hazardous waste treatment disposal to private hazardous waste facilities subject to the limits of the size of this small industry. In this way, the initial costs of developing a hazardous waste treatment facility can be circumvented.

5.2.3 Competition

Serious competitive effects due to brand switching or product switching are not expected due to the regulation on the hazardous waste streams in the organic chemicals industry. However, due to the diverse nature of the industry, the magnitude of cost on the various producers of each of the products will be highly variant. Accordingly, competitive forces may cause certain firms to reduce their profitability in order to maintain prices set by firms with lower abatement costs or to increase their profitability by meeting costs set by firms with higher abatement costs. As discussed in Section 5.2.1, however, the overall magnitude of cost should be small and therefore the resulting impacts are not expected to cause plant shutdowns or serious brand or product switching. The impacts that are felt are likely to be less severe on large diversified plants which generally are owned by larger firms. Accordingly, industry concentration is potentially subject to marginal increases.

Evidence of the small magnitude of the probable impacts of the regulations appears to be found in present industry practice. Many of the required hazardous waste treatment technologies have already been instituted by producers on their own initiative. Producers have been able to justify these pollution control expenditures predicated on the reduction of liability from removing hazardous wastes from possible leakage into vulnerable ecosystems. These investments have been made on a firm-by-firm basis and are not industry-wide. It nonetheless appears that firms can support such systems without marked changes in product prices or profits even if their competition incurs negligible costs.

5.3 Impacts on the Nation

The economic impacts of regulating the organic chemicals industry will extend to the nation as a whole. This section integrates the impacts resulting from the costs incurred by the industry into the fabric of the national economy. The discussion concerns itself with impacts on the following national parameters: (1) inflation, (2) employment, (3) regional dislocations, (4) foreign trade, and (5) GNP.

5.3.1 Inflationary Impacts

Organic chemicals find widespread use in the existing national economy. They are used as inputs for other manufacturing processes and in a wide variety of end uses. Accordingly, any cost increases for the organic chemical products will reverberate throughout the economy. Because no increases in productivity will accompany price increases resulting from hazardous waste treatment, these increases will be inflationary. Table 5-46 displays three estimates of the percent contribution of hazardous waste abatement costs in the organic chemicals industry to the wholesale price index for all commodities. As can be seen from this table, the expected change in the wholesale price index ranges from 0.007 to 0.015 percent. Accordingly, a noticeable inflationary impact will result from hazardous waste regulations on the organic chemicals, pesticides, and explosives industries.

5.3.2 Employment Impacts

Because a rather limited decline in demand is expected to occur as a direct result of these regulations, and because organic chemicals production utilizes minimal amounts of labor, no decrease in production employment is anticipated due to the regulation. In fact, overall employment is expected to increase slightly due to the necessity of firms' hiring workers to operate hazardous waste treatment facilities. Unfortunately, no data have

TABLE 5–46

PERCENT CONTRIBUTION OF HAZARDOUS WASTE REGULATIONS ON THE ORGANIC CHEMICALS INDUSTRY TO INFLATION OF THE WHOLESALE PRICE INDEX (ALL COMMODITIES)

ESTIMATE	WEIGHT OF ORGANIC CHEMICALS, PESTICIDES AND EXPLOSIVES IN WPI*	PERCENT INCREASE IN COST**	PERCENT INCREASE IN WPI
High estimate	0.01849	0.8	0.015
Mid-range	0.01849	0.6	0.011
Low estimate	0.01849	0.4	0.007

* Source: U.S. Bureau of Labor Statistics
** Source: Energy Resources Company Inc. estimates.

yet been developed quantifying the employment required nationally to operate Level III treatment and disposal facilities.

5.3.3 Regional Dislocations

The entire organic chemicals industry tends to be clustered in the Gulf Coast in a fashion similar to the six highly impacted segments. Accordingly, any significant changes in business levels and/or employment will be felt most strongly in this region. However, as a direct result of hazardous waste regulation on the organic chemicals industry, only small-scale increases in employment and business levels are anticipated. The Gulf Coast area will be the recipient of the greater part of these increases, but the regulation is not likely to cause any dramatic shifts in this or other regions of the nation.

5.3.4 Impacts on Foreign Trade

The small scope of this study makes it difficult to generalize about the impacts of this regulation on foreign trade. Few other nations have regulations equivalent to those anticipated domestically. Therefore, foreign producers will be able to manufacture organic chemicals without incurring the costs for hazardous waste treatment. The abatement cost alone is not likely to be large enough to create a new market for imported chemicals but will add further pressures on domestic manufacturers of those products, such as perchloroethylene, which are already subject to significant foreign competition. Similarly, costs of exported American products will face a small-scale increase while the foreign competition will not. However, just as domestic firms have already been able to undertake abatement on their own and remain competitive with those firms which have not undertaken hazardous waste treatment, foreign markets for domestic chemicals are not likely to be affected.

5.3.5 Impacts on GNP

The marginal impact of the regulation on sales in the industry is likely to be a small reduction in expected industry growth. The magnitude of this reduction will be dependent upon the price elasticity of demand for the industry. The larger the elasticity, the larger the decline in sales. This decline in chemicals production will be offset to some extent by sales associated with waste treatment activities.

Although no new products are likely to result from this regulation, the economy will experience an increase in the waste treatment sector due to the operation of new treatment facilities. Accordingly, GNP will be expected to increase by the full cost of anticipated hazardous waste treatment while it is reduced by a slackening in demand for organic chemicals. A price elasticity of demand of 1.0 for the industry as a whole will leave real GNP unchanged. A lower elasticity will increase GNP while a higher one will reduce it. If chemical sales do not decline, the estimated $137 million increase in GNP due to waste treatment will increase GNP by less than one-hundredth of a percent from its 1975 level.

NOTES TO CHAPTER FIVE

1. The analysis assumed a 15 percent cost of capital and a 10-year life for the investment. The latter assumption will not be applicable in cases where firms feel a 3- to 4-year planning horizon better reflects their uncertainties about the market.

2. Personal communication, Tom Plonlin, Dow Chemical Co., to Jeffery Stollman, ERCO, December 9, 1977.

3. Personal communication, Donald Smith, Administrative Assistant, Office of the Director of Environmental Affairs, DuPont, to John Eyraud, ERCO, August 29, 1977.

4. Personal communication, David Hill, Sales Manager, Chloromethane Solvents, Diamond Shamrock, to John Eyraud, ERCO, September 22, 1977.

5. Personal communication, Donald Smith, Administrative Assistant, Office of the Director of Environmental Affirs, Dupont, to John Eyraud, ERCO, August 29, 1977.

6. Personal communication, Mr. Shields, Allied Chemical, to John Eyraud, ERCO, September 22, 1977.

7. Personal communication, L.P. Haxby, Manager, Environmental Affairs, Shell Oil Co., to ERCO, August 30, 1977; personal communication, Charles Sercu, Director of Environmental Quality, Dow Chemical, U.S.A., to John Eyraud, ERCO, August 30, 1977.

8. DuPont, however, may currently be incinerating their wastes as noted in a personal communication, D.W. Smith, Administrative Assistant, Office of the Director of Environmental Affairs, DuPont, to J. Eyraud, ERCO, August 29, 1977.

9. TRW, Inc., Assessment of industrial hazardous waste practices: Organic chemicals, pesticides and explosives industries, prepared for the U.S. Environmental Protection Agency, 1976.

10. Personal communication, Dr. Gerald Gruber, TRW, Inc., to Jeffery Stollman, ERCO, October 21, 1977. Certain explosives purchased by the government are likely to have dramatically higher abatement cost/price ratios. However, because these are produced only in response to government orders for defense purposes, there will be negligible economic impact on these segments of the industry.