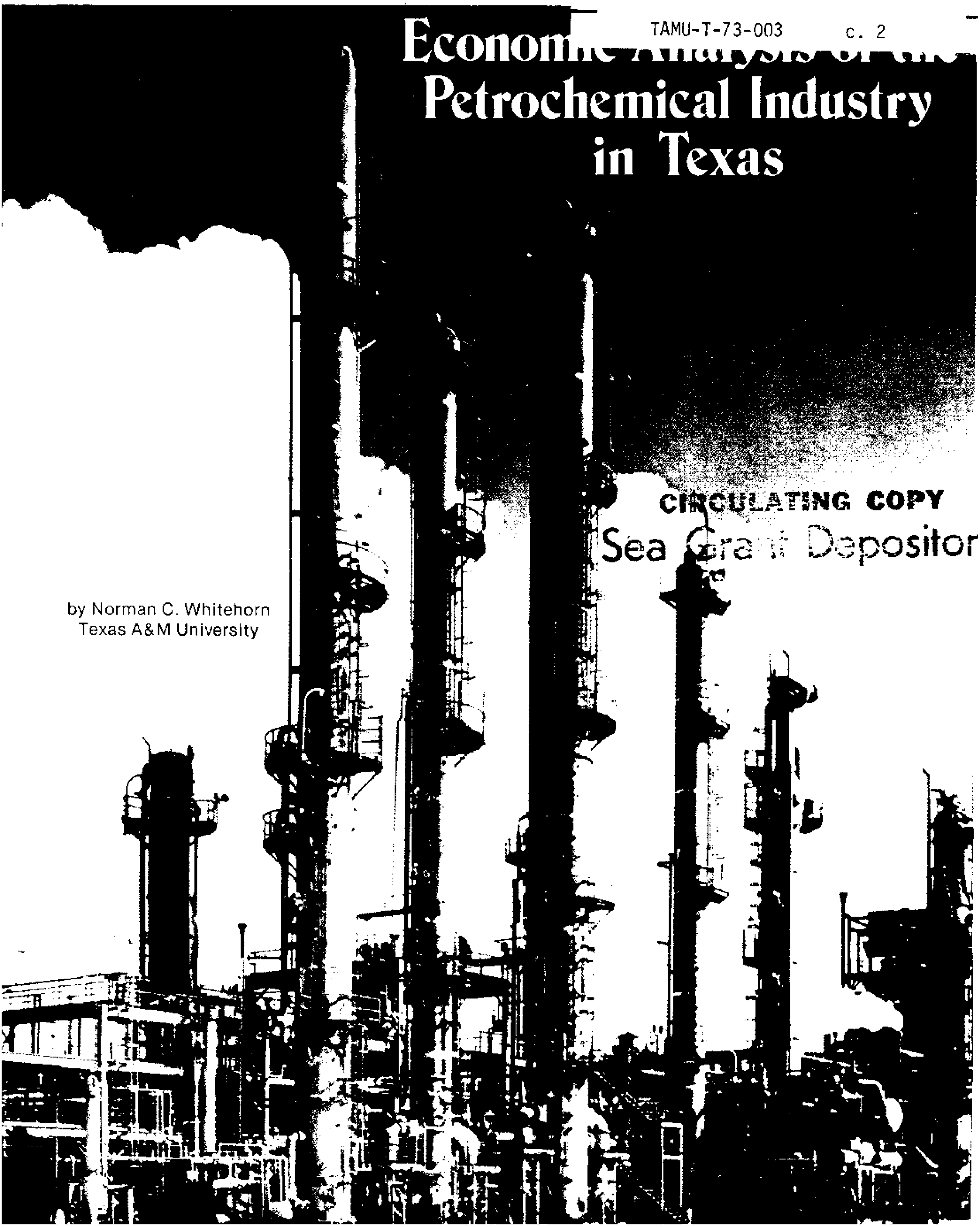
Economic Analysis of the Petrochemical Industry in Texas



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ECONOMIC ANALYSIS OF THE PETROCHEMICAL INDUSTRY IN TEXAS

MAY, 1973

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FOREWORD

It has been known for some time that the petrochemical industry is a giant among the manufacturing industries in Texas. This report is an effort to look at quantitative values of selected factors in determining the economic impact the industry has on the state's economy. Employment and payrolls, sales, value added to manufacture, capital expenditures, and investments are analyzed together with the multiplier concept in comparing the industry's contribution to the total economy.

The Industrial Economics Research Division is grateful to the individual firms interviewed for providing generously of their time and information. Assistance was also received from the Petroleum Publishing Company, Gulf Publishing Company, and the Synthetic Organic Chemical Manufacturers Association. Mr. Tom Ponder, Petrochemicals Editor of Hydrocarbon Processing and Mr. Harry Whitworth, executive secretary of the Texas Chemical Council rendered valuable assistance to the study in assessing the industry as a whole. Particular appreciation goes to Dr. C. D. Holland, Head of the Department of Chemical Engineering, Texas A&M University, and Mr. J. R. Hickey, The Dow Chemical Company, for their technical assistance throughout the study and the writing of this report.

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James R. Bradley, Head
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May, 1973

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF FIGURES

SUMMARY

The petrochemical industry in Texas is large, complex, and integrated. It exerts a strong influence on industrial activities and provides a tremendous economic impact upon the state's economy. Petrochemicals are defined for this report as those chemicals derived from petroleum and/or natural gas, but excluding all fuel and energy products such as gasoline, fuel oil, natural gas for fuel, kerosene, lubricating oils, as well as asphalt, wax, and coke.

A recent survey identified 82 firms operating 139 petrochemical manufacturing plants in Texas. While there are plants located in every part of the state, more than 67 percent by number and 88 percent by capacity are located in the Coastal Zone. By volume, the Texas Gulf Coast has the greatest United States concentration of chemical plants, producing more than 40 percent of every basic petrochemical, 80 percent of the synthetic rubber, and 60 percent of the nation's sulfur. By conservative estimates, the total production of petrochemicals in Texas in 1971 was between 75 and 85 billion pounds. Ethylene is produced in greatest quantity, with propylene and benzene next.

Employment in all manufacturing industries in Texas increased 142 percent from 1947 to 1970, while employment in the chemical industry alone increased 265 percent. In 1970, the average annual salary in Standard Industrial Classification 28, chemical and allied products, was slightly higher than $10,000 while the state average for all manufacturing industries was $7,700. The only other manufacturing industry as high as $10,000 was petroleum.

The value of shipments by the petrochemical industry in Texas

was $4,372,900,000 in 1970 or 14 percent of the total for all manufacturing industries. The "value added" of petrochemicals in recent years has consistently been the highest of any manufacturing industry in the state, amounting to more than $2.3 billion in 1970. The total plant investment of the petrochemical industry in Texas was estimated to be more than six billion dollars in 1971.

Using the <u>closed model output state multipliers</u>, calculated by the Governor's Office in its recent input-output analysis of the Texas economy, the dollar impact of the petrochemical industry on the economy in 1970 was more than $10.5 billion, but probably less than $14.6 billion. This included all direct, indirect, and induced effects caused by employment, payrolls, and taxes, as well as direct sales.

Most of the feedstocks for petrochemical plants are obtained from nearby refineries after thay have been "stripped" or processed from natural gas or crude oil. Over the past several years, Texas has consistently produced 58 percent of the entire domestic supply of feedstocks. Only about five percent of the current United States petroleum demand is used as feedstock for the petrochemical industry; the remaining 95 percent goes into the market for energy products.

Future demand for petrochemicals will depend primarily on the growth of plastics, fibers, and other synthetic materials. The total demand for aromatics and olefins used in these consumer products is anticipated to range between 73 and 91 billion pounds per year by 1980. Feedstocks for ethylene production (the major petrochemical) will change from nearly all LP-gas (Liquefied petroleum gas) to only 57 percent LP-gas by 1980, with the balance coming from the heavy liquids of naphtha and gas-oil cracking.

The shift to heavy liquids will have a pronounced effect on the economics as well as the processing technology of ethylene manufacture. Existing processing plants will need to be converted to handle the heavier liquids. Plant and equipment investment required for this change in feedstock will be substantial; in the \$150-\$200 million range.

Costs of feedstocks and labor will rise. Additional costs will be incurred for pollution control and maintenance of government regulations required by the recent Occupational Safety and Health Act and the Toxic Substances Act.

Texas' petrochemical industry began during the 1920's. The 1950's and early 1960's marked the industry's greatest growth, ranging annually from 10 to nearly 20 percent. Although it dipped in the late 1960's, the growth rate for the next few years appears to be good with estimates between seven and eight percent annually.

Economic factors most likely to change the future level of petrochemical activity in the state are the availability and cost of feedstocks and the availability and cost of energy. Feedstock shortage is the most important potential deterrent to growth for the industry in Texas.

INTRODUCTION

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Overview of the Industry

As one views the petrochemical industry today he sees a large, complex, integrated industry which, although relatively young in existence, already has a strong influence on many facets of human activities. Typical of many industries in some respects, it is difficult to give an exact date of its beginning.

Some of the earlier activities came during World War I, due to both increased military and civilian needs and to shortages of many chemicals previously obtained from Germany. Toward the end of the 1930's, the petrochemical industry gained momentum through the development of ethylene and the other olefins, propylene and butylene.

During and immediately after World War II, the petrochemical industry had its first large growth period. Huge demands existed for rubber, plastics, explosives, fertilizer, solvents and other chemicals needed for conduct of the war as well as for home uses. Coupled with this increased demand was the reduced supply of raw materials due to the action of hostile countries during the war. Because of these two developments, Texas, with its vast supply of economical raw materials, petroleum and natural gas, moved rapidly into the manufacture of petrochemicals. Several plants along the Texas Gulf Coast were built during the early 1940's to supply such needed petrochemicals as ethylene and butadiene. Originally built or contracted for by the Federal government, these plants were later operated by private corporations.

By 1940, only one producer manufactured synthetic rubber in any quantity (only 2,468 long tons). In 1941, the total output for the nation of synthetic rubber was slightly more than 8,000 tons; three years later the industry was producing more than 800,000 tons.[1] Most of this increased production came from the Texas Gulf Coast, where the raw materials, butadiene and styrene, were plentiful and relatively inexpensive.

The petrochemical industry is unique in some aspects. It is not fully understood by many individuals who actually depend heavily on the industry. Unlike the petroleum industry, it takes its raw materials from petroleum and natural gas. The petroleum industry provides, primarily, energy products for transportation, power generation, and heating, while the petrochemical industry manufactures synthetic organic chemicals, fibers, rubber and plastics. Only about five percent of the current United States petroleum demand is used as feedstock for the petrochemical industry; the remaining 95 percent goes into the market for energy products.[2]

The petrochemical industry takes petroleum raw materials--primarily liquified petroleum gases (LPG), or certain liquid fractions of crude oil--and manufactures from them 1) a broad array of "basic" petrochemicals, and 2) an even wider range of "derivatives", which are produced from the basic chemicals through further chemical processing.

Most of the intermediate products of the petrochemical industry--both the basic chemicals and the derivatives--are practically unknown

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[1]Don Whitehead, The Dow Story, (New York: McGraw-Hill Book Company, 1968) pp. 184-185.

[2]"The Petrochemical Industry and Oil Import Controls," produced and published with the cooperation of Celanese Corporation, Dow Chemical Company, I. E. DuPont de Nemours and Company, Eastman Kodak Company, Monsanto Company, National Distillers and Chemical Corporation, Olin Mathieson Chemical Corporation, Publicker Industries, Inc., and Union Carbide Corporation, March, 1969, pp. 8, 14.

to the general public, simply because the average person never sees any of them, and certainly doesn't buy any. Customers of the petrochemical industry are other industries that use petrochemicals as raw materials to manufacture thousands of consumer products, which the average person does buy, and use, every day.[3]

Purpose of Study

The economic impact generated by any organization gives a descriptive, analytical and somewhat quantitative measurement of that organization's contribution to the general economy of a particular area. These measurements provide guidelines and render valuable assistance to government, business and industry leaders, research organizations and finally to the interested public in decision making and general planning for the economic well-being of a community or region.

Since the Spindletop discovery near Beaumont in 1901, petroleum and its products have played an increasingly important role in the economy of Texas. This study analyzes the structure and some of the basic characteristics of the petrochemical industry. An effort has been made to determine the economic impact of the petrochemical industry in Texas on the economy.

This study can be helpful to industry in assessing its role in inter-industry relationships and further investments and activities. Results of the study can be used as a benchmark for further research into not only the petrochemical industry but also other organizations. Additionally, information from the study can create an awareness of needs of the industry which can be met and assisted only by government

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[3] Ibid., p. 22.

agencies (national, state, or local) working with the industry.

Scope of Study

Petrochemicals are manufactured world-wide. Plants are found in all areas where there is or has been a good supply of raw materials (petroleum and natural gas). In 1971, 1,466 plants were operating in the free world. Of this total, 622 were located in the United States.[4]

A survey was made in late 1972 of the petrochemical firms with plants located in Texas. The results of that survey, along with existing published economic data constitute the basis of this study. The survey identified 82 firms with 139 plants manufacturing petrochemicals in Texas. Included in the total were 26 sulfur plants and seven ammonia plants.

This study includes how each phase (manufacturing, marketing, transportation, employment, etc.) of the Texas petrochemical industry contributes to the economy. Figure 1 is a map of the study area and shows the general location of the plants. While there are plants located in every part of the state, more than 67 percent by number and 88 percent by capacity are located in that region defined by the Governor's Office as the Coastal Zone.

By volume, the Texas Gulf Coast has the greatest United States concentration of chemical plants, producing more than 40 percent of every basic petrochemical, 80 percent of the synthetic rubber, and 60 percent of the nation's sulfur. Principal chemical products include:

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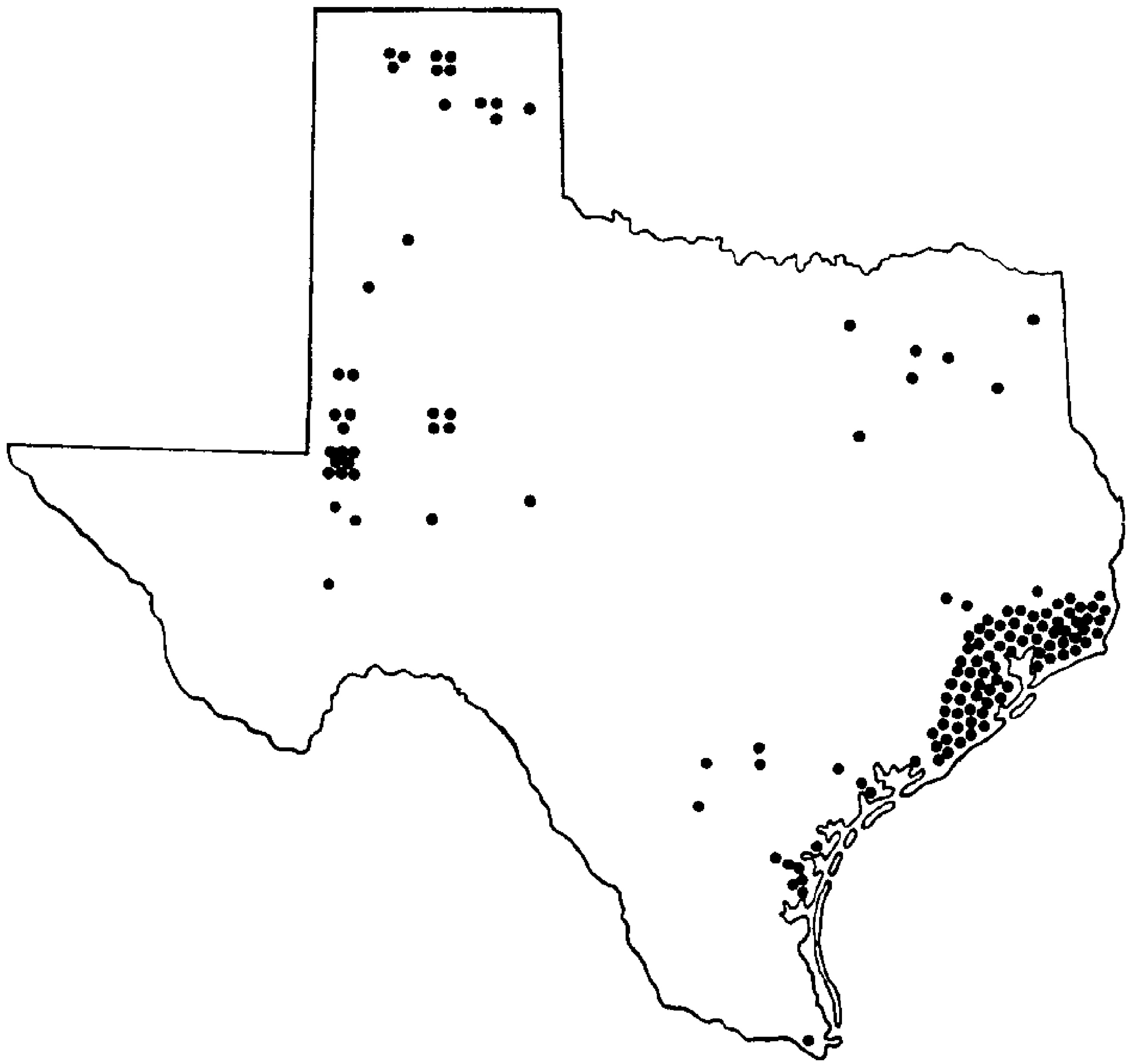
[4]"The World's Petrochemical Plants, 1971," World Petroleum, Volume 42, No. 12, December, 1971, p. 36.



LOCATION OF PETROCHEMICAL PLANTS IN TEXAS

FIGURE 1

Ethylene--Capacity in 1969 was approximately 15 billion pounds in the Gulf area, twice that in 1966; the heaviest concentration of facilities in the world.

Propylene--Capacity of plants on the Texas Coast was 7.5 billion pounds in 1969. Sixteen plants produce propylene and five make propylene derivatives.

Butadiene--Three-fourths of the United States capacity of 1.7 million tons is on the Texas Gulf Coast. A number of other sources of synthetic rubber also are produced as related chemicals.

Benzene--Oil refiners and chemical plants on the Texas Gulf Coast have capacity to produce 750 million gallons and expansion to more than 800 million gallons yearly is expected by the time complete figures are in for 1972.

Toluene--Produced almost exclusively from petroleum refining, this material is used in gasoline solvents and other products. Sixteen plants produce toluene on the Texas Coast.

Xylenes--Gulf Coast plants produce approximately one billion pounds of para-xylene and 630 million pounds of ortho-xylene yearly.[5]

Most firms began their petrochemical operations in Texas after 1940. Table 1 indicates that 53 firms began producing petrochemicals between 1940 and 1969. Just as there was a spurt in the growth of

TABLE 1

YEAR FIRMS BEGAN PETROCHEMICAL OPERATION IN TEXAS

YEARS	NUMBER OF FIRMS	PERCENT
1970-1972	3	4.6
1960-1969	17	26.6
1950-1959	21	32.8
1940-1949	15	23.4
1930-1939	4	6.3
Before 1930	4	6.3
TOTAL	64	100.0

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

[5] Texas Almanac, 1972-73, A. H. Belo Corporation, Dallas, Texas, 1972.

petrochemicals during the 1940's due to the increased demand for synthetic rubber partially brought on by the war, the growth of the plastics industry was one of the more spectacular industrial success stories of the 1950's.[6] Because of relatively inexpensive and available raw materials, much of this growth occurred in Texas.

Site selection for any industrial plant is extremely important and should involve consideration of many factors. Table 2 depicts factors used by most petrochemical firms in Texas for site selection of existing plants. By a very wide margin (47 times out of 60), "nearness to raw materials" ranked first as a reason for a firm building a petrochemical plant in Texas. "Availability of an existing facility", "nearness to markets", and "labor availability" ranked high as factors considered for plant location.

Definition of Terms

"Petrochemicals" are understood differently in different places. In many places "petrochemicals" are loosely defined, sometimes with a very broad connotation. Within the industry itself are widely different views on a definition. Sometimes the first-line raw materials and monomers are called petrochemicals. On other occasions the term is broadened to include polymers and plastics.[7]

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[6] Don Whitehead, op. cit., p. 236.

[7] Arthur M. Brownstein, editor, U. S. Petrochemicals, Technologies, Markets, and Economics, (Tulsa: The Petroleum Publishing Company, 1972), pp. 46-47.

TABLE 2

LOCATION SELECTION MOTIVES

FACTOR	NUMBER OF RANKINGS BY FIRMS 1st	2nd	3rd	4th	TOTAL TIMES SELECTED
Nearness to Raw Materials	47	5	1	0	53
Availability of Existing Facility	7	6	3	0	16
Nearness to Markets	5	8	2	1	16
Labor Availability	1	7	13	5	26
Transportation	0	13	7	4	24
Availability of Land	0	5	14	5	24
Nearness to Water Supply (Sea water and fresh water)	0	1	1	0	2
Community Desirability	0	0	1	1	2
Climate	0	0	1	0	1
Dispersion of Vital Industry	0	0	1	0	1
Economic Fuel Cost	0	0	0	1	1
Favorable Business Climate	0	0	0	1	1
TOTAL	60	45	44	18	--

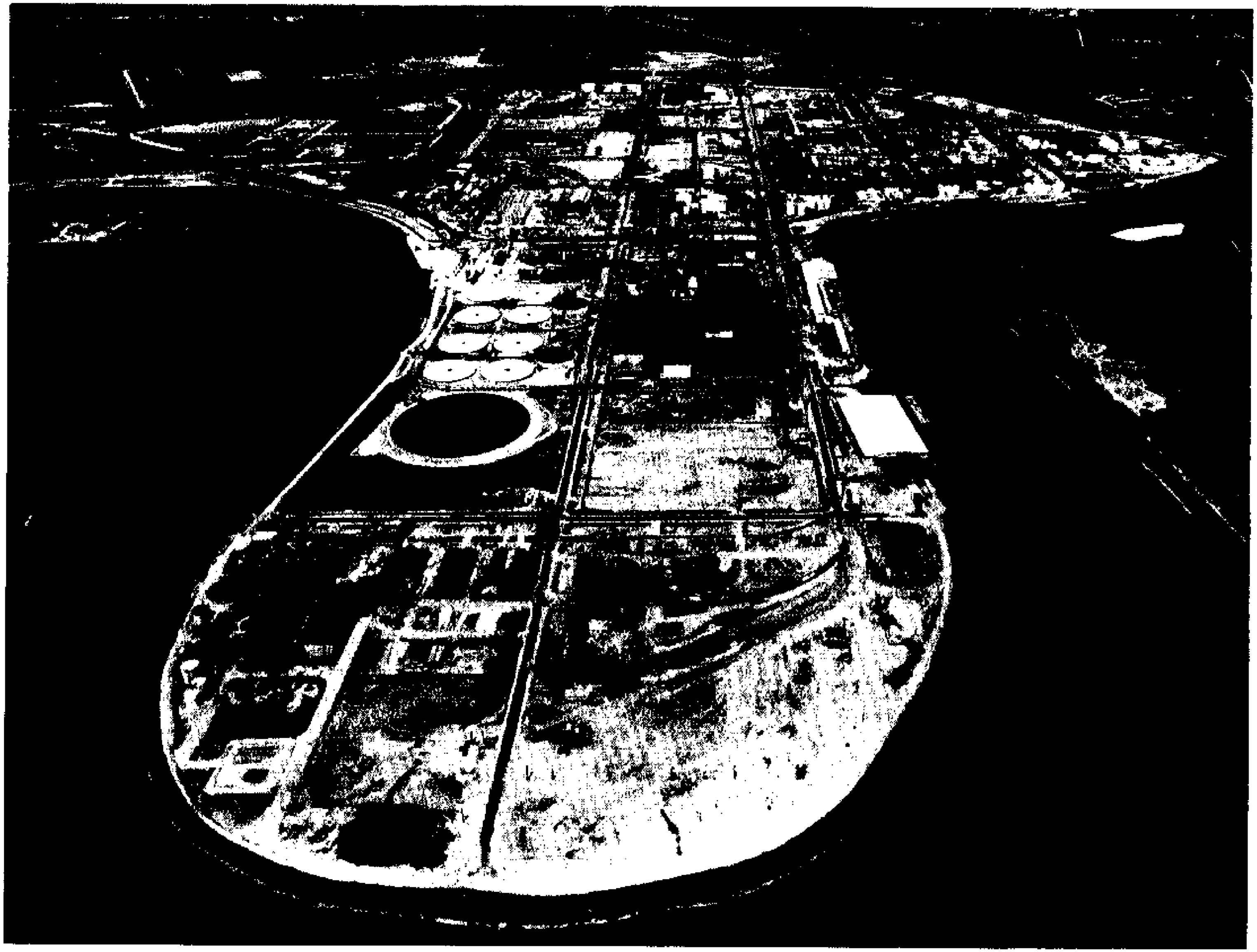
SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

Stanford Research Institute[8] has classified organic chemicals under three headings on the basis of the following definitions:

1) Primary Chemical--the first point at which a substance exists as an isolated and reasonably pure chemical. Prior to this stage, it will have been present in a raw material such as coal or will have been a component of a mixture such as a refinery gas stream.

2) Intermediate Chemical--one for which a definite chemical precursor can be identified. In addition, most of the supply of an intermediate chemical will undergo further chemical reactions to produce a variety of other chemicals.

[8]Chemical Information Service, Chemical Origins and Markets (Menlo Park, California: Chemical Information Service, Stanford Research Institute, 1967), p. 77.



Plant A in Dow Chemical U. S. A.'s Texas Division at Freeport. Photo courtesy of Dow Chemical.

3) End Chemical--one which will undergo no further chemical change prior to usage, although it may subsequently undergo physical modification or become part of a mixture.

For this report, petrochemicals are defined as those "chemicals derived from petroleum and/or natural gas, excluding all fuel and energy products such as gasoline, fuel oil, natural gas for fuel, kerosene, lubricating oils, as well as asphalt, wax, and coke." The definition includes ammonia and sulfur where these products are derived from petroleum or natural gas. Furthermore, with the possible exception of certain solvents, the definition includes only those chemicals sold to other plants and used as raw materials for further processing. It does not include end use or consumer products.

The Standard Industrial Classification (SIC) for chemicals as described in the Standard Industrial Classification Manual for 1967 by the Executive Office of the President, Bureau of the Budget, is used in this report. Table 3 lists the SIC numbers and categories of the petrochemical manufacturers in Texas.

By far the major portion of the chemical industry in Texas has its origin in petroleum and natural gas. There is only a small amount of other chemical processing which includes some of the metal compounds such as aluminum, potassium, sodium, magnesium, iron, copper and nickel.

Therefore, in order to utilize existing data, some information presented is for the broad category of chemicals listed as "SIC 28, Chemicals and Allied Products" and was obtained from the Bureau of Census.

It is estimated that about 1,400 to 1,600 chemicals of commercial significance are produced in the United States. The number of

TABLE 3

STANDARD INDUSTRIAL CLASSIFICATION OF TEXAS PETROCHEMICAL MANUFACTURERS

NUMBER	CATEGORY
2815	Cyclic Intermediates
2818	Miscellaneous Synthetic Organic Chemicals and other Industrial Organic Chemicals
2819	Synthetic Ammonia, Sulfur, Refined or Recovered from Hydrocarbons
2821	Thermoplastic and Thermosetting Resins (except resins for protective coatings)
2822	Synthetic Rubber
2871	Agricultural Chemicals
2895	Carbon Black

SOURCE: 1972 Directory of Texas Manufacturers, Bureau of Business Research, The University of Texas at Austin, Austin, Texas; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

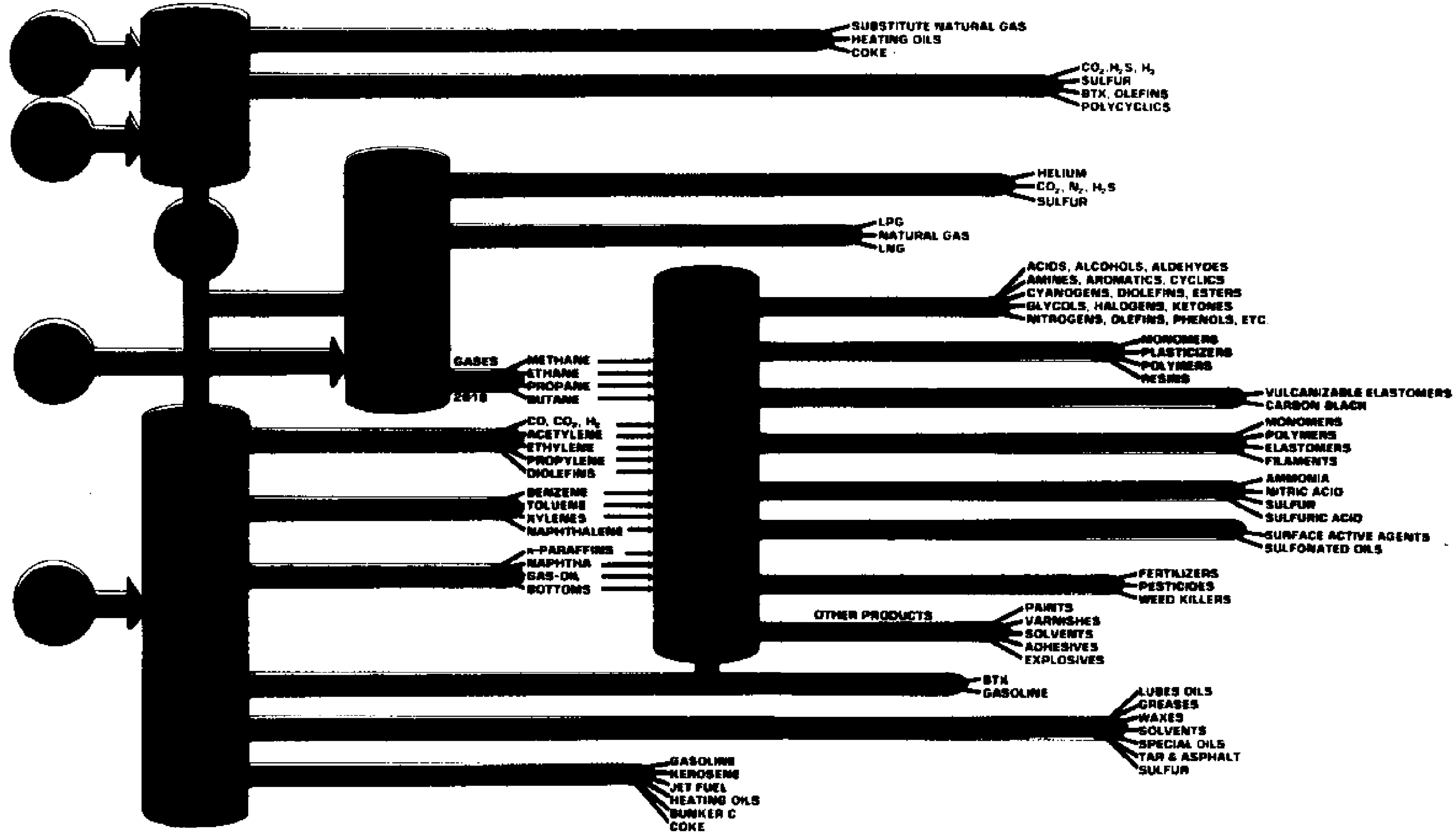
chemicals tagged as "petrochemical" are in the range of 800 to 1,000.[9]

Figure 2 is a schematic flow chart depicting the petrochemical processing industry, source of its feedstocks, and destination of its products.

Methodology

The survey was made in late 1972 of those firms manufacturing petrochemicals in Texas. In-depth interviews were conducted with 68 of the state's 82 firms producing petrochemicals. Some information was obtained from six other firms. Much of the information presented in this report is a compilation of the information collected and a consensus of 83 percent of the entire industry. Data collected

[9] R. Foy Phillips, "A Look at a Complex, Expanding, Bustling Industry--Petrochemicals," Chemical Engineering, May 22, 1967, p. 176.



SIC CLASSIFICATIONS IN 1300, 2800, 2900, AND 4900 SERIES SHOWN FOR ALL STREAMS

USED BY PERMISSION OF HYDROCARBON PROCESSING MAGAZINE AND THE GULF PUBLISHING COMPANY

FLOW CHART OF THE PETROCHEMICAL INDUSTRY

FIGURE 2

are for the year 1971. Additionally, data previously collected by other organizations and agencies are used where necessary.

IMPACT ON TEXAS' ECONOMY

IMPACT ON TEXAS' ECONOMY

Structure of the Industry

The term "structure of the industry" usually refers to certain characteristics of the industry as a whole that determine the relationship of individual firms to each other and, in a secondary sense, to other industries and finally to the consumer. Using the broader term "market structure", Bain[1] says "for practical purposes means those characteristics of the organization of a market which seem to influence strategically the nature of competition and pricing within the market."

Some characteristics most commonly emphasized and also dealt with in this report, are the degree of concentration of firms, size of firms, product differentiation, and condition of entry into the industry.

In 1972, Fortune[2] ranked by sales the 500 largest industrial corporations in the United States. Parent companies of 45 of the 82 petrochemical firms in Texas are included in that list. Seven other petrochemical firms are owned jointly by companies among the largest 500, and three are owned by large utilities. Table 4 lists the parent companies of 20 petrochemical firms. They are ranked in the top 50 largest United States industrial corporations. The total sales of all products in 1971 for the 20 firms ranged from $1,981,383,000 to $18,700,631,000 and the total assets ranged from $1,647,715,000 to $20,315,249,000. This gives some indication that the petrochemical

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[1]Joe S. Bain, Industrial Organization, (New York: John Wiley & Sons, 1962), pp. 7-9.

[2]"The 500 Largest Industrial Corporations," Fortune, Volume 65, No. 5, May, 1972, pp. 184-224.

TABLE 4

PARENT COMPANIES OF PETROCHEMICAL FIRMS IN TEXAS RANKED BY SALES AND ASSETS 1971

COMPANY	RANK OF 500 LARGEST INDUSTRIAL CORPORATIONS	SALES ($000)	ASSETS ($000)
Standard Oil (NJ) (Enjay Chemical)	2	18,700,631	20,315,249
Mobil Oil (Mobil Chemical)	6	8,243,033	8,552,273
Texaco	8	7,529,054	10,933,292
Gulf Oil (Gulf Oil Chemicals)	11	5,940,002	9,465,762
Standard Oil (Ind) (Amoco Chemicals)	15	4,054,293	5,650,724
Shell Oil (Shell Chemical)	16	3,892,373	4,646,282
DuPont	17	3,848,200	3,998,500
Goodyear Tire & Rubber (Goodyear Chemical)	19	3,601,565	3,183,547
Atlantic Richfield (Arco Chemical)	22	3,134,863	4,704,105
Continental Oil (Continental Carbon)	23	3,051,060	3,048,709
Union Carbide	25	3,037,529	3,554,668
Eastman Kodak (Texas Eastman)	28	2,975,928	3,298,032
Tenneco (Tenneco Chemicals)	32	2,840,597	4,565,170
Firestone Tire & Rubber (Firestone Synthetic Rubber)	34	2,483,599	2,344,350
Occidental Petroleum	36	2,400,012	2,580,028
Phillips Petroleum	37	2,363,199	3,166,699
Monsanto	42	2,087,100	2,153,500
Dow Chemical	46	2,052,711	3,078,807
W. R. Grace	47	2,048,873	1,647,715
Union Oil of California	50	1,981,383	2,564,770

SOURCE: <u>Fortune</u>, Volume 65, No. 5, May, 1972, Chicago, Illinois; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

industry is fairly evenly distributed among several firms.

It should be noted, however, that the ranking by Fortune is not necessarily a ranking in petrochemical production and sales. Fortune ranks by total sales of all products.

During the 1950's and 1960's integration increased considerably. Generally, integration in a firm may take any one or a combination of three approaches--1)vertical backward integration; 2) vertical forward integration, or 3) horizontal integration. All three approaches have been used in the petrochemical industry.

Sherwood[3] in his discussion of vertical forward integration in the petrochemical industry says:

> It is axiomatic that the security of a business venture increases as we approach the end markets. The number of potential customers increases as we get closer to the end market. At the same time, the volume sold to each customer becomes smaller, so that loss of a particular outlet becomes less fatal to the venture. As a corollary, however, the approach to the end markets also requires a more complex sales effort and more intensive technical service in support of sales.
>
> The ability to bolster the venture's position, frequently coupled with a higher potential return on investment, has been a major consideration in favor of forward integration, i.e., diversification in the direction of the end markets.

Thus, it is interesting to note that the six largest industrial firms producing petrochemicals are petroleum companies, which have integrated forward to the manufacturing and marketing of petrochemicals since 1940. Of the 45 firms producing petrochemicals in 1971 and ranked in Fortune's 500 largest industrial corporations, 21 are basically petroleum companies taking advantage of their good supply of raw materials and integrating forward toward their end markets.

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[3]Peter W. Sherwood, "Practical Approaches to Petroleum Diversification," World Petroleum, Volume 38, No. 11, October, 1972, p. 56.

Production

Chemical Information Service of the Stanford Research Institute[4] lists 11 chemicals as primary organics, 89 as organic intermediates, and 110 as organic end chemicals. By slight changes in processes, it is easy to arrive at several hundred different petrochemicals. Most of these petrochemicals are produced by more than one firm. Table 5 ranks six of the highest productive petrochemicals in 1970.

TABLE 5

UNITED STATES PRODUCTION AND VALUE
OF PETROCHEMICALS
1970

PETROCHEMICAL	PRODUCTION (Pounds)	PRODUCTION VALUE (Dollars)
Ethylene	15,950,000,000	526,400,000
Benzene	8,537,000,000	256,100,000
Propylene	8,100,000,000	243,000,000
Toluene	5,001,000,000	125,000,000
Styrene	4,353,000,000	304,700,000
Butadiene	3,054,000,000	256,500,000

SOURCE: Stanford Research Institute, Menlo Park, California; and Industrial Economics Research Division, Texas A&M University, College Station, Texas.

These petrochemicals are also the highest produced in quantity in Texas. Table 6 gives the capacity for production in Texas as compared to the United States. In terms of "industry structure," a large number of firms produce each of the chemicals.

It is difficult to arrive at a total production figure for petrochemicals. Of the 82 firms in Texas, 62 produced 68,726,418,339

[4]Chemical Information Service, op. cit., p. 3.

TABLE 6

CAPACITY DISTRIBUTION OF MAJOR
PETROCHEMICAL PRODUCTION*
1972

PETROCHEMICAL	NO. OF PRODUCERS		CAPACITY (BILLION LBS.)	
	U.S.	TEXAS	U.S.	TEXAS
Ethylene	25	17	21.6	10.6
Propylene	37	19	14.8	9.3
Benzene	18	11	11.4	3.8
Toluene	14	8	6.9	2.1
Styrene	13	8	5.7	3.4
Butadiene	20	13	4.0	3.3

* Only the major producers.

SOURCE: The Petroleum Publishing Company, Tulsa, Oklahoma; Ericsson Chemical Service, Houston, Texas; and Industrial Economics Research Division, Texas A&M University, College Station, Texas.

pounds of petrochemicals for sale or distribution in 1971. The volume capacity of 14 additional firms was 7,586,147,800 pounds. Assuming the 14 firms were able to produce 85 percent of capacity, the total estimated volume of production for 76 firms was 75,175,643,969 pounds. No reliable figures could be obtained on the production or the capacity of the six remaining firms. By conservative estimates, the total production of petrochemicals in Texas in 1971 was more than 75 billion pounds but probably less than 85 billion.

Employment

In addition to the size of firms regarding their capacity of production, another feature of industry structure is size of firms according to employment. The Texas petrochemical industry reveals a similar pattern to the national one. Table 7 shows the employment range of 68 firms surveyed in Texas. The figures shown indicate only

TABLE 7

EMPLOYMENT DISTRIBUTION BY FIRMS
1971

EMPLOYMENT RANGE	NUMBER OF FIRMS	PERCENT
Less than 8	2	2.9
8-24	4	5.9
25-49	6	8.8
50-99	5	7.4
100-249	14	20.6
250-499	9	13.2
500-999	13	19.1
1,000-4,999	12	17.7
More than 5,000	2	2.9
Labor Contracted	1	1.5
TOTAL	68	100.0

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

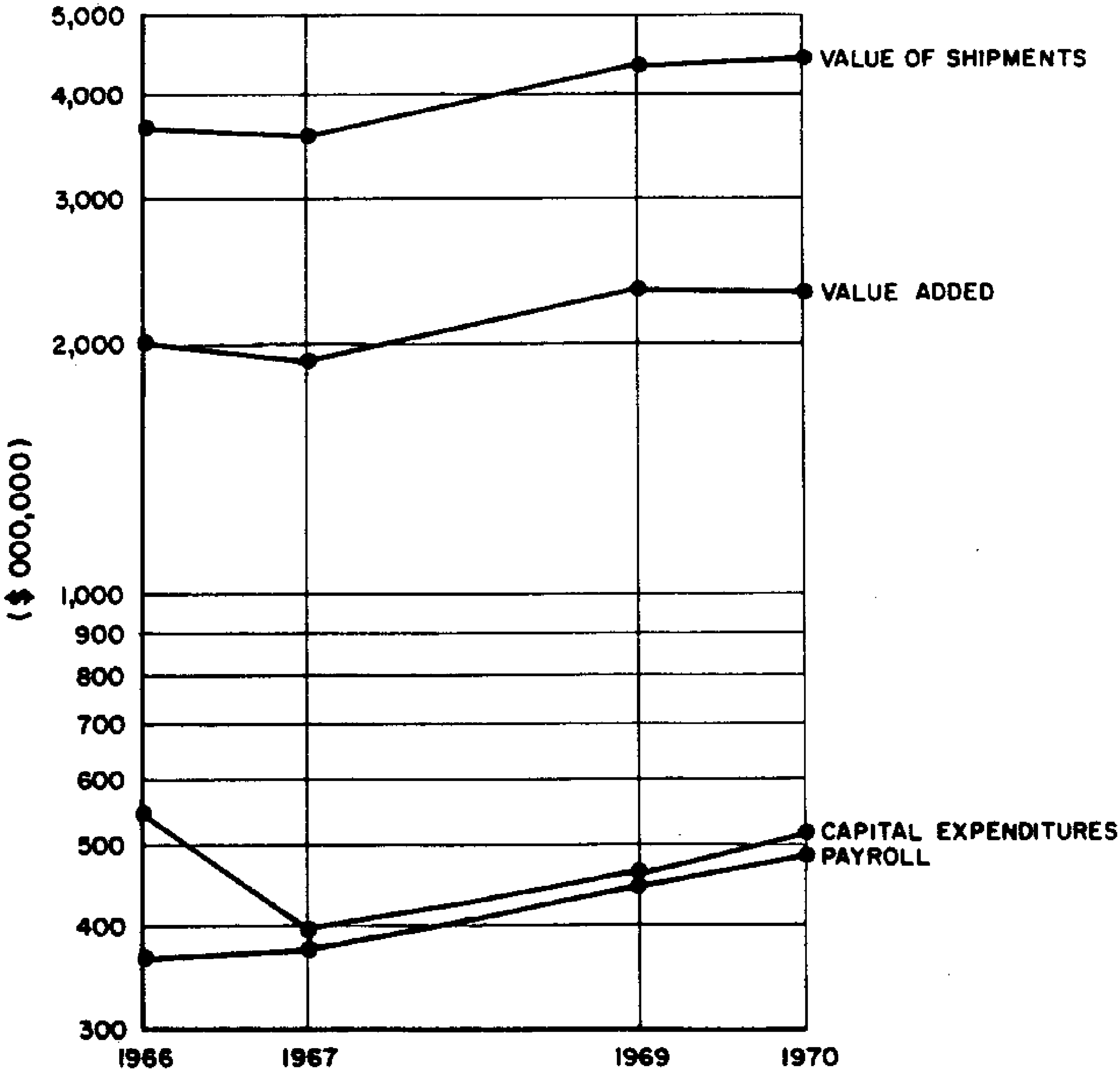
the employment in Texas plants.

Measures of Direct Economic Impact

Economic impact can be measured in many ways. Several features examined in this study include employment and payrolls, sales, value added, capital expenditures and plant investment. Figure 3 indicates minor fluctuations in each of these areas but with a general increase over the period of 1966 to 1970. Table 8 also shows these relationships.

Employment and Payrolls

Employment usually is considered a direct impact on the economy. Full employment is the goal of every government administration. Nationally, economic growth and efficiency are realized the greatest when full employment and full production are achieved or, stated negatively, when unemployment is avoided. The same principle holds



DOLLAR VALUE OF PAYROLLS, CAPITAL EXPENDITURES, SHIPMENTS, AND VALUE ADDED TO SHIPMENTS OF THE PETROCHEMICAL INDUSTRY, 1966-1970

FIGURE 3

TABLE 8

EMPLOYMENT, PAYROLL, VALUE ADDED, VALUE OF SHIPMENTS, AND CAPITAL EXPENDITURES OF THE PETROCHEMICAL* INDUSTRY IN TEXAS 1966-1970

YEAR	EMPLOYMENT (000)	PAYROLL ($000,000)	VALUE ADDED ($000,000)	VALUE OF SHIPMENTS ($000,000)	CAPITAL EXPENDITURES ($000,000)
1970	47.7	482.0	2,322.1	4,372.9	517.4
1969	45.1	449.0	2,326.4	4,332.9	461.6
1967	41.9	372.5	1,900.5	3,591.5	396.4
1966	42.5	365.3	2,007.2	3,686.6	540.9

*SIC 281, 282, 287, and 289

SOURCE: Annual Survey of Manufacturers, Bureau of the Census, United States Department of Commerce, Washington, D. C.

true for a smaller economic region.

For the past two decades employment in petrochemicals has provided stability and growth to the general economic condition of Texas. Employment in all manufacturing industries in Texas increased 142 percent from 1947 to 1970, while employment in the chemical industry increased 265 percent.[5]

Salaries paid to employees in the chemical industry have consistently ranked among the highest in the state among all manufacturing industries. In 1970, the average annual salary in SIC 28, chemicals and allied products, was slightly higher than $10,000, while the state average for all manufacturing industries was $7,700. The only other manufacturing industry higher than $10,000 was SIC 29, Petroleum and Coal Products.[6]

[5]Texas Almanac, 1954-1955 and 1972-73, op. cit.

[6]Annual Survey of Manufacturers, 1970, Bureau of the Census (Washington, D. C.: U. S. Department of Commerce, December, 1972).

In the survey just concluded, 67 petrochemical firms in Texas represented a total employment in 1971 of 45,655 with an annual payroll of $552,795,907, for an average annual salary per employee of $12,108. Assuming this is a representative sample of the industry, the average annual salary in the petrochemical industry is slightly higher than both other chemical and other manufacturing industries.

Sales

Sales constitute the value of industry shipments. In the manufacture of petrochemicals, many products are made and utilized within the plants to be used in the further processing of other petrochemicals. Ethylene is a prime example of this; it is first processed from refinery gas, liquefied petroleum gases (propane/ethane) or liquid hydrocarbons and further used in the manufacture of many other petrochemicals.

The value of industry shipments includes all products sold, transferred to other plants of the same company, or shipped on consignment. The value of shipments by the petrochemical industry in Texas was $4,372,900,000 in 1970, or 14 percent of the total for all manufacturing industries.[7]

Petrochemical sales from 58 Texas plants in 1971 are shown in Table 9. Nearly half of those reporting had sales exceeding $20,000,000.

Value Added

"Value added by a firm or an industry is its dollar sales minus its purchases of intermediate products from other firms or industries."[8]

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[7] Annual Survey of Manufacturers, 1970, Ibid.

[8] Donald Stevenson Watson, Price Theory and Its Uses, (New York: Houghton Mifflin Company, 1963), p. 390.

Aerial view of the Texas Eastman plant. Photo courtesy of Texas Eastman.

TABLE 9

PETROCHEMICAL SALES FROM TEXAS PLANTS
1971

SALES ($)	NO. OF FIRMS
up to 100,000	3
100,000 to 1,000,000	6
1,000,000 to 20,000,000	24
20,000,000 to 50,000,000	9
50,000,000 to 100,000,000	6
100,000,000 to 500,000,000	10

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

This measure of manufacturing activity avoids the duplication in the value of shipments figure which results from the use of products of some firms as materials by others. Consequently, it is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas.[9]

Value added is derived by subtracting the cost of materials, supplies, containers, fuel, purchased electricity, and contract work from the value of shipments for products manufactured plus receipts for services rendered.

The value added of petrochemicals in recent years consistently has been the highest of any manufacturing industry in the state. Other industries may have a greater employment and, consequently, a higher payroll, but in value added, as Watson[10] further defines as the "value

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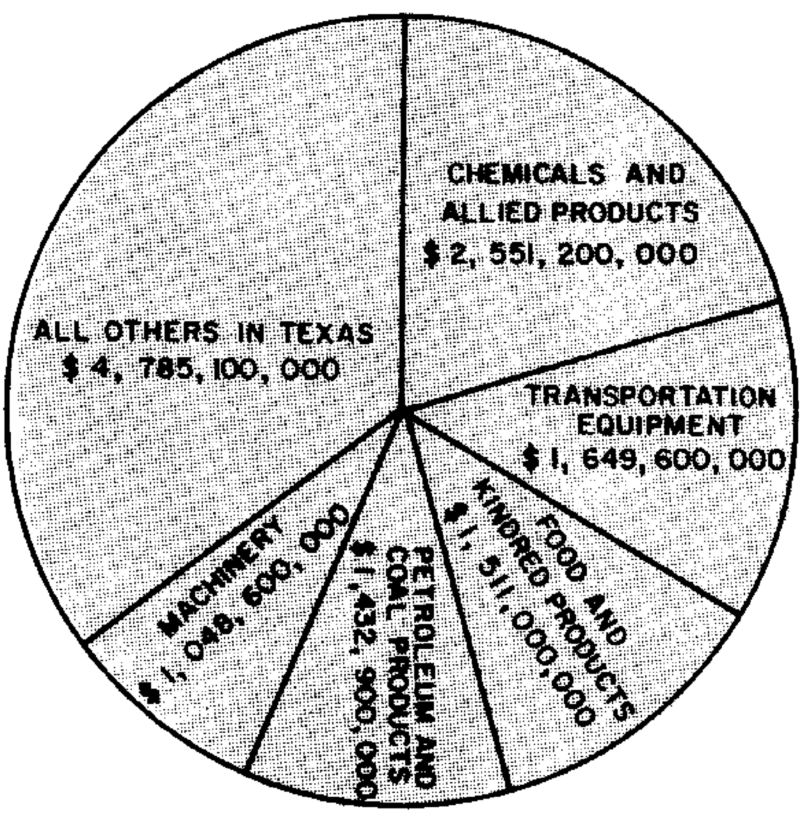
[9] _Annual Survey of Manufacturers, 1970_, _Ibid_.

[10] Donald Stevenson Watson, _op. cit._, p. 390.

of the services of the workers and of the owners in the firm or industry," petrochemicals rank the highest.

Table 10 shows the relationship of the five manufacturing industries in Texas with the highest value added to each other and to the state. Petrochemicals (SIC 281, 282, 287, and 289) in 1970 were responsible for 17.9 percent of the total value added by manufacturing for the state.

The importance of the value added by manufacture of petrochemicals may be seen more clearly in Figure 4. In the graph, petrochemicals are included (accounting for 91 percent) in the broad, two-digit category SIC 28 (chemicals and allied products).



VALUE ADDED BY MANUFACTURE OF HIGHEST SIC CATEGORIES OF MANUFACTURED PRODUCTS IN TEXAS
1970
FIGURE 4

TABLE 10

VALUE ADDED OF FIVE MAJOR MANUFACTURING INDUSTRIES
1963-1970
(Million Dollars)

MANUFACTURING INDUSTRY (SIC)	1963		1967		1969		1970	
	VALUE ADDED	PERCENT OF TOTAL	VALUE ADDED	PERCENT OF TOTAL	VALUE ADDED	PERCENT OF TOTAL	VALUE ADDED	PERCENT OF TOTAL
20-Food	929.5	13.1	1,172.3	10.7	1,371.4	10.6	1,511.1	11.6
28-Petrochemical	**1,524.1**	**21.4**	**1,900.5**	**17.4**	**2,326.4**	**18.0**	**2,322.1**	**17.9**
29-Petroleum	1,005.7	14.1	1,800.5	16.5	1,670.5	12.9	1,432.9	11.0
35-Machinery	510.4	7.2	773.6	7.1	995.8	7.7	1,048.6	8.1
37-Transportation Equipment	615.6	8.7	1,248.1	11.4	1,295.2	10.0	1,649.6	12.7
All Others	2,534.2	35.5	4,027.4	36.9	5,262.7	40.8	5,014.2	38.7
Total for State	7,119.5	100.0	10,922.4	100.0	12,922.0	100.0	12,978.5	100.0

SOURCE: Annual Survey of Manufacturers, Bureau of the Census, United States Department of Commerce, Washington, D. C.; and Industrial Economics Research Division, Texas A&M University, College Station, Texas.

Capital Expenditures

According to the Bureau of Census, capital expenditures are those expenditures for 1) permanent additions and major alterations to manufacturing establishments and 2) new machinery and equipment used for replacement purposes and 3) additions to plant capacity if they are of the type for which depreciation accounts are ordinarily maintained.[11] In 1970 the petrochemical industry invested $517,400,000 in capital expenditures. As was shown in Table 8, this expenditure has been fairly constant over the past few years which, among other things, indicates some of the long range plans for the petrochemical industry in Texas.

Investment

A firm's investment in its physical facilities often is an indication of its long range plans. While certain external factors, such as raw material supply, labor availability, markets, etc., may influence decisions on future plant locations, present facilities investments also can provide insight into the industry's priorities in maintaining its position in a region.

In 1971, the combined plant financial investment of 58 of the 82 petrochemical firms in Texas was $5,210,848,000. This accounted for only the plant facilities in Texas. As might be expected, several firms were reluctant to give this type of information. However, by using published data and a ratio of plant investment to employment, the total plant investment of the petrochemical industry in Texas was estimated to be $6,140,463,000.

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[11] Annual Survey of Manufacturers, 1970, op. cit., p. A-3.

Multiplier Effect

In addition to any direct impact on the economy, an indirect effect accounts for the re-spending cycle stimulated by direct employment, payrolls, and value of shipments. This effect, known as the "multiplier effect," is still considered an effective tool for analyzing economic growth. It is based upon two facts. The economy is characterized by repetitive, continuous flows of expenditures and income wherein the dollars spent by one individual are received as income by another. Any change in income will cause both consumption and saving to vary in the same direction as, and by a fraction of, the change in income.[12]

A further explanation of the multiplier concept states that an increase in the output of a region will lead to an increase in regional employment and, therefore, to an increase in regional income. The increased income will, in turn, be spent to induce a second round of increased regional employment and income, which will also be spent to induce more income, and so on, to a finite limit. The calculated regional multiplier is an estimate of the total amount of income generated by the addition of one dollar of new income into the region.[13]

During the past three years, the Division of Planning Coordination in the Governor's Office and a group of state agencies sponsored an extensive input-output analysis of the structure of the statewide and regional economies. The objectives were to measure the gross output of each sector of the state's economy, to measure the inputs of each

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[12]Campbell R. McConnell, Economics: Principles, Problems, and Policies, (New York: McGraw-Hill Book Company, 1966), pp. 243-247.

[13]Eric Schenker, "Present and Future Income and Employment Generated by the St. Lawrence Seaway," (Milwaukee, Wisconsin: Center for Great Lakes Studies, the University of Wisconsin-Milwaukee, 1971).

sector, to calculate the interdependency among the producing sectors, (including each sector's multiplier), and to estimate the structure of the state's economy in quantitative terms.

Table 11 gives a list of the individual sectors included in the petrochemical industry along with the closed model output state multipliers which have been calculated for each sector by the Governor's Office. Since no state multiplier has been calculated for the total sectors in the petrochemical industry, the multiplier must be viewed somewhere within the range between 2.41431047 and 3.33624615.

TABLE 11

MULTIPLIER COEFFICIENTS OF SECTORS INCLUDED IN THE TEXAS PETROCHEMICAL INDUSTRY

SECTOR NUMBER	SECTOR NAME	MULTIPLIER COEFFICIENT	SIC'S CONTAINED WITHIN SECTOR
53	Cyclic Crudes and Intermediates	3.33624615	2815
54	Organic Chemicals	2.67259550	2818
55	Inorganic Chemicals	2.42304049	2819
56	Fibers, Plastics	2.76672945	2821, 2823, 2824
57	Synthetic Rubber	2.71296324	2822
59	Agricultural Chemicals	2.60820147	2871, 2872, 2879
62	Other Chemicals	2.41431047	2861, 2891, 2892, 2893, 2895, 2899

SOURCE: Division of Planning Coordination of the Governor's Office, Austin, Texas; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

Total Value of Impact

The value of the petrochemical industry output was referred to previously in Table 8 as the value of industry shipments, including all products whether sold, transferred to other plants of the same company, or shipped on consignment. This is also referred to as direct sales of the industry, which contributes a direct impact upon the economy. The direct value of the state's petrochemical industry shipments in 1970 was $4,372,900,000. Table 12 shows the range of the dollar value of the economic impact using the lowest and the highest multiplier coefficient for sectors in the petrochemical industry. Briefly stated, the dollar value of impact of the petrochemical industry on the Texas economy in 1970 was more than $10,557,500,000 but probably less than $14,589,100,000. This included the indirect and induced effects caused by employment, payrolls, and factors other than direct sales.

TABLE 12

ECONOMIC IMPACT OF THE PETROCHEMICAL INDUSTRY
1970

MULTIPLIER COEFFICIENT	DOLLAR VALUE OF INDUSTRY SHIPMENTS (MILLION)	DOLLAR VALUE OF IMPACT (MILLION)
2.41431047	$ 4,372.9	$ 10,557.5
3.33624615	4,372.9	14,589.1

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

RAW MATERIAL SUPPLY

RAW MATERIAL SUPPLY

Basically, two major types of raw materials, or feedstocks, are used for petrochemical production. One is natural gas liquids, which comes from natural gas production. The other is heavy liquids distilled from crude oil, or even crude oil itself. While the economical price of natural gas in the United States makes it most attractive as a feedstock for many petrochemicals, crude oil-based feedstocks result in the manufacture of a greater variety of petrochemicals. Many of these chemicals are key intermediates used in the production of numerous synthetic products such as fibers and rubbers.

Since many petrochemicals can originate from either of these types of feedstocks, such factors as availability of raw material, cost of raw material, processing cost, and by-product production often dictate the feedstock to be used. A primary example of this is the production of ethylene.

Costs

When cracking ethane, 82 percent of the feedstock is converted to ethylene. In contrast, when cracking gas oil, only 11 percent of the feedstock goes to ethylene. Thus the accounting methodology also becomes important to the understanding of the feedstock contribution to total costs. For the heavier feedstocks such as gas oil, a co-product accounting system, where feedstock costs are prorated among all products, is usually used. The treatment used here has been to consider residual gas value as a by-product credit reducing gross raw material costs. Then all other materials are treated as co-products of ethylene manufacture.[1]

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[1]Arthur M. Brownstein, ed., op. cit., pp. 28, 29.

Details of this evaluation are given in Table 13 on costs of ethylene manufacture at the rate of one billion pounds per year. It demonstrates that feedstock costs comprise 53 percent of total costs in cracking ethane and 85 percent of total costs of petrochemicals when cracking gas oil. Table 14 shows the material balances for these two cracking operations.

TABLE 13

COSTS OF ETHYLENE MANUFACTURE[a]

ITEM	ETHANE 3¢/GAL. $ MILLION PER YEAR	ETHANE 3¢/GAL. PERCENT OF TOTAL COSTS	GAS OIL 8¢/GAL. $ MILLION PER YEAR	GAS OIL 8¢/GAL. PERCENT OF TOTAL COSTS
Feedstock	12.000		91.900	
Less residual gas	1.140		4.400	
Net feedstock	10.860	53	87.500	85
Direct Costs				
Utilities	4.500		8.000	
Catalyst & Chemicals	0.631		1.000	
Labor & supervision	0.572		0.700	
Maintenance	0.770		1.000	
	6.473	32	10.700	10
Indirect Costs				
Depreciation	2.370		3.000	
General overhead	0.474		1.500	
Taxes & insurance	0.237		0.300	
	3.081	15	4.800	5
Total Costs	20.414	100	103.000	100
Total MM lb. products	1075		7750	
Unit product cost, ¢/lb.	1.9[b]		1.33[b]	

[a]Data: SRI Report, Volume II, Page 77.
[b]These data do not include sales, research, administration or other corporate expenses, nor income taxes or profit on the investment.

SOURCE: US Petrochemicals, The Petroleum Publishing Company, Tulsa, Oklahoma; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

TABLE 14

CRACKING PRODUCTS

PRODUCT	ETHANE[a] MM LB/YR	ETHANE[a] PERCENT	/GAS OIL[b] MM LB/YR	/GAS OIL[b] PERCENT
Ethylene	1,000	93	1,000	13
Propylene & higher	75	7		
Propylene	-		1,000	13
Butenes & butadiene	-		750	9
Pentanes & higher	-		5,000	65
	1,075	100	7,750	100

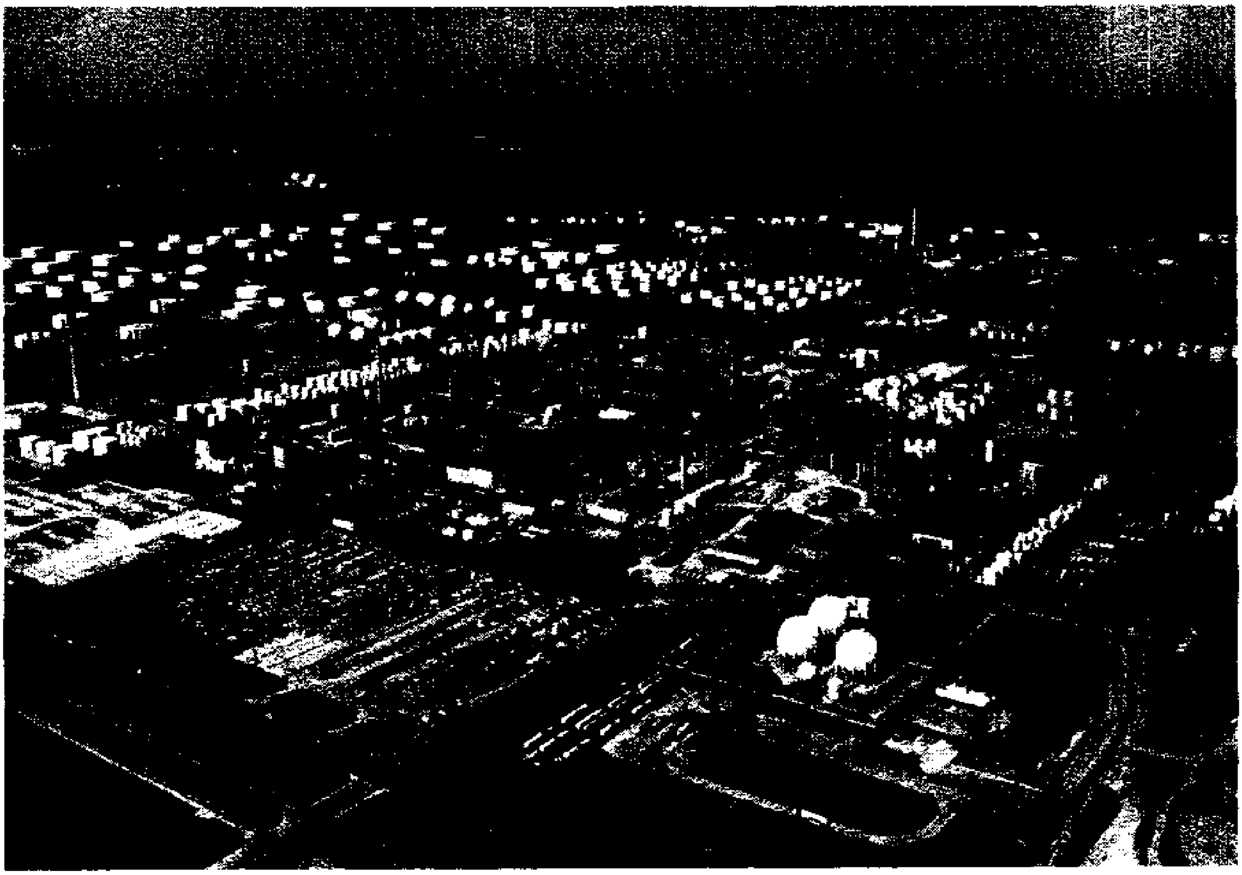
[a]As residue gas was 150 MM lb., about 82 percent of the feedstock was converted to ethylene.
[b]Residue gas 1,000 MM lb.; 11 percent feedstock to ethylene.

SOURCE: US Petrochemicals, The Petroleum Publishing Company, Tulsa, Oklahoma; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

Sources

When considering the supply of raw materials for petrochemicals, it should be remembered that basically the same materials--natural gas and crude oil--have been the nation's source of energy products for many years. Many people at one time thought the supply of these natural resources was unlimited. Now the nation is beginning to experience a sharp decrease in the domestic supply. Bragg and Bradley[2] listed three major factors as contributing to the energy problem--population growth, rising standard of living, and reduced oil production. As stated earlier in this report, 95 percent of the petroleum demand goes for energy products and only five percent to the petrochemical industry. It is safe to assume, therefore, that the

[2]Daniel M. Bragg and James R. Bradley, "The Economic Impact of a Deepwater Terminal in Texas," Sea Grant Report TAMU-SG-72-213, Texas A&M University, College Station, Texas, November 1972.



Aerial view of Shell's Deer Park Chemical plant. Photo courtesy of Shell Chemical Company.

manufacture of energy products has substantial influence over the raw material supply for petrochemicals.

In Texas the petrochemical industry uses both natural gas and crude oil as feedstocks for further processing. Most petrochemical plants, however, take as their raw materials "first-line" chemicals or monomers after these chemicals have been stripped or processed from natural gas or crude oil by refineries. Consequently, most of the feedstocks for petrochemical plants are obtained from nearby refineries. Table 15 shows the production of petrochemical feedstocks by refinery districts in the United States from 1964 to 1968. Texas consistently produced 58 percent of the entire domestic supply of feedstocks. Table 16 indicates that, in 1971, 53 of 65 Texas firms received more than 80 percent of their raw materials from Texas. Thirty-five received all their raw materials from Texas, and nine firms imported some feedstocks. Eighteen firms declined to indicate their source.

TABLE 15

UNITED STATES PRODUCTION OF PETROCHEMICAL FEEDSTOCKS BY REFINERY DISTRICTS 1964-1968 (Thousands of Barrels)

YEAR	TEXAS GULF COAST	TEXAS INLAND	LOUISIANA GULF COAST	ALL OTHERS	TOTAL UNITED STATES	TEXAS PERCENT OF TOTAL
1968	78,258	4,579	23,247	36,323	142,407	58.2
1967	71,628	4,394	20,171	35,162	131,355	57.9
1966	65,177	4,101	19,400	31,903	120,581	57.5
1965	59,187	4,096	17,994	27,285	108,562	58.3
1964	57,290	3,571	18,140	25,845	104,846	58.1

SOURCE: American Petroleum Institute, "Petroleum Facts and Figures, 1971 Edition," API, Washington, D. C., 1971.

TABLE 16

SOURCE OF RAW MATERIALS FOR PETROCHEMICAL PLANTS IN TEXAS
1971

SOURCE	PERCENT OF FIRM'S TOTAL SUPPLY OF RAW MATERIALS 1-20	21-40	41-60	61-80	81-100	TOTAL
	Number of Firms					
Texas	0	1	5	6	53*	65
Other States	11	4	6	2	0	23
Foreign	8	1	0	0	0	9

* 35 firms receive all raw materials from Texas

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

The complexity of petrochemical processing, mentioned earlier, is demonstrated also in the raw materials used by processing plants. Raw materials are used sometimes in the manufacture of products which, in turn, may be used only in further processing of other products. A good example of this is ethylene. In many instances ethylene is manufactured by a plant, not to be sold, but to be used in the processing of other chemicals to be sold. Raw materials may also be used to make products which become raw materials for other plants. This cycle may be repeated several times, with products still classified as intermediate chemicals.

Supply/Demand

As previously shown in Table 2, an overwhelming majority of firms (47 of 60) ranked "nearness to raw materials" as a primary reason for building a plant in Texas. The state has had an abundant supply of both crude oil and natural gas for four decades, producing annually more than one-third of the total domestic supply of crude oil in the United States.

Table 17 shows the amount of production of natural gas and crude oil in Texas during the period 1950 to 1970. While the level of production in Texas of both raw materials has generally increased over the years, the demand has increased even more. In addition, known reserves of both oil and gas are declining rapidly. Figures 5 and 6 illustrate this fact quite plainly. In 1985, the domestic supply of natural gas will account for only about 56 percent of the potential demand for gas; the domestic supply of crude oil will account for only 49 percent of its demand. With about 95 percent of all gas and oil going to the energy market, there will be strong competition for petrochemical feedstocks.

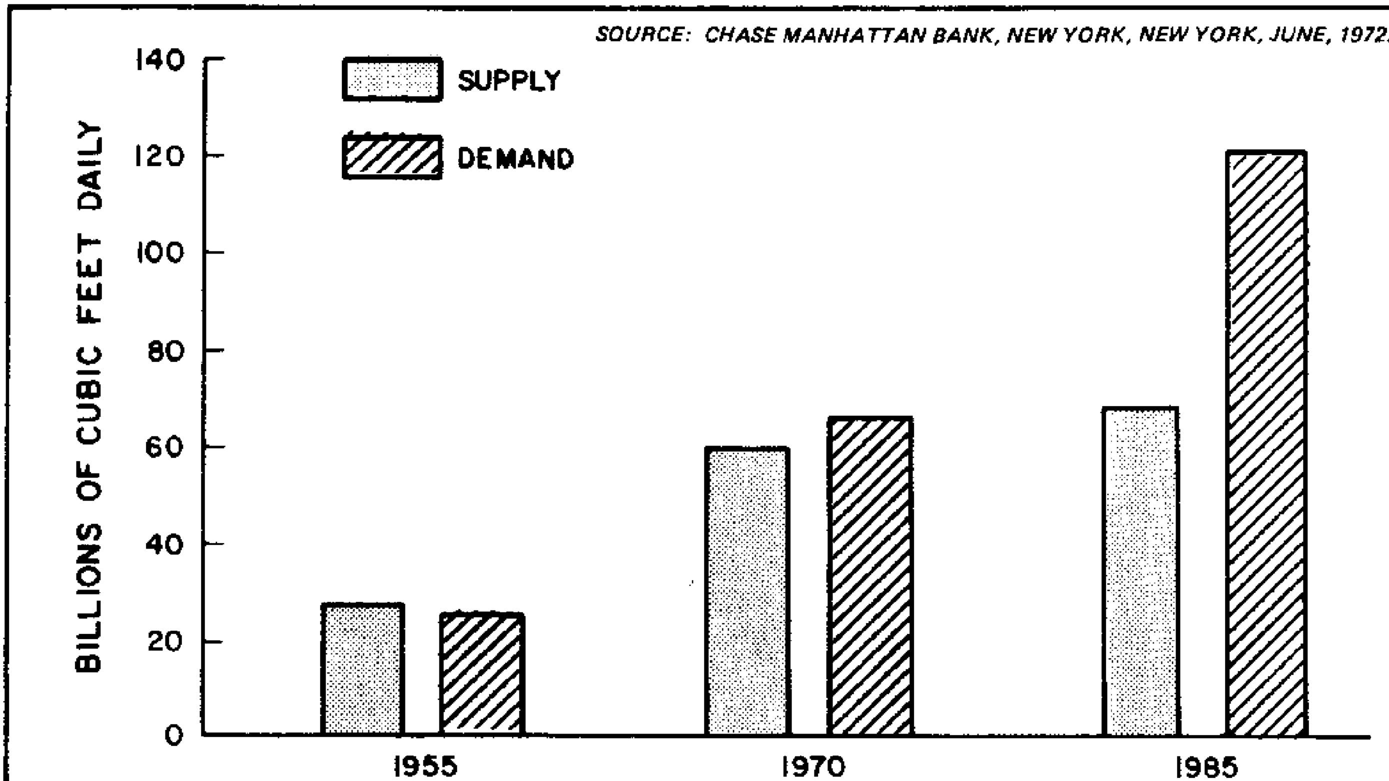
TABLE 17

TEXAS OIL AND GAS PRODUCTION, UNITED STATES OIL PRODUCTION AND PERCENT PRODUCED IN TEXAS 1950-1970

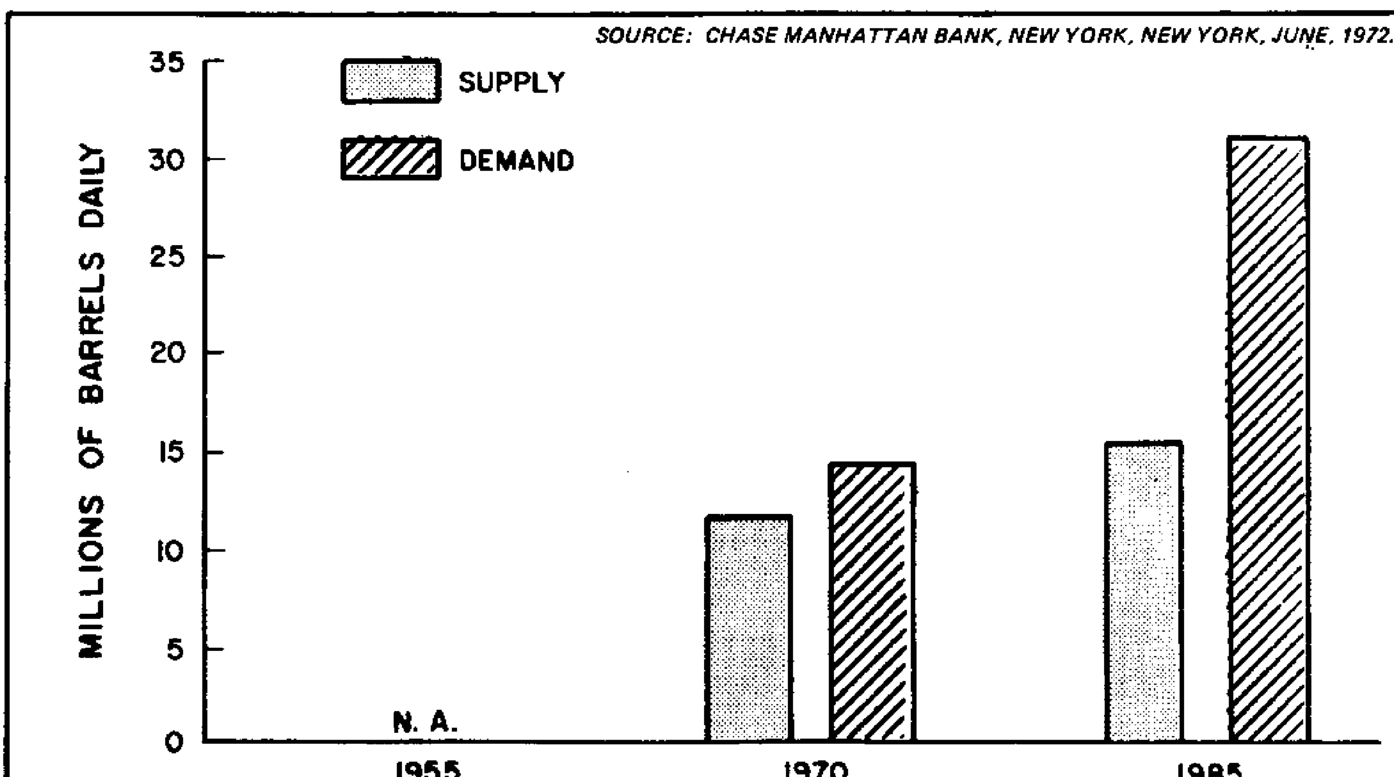
YEAR	NATURAL GAS TEXAS (MILLION CU. FT.)	CRUDE OIL TEXAS (000,000 BBLS.)	CRUDE OIL U.S. (000,000 BBLS.)	PERCENT U.S.
1970*	8,419,790	1,249,557	3,515,533	35.5
1965	6,636,555	1,000,749	2,848,514	35.1
1960	5,892,704	927,479	2,574,933	36.0
1955	4,730,798	1,053,297	2,484,428	42.4
1950	3,126,402	829,874	1,973,574	42.0

*Preliminary figures

SOURCE: <u>Texas Almanac</u>, 1972-73, A. H. Belo Corporation, Dallas, Texas.



UNITED STATES GAS SUPPLY AND DEMAND
FIGURE 5



UNITED STATES OIL SUPPLY AND DEMAND
FIGURE 6

MARKETS

MARKETS

Products

As indicated earlier, petrochemicals manufactured in Texas consist chiefly of primary and intermediate chemicals which must undergo further chemical reactions to produce end products. Appendix A lists the major petrochemicals produced in Texas in 1971. No attempt was made to determine the quantity of each chemical produced, but each one is a major product of one or more firms. It is generally conceded by the industry that ethylene is the petrochemical produced, by far, in the highest quantity, followed by benzene, propylene, butadiene, and others. Appendix B lists some of the derivatives of ethylene which are very common in petrochemical processing in Texas.

In most instances of petrochemical processing in Texas, the finished product is still an intermediate chemical to be shipped elsewhere for further processing. Of 66 firms responding to the question, 49 ship a portion of their production elsewhere, while 33 ship all their production to be further processed.

Petrochemicals and their derivatives end up in most every household or business establishment. The bulk of petrochemicals find their way to the consumer through plastics, synthetic rubber, textiles, solvents, and fertilizers. Other consumer goods using petrochemicals are drugs, cosmetics, dyes, paints, detergents, insecticides, films, explosives, perfumes, and foods.

Location of Markets

The location of markets for petrochemicals processed in Texas vary according to the type of petrochemical. With the agricultural chemicals such as ammonia, sulfur, and urea, a ready market is available

Synthetic rubber stored in warehouse at Goodyear Beaumont Chemical plant. Photo courtesy of Goodyear Tire and Rubber.

locally. Most of these products do not leave the state. In certain areas of West Texas, the entire market may cover only a few counties. These chemicals do not require further processing, but may, in some instances, be blended or mixed before sale to the consumer.

Many of the first line hydrocarbons such as ethylene, propylene, butadiene, benzene, styrene, toluene, and xylene are sold locally for further processing. These chemicals become the feedstocks for further processing and for other products produced by Texas plants. Ethylene is listed by 15 plants as a major raw material, propylene and benzene each listed by nine plants, butadiene by seven, and butylene by six.

The markets of the polymers and some of the aliphatic chemicals, those which have had further processing such as polythylene, polypropylene, ethylene oxide, ethylene dichloride, methanol, synthetic rubber, vinyl acetate and some of the alcohols, are generally located outside the state. The petrochemicals used in the plastics industry are shipped to the heavily urbanized areas in the Northeast and along the East Coast. The textile industry concentrated along the East Coast is the largest market for those petrochemicals and synthetic fibers to be used in textiles. The markets for carbon black and synthetic rubber are concentrated in several areas. There is a fair size market in Texas, large markets in the heavy industrialized Midwest, the West Coast, and even a foreign market.

While there are exceptions in all market locations for petrochemicals, these seem to be the general locations. As economic and technological conditions change in other industries and areas, the locations of petrochemical markets have a tendency to change also.

Location of Competitors

A firm's competition usually is considered to be those other firms engaged in and producing similar products, especially those strategically located so as to compete for a given market. This is true of the petrochemical industry. Many firms listed as competitors those firms located in other sections of the United States. Because of universal consumer demands of some products, labor and transportation costs, raw material availability and other related factors, in some petrochemical processing areas world wide competition is evident.

For this study, concentration of firms in petrochemical processing activities is confined to Texas. As is readily seen from general observation and as noted earlier, the heaviest concentration of all petrochemical activities is on the Texas Gulf Coast. Table 18 shows the concentration of processing plants for those petrochemicals of greatest production in the state.

TABLE 18

CONCENTRATION OF PROCESSING PLANTS IN TEXAS
FOR SELECTED PETROCHEMICALS
1971

PETROCHEMICALS	NUMBER OF PLANTS
Ethylene	16
Benzene	17
Propylene	19
Carbon Black	14
Toluene	13
Butadiene	13
Polyethylene	12
Ethylene Glycol	9
Ethylbenzene	77
Styrene, Styrene Resins and Monomers	9
SB Rubber	6
Other Synthetic Rubber	7

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

TRANSPORTATION

TRANSPORTATION

Transportation of feedstocks for the petrochemical processing plants in Texas is generally uncomplicated. This does not imply, however, that costs, methods, and other problems do not arise. Since most petrochemical plants take their feedstocks from nearby petroleum refineries and natural gas plants, transportation in many instances is only for short distances, sometimes just across a fence or a road.

As feedstocks are usually a liquid at this stage of processing, the most practical and economical method of transportation is by pipeline. This method is used far more frequently than any other, with 67 of 68 firms interviewed receiving a portion of their raw materials by pipeline. Forty-two firms received more than three-fourths of their raw materials by pipeline, while 14 firms use the pipeline for all their supply. For greater distances, barge and rail ranked next highest as transportation methods for receiving raw materials. Some raw materials are received by truck and a small amount by ship.

Transportation of the finished product changes slightly. Table 19 shows the transportation methods most commonly used by petrochemical firms, the number of firms using each method, and the volume shipped by each method. The volume shipped by pipeline is less than that of raw materials, even though much of the chemical is still a liquid. Finished products to be used as raw materials for other local processing plants account for most of the pipeline shipments. Rail transportation accounts for nearly one-third of the products shipped. Total volume shipped by rail and barge combined is more than 57 percent of all shipments.

TABLE 19

METHOD AND VOLUME OF FINISHED PRODUCT
SHIPPED BY NUMBER OF FIRMS
1971

TRANSPORTATION METHOD	NUMBER OF FIRMS	POUNDS (MILLIONS)	PERCENT OF TOTAL VOLUME
Rail	49	20,735	31.4
Barge	38	17,337	26.3
Pipeline	25	13,059	19.8
Truck	58	7,857	11.9
Ship	27	7,000	10.6
Total	Not Additive*	65,988	100.0

* 62 firms included

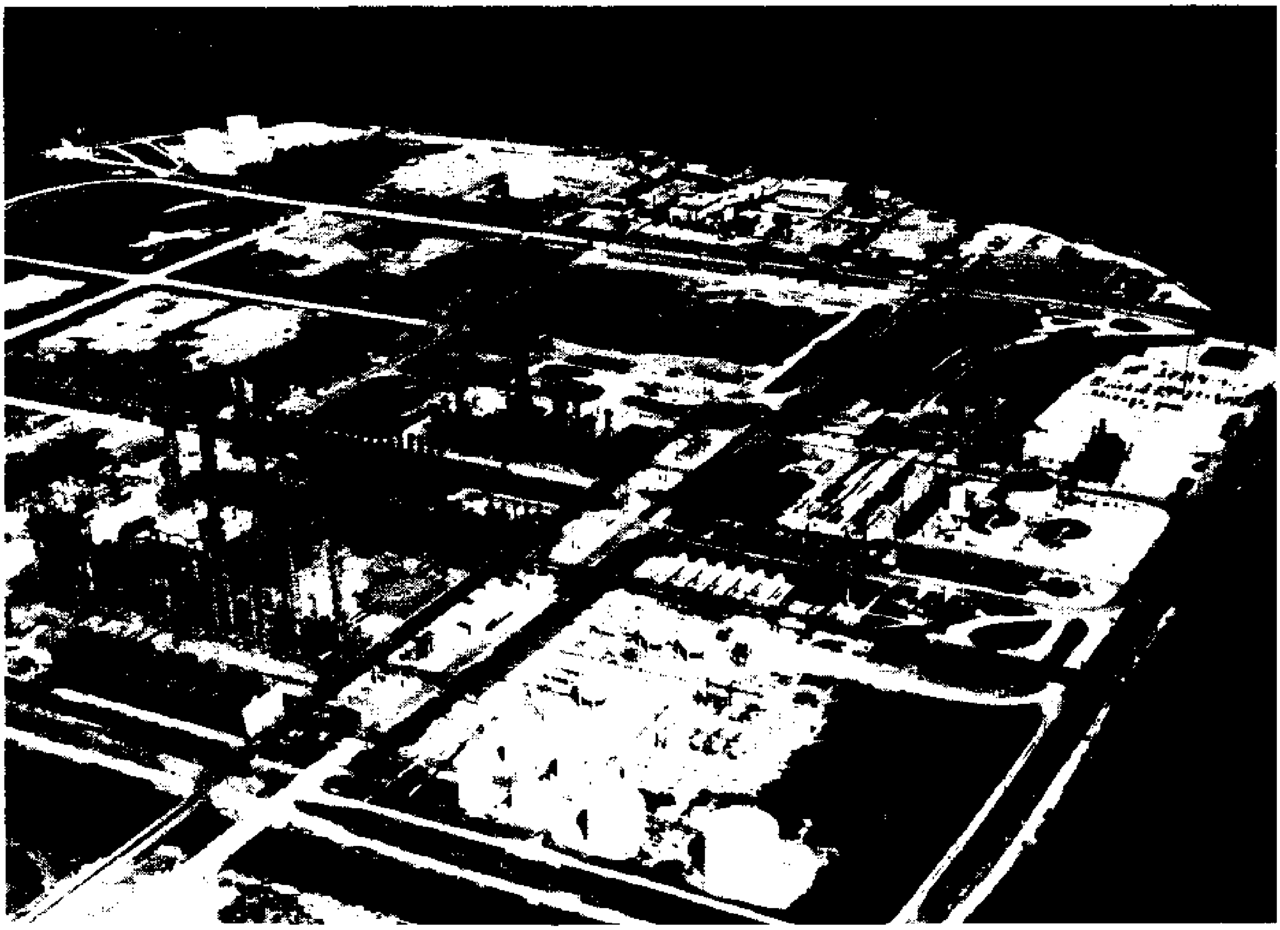
SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

The barge traffic is almost entirely on the Gulf Intracoastal Waterway. With its completion in 1949, the Waterway has played a vital role in the development of the petrochemical industry. More than 80 percent of Texas' petrochemical plant capacity is located either directly on the Waterway or is easily accessible by connecting water routes. Petrochemical feedstocks are transported daily by barge from oil refineries to processing plants. Thirty petrochemical firms depend heavily on the Waterway for raw materials.

Total tonnage of all goods shipped on the Texas section of the Gulf Intracoastal Waterway during 1971 was 67,617,562 tons.[1] Of this volume, approximately 9,000,000 tons were petrochemical products, in addition to roughly the same volume or more of feedstocks coming into the plants. Much of the shipment of petrochemicals, especially

[1]Colonel Nolan C. Rhodes, United States Department of the Army, Corps of Engineers, Galveston District, Galveston, Texas, News Release, August 4, 1972.

synthetic rubber going to the large rubber goods plants of the Midwest, is routed by barge on the Intracoastal Waterway through Louisiana and up the Mississippi River.



Aerial view of Mobil Chemical Company's Olefins-Aromatics Complex in Beaumont. Photo courtesy of Mobil Chemical Company.

OUTLOOK FOR PETROCHEMICALS

INDUSTRIAL
ECONOMICS
RESEARCH
DIVISION

OUTLOOK FOR PETROCHEMICALS

Demand and Supply

It is well known that the petrochemical industry interacts with many other industries in supplying raw materials. The end uses of most aromatics and olefins are found in plastics and fibers. Therefore, the demand for these petrochemicals depends primarily on the growth of plastics, fibers, and other synthetic materials, rapidly becoming vital materials in our complex society. The total demand for aromatics and olefins is anticipated to be in the range between 73 and 91 billion pounds per year by 1980, which is an average growth rate of 6.8 to 9.2 percent.[1] Table 20 shows projections for the United States demand of the basic petrochemicals. The key basic petrochemical has been and apparently will continue to be ethylene. The demand for ethylene alone is forecasted to be about 36 billion pounds per year in 1980.

Until recently, ethylene production was principally based on liquefied petroleum gas, commonly referred to as LP-gas. Indications are that in the very near future the domestic availability of LP-gas will not be sufficient for the increasing demand for ethylene. Heavier feedstocks will then be used in greater amounts for the production of ethylene, as indicated in Table 21. Based on 1980 projections of 35 to 40 billion (or higher) pounds per year of ethylene, only about 57 percent will come from natural gas liquids. The balance will come from naphtha and gas-oil cracking. Some in the petrochemical industry see an even higher percentage of naphtha and

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[1] W. W. Reynolds, "Investing in Primary Petrochemicals," Chemical Engineering Progress, Volume 68, No. 9, September, 1972, pp. 29-35.

TABLE 20

UNITED STATES BASIC PETROCHEMICAL DEMAND
(1,000 Metric Tons)

PETROCHEMICAL	1971	1975	1980
Ethylene	7,860	10,900	16,350
Benzene	4,040*	5,130	7,130
Propylene	3,810	5,000	7,280
Butadiene	1,450	1,680	2,140

*1972 figure used since 1971 not available.

SOURCE: Market Data 1973--Hydrocarbon Processing, Gulf Publishing Company, Houston, Texas; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

TABLE 21

UNITED STATES ETHYLENE PRODUCTION
BY TYPE OF FEEDSTOCK
(Percent)

FEEDSTOCK	1971	1973	1980
Ethane, Propane, Butane	82	60	57
Naphtha, Cat Gas Oil	18	40	43
TOTAL	100	100	100

SOURCE: U. S. Petrochemicals, The Petroleum Publishing Company, Tulsa, Oklahoma, 1972.

heavy liquids as ethylene production feedstocks by 1980. As this trend in the change of feedstocks takes place, other changes also will occur. Fewer gas liquids ethylene capacity plants will be built. The conversion to heavy liquids will have a pronounced effect on the economics of ethylene manufacture.

Since most ethylene today is produced from ethane, propane, or butane, the petrochemical industry produces very little of the energy products. Figure 7 plots the specific gravity of various feedstocks against the yield of energy products. Less than 10 percent of the currently used feedstocks are converted to products which are consumed in the energy sectors. On the other hand, if naphtha and gas oil are used more extensively, as much as 40 percent will go into energy products.

In Figure 8, the product yield is shown in terms of energy products, fuel gas, and petrochemicals produced from one billion pounds per year ethylene plant. In the heavy liquids era that we are now entering, the net total annual production is slightly over four billion pounds for a gas oil feedstock, only 54 percent of which are basic petrochemicals. If naphtha is the feedstock, the net total pounds are slightly less, about three billion, of which petrochemicals are only 66 percent. This contrasts with ethane as a feedstock, where 97 percent of the production consists of petrochemicals.[2]

Coupled with the increased demand for petrochemical feedstocks is the increased demand for energy products. Lately there has been much discussion about an energy crisis and much controversy about who is to blame. During short intervals of extremely cold weather, shortages of fuel were apparent in many sections of the United States, including Texas. Gasoline rationing in some form is a possibility in the not-too-distant future in certain areas of the United States, unless an increased supply of raw materials can be obtained. Recent relaxation of some import quotas has helped the situation, but this is only a temporary measure.

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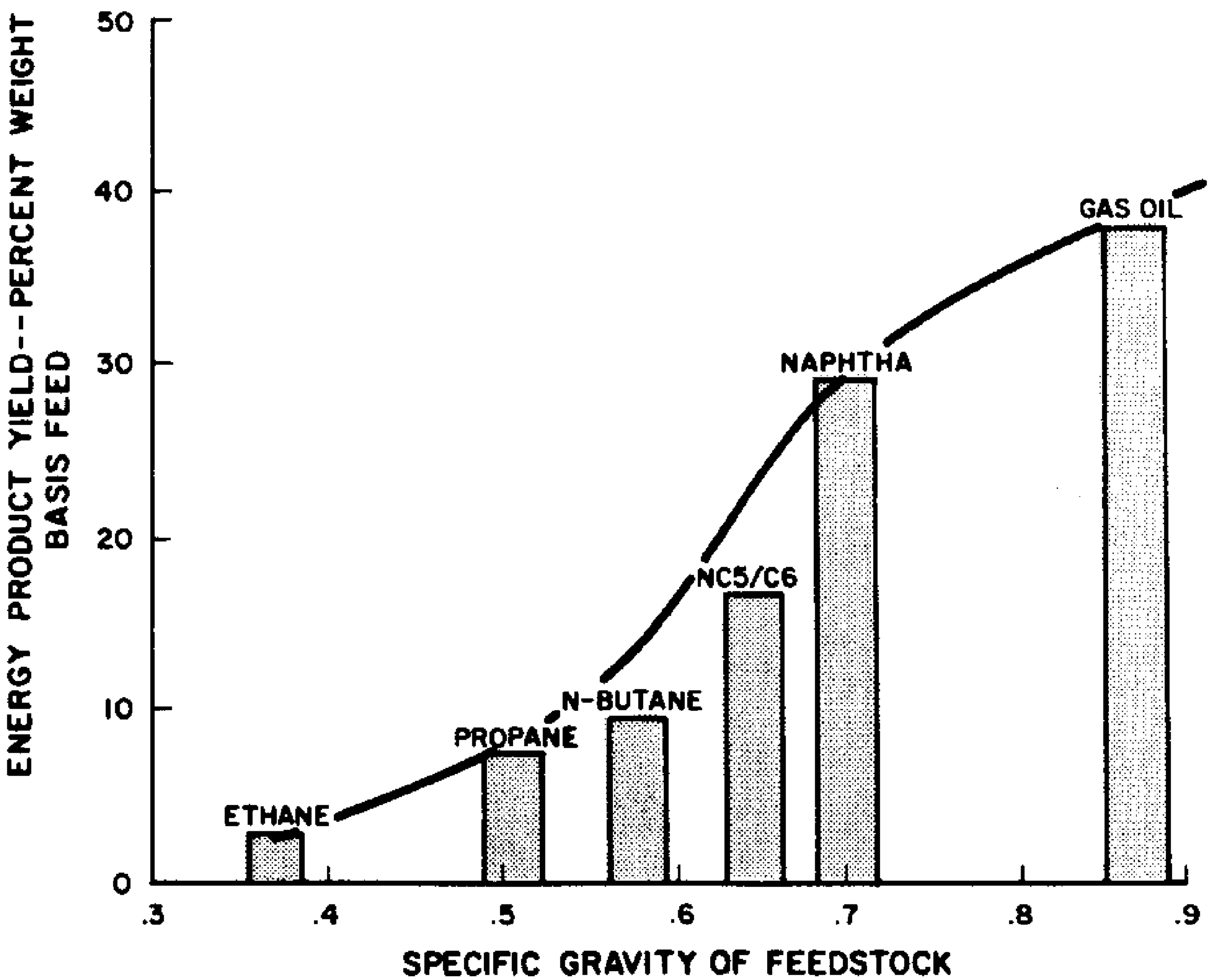
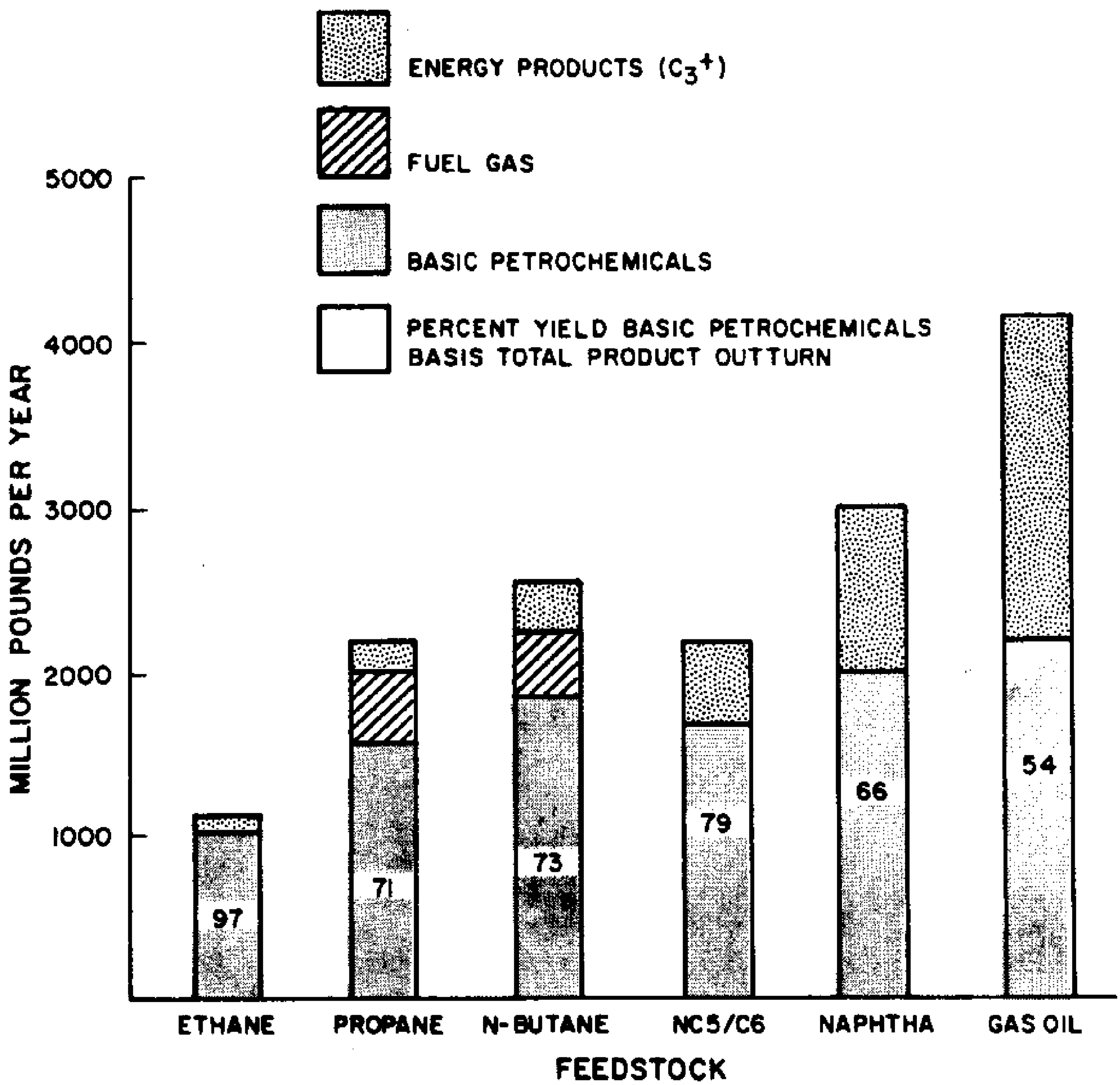
[2]W. W. Reynolds, Ibid.



YIELD OF ENERGY PRODUCTS AS A FUNCTION OF OLEFIN PLANT FEEDSTOCK

FIGURE 7



OLEFINS PLANT PRODUCT YIELDS
BASIS: 1000 MMLB/YR C_2= PRODUCTION
FIGURE 8

Both petrochemicals and energy products presently depend heavily on petroleum and natural gas for their existence. It is likely, possibly in the next decade, that the available supplies of petroleum and natural gas will not be sufficient to provide for the total energy and chemical feedstock requirements. Currently, about 95 percent of the raw materials go to the energy market, but several industry leaders have indicated they feel the chemical industry will be able to out-compete the energy industry for at least the lighter portion of the crude barrel.

This observation "derives from the fact that there are alternative sources of energy--atomic energy plants and coal--which can provide for a significant portion of the requirement of the total energy market. There are no similar practical alternatives in regard to the feedstocks required for petrochemicals, and for their derivative products such as plastics, synthetic fibers, and even pharmaceuticals. In future decades these materials will be as important to the world economy as the fuel itself."[3]

Other observations from equally reliable sources seem to indicate the trend will be to use recycled materials to satisfy the enormous demand for petrochemical products. This would be especially true in the case of some plastics and synthetic rubber.

Recent trends in the ocean-shipping industry, with particular regard to the size of vessels, are of interest to all industries involved in ocean commerce. This is especially true of the oil industry in using "supertankers" to transport crude and petroleum

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[3]William C. King, "Petrochemicals Face Reality," World Petroleum, Volume 42, No. 5, June, 1971, p. 210.

New billion lb/yr ethylene plant at Shell's Deer Park Chemical plant.
Photo courtesy of Shell Chemical Company.

products in large quantities. While the economies of scale (lower cost of transportation, safer because size makes them more seaworthy, and reduced manpower because of increased automation)[4] have heightened their popularity, the ports along the Texas Gulf Coast still cannot handle the large tankers. Deepest berths available are only 40 feet, while many of the supertankers need as much as 55 to 90 feet. As a result, the large oil refining industry and the petrochemical industry along the Texas Gulf Coast are faced with a vital decision in world competition.

In recent months the idea of constructing an offshore port facility capable of accommodating the supertankers has been widely discussed by university and research personnel, by state legislatures, the federal government, and by industry leaders themselves. The general feeling among petrochemical industry leaders is favorable toward the offshore port. While most petrochemical plants obtain their raw materials locally from oil refineries, their processing activities vary directly with the oil supply available to the refineries. Industry leaders see several benefits which might be derived from an offshore port off the Texas coast:

1) increase in availability of raw materials;
2) a tendency to lower the price of raw materials;
3) lower transportation costs; and
4) expanded growth for both plants and economic region.

An added attraction for the petrochemical industry is that, due to recent developments in tanker transportation of liquid natural gas

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[4]Dan M. Bragg and James R. Bradley, "Work Plan for a Study of the Feasibility of an Offshore Terminal in the Texas Gulf Coast Region," Sea Grant Report TAMU-SG-71-212, Texas A&M University, College Station, Texas, June, 1971, page 3.

(LNG), feedstock imports may be increased directly. It may be a few years, however, before the volume of this type of import is significant.

Markets

A change in market patterns and locations for petrochemicals is anticipated by some industry leaders. With the coming of highly industrialized and urban areas to Texas, as the Dallas-Fort Worth area and the Houston-Gulf Coast area, a portion of the markets previously located in the northeast will be relocated in Texas. This may be true especially in the case of some plastics such as polyvinyl chloride used in manufacturing pipe for irrigation, plumbing, and related uses. With heavy markets for these finished products already in the southwest, it would certainly be practical for the economy for some of these manufacturing plants to be located in Texas.

Costs

Raw Materials

The basic feedstocks constitute a large portion of total costs associated with petrochemical processing. Reynolds[5] indicates that feedstock and capital charges make up nearly 90 percent of costs in primary processing. These costs tend to be lower and operating expenses higher, however, with polymer manufacturing. As value is added proceeding from primary to polymer processing, the percentage of overhead and sales costs increases while that of raw material costs declines.

For years, the United States has enjoyed the benefits of low-cost natural gas liquids. Many industry experts expect, however, that

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[5]W. W. Reynolds, op. cit.

substantial increases in the price of these domestically produced feedstocks in the next few years will make them non-competitive with foreign feedstocks. The foreign feedstock presently most attractive in price that can adequately serve as an alternative feedstock to domestic natural gas liquids is naphtha. Some industry leaders have indicated our domestic feedstock is at least 60 percent higher than the foreign price.

This approach is seriously challenged by others who maintain that although domestic petrochemical feedstocks are slowly increasing, they are still internationally competitive.

Recent trends of petrochemical firms establishing and maintaining plants overseas indicate a change in petrochemical trade balances. As revealed in the recent survey of petrochemical firms, their locating in Texas was due to not only an ample supply of raw materials but also an economically priced supply.

In 1959, the United States had nearly two-thirds of the world's productive capacity for the key petrochemicals. Overseas plants were small and generally less efficient than United States installations.

But since that time, world demand for chemicals, plastics, and synthetic fibers has increased tremendously. Large, modern, efficient plants have been built in Europe. These operations are aided by the availability of low-cost raw materials from the oil fields of Africa and the Middle East. During the same period of time European petrochemical capacity has increased almost five-fold. In the Far East, Japanese exports of organic chemicals and plastics have increased considerably. America's share of world export markets has dropped by about 20 percent. United States imports of petrochemicals have risen much faster than exports.[6]

The obvious conclusions to be drawn from relocation of plants overseas include loss of domestic investment, jobs, tax revenues, and a drastic reduction in contribution to the general economy.

Labor

The cost of labor in general is increasing each year. The rate of increase varies with such factors as geographical location, labor union strength and influence, inflation, and the type of chemical processing. As noted in the discussion of raw material costs, labor costs make up a smaller part of total costs in primary chemical processing than in polymer manufacture. Morley[7] indicated in a recent talk before business leaders that the petrochemical industry leaders in the Houston area "expect labor, energy, and raw materials all to increase this year (1973), with labor increasing less perhaps than it has in the past because of government wage constraints."

Plant Investments

The traditionally high growth rate of the petrochemical industry is probably the most important factor behind plant investments in Texas. These investments are huge by any standard. Costs are extremely high and can be rationalized only because of the enormous demand and economies of scale associated with the size of the plant. Several firms either have recently built or are in the process of

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[6] "The Petrochemical Industry and Oil Import Controls," Ibid.

[7] John C. Morley, Executive Vice President, Enjay Chemical Company, talk before Houston Outlook Conference sponsored by the Houston Chamber of Commerce, Houston, Texas, January 17, 1973.

building one or more of these "jumbo" size plants. Due to the high volume of ethylene production either for internal consumption or as a salable product, ethylene plant units lend themselves conveniently to extra large plants. An industry economist cites dollar figures on the costs of these plants:

> In 1950, a standard efficient unit to manufacture ethylene including all offsites, cost about $10 million for a plant of about 100 million pounds per year of capacity. Anyone contemplating building an ethylene plant today must think in terms of a plant size of around one billion pounds per year and a capital outlay up to $135 million. By late decade, the standard size should reach 1.2 billion pounds per year and require a capital outlay of about $160 million. Investment in an ethylene plant is no longer a minor capital outlay, but is of such magnitude that it has easily become the giant investment of the industry.[8]

Pollution Control

Pollution control has been with us in varying degrees for a long time. Only in the last decade, however, have government, industry, and the public shown sufficient awareness of the problems associated with the environment that stringent regulations are exercised to protect it from further abuse. With the creation of the Environmental Protection Agency in 1971, recent Congressional legislation is being administered. Other governing bodies have created state, county, and city agencies to assist in pollution control.

One of the more significant costs for petrochemical producers in the future will be that of protecting the environment. A McGraw-Hill survey shows that the total 1971 industrial investment for pollution control was over $12.5 billion. The chemical industry spent about $260 million. Investment for this purpose was predicted to be about

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[8] W. W. Reynolds, op. cit.

7.7 percent of the total petrochemical investment in 1972, increasing to as much as 10 to 12 percent thereafter.[9]

Other Costs

Other costs that will be increasing possibly at a slower rate include market costs, continued research and development, and maintenance. Other specific government regulations which may increase a firm's costs are the recent Occupational Safety and Health Act and the Toxic Substances Act.

Growth

Historically, the growth rate of the petrochemical industry has been very good. The 1950's and early 1960's marked the period of greatest growth of the industry, with an annual growth rate ranging from 10 percent to nearly 20 percent. By the late 1960's the accelerated growth had slowed considerably, but now in the early 1970's, it seems to be on the upswing again. Table 22 includes growth rate data for the chemical and allied products industry from 1965 to 1970. Although the major sectors of the industry show different trends, the state of the petrochemical industry is definitely related to the parent industry. Shipments grow at four times the pace of net income. Net income, if expressed in constant value dollars, would be significantly less.

Overall growth rates appear to be good. Not all the figures for 1972 are available yet, but preliminary estimates show between seven and eight percent growth for some 60 major petrochemicals in the United States and also in Europe. Japan's petrochemicals are growing

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[9]Arthur M. Brownstein, editor, op. cit.

TABLE 22

GROWTH RATES OF THE CHEMICAL AND ALLIED PRODUCTS INDUSTRY
1965-1970

MAJOR SECTOR	YEAR 1965	1966	1967	1968	1969	1970	AVERAGE ANNUAL GROWTH (PERCENT)
Shipment*	37.5	40.8	42.3	46.4	48.7	49.6	5.8
Net Income*	3.2	3.5	3.26	3.53	3.59	3.43	1.4
Capital Expenditures*							
(Domestic)	2.73	3.26	3.06	2.83	3.10	3.44	4.8
(Foreign)	0.86	1.04	1.21	1.21	1.11	1.35	9.4
Research & Development*	1.20	1.27	1.37	1.44	1.54	1.62	6.2

* $Billion

SOURCE: US Petrochemicals, The Petroleum Publishing Company, Tulsa, Oklahoma; and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

a little faster.

At least one industry leader looks for Texas Gulf Coast petrochemicals to have a good year in 1973. Appearing before the 1973 Houston Outlook Conference, John C. Morley,[10] Executive Vice President of Enjay Chemical Company, indicated that when all the numbers are in, in his judgment, 1972 sales would be up 10 percent and profits up about 20 percent for the major chemical companies. In 1973 he forecasted a strong demand for all petrochemicals, perhaps heaviest in plastics. His conclusion was that "sales should be up about 9 to 10 percent in 1973 and profits up perhaps by 15 percent."

Representatives of the various petrochemical plants in Texas indicate a firm conviction that petrochemical growth in Texas will parallel the national pattern. Table 23 shows the trend of production

[10]John C. Morley, op. cit.

TABLE 23

PROJECTED AVERAGE ANNUAL GROWTH RATES IN CHEMICAL PRODUCTION BY FIRMS IN TEXAS 1972-1976

AVERAGE ANNUAL GROWTH RATE (PERCENT)	NUMBER OF FIRMS
Above 20	2
11-20	6
6-10	29
3-5	13
1-2	11
Less than 1	13
TOTAL	74

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

growth rates expected in Texas for the next five years. While it may be difficult to project with much accuracy the increased production over the next five years, this does give some indication of the industry's anticipation of its growth. Some of the higher production rates include specific plans for new plant or unit construction and for the chemicals in highest demand, while some of the lower rates involve certain chemicals that the plant is preparing to gradually phase out of production even though the firm will continue its production at another location.

Table 24 gives similar five-year employment growth projections. The average growth rate indicated for employment growth is lower than for production growth.

Deterrents to Growth

Generally speaking, Texas provides a healthy climate for the

TABLE 24

PROJECTED AVERAGE ANNUAL EMPLOYMENT GROWTH RATES BY CHEMICAL FIRMS IN TEXAS 1972-1976

AVERAGE ANNUAL GROWTH RATES (PERCENT)	NUMBER OF FIRMS
8-10	3
5-7	5
3-4	7
1-2	31
Less than 1	26
TOTAL	72

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

continued growth of the petrochemical industry. However, there are factors considered by many firms which hinder the growth of that firm or plant within the state or a certain section of the state. Table 25 ranks in order of importance 10 factors given by industry leaders as deterrents to growth. Some of these factors will be difficult to overcome due to circumstances beyond the control of government, industry, and even the general public. Other factors given as deterrents to growth are inadequate fresh water supply, marketing costs, distance from deep water, environmental problems, environmental pollution control "politics", expensive utilities, urban population growth, governmental and political climate, construction costs, shortage of construction labor, depressed sulfur market, and inadequate shipping facilities.

Economic Factors

Certain economic factors should be considered when viewing the outlook for the petrochemical industry in Texas. Representatives from

TABLE 25

DETERRENTS TO GROWTH IN TEXAS

FACTORS	RANK
Shortage of feedstocks	1
Remoteness from main market area	2
Energy (fuel) availability and cost	3
High state and local taxes and inequity in taxes	4
Transportation costs including high rail rates	5
Raw material costs	6
Saturation of some type of processing plants	7
Labor costs	8
Pollution abatement laws too stringent	9
Land transportation to markets	10

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

68 petrochemical firms ranked those factors which could change the future level of activity in their operations. Table 26 shows the rankings of the economic factors.

The two factors of greatest concern to the petrochemical industry are the availability and cost of feedstocks and the availability and cost of energy (fuel) sources. Other factors considered are location of future markets, availability and cost of capital, price of substitute products, inflation, general economic climate, population growth, foreign trade policy, and exports of agriculture products.

Technological Factors

A similar ranking was made of technological factors which may change the future level of petrochemical activity in Texas. This

TABLE 26

ECONOMIC FACTORS WHICH MAY CHANGE THE FUTURE LEVEL OF PETROCHEMICAL ACTIVITY IN TEXAS

FACTORS	RANK
Availability and cost of feedstocks	1
Availability and cost of energy sources	2
Product demand and prices	3
Labor costs	4
Foreign imports and competition	5
Government regulations (safety, environment, price, etc.)	6
Transportation costs	7
Tax levels	8
Environmental costs	9
Product distribution costs	10

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

ranking is shown in Table 27.

An example of a substitute feedstock has already been discussed briefly in the possibility of using imported naphtha or other heavy liquids distilled from crude oil as substitutes for natural gas liquids in the processing of ethylene and other monomers. This would require changes in both processing techniques and equipment.

TABLE 27

TECHNOLOGICAL FACTORS WHICH MAY CHANGE THE FUTURE LEVEL OF PETROCHEMICAL ACTIVITY IN TEXAS

FACTORS	RANK
New and improved processes	1
New product development	2
Development of improved products	3
Environmental control technology	4
Availability of substitute products	5
Availability of substitute feedstocks	6
Obsolescence of products, processes, and/or process equipment	7
Development of alternate fuel (energy) sources	8

SOURCE: Industrial Economics Research Division, Texas A&M University, College Station, Texas.

APPENDIX A

MAJOR PETROCHEMICALS MANUFACTURED IN TEXAS IN 1971

Acetaldehyde
Acetic Acid
Acetic Anhydride
Acetone
Acetylene

Acrylates
Acrylic Acid
Acrylonitrile
Adipic Acid
Adiponitrile

"Alathon" Polyethylene
Aliphatic Solvents
Alkylated Phenols
Alkylbenzene
Alkylleads

Allyl Chloride
Alpha Olefins
Ammonia (Anhydrous)
Ammonia Nitrate
Ammonium Sulfate

Anti-knock Compounds
Aromatic Disulfides
Aromatic Solvent 100
Benzene
Butadiene

N-Butane
N-Butanol
N-Butyl Alcohol
S-Butyl Alcohol
Butyl Acrylates

Butylenes
Butyraldehyde
Butyric Acid
Caprolactam
Carbon Black

Chlorinated Solvents
Chloroprene
Copolymers
Cresol
Cresylic Acids

Cumene
Cyclohexanane
Cyclohexane
Diacetone Alcohol
Diethyl Aluminum Chloride

Diethylene Glycol
Di Isobutyllene
Di Propylene Glycol
Dodecene
Dripolene

Durene
EPEM Rubber
Epichlorhydrin
Epoxy Resins
Ethanol

Ethanolamines (mono, di, tri)
Ethyl Acetate
Ethyl Acrylates
Ethylbenzene
Ethyl Chloride

Ethylene
Ethylene Dichloride
Ethylene Glycol
Ethylene Glycol Monomethyl Ether

Ethylene Oxide
Ethylene-Vinyl Acetate Copolymers
2-Ethylhexanol
2-Ethylhexyl Acrylates

Formaldehyde
Formic Acid
Glycerine
Glycidol
Heavy Hydrocarbons

Heptane
Hexamethylene Diamine
Hexane
Hexanediol
Hexylene Glycol

Hydroquione
Isobutane
Isobutyl Acetate
Isobutylene
Isobutylene Polymer

Isopentane
Isophthalic Acid
Isoprene
Isoprene Monomer
Isopropyl Alcohol

Linear Detergent Alcohols
Linear Paraffins
Liquid Hydrogen Sulfide
Liquid Sulfur
Lous Molecular Weight Polymers

Melamine
5 Mercaptans
Methanol
Methyl Alcohol
Methyl Acrylates

Methyl Ethyl Alcohol
Methyl Ethyl Ketone
Methyl Formate
Methyl Mercaptan
Mixed Aromatics

Mixed Lead Alkyls
Monorpopylene Glycol
Naphthalene
Neoprene
Nonene

"Nordez" Hydrocarbon Rubber
Normal Alpha Olefins
Nylon 6
Nylon Salt
Octane

Orthoxylene
Oxides
Oxo Alcohols
Panasel Products
N-Paraffins

Paraxylene 1
Paraxylene 2
Paraxylene 3
Pentane
N-Pentane

Phenol
Phtholic Anhydride

Phtholic Esters
Plasticizer Alcohols
Polybutane
Polycaprolactam
Polyethylene

Polyglycol
Polyisoprene Rubber
Polymers
Polyolefin Resins
Polyphenol

Polypropylene
Polystyrene
Polyvinyl Alcohol
Propanol
Propion Aldehyde

Propionic Acid
Propylene
Propylene Oxide
Pseudocumene
Resin 18

Resin Oil
Rubber Chemicals
SBR Rubber
Styrene
Styrene Butadiene Latex

Styrene Monomer
3 Sulfides
Sulfur
Surfactants
Surlyn^{R} Ionomer Resins

Synthetic Polybutadiene
Synthetic Rubber
Therephthalic Acid
Tertiary Butyl Alcohol
Tertiary Butyl Hydroperoxide

Tetraethyl Lead
Tetrahydrofuran
Triethyl Aluminum
Tri-Isobutylene
Toluene

Urea
Vinyl Acetate
Vinyl Chloride Monomer
Vinyl Cyclohexane
Xylene

Xylenals
p-Xylene

APPENDIX B

ETHYLENE DERIVATIVES*

- I. Acetaldehyde (See VI-A)
- II. Organo-Metallics
  - A. Aluminum Triethyl
    - 1. Linear Alpha Olefins
      - a. Ethylene Copolymers
      - b. Oxo-Linear Alcohols
      - c. Sulfonated Surfactant
      - d. Linear Alkylphenols
    - 2. Straight Chain Primary Alcohols
      - a. C_6 to C_{12} (Plasticizers)
      - b. C_{12} to C_{18} (Biodegradable Surfactants)
      - c. Petroleum Product Additives
  - B. Alkylated Boranes
  - C. Diethylaluminum Hydride
    - 1. Catalyst Reducing Agent
- III. Ethylbenzene
  - A. Diethylbenzene
    - 1. Divinylbenzene
      - a. Elastomers
      - b. Drying Oils
      - c. Resins
  - B. Styrene
    - 1. SBR Rubber
    - 2. Polystyrene Plastics
    - 3. Styrene-Butadiene Copolymer Plastics
    - 4. Chlorostyrene
    - 5. Styrene-Divinylbenzene Copolymer Plastics
    - 6. Styrene-Alkyd Polyesters for Protective Coatings
    - 7. Styrene-Acrylonitrile Copolymer Plastics
    - 8. Acrylonitrile-Butadiene-Styrene Resins
    - 9. Styrene-Maleic Anhydride Copolymer
    - 10. Styrene Plastics, Other
    - 11. Styrenated Oils
    - 12. Modidified S-Type Elastomer
  - C. Acetophenone
    - 1. Methylphenylcarbinol
    - 2. Solvent
    - 3. Perfumes
    - 4. Pharmaceuticals
  - D. Benzoic Acid
    - 1. Hexahydrobenzoic Acid
      - a. Caprolactam
        - (1)Nylon 6
    - 2. Phenol
      - a. Bisphenol A
        - (1) Epoxy Resins
        - (2) Polycarbonate Resins
      - b. Octylphenol
        - (1) Surface Active Agents
        - (2) Plasticizers
        - (3) Antioxidants
      - c. Nonylphenol
        - (1) Lube Oil Additives
        - (2) Phenolic Resins
      - d. Phenol, Ethoxylated
      - e. Dodecylphenol
      - f. Phenolic Resins
        - (1) Phenol-Formaldehyde
        - (2) Phenol-Furfural
      - g. Cyclohexanol
        - (1) Adipic Acid
          - (a) Adipate Plasticizers
          - (b) Polyurethanes
      - h. Cyclohexanone Oxime
        - (1) Caprolactam
          - (a) Nylon 6
      - i. Salicylic Acid
        - (1) Acetylsalicylic Acid
        - (2) Dyes
        - (3) Preservative
        - (4) Medicine
      - j. 2, 4-Dichlorophenoxyacetic Acid (Herbicides)
      - k. Solvent Refining
      - l. Pentachlorophenol (wood preservative)
      - m. Phenyl Phosphates
        - (1) Plasticizers (Triphenyl Phosphate)
        - (2) Gasoline Additives (Cresyl and Methyl)
        - (3) Diphenyl Phosphate
      - n. Triphenyl Phosphate
        - (1) Plastics Stabilizer
      - o. 2, 6-Xylenol, Synthetic
      - p. Hydroxyphenylstearic Acid
        - (1) Anti-Oxidant in Instrument Oil
        - (2) Corrosion Inhibitor
      - q. Nitrophenol
        - (1) Parathions
      - r. Picric Acid
        - (1) Dyes
        - (2) Explosives
      - s. Chlorophenols
        - (1) Synthesis of Dyes, Fungicides and Drugs
    - 3. Sodium Benzoate
      - a. Food Preservative
      - b. Antiseptics
      - c. Dyes
    - 4. Sucrose Benzoate
      - a. Melamina-Alkyd Enamel
      - b. Acrylic Coatings
      - c. Lacquers
    - 5. Perfumes and Medicinals
      - a. Benzyl Benzoate
    - 6. Plasticizers
      - a. Diethylene Glycol Dibenzoate
    - 7. Polyester Dyes
      - a. Methyl Benzoate
      - b. Butyl Benzoate
    - 8. Flavor Chemical
    - 9. Pharmaceuticals
  - E. Ethyl Anthraquinone
    - 1. Hydrogen Peroxide
      - a. Epoxidation of Fats and Oils
      - b. Bleach
      - c. Tert-Amine Oxide
- IV. Ethylene Dibromide
  - A. Succinonitrile
    - 1. Brightner in Nickel-Plating Bath
    - 2. Selective Solvent for Extracting Aromatic Compounds
  - B. Tetraethyl Lead Scavenger

C. Fumigant
D. Dyes
E. Pharmaceuticals
F. Solvent

V. Polyethylene
  A. Low Density
    1. Film and Sheet
    2. Cables and Piping
  B. High Density
    1. Injection Molding
    2. Blow Molding
    3. Monofilament and Piping

VI. Ethyl Alcohol
  A. Acetaldehyde
    1. Acetaldol
      a. 1, 3 Butylene Glycol
        (1) Polyesters
        (2) Urethane Coatings
        (3) Adipate Plasticizer
        (4) Humectant
        (5) Printing Ink
        (6) Dyestuff
      b. Crotonaldehyde
        (1) n-Butyraldehyde
          (a) n-Butyl Alcohol
          (b) Butyric Acid
          (c) 2-Ethyl Hexanol (See VI-A-4)
        (2) Rubber Accelerator
        (3) Synthesis of Crotonic and Sorbic Acid
    2. Acetic Acid
      a. Acetanilide
        (1) Peroxide Stabilizer
        (2) Dye Intermediate
        (3) Medicinals
      b. Acetic Anhydride
        (1) Acetyl Salicylic Acid (Aspirin)
        (2) Vinyl Acetate (See VI-A-2-h)
        (3) Cellulose Acetate Esters
      c. Acetyl Chloride
        (1) Organic Preparations
        (2) Dyestuffs
      d. Ammonium Acetate
        (1) Acetamide
          (a) General Solvent
          (b) Soldering Flux Ingredient
          (c) Antiacid in Lacquers, Explosives and Cosmetics
          (d) Plasticizers in Leather, Cloth, and Films
      e. Cellulose Acetate
      f. Chloracetic Acid
        (1) 2, 4-D and 2, 4, 5-T Acids (Herbicides)
        (2) Sodium Carboxymethyl-cellulose
          (a) Detergent Promoter
          (b) Water Binder and Emulsion Stabilizer
          (c) Paper and Textile Sizing
          (d) Latex Paint
          (e) Foods (e.g., Ice cream)
        (3) Ethyl Chloroacetate
        (4) Glycine
          (a) Organic Synthesis
          (b) Food Additive
        (5) Synthetic Caffeine and Sarcosine
        (6) Thioglycolic Acid
          (a) Reagent for Iron
          (b) Permanent Wave Solution
          (c) Vinyl Stabilizer
      g. Ethyl Acetate / Butyl Acetate / Isopropyl Acetate
        (1) Solvents for
          (a) Plastics
          (b) Lacquers
          (c) Synthetic Resins
          (d) Natural Gums
        (2) Perfumes
        (3) Flavoring Extract
      h. Vinyl Acetate
        (1) Polyvinyl Acetate
          (a) Polyvinyl Alcohol
              Polyvinyl Butyral
              Polyvinyl Formal
        (2) Polyvinyl Chloride-Acetate Resins
          (a) Industrial Plastic Products
          (b) Surface Coatings
          (c) Rug Backing
          (d) Safety Glass
    3. Acetic Anhydride (See VI-A-2-b)
    4. 2-Ethyl Hexanol
      a. Plasticizer
      b. Defoamer and Wetting Agent
    5. Pentaerythritol
      a. Explosives
      b. Synthetic Lubricant
      c. Molding Resins
      d. Alkyd Resins
    6. Chloral
      a. Manufacture of DDT
      b. Chloral Hydrate
        (1) Liniment
    7. Peracetic Acid
      a. Bleaching Textiles, Paper, Oils
      b. Polymerization Catalyst
      c. Food Processing Bactericide/Fungicide
      d. Epoxy Resin Precursor
      e. Oxidant in Organic Synthesis
    8. Paraldehyde
      a. Rubber Accelerator and Antioxidant
      b. Dye Intermediate
      c. Solvent for Fats, Resins, and Cellulose Derivatives
    9. Pyridine
      a. Niacin
      b. Nicotinamide
      c. Piperidine
        (1) Rubber Chemicals
      d. Antihistamines
      e. Dyestuffs
    10. Trimethylopropane
      a. Alkyd Coatings
      b. Urethane Foams
      c. Silicone Lube Oils
      d. Lactone Plasticizer
      e. Textile Finishes

B. Ethyl Ether
   1. Solvent
   2. Anesthetic
C. Acetic Acid (See VI-A-2)
D. Chloral (See VI-A-6)
E. Chloroform
F. Diethylamine
   1. Corrosion Inhibitor
   2. Rubber Accelerator
   3. Insecticides
   4. Textile Finishing Agent
G. Ethyl Acetate (See VI-A-2-g)
H. Ethyl Bromide
   1. Organic Synthesis
   2. Refrigerant
   3. Solvent
   4. Grain and Fruit Fumigant
I. Ethyl Chloride (See VII)
J. Ethylene Dibromide (See IV)
K. Glycol Ethers
L. Solvent
M. Fuel

VII. Ethyl Chloride
   A. Tetraethyl Lead
   B. Ethyl Cellulose
      1. Adhesives
      2. Injection Plastics
      3. Protective Coatings
      4. Pigment-Grinding Base
      5. Toughening Agent in Plastics
   C. Refrigerant
   D. Anesthetic

VIII. Ethylene Dichloride
   A. Piperazine
      1. Corrosion Inhibitor
      2. Insecticide
      3. Medicinals
   B. Ethylenediamine
      1. Ethylenediaminetetraacetic Acid
         a. Chelating Agent
      2. Adhesive
      3. Textile Lubricant
      4. Corrosion Inhibitor in Antifreeze
      5. Stabilizing Rubber Latex
      6. Neutralizing Acid Oils
      7. Solvent for Fibrin and Albumin
   C. Ethyleneimine (See X)
   D. Vinyl Chloride
      1. Fibers
      2. Plastics
   E. Trichloraethane
      1. Vinylidene Chloride
         a. Films
         b. Fibers
         c. Plastics
      2. Tetrachloroethane
         a. Trichloroethylene
         b. Pentachloroethane
            (1) Perchloroethylene
            (2) Solvent
   F. Tetraethyl Lead Scavenger
   G. Dichloroethyl Formal
      1. Solvent
      2. Intermediate for Polysulfide Rubber
   H. Agricultural Fumigant

IX. Ethylene Chlorohydrin
   A. Ethylene Oxide (See XI)
   B. By-Products
      1. Ethylene Dichloride (See VIII)
      2. Dichloraethyl Ether
         a. Solvent for
            (1) Ethyl Cellulose
            (2) Fats
            (3) Oils
            (4) Waxes
            (5) Gums
            (6) Resins
            (7) Soaps
         b. Textile Scouring
         c. Finish Remover

X. Ethyleneimine
   A. N-(2-Hydroxyethyl) Ethyleneimine
      1. Modify Paper, Wood, and Cellulose Fibers
   B. Triethylenediamine
      1. Urethane Foam Catalyst
   C. Polyethyleneimines
      1. Adhesive Coatings
      2. De-Emulsifiers
      3. Corrosion Inhibitors
      4. Paper Processing
   D. Tris-(1-Aziridinyl) Phosphine Oxide (APO)
      1. Textiles (Fire-Resistance and Crease-Proofing)
   E. Flocculant for Water Treatment
   F. Anchoring Agent for Printing
   G. Surface Active Agents
   H. Pesticides

XI. Ethylene Oxide
   A. Ethylene Glycol
      1. Antifreeze
      2. Polyethylene Terephthalate
         a. Polyester Fibers and Film
      3. Dioxane
         a. Solvent for
            (1) Cellulose Acetate
            (2) Fats and Oils
            (3) Paints
            (4) Varnish Removers
         b. Wetting Agent in Textile Processing
         c. Cements
         d. Cosmetics and Deodorant
         e. Fumigant
         f. Glues
         g. Polishing Compositions
         h. Stabilizer in Chlorinated Solvents
      4. Ethylene Carbonate
         a. Solvent for Resins and Polymers
         b. Extraction Solvent
         c. Synthesis of Rubber Chemicals and Textile Agents
      5. Ethylene Glycol Dinitrate
         a. Explosive Freezing Inhibitor
      6. Glyoxal
         a. Imidazoles
            (1) Organic Synthesis
            (2) Catalyst for Epoxy, Polyurethane Resins
            (3) Corrosion Inhibitor
            (4) Dyeing Auxiliary
         b. Durable-Press Fabric
         c. Wet Strength Agent for Paper
         d. Embalming Fluid
         e. Adhesive Modifier

7. Methyldioxolane
    a. Solvent Extraction
    b. Plasticizer
    c. Organic Synthesis
    d. Natural Gas Purification
    e. Spinning Solvent for Synthetic Solvent
8. Softening Agent for Paper Fibers and Leather

B. [Diethylene Glycol]
C. [Triethylene Glycol]
1. Esters
    a. Plasticizers for Rubber and Vinyl Chloride Resins
2. Hydraulic Brake Fluid
3. Chemical Sterilization of Air
4. Solvent for Nitrocellulose, Gums and Resins
5. Textile Conditioner
6. Gas Dessicant
7. Extractant in "UDEX" Units
8. Air Conditioning Dehumidifier
9. Lube Oil Viscosity Improver

D. Polyethylene Glycol
1. Nonionic Surfactant
2. Lubricants
3. Paper Coatings
4. Adhesives
5. Cosmetic

E. [Ethoxylated Alkyl Phenols]
F. [Ethoxylated Higher Alcohols]
1. Nonionic Surfactants
    a. Anionic Surfactant

G. Polyethylene Glycol Fatty Esters
H. Ethoxylated Sorbitol Fatty Esters
I. Ethoxylated Fatty Amines and Amides
J. Ethoxylated Higher Mercaptans
K. Poly (Mixed Ethylene, Propylene) Glycol
1. Surfactant
2. Oil Drilling Chemicals
3. Hydraulic Fluids
4. Lubricants

L. Polypropylene Glycol, Ethoxylated
1. Polyols for Urethane Foams
2. Surfactants

M. Ethylene Glycol Monomethyl Ether
1. Ethylene Glycol Monomethyl Ether Acetate
    a. Lacquer Solvent
2. Jet Fuel Additive
3. Solvent for Cellulose Acetate Nitrocellulose, Lacquers, and Printing Ink
4. Promotes Dye Penetration

N. Ethylene Glycol Monoethyl Ether
1. Ethylene Glycol Monoethyl Ether Acetate
2. Improves Leather Dye Leveling

O. Ethylene Glycol Monobutyl Ether
1. Di-Butoxyethyl Phthalates
2. Solvent for Hot Spray Lacquers and Aerosol Nitrocellulose Lacquers
3. Coupling Agent for Water to Dry-Cleaning Soap
4. Solvent for Alkyd, Phenolic, Polyamide, Thermosetting Acrylics
5. Mutual Solvent for Soluble Oils and Insecticides
6. Herbicidal Esters of 2, 4-D and 2, 4, 5-T

P. Diethylene Glycol Monomethyl Ether
1. Coalescing Agent for Latex Paint
2. Solvent for Brushing Lacquer and Non-Grain-Raising Wood Stain
3. Diluent for Hydraulic Brake Fluids
4. Solvent for Stencil Inks and Textile Dye Pastes

Q. Diethylene Glycol Monoethyl Ether
1. Ethyldiethoxy Phthalates
2. Film Coalescing Agent in Latex Paint

R. Diethylene Glycol Monobutyl Ether
1. Solvent in High Baked Enamels
2. Dispersant for Vinyl Chlorides in Organosols

S. Monoethanolamine
1. Acetylethanolamine
    a. High Boiling Solvent for Fountain Pen Ink
    b. Humectant for Paper, Glues, and Inks
    c. Textile Conditioner
    d. Polish Ingredients
    e. Plasticizer for Polyvinyl Alcohol
2. Phenylethanolamine
    a. Phenyldiethanolamine
        (1) Acetate Rayon Dyes
    b. Dyestuffs
    c. Organic Synthesis
3. Tolylethanolamine
    a. Tolydiethanolamine
        (1) Emulsifier
    b. Dyestuff Intermediate
4. Emulsifier for Cosmetics, Agricultural Sprays, and Paints
5. Intermediate for Soaps and Detergents
6. Corrosion Inhibitor
7. Acid Gas Absorbent

T. Diethanolamine
1. Fatty Diethanolamides
2. Diethanolamine Lauryl Sulfate
3. Morpholine
4. Liquid Detergents for
    a. Emulsion Paints
    b. Cutting Oils
    c. Shampoos
    d. Cleaners
5. Textile Specialties
6. Absorbent for Acid Gas
7. Solubilizing 2, 4-D

U. Triethanolamine
1. Fatty Acid Soaps
2. Wool Scouring
3. Textile Antifume Agent

V. Aminoethylethanolamine
1. Rubber Products
2. Insecticides and Fungicides
3. Fatty Imidazolines

W. Diethylaminoethanol
X. Dimethylaminoethanol
Y. Choline
1. Natural Feed Supplement
2. Catalyst
3. Curing Agent
4. Control of pH

Z. Phenethyl Alcohol
   1. Cosmetic
   2. Perfumery
   3. Preservative

AA. Alpha-Acetobutyrolactone (Intermediate for Vitamin Compounds)

BB. Hydroxyethylcellulose
   1. Latex Paint Thickner
   2. Adhesives
   3. Protective Colloid in Vinyl Acetate Polymerization
   4. Portland Cement Compositions

CC. Dichloroethyl Formal

DD. Ethylene Bromohydrin

EE. Isethionic Acid
   1. Synthetic Detergent
   2. Rust Inhibitors
   3. Lube-Oil Additives

XII. Ethylene/Ethyl Acrylate Copolymer

XIII. Ethylene/Propylene Elastomers

XIV. Ethylene/Vinyl Acetate Copolymer

XV. Diethyl Ketone (3-Pentanone)

XVI. Propionaldehyde
   A. Propionic Acid
      1. Propionates for Bread Mold Inhibitor and General Fungicide
      2. Emulsifying Agent
      3. Nickel Electroplating Solutions
      4. Perfume Esters
      5. Solvent Mixtures for Cellulose Derivatives
      6. Herbicides
      7. Plasticizers
   B. Alkyd Resins

XVII. Vinyl Acetate (See VI-A-2-h)

XVIII. Vinyl Toluene

   A. Surface Coatings

*Chemical Information Service, Chemical Origins and Markets (Menlo Park, California: Chemical Information Service, Stanford Research Institute, 1967), pp. 10-13.

BIBLIOGRAPHY

BIBLIOGRAPHY

American Petroleum Institute. "Petroleum Facts and Figures, 1971 Edition." Washington, D. C.: API, May, 1971.

Annual Survey of Manufacturers, 1970. Washington, D. C.: U. S. Department of Commerce, Bureau of the Census, December, 1972.

Bain, Joe S. Industrial Organization. New York: John Wiley & Sons, 1962.

Bragg, Dan M. and James R. Bradley. "Work Plan for a Study of the Feasibility of an Offshore Terminal in the Texas Gulf Coast Region. College Station, Texas: Sea Grant Report TAMU-SG-71-212, Texas A&M University, June, 1971.

Bragg, Daniel M. and James R. Bradley. "The Economic Impact of a Deepwater Terminal in Texas." College Station, Texas: Sea Grant Report TAMU-SG-72-213, Texas A&M University, November, 1972.

Brownstein, Arthur M., editor. US Petrochemicals, Technologies, Markets, and Economics. Tulsa: The Petroleum Publishing Company, 1972.

Chemical Information Service. Chemical Origins and Markets. Menlo Park, California: Stanford Research Institute, 1967.

1972 Directory of Texas Manufacturers. Austin, Texas: Bureau of Business Research, The University of Texas at Austin.

King, William C. "Petrochemicals Face Reality." World Petroleum, Volume 42, No. 5, June, 1971.

McConnell, Campbell R. Economics: Principles, Problems, and Policies. New York: McGraw-Hill Book Company, 1966.

Morley, John C. Talk before Houston Outlook Conference. Houston, Texas: Houston Chamber of Commerce, January 17, 1973.

"Outlook for Energy in the United States to 1985." New York: The Chase Manhattan Bank, June, 1972.

Phillips, R. Foy. "A Look at a Complex, Expanding, Bustling Industry--Petrochemicals." Chemical Engineering, May 22, 1967.

Reynolds, W. W. "Investing in Primary Petrochemicals." Chemical Engineering Progress, Volume 68, No. 9, September, 1972.

Rhodes, Nolan C., Col. United States Department of the Army, Corps of Engineers, Galveston District, Galveston, Texas, News Release, August 4, 1972.

Schenker, Eric. "Present and Future Income and Employment Generated by the St. Laurence Seaway." Milwaukee, Wisconsin: Center for Great Lakes Studies, the University of Wisconsin-Milwaukee, 1971.

Sherwood, Peter W. "Practical Approaches to Petrochemical Diversification." World Petroleum, Volume 38, No. 11, October, 1972.

Texas Almanac, 1972-73. Dallas, Texas: A. H. Belo Corporation.

Texas Input-Output Model. Austin, Texas: Office of the Governor, 1972.

"The 500 Largest Industrial Corporations." Fortune, Volume 65, No. 5, May, 1972.

"The Petrochemical Industry and Oil Import Controls." Produced and published with the cooperation of Celanese Corporation, Dow Chemical Company, I. E. DuPont de Nemours and Company, Eastman Kodak Company, Monsanto Company, National Distillers and Chemical Corporation, Olin Mathieson Chemical Corporation, Publicker Industries, Inc., and Union Carbide Corporation, March, 1969.

"The World's Petrochemical Plants, 1971." World Petroleum. Volume 42, No. 12, December, 1971.

United States Tariff Commission. "Synthetic Organic Chemicals, United States Production and Sales, 1970." Washington, D. C.: United States Government Printing Office, 1972.

Watson, Donald Stevenson. Price Theory and Its Uses. New York: Houghton Mifflin Company, 1963.

Whitehead, Don. The Dow Story. New York: McGraw-Hill Book Company, 1968.