Industry & Trade Summary

Polyethylene Resins in Primary Forms

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UNITED STATES INTERNATIONAL TRADE COMMISSION

COMMISSIONERS

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PREFACE

In 1991 the United States International Trade Commission initiated its current *Industry and Trade Summary* series of informational reports on the thousands of products imported into and exported from the United States. Each summary addresses a different commodity/industry area and contains information on product uses, U.S. and foreign producers, and customs treatment. Also included is an analysis of the basic factors affecting trends in consumption, production, and trade of the commodity, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.[1]

This report on polyethylene resins in primary forms covers the period 1987 through 1991 and represents one of approximately 250 to 300 individual reports to be produced in this series during the first half of the 1990s. Listed below are the individual summary reports published to date on the chemicals sector.

USITC publication number	*Publication date*	*Title*
2458(CH-1)	November 1991	Soaps, Detergents, and Surface-Active Agents
2509(CH-2)	May 1992	Inorganic Acids
2548(CH-3)	August 1992	Paints, Inks, and Related Items
2578(CH-4)	November 1992	Crude Petroleum
2588(CH-5)	December 1992.........	Major Primary Olefins
2590(CH-6)	February 1993..........	Polyethylene in Primary Forms

[1] The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

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INTRODUCTION

This report covers polyethylene resins in primary forms with available data for a 5-year period beginning in 1987 and ending in 1991. The commodities in this summary are contained in standard industry classification (SIC) grouping 2821, along with other plastic resins in primary forms. Polyethylenes are part of a larger group of plastics known as thermoplastics which are plastics that are capable of being repeatedly resoftened by increases in temperature.[1] The polyethylene products that this summary covers include high-density; low-density; linear low-density; very low-density; high molecular weight-high-density; ultrahigh-molecular-weight polyethylene; and ethylene-vinyl acetate.[2] These resins are in primary forms, meaning that the material has not been fabricated or formed into a product.

Polyethylene was first produced in the 1930s by Imperial Chemical Industries, Ltd. (ICI), in England during studies of the effects of high pressures on chemical reactions. The material was overlooked for the first few years after discovery because its attributes were not known. During the ensuing years the development of new and more sophisticated testing equipment allowed researchers to measure and investigate the substance's true properties. Polyethylene was found to have excellent dielectric properties and had its first application as a wire insulation material for the Allied Forces during World War II. The material was produced in England for the war in the late 1930s, but it did not reach commercial production in the United States until 1943.

From its modest beginnings polyethylene has grown to become the largest volume plastic material in the world. Today it has diversified applications in many market segments. Most significant are the inroads made in the packaging, construction, consumer, and electronics industries.

Polyethylene production has steadily increased since its first commercial applications. Almost every industrialized country has polyethylene production facilities, with the United States leading the way with capacity of 10.8 million tons. Western Europe is a close second with 9.7 million tons. As a net exporter of polyethylene resins, the United States has exported an average of 14 percent of total production over the last 5 years. However, new plant constructions and capacity expansions in Europe and East Asia could impact future U.S. exports of polyethylene resins.

U.S. INDUSTRY PROFILE

Product Description and Attributes

The materials covered in this summary, polyethylene in primary forms, include commodity polyethylene resins, which are produced in large volume with low unit value, and specialty polyethylene resins, which are produced in smaller quantities and typically have higher value applications. The commodity resins include low-density polyethylene, linear low-density polyethylene, and high-density polyethylene. Specialty resins include very low-density polyethylene; high molecular weight-high-density polyethylene; ultrahigh-molecular-weight, high-density polyethylene; ultralow-density polyethylene; and ethylene-vinyl acetate. A profile of the U.S. industry is depicted in figure 1.

Since polyethylene resin was first produced commercially in the United States in 1943, its production has steadily increased, reaching 9.1 billion kilograms in 1990.[3] Low-density polyethylene was the first polyethylene to reach commercial production. In 1957 high-density polyethylene was introduced, followed by ethylene-vinyl acetate in 1964 and linear low-density polyethylene in 1978.

The plastic industry and the Government use the density of each type of polyethylene resin to identify it. The two major categories of polyethylene are high and low-density; a resin with a specific gravity of 0.94 and higher is considered a high-density resin and a resin with a specific gravity of less than 0.94 is considered low-density. The density of the resin not only classifies it, but more importantly is a major determinant of its properties and thus its uses. As the density of the polymer increases, chemical resistance, tensile strength, and stiffness increase and permeability, environmental stress cracking, and toughness decrease. In addition to the critical factor of density, molecular weight and molecular structure also determine the properties of the polyethylene. Table 1 describes the characteristics of the products covered in this summary.

The properties of polyethylene—flexibility, stiffness, toughness, melt temperature, permeability, electrical resistance, and chemical resistance—are measured by the industry to determine the best applications for a particular resin. Industry-related measurements such as melt index (MI), intrinsic viscosity, and Shore D Hardness have been developed to provide standard methods to differentiate resins. Unique mixes of properties determine end-use applications in numerous markets. For example, plastic grocery bags require a resin that has good flexibility and strength but not chemical resistance and electrical resistance properties.

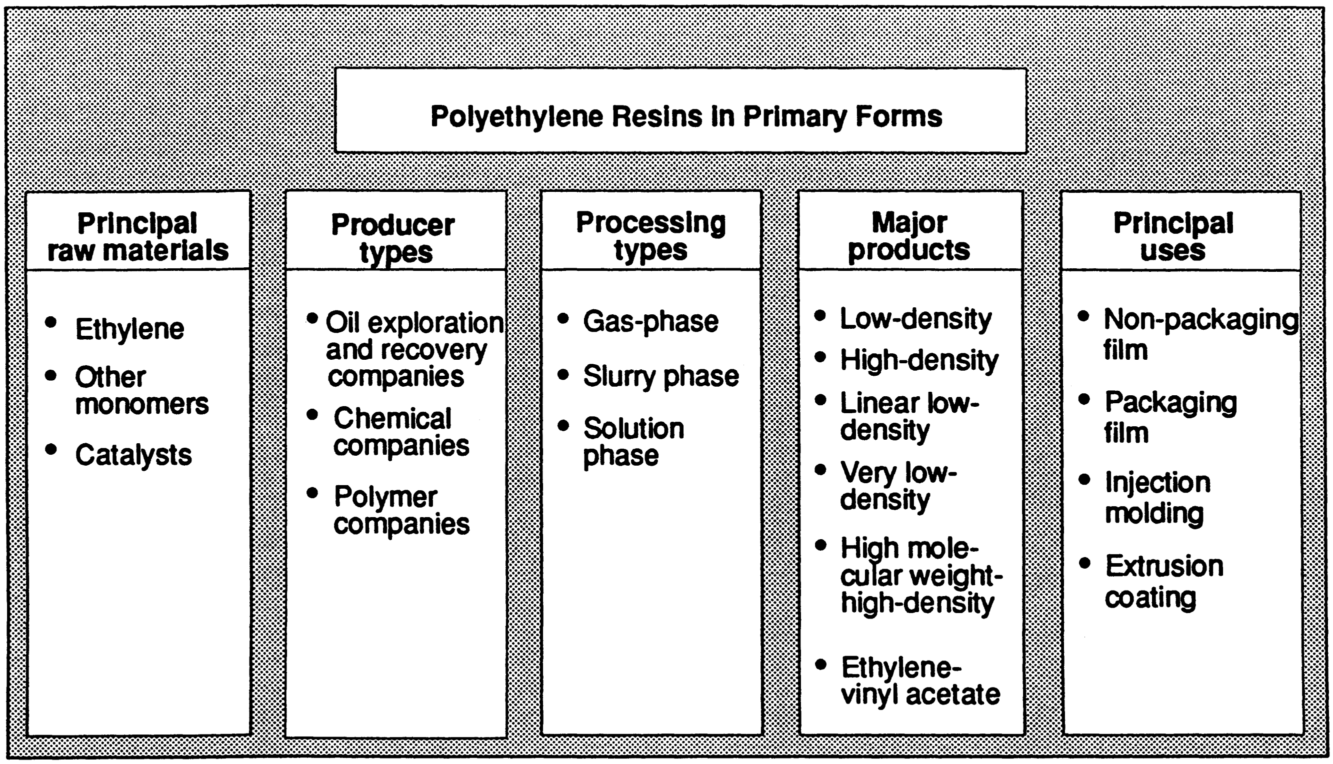
Most U.S. producers sell polyethylene by trade names. Some of the common trade names of polyethylene and the corresponding producing companies are shown in table 2. The use of trade names has increased in recent years as companies tailor their resins and resin blends to specific markets and uses. New technology and developments in the polymerization process have allowed companies to

[1] Thermoplastics and thermosets (which cannot be resoftened by heat) constitute the plastics industry.

[2] See appendix A for glossary of industry terms.

[3] U.S. International Trade Commission, *Synthetic Organic Chemicals, U.S. Production and Sales, 1955 and 1990*; U.S. Tariff Commission Report No. 198, Second Series, and USITC Publication 2470.

Figure 1
U.S. polyethylene industry: Principal raw materials, producer types, processing types, major products, and principal uses



Source: USITC staff.

produce a wider range of resins with specific properties.

Production Processes

Polyethylene is a synthetic polymer produced by chemical synthesis. The polymer is formed by a chain-growth process and thus is referred to as an addition polymer. A radical-initiated polymerization of ethylene yields polyethylene, as indicated below:

$$nCH_2{=}CH_2 + \text{catalyst} \rightarrow [CH_2CH_2CH_2CH_2]_n$$

The main raw material needed for polyethylene production is ethylene. If ethylene is the sole raw material, the polyethylene is referred to as a homopolymer. Alternatively, if ethylene is reacted with other α-olefins, such as butene, hexene, and octene, a copolymer is produced. The type and quantity of raw materials used determine the properties of the resulting polyethylene. The catalyst is also an important determinant of the properties of the polyethylene. A wide variety of catalysts are used to initiate the reaction. The two major types of catalysts are metallocene single-site catalysts and Ziegler-Natta aluminum alkyl/metal chloride catalysts. The catalyst establishes the molecular structure of the polymer. For example, metallocene single-site catalysts allow precise control of the reaction by confining the polymerization to a single site on the polymer chain, thus producing uniform branching from the carbon backbone.

Figure 2 depicts the production process of polyethylene. A hydrocarbon source, usually crude petroleum or natural gas, is used to produce ethylene, which in turn is converted to polyethylene. Approximately 0.98 kilograms (kg) of ethylene is needed to produce 1 kg of low-density polyethylene, and 1.01 kg is needed to produce 1 kg of high-density polyethylene. The material is normally produced by continuous process in a large reaction vessel. Low-density polyethylene is produced in a high-pressure environment, whereas high-density and linear low-density polyethylene are produced in low-pressure chambers.

The production processes of the three largest volume polyethylenes—high, low, and linear low are examined below. The two main processes to produce low-density (high-pressure) polyethylene include high-pressure tubular and high-pressure stirred-autoclave. Pressurized ethylene (raw material), initiators, and chain-transfer agents must be fed into the reaction vessel. The details of the production process are not available, because major producing companies consider the information proprietary. High-pressure reactors incur greater operating cost

Table 1
Polyethylene resins: Product characteristics

Type	Density (grams/cubic centimeter)	Monomers	Reaction vessel pressure	Linearity	Principal processing type	End-use example
Low-density	<.940	ethylene α-olefins	high	branched	extrusion injection molded	food packaging
Linear low-density	.910-.925	ethylene butene hexene octene	low	linear	extrusion injection molded	garbage bags
Medium-density	.926-.940	ethylene α-olefins	(1)	(1)	(1)	(1)
High-density	>.940	ethylene α-olefins	low	linear	extrusion injection molded blow molded thermoforming	milk & detergent bottles
Very low-density	<.915	ethylene butene hexene octene	low	linear	extrusion injection molded	packaging film
High molecular weight-high-density	.941-.965	ethylene butene hexene octene	low	linear	extrusion	grocery sacks
Ultrahigh-molecular-weight high-density	>.940	ethylene α-olefins	low	linear	compression molding	machine parts
Ultralow-density	.890-.915	(1)	low	linear	(1)	(1)
Ethylene-vinyl acetate	(1)	ethylene vinyl acetate	(1)	(1)	injection molded blow molded extrusion	food wrap

[1] Not available

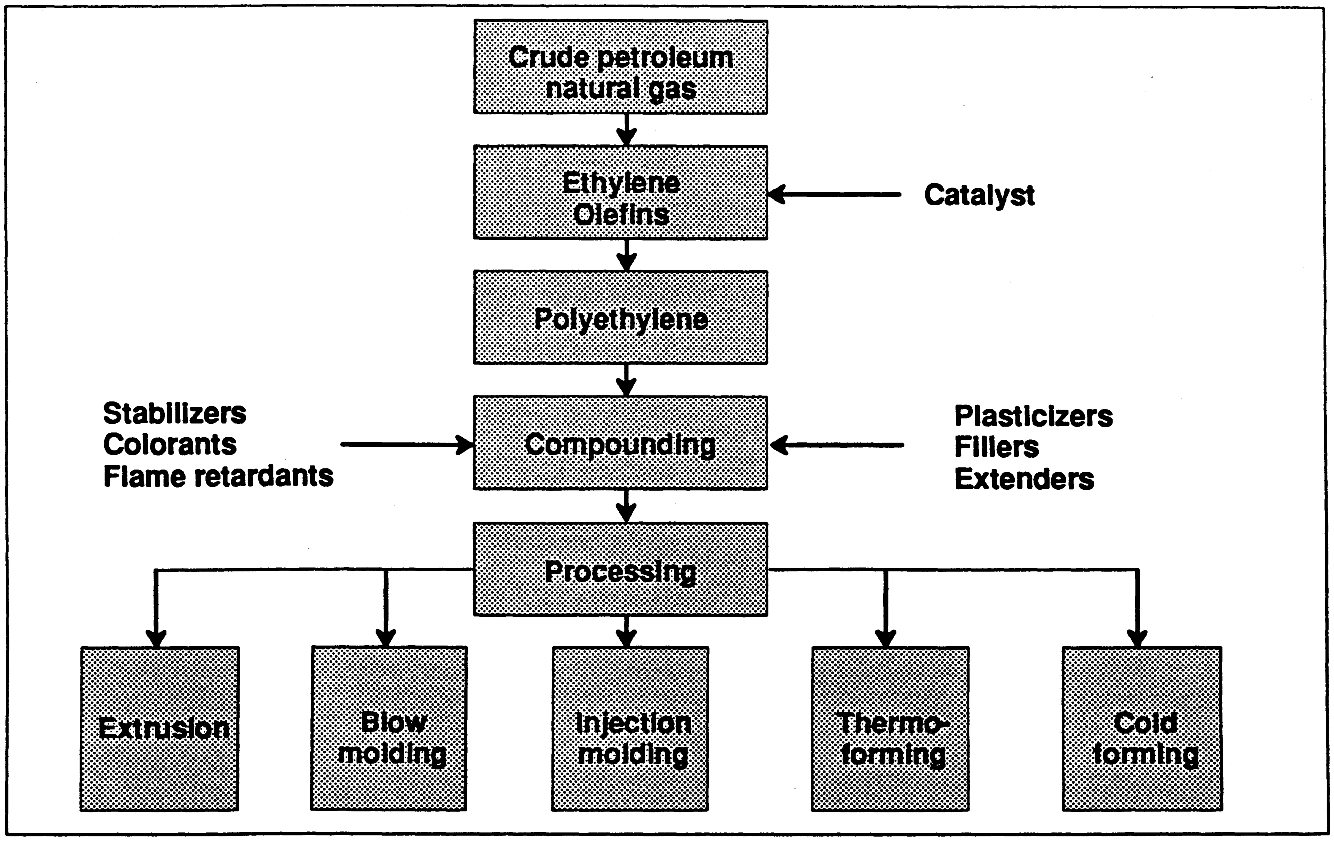
Source: *Modern Plastics Encyclopedia.*

Table 2
Trade names of polyethylene in primary forms

Trade name	Type	Company
Neopolen	Polyethylene	BASF
Attane	Very low-density polyethylene	Dow
Dowlex	Polyethylene	Dow
Alathon	Polyethylene	DuPont
Tenite	Polyethylene	Eastman
Escorene	Low and linear low-density polyethylene	Exxon
Exact	Polyethylene	Exxon
Hostalen	Polyethylene	Hoechst Celanese
Marlex	Polyethylene	Phillips
Petrothene	Low, linear low, high-density polyethylene	Quantum
Microthene	Polyethylene in powder form	Quantum
Ultrathene	Ethylene-vinyl acetate	Quantum
Fortiflex	High-density polyethylene	Solvay
Unival	High-density polyethylene	Union Carbide
Flexomer	Very low-density polyethylene	Union Carbide
Unipol	Process	Union Carbide

Source: *Modern Plastics Encyclopedia, Plastics World.*

Figure 2
Polyethylene precursors and derivatives



Source: Compiled by USITC staff.

than low-pressure reactors do because pressurization of the inputs is expensive and the chances of an uncontrolled reaction are greater.

There are three main types of reaction processes for low-pressure polyethylenes—i.e., high-density and linear low-density polyethylene. Some companies have a swing reactor that can accommodate high and linear low production. The types of processes are mentioned below but the details are not known, due to limited available information. One type of process is a gas-phase reaction wherein ethylene gas is converted directly into a solid polymer. Union Carbide's patented Unipol® process is reported to use this type. The second major type of process is a slurry-phase reaction. The raw material is dissolved in a hydrocarbon diluent where the solid polymer is suspended as it forms. Many of the Japanese companies are reported to use this type of process. The third type involves a solution-phase reaction wherein ethylene is dissolved in a solvent and the polymerization takes place in the solution.

Once a commercial-scale process is developed, it will customarily be patented by the company, which will generate revenue through process licensing as well as through product sales. Union Carbide's Unipol® process has worldwide licensing applications. In 1991 five new facilities were constructed to produce polyethylene using this process.[4] Himont's Spherilene process is also reported to have worldwide applications.

Most recently Japan's Mitsui Petrochemical company announced the development of a new process that can continuously produce low-density, linear low-density, and high-density polyethylene. This process is the first to claim these capabilities, which could have a big impact on the industry. The process utilizes a new catalyst to produce the full range of polyethylenes. The company is in the process of building a pilot plant that will test the process for commercial use.

After polymerization the polymer usually undergoes some type of compounding to aid in processability and utility. The following materials are commonly added to the resin: extenders, fillers, colorants, flame retardants, and antioxidants. The polymer may take many forms after production depending on its intended use. The most common forms are powder, flake, in solution, or extruded into pellets.

Polyethylene will be further processed for its end use after compounding. Polyethylene can be extruded into sheet, film, or coatings; blow-molded or

[4] "Indonesia Picks Unipol Tech for PE/PP Complex," *European Chemical News*, Feb. 10, 1992, p. 25.

injection-molded into bottles and containers; thermoformed; or coldformed.

Product Applications

Polyethylene has broad applications in numerous industry segments. The largest market (by volume) for polyethylene is packaging, followed by building, housewares, electrical/electronics, toys, transportation, furniture, and appliances. Table 3 shows the volume usage by market type for 1991.

Although high and low-density polyethylene are both used in the packaging industry (figures 3 and 4), they have different applications. As shown in figure 5, 36 percent of high-density polyethylene is blow-molded. Typical applications, in order of magnitude, are milk and water bottles, household chemical bottles, pails, and sheet. Alternatively, low and linear low-density (figure 6) are extruded into film (62 percent). Major applications include trash bags, stretch wrap for packaging, and food wrap.

Market Structure

Polyethylene is produced in the U.S. by petroleum and natural gas companies, chemical companies, and specialty polymer companies. Polyethylene is used captively by the producer, sold by the producer in compounded form directly to a fabricator, or funneled through a compounding or distributorship intermediary before reaching the fabricator.

Establishments

Currently there are 16 U.S. producers of the major polyethylene resins as shown in Table 4. No single firm accounts for more than 16 percent of the total capacity. All are publicly held companies with the exception of Westlake Polymers. Paxon is a joint-venture operation; Exxon and Allied Signal are the controlling parties. Various subsidiary and controlling interest situations are as follows: Eastman is a subsidiary of the Eastman Kodak Company; Hoechst Celanese is a subsidiary of Hoechst AG; ARCO has a 49.9-percent interest in Lyondell; and Solvay is a subsidiary of Solvay & Cie of Belgium.

In addition to the major polymers mentioned above, ethylene-vinyl acetate and other copolymers of ethylene make up a small portion (approximately 3 percent) of the resins covered in this report. In 1990 there were five U.S. producers of ethylene vinyl acetate—Exxon, National Starch and Chemicals, Quantum, and Reichold. Other ethylene copolymers are produced by Dow, Eastman, Eval, Exxon, and Sequa.

According to industry sources, three new producers will begin production in 1992. Montecatini was scheduled to begin polyethylene production in Himont's Bayport, TX, olefins facility in April 1992 and has further plans to construct another facility in Lake Charles, LA, with a capacity of 200,000 tons per year (tpy).[5] Himont and Formosa Plastics are scheduled to begin polyethylene production at the end of 1992; annual capacity for Himont is slated at 180,000 tons, whereas Formosa's annual capacity is expected to be 134,000 tons.[6]

Phillips is expected to increase capacity in 1992 as it rebuilds its polyethylene facility after an explosion and fire destroyed the plant in 1989. Total operational capacity at the end of 1991 was 816,000 tpy, and startup of the final line was scheduled for early 1992.[7] An explosion at Union Carbide's Seadrift, TX, facility in 1991 curtailed production for several months during that year, but the plant is believed to be back to normal operating capacity at this time.[8]

Some companies are backward integrated to petroleum exploration and ethylene production, others are forward integrated for product fabrication, and some are both backward and forward integrated. Companies with limited integration are usually specialty chemical companies. Polyethylene resins usually account for a larger percent of sales for these chemical companies compared with more diversified petroleum companies.[9]

Geographic Distribution

Geographic distribution of U.S. polyethylene producers is heavily concentrated in the southern parts of Texas and Louisiana as shown in figure 7. This accumulation of polyethylene producers is due to the concentration of raw material producers in this area. Ethylene, the major material used for polyethylene production, is not easily shipped, because it is a highly volatile substance. The majority of ethylene shipments are transported by pipeline. This area contains many petroleum refineries and ethylene pipelines that provide the necessary raw material for polyethylene production.

Employment

Employment statistics for polyethylene resins are not available, due to aggregation of all resins in primary forms into one SIC code. Table 5 shows total employment and production worker employment for 1987 through 1991, based on Commission staff estimates. Production workers constitute approximately 60 percent of total employees.

Pricing

Market prices of commodity high and low-density resins have ranged from a low of 26¢/lb in the third quarter of 1991 to a high of 50¢/lb in the fourth quarter of 1988. Prices for polyethylene are driven by market factors—supply and demand—and by price of the raw material—ethylene. Polyethylene prices have averaged approximately 15¢/lb more than ethylene prices during

[5] "Montecatini Plans Early PE Production," *Chemical Marketing Reporter*, Dec. 16, 1991.

[6] Peter Savage, "Recession Forces U.S. PE Producers Into Tight Corner," *European Chemical News*, Feb. 10, 1992.

[7] "Phillips Back on Track in Polyethylene Market," *Chemical Marketing Reporter*, Feb. 24, 1992.

[8] Union Carbide Corp., *Annual Report 1991*.

[9] Compiled from company annual reports.

Table 3
Major U.S. markets for polyethylene, 1991

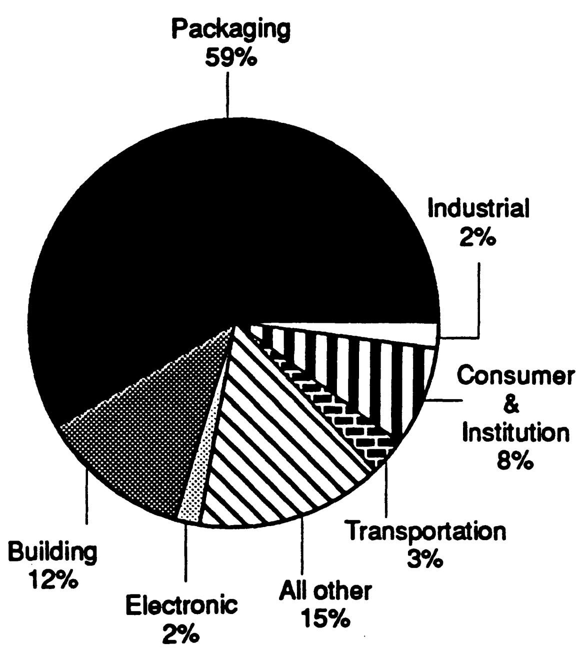
(1,000 metric tons)

Type	High-density	Low-density	Total
Appliances	([1])	([1])	10
Building			
Pipe, fittings, conduit	244	61	305
Profile extrusions	([1])	([1])	7
Vapor barriers	0	108	108
Total	244	169	420
Electrical/Electronics	64	159	223
Furniture	([1])	([1])	10
Housewares	119	204	323
Packaging			
Closures	37	15	52
Coatings	24	370	394
Containers			
Blow molded	1,145	37	1,182
Injection molded	499	104	603
Film	309	1,696	2,005
Total	2,014	2,222	4,236
Toys	78	79	157
Transportation[2]			
Cars, vans, light trucks	([1])	([1])	85
Other	([1])	([1])	8
Total	([1])	([1])	93

[1] Breakdown between high-density and low-density is not available.
[2] Includes Canada.

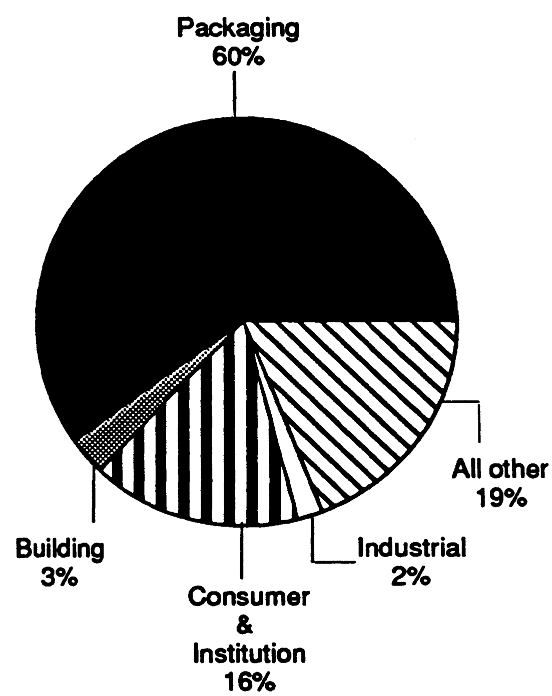
Source: *Modern Plastics.*

Figure 3
U.S. markets for high-density polyethylene, 1990



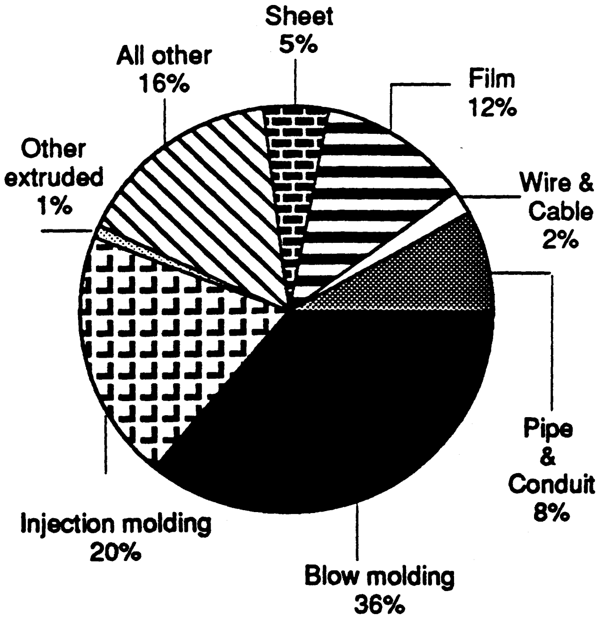
Source: *Facts & Figures of the U.S. Plastics Industry.*

Figure 4
U.S. markets for low and linear low-density polyethylene, 1990



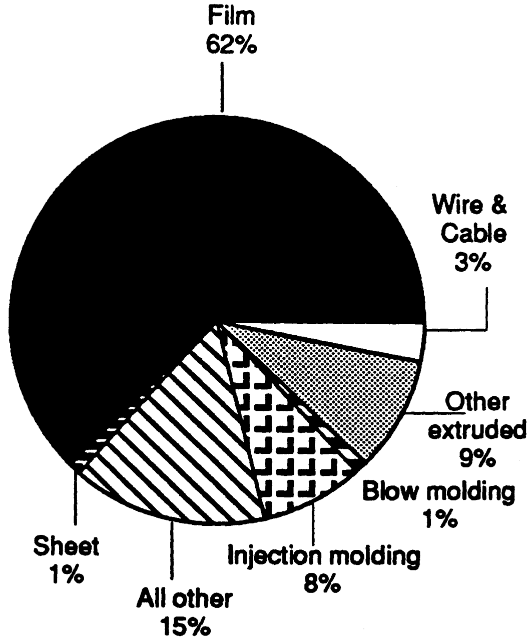
Source: *Facts & Figures of the U.S. Plastics Industry.*

Figure 5
High-density polyethylene: U.S. consumption by end uses, 1990



Source: *Facts & Figures of the U.S. Plastics Industry.*

Figure 6
Low and linear low-density polyethylene: U.S. consumption by end uses, 1990



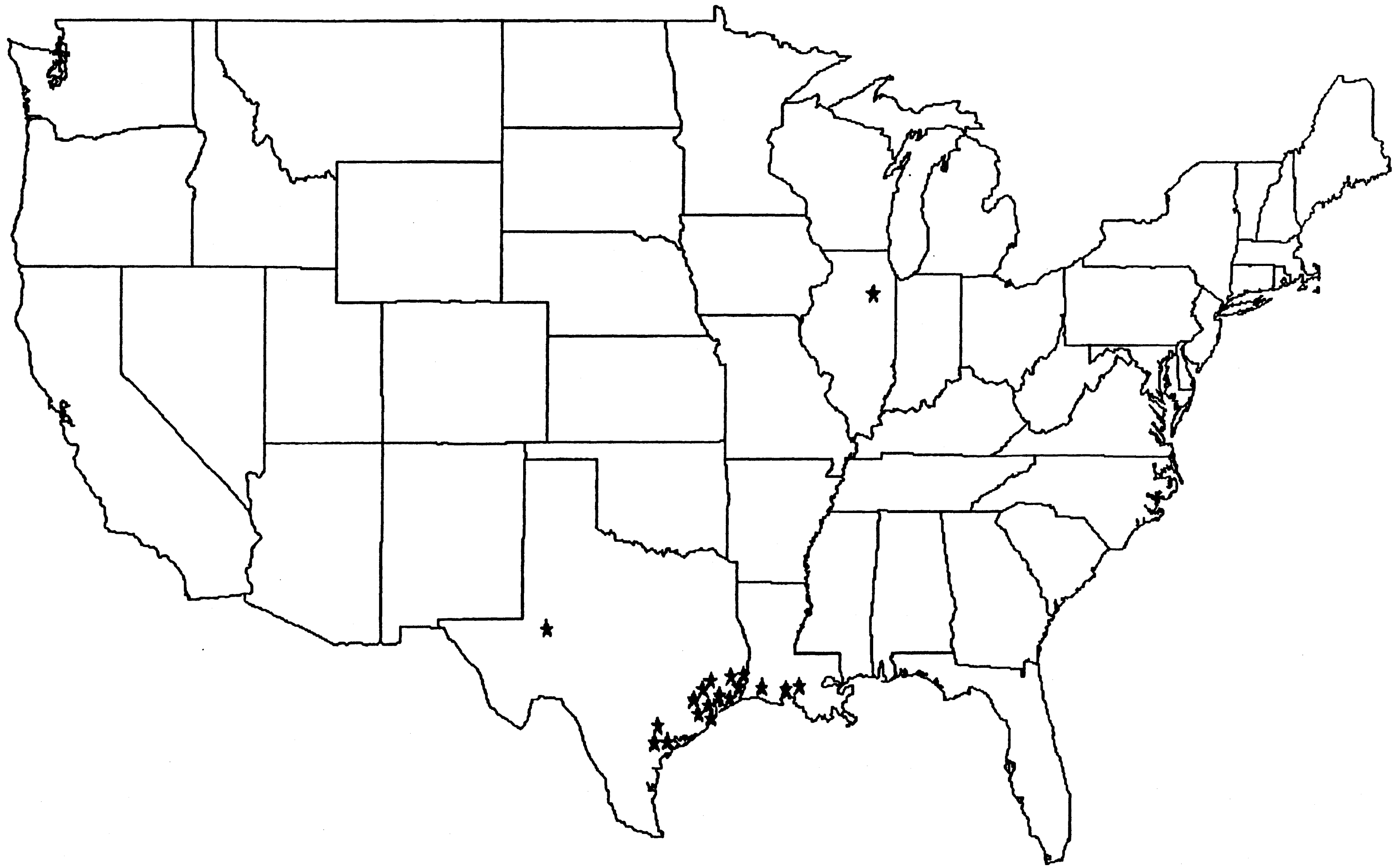
Source: *Facts & Figures of the U.S. Plastics Industry.*

Table 4
Polyethylene resins in primary forms: U.S. nameplate capacity, 1991
(1,000 metric tons per year)

Company	Low-density	High-density	Linear low/high	Total
Chevron	417	261	200	878
Dow	440	122	753	1,315
DuPont	345			345
Eastman	295			295
Exxon	295	120	408	823
Hoechst Celanese		159		159
Lyondell	57			57
Mobil	227		554	771
Occidental		794		794
Paxon		544		544
Phillips		544		544
Quantum	646	764	288	1,698
Rexene	184			184
Solvay		649	45	694
Union Carbide	227		1,134	1,361
Westlake Polymers	318			318
Total	3,451	3,957	3,372	10,780

Source: *Chemical Marketing Reporter.*

Figure 7
Geographic distribution of polyethylene producers



Source: Compiled by USITC staff.

Table 5
U.S. employment data for polyethylene resins in primary form

Year	Total employment	Production workers
1986	16,957	10,571
1987	16,890	10,470
1988	17,490	10,800
1989	17,360	10,584
1990	18,834	11,370

Source: Estimated by Commission's staff based on U.S. Department of Commerce, Bureau of the Census.

the 5-year period. Figure 8 shows the historic prices of low and high-density polyethylene in relation to ethylene prices.

Because ethylene is derived from petrochemical feedstocks, its price is reflective of crude petroleum prices, shown in figure 9. Crude petroleum prices jumped by about $15/barrel during the second and third quarter of 1990 due to unrest in the Persian Gulf. The ethylene price jump lagged the petroleum price jump by about 3 months. The latent effect of the Persian Gulf crisis caused slight rises in polyethylene prices during the last 3 months of 1990.

The recent declines in low-density polyethylene prices can be attributed to drops in crude petroleum and ethylene feedstock prices. Prices have remained weak due to the sluggish U.S. economy and the large polyethylene and ethylene capacity buildup.[10] Total nameplate polyethylene capacity has increased by a reported 40 percent during the past 4 years.[11] Indicative of the weak market conditions during the last few years, capacity utilization rates have fallen (figures 10 and 11).

Consumer Characteristics and Factors Affecting Demand

The demand for polyethylene has been reported to be 98 to 99 percent correlated to gross national product (GNP).[12] Polyethylene demand is not as volatile as other materials during business cycles, because it is used in consumer product applications such as food wrap and milk bottles, which are affected little by economic change.

Increased environmental concerns by the public in recent years could have a significant impact on future demand for polyethylene. As recycling rates continue to escalate, more of the virgin market will be eroded.

[10] Savage, "Recession Forces U.S. PE Producers Into Tight Corner," p. 16.
[11] Bernie Miller, "New Film Resins Push Performance," *Plastics World*, vol. 50, No. 6 (May 1992), p. 47.
[12] Savage, "Recession Forces U.S. PE Producers Into Tight Corner," p. 17.

Environmental Considerations and Recycling

The plastics industry has been increasingly involved in recycling as communities, municipalities, industry, and citizens look for alternatives to disposing of wastes. Since 1970 approximately 75 percent of operating landfills in the United States have closed due to stricter environmental regulations and reductions in landfill capacity.[13] These closings have contributed to escalating landfill costs, which have prompted communities to look for alternative methods of disposal. Recycling has become the most popular alternative because other options, such as incineration, have adverse effects on the environment.

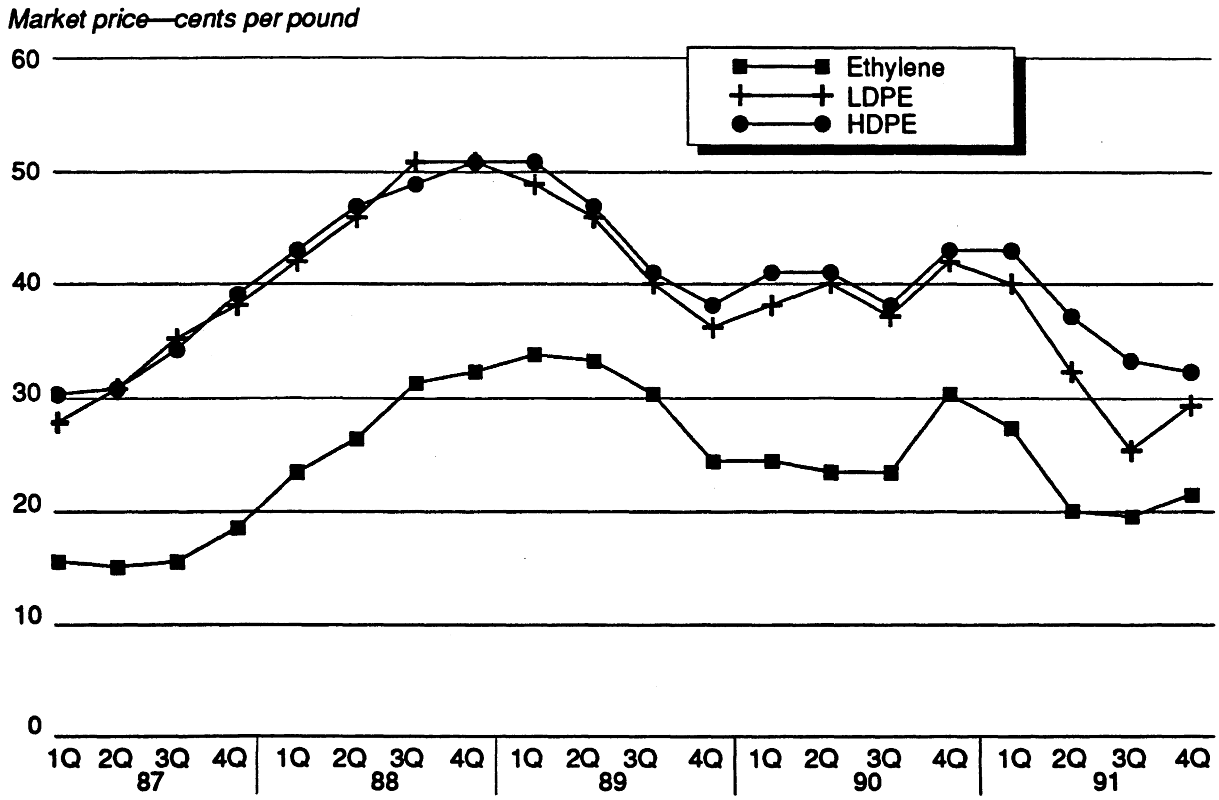
In 1988 plastics accounted for approximately 8 percent of the weight of all landfilled material but 20 percent of the volume.[14] Separate landfill statistics for polyethylene are not available, but polyethylene is believed to contribute a significant share of the total because it is the largest volume resin produced and is used mainly in nondurable goods.

Recycling of plastics has increased dramatically in the last 2 years. High-density polyethylene has the highest recycling rate among all the polyethylenes, with a reported rate of 4 percent.[15] The high-density recycling rate is expected to increase annually by 4 percent through 1995; by 2000, 12 percent of high-density polyethylene is predicted to be recycled.[16] Approximately 7.5 percent of the virgin high-density market could be displaced by recycled material by 2000. Recycling rates for the other polyethylene resins are not available.

Table 6 lists the polyethylene producers that have started or are expected to operate recycling plants. In addition to these producers there are a growing number of other recycling businesses in the United States. Plastics recycling is predicted to grow tremendously during the 1990s as communities face more solid waste issues.

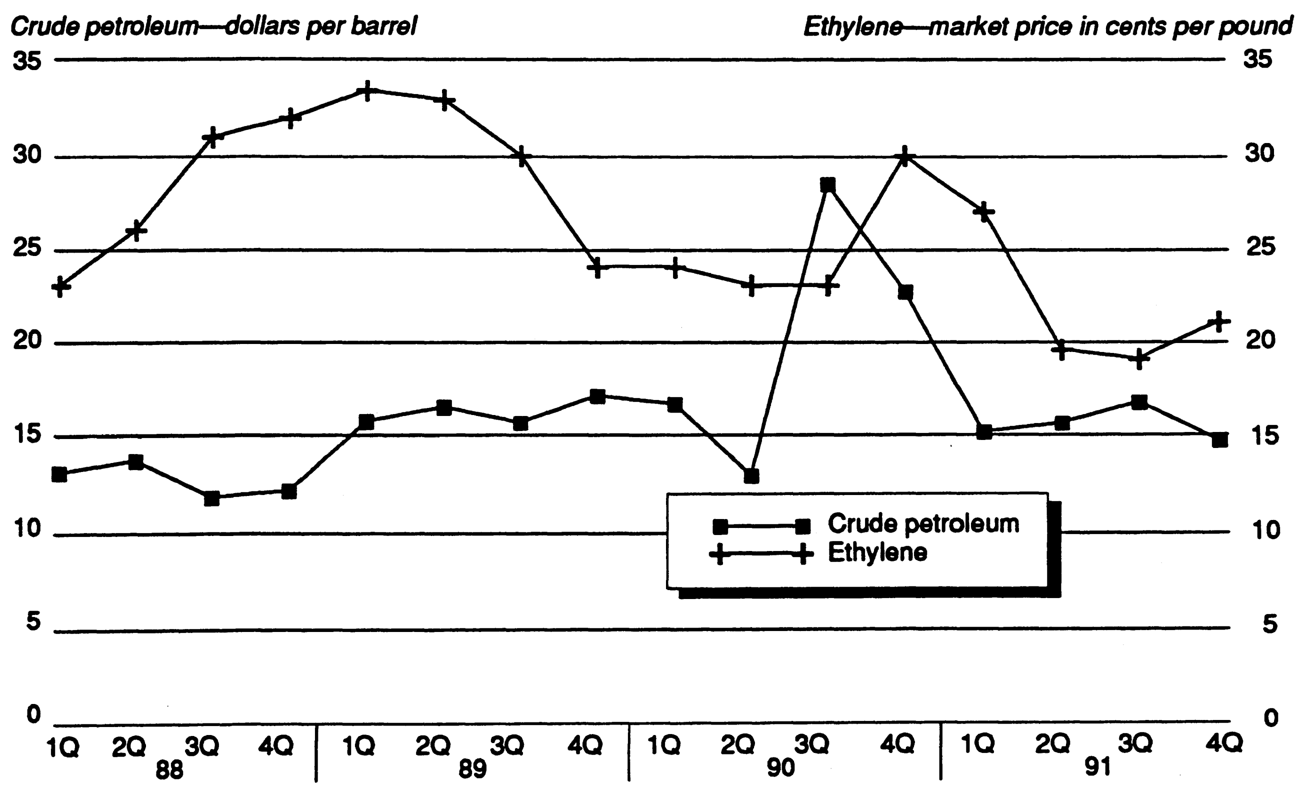
[13] R.J. Ehrig, *Plastics Recycling: Products and Processes*, (New York: Hanser, 1992), p. 3.
[14] Ibid.
[15] "Recycling '91," *Chemical Marketing Reporter Special Report*, Sept. 9, 1991, p. SR3.
[16] "Phillips Back on Track in Polyethylene Market," *Chemical Marketing Reporter*, Feb. 24, 1992.

Figure 8
U.S. ethylene and polyethylene prices, 1987-91



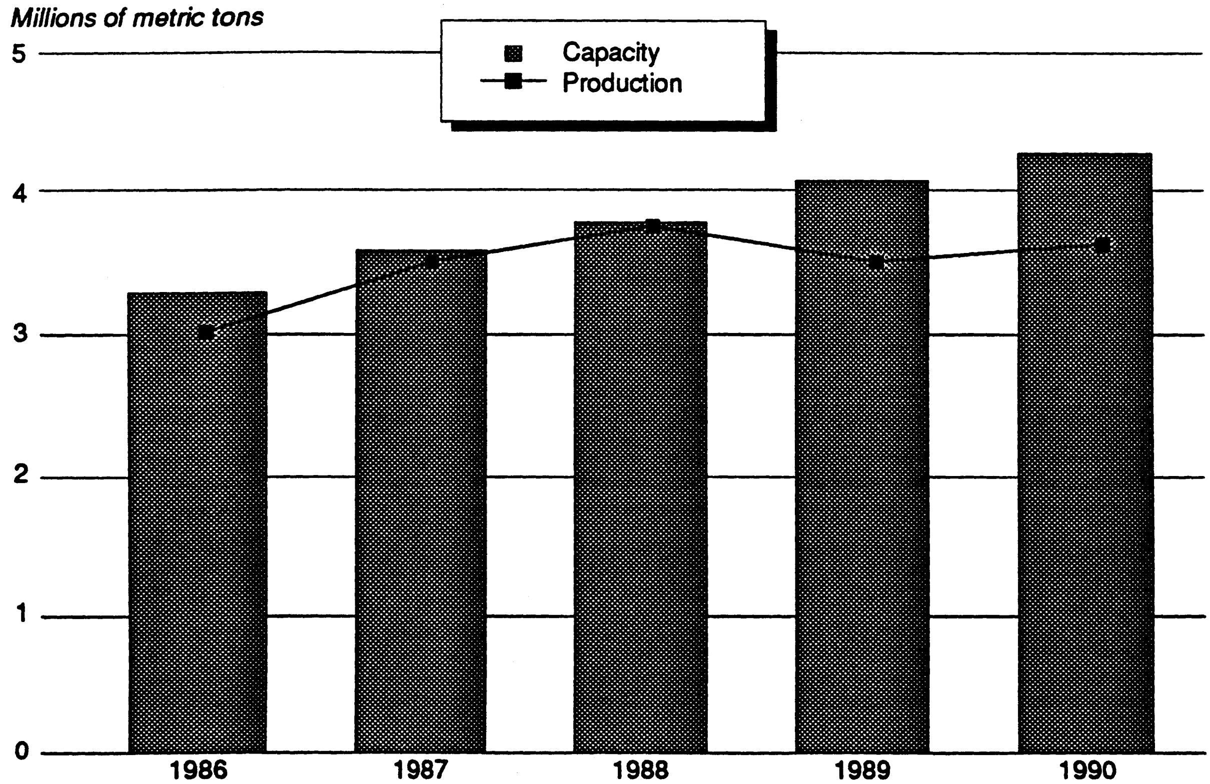
Source: *Modern Plastics.*

Figure 9
U.S. crude petroleum and ethylene prices, 1988-91



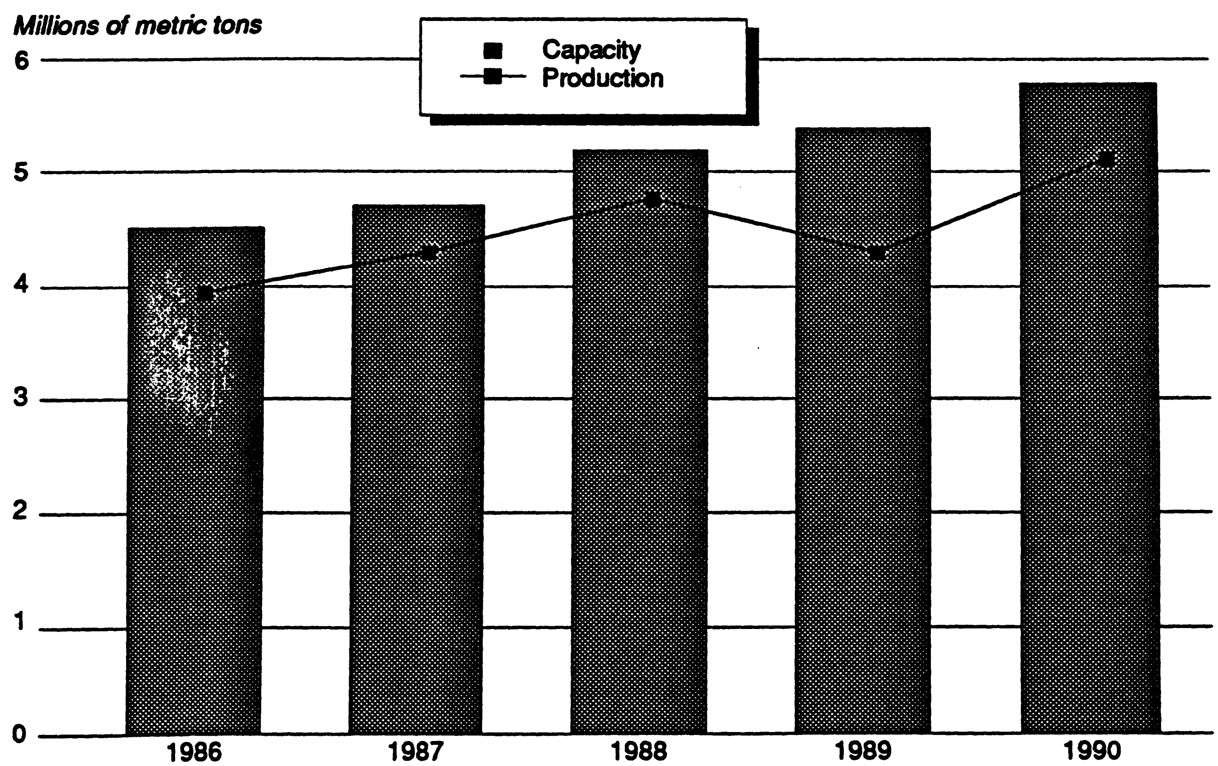
Source: Crude petroleum—*Energy Information Administration/Monthly Energy Review*; Ethylene—*Modern Plastics.*

Figure 10
High-density polyethylene: U.S. capacity and production, 1986-90



Source: *Facts & Figures of the U.S. Plastics Industry.*

Figure 11
Low and linear-low density polyethylene: U.S. capacity and production, 1986-90



Source: *Facts & Figures of the U.S. Plastics Industry.*

Table 6
U.S. polyethylene producers with recycling operations, 1991-93

Company	Location	Capacity	Startup date
		1,000 tons per year	
Exxon	Summerville, SC	9	1992
Hoechst Celanese	Spartanburg, SC	14	1992
Occidental	Dallas, TX	18	1993
Phillips	Tulsa, OK	8	1991
Quantum	Heath, OH	14.5	1991
Union Carbide	Piscataway, NJ	25	1991

Source: *Modern Plastics, Plastics Technology, Chemical Marketing Reporter,* and *Plastics World.*

FOREIGN INDUSTRY PROFILE

Overview

World polyethylene capacity was reported to be 45 million metric tons annually in 1990.[17] The United States is the single largest producing country, with nameplate capacity of 10.8 million metric tpy, followed by Western Europe with 9.7 million metric tpy, and Japan with 3.5 million metric tpy. Most industrialized countries of the world have polyethylene capacity. Table 7 shows reported capacity, production, consumption, imports, and exports for various countries for 1990.

The United States, Canada, and Japan are all net exporters of polyethylene. In 1990 the United States exported approximately 12 percent of production, whereas Canada exported 56 percent and Japan exported 12 percent. Most developing countries are net importers of polyethylene. East Asian countries such as Thailand, Malaysia, and Taiwan, have been large-volume importers of polyethylene. In 1989, polyethylene net imports in the Asia-Pacific region totaled 1.3 million metric tons.[18] These developing countries have historically relied on imports because their domestic chemical infrastructure is either nonexistent or incapable of meeting rising demand. However, large increases in polyethylene capacity are planned in the near future. China is scheduled to have 800,000 metric tons come on line by 1995; whereas Thailand is reported to increase capacity by 140,000 metric tons by 1993.[19] These Far East capacity expansions and the resultant increase in production are expected to decrease the net imports of polyethylene by 450,000 metric tons annually by 1995.[20]

Major world polyethylene producers include large multinational conglomerates, multinational petroleum exploration and recovery companies, multinational chemical companies, and state-owned enterprises. Table 8 lists major world producers, country affiliation, and state ownership status.

Western Europe

Almost every country of Western Europe has polyethylene production capabilities. Europe moved from being a net exporter of polyethylene in the late 1980s to being a net importer in the 1990s.[21] The polyethylene industry has experienced capacity increases in recent years, which is expected to continue during 1992. About 800,000 metric tpy are expected to come on stream in 1992.[22] Annual nameplate capacity was 9.7 million tpy in 1991.

European polyethylene prices were quite volatile during 1990 and 1991. Polyethylene prices were relatively high (2.3 Deutsche mark (DM)/kg) in late 1990 and early 1991 because of perceived higher feedstock prices resulting from the Persian Gulf War. After the war, feedstock prices declined, and polyethylene prices slowly decreased to 1.3 DM/kg in November 1991. Prices remained weak due to limited demand and high inventory levels.[23] Annual operating rates for 1991 reflected the market situation and decreased to 81.5 percent.[24] Producers' profits have decreased as a result.

In 1990 Western Europe produced 4.5 million metric tons of low-density polyethylene, 677,000 metric tons of linear low-density, and 2.8 million metric tons of high-density polyethylene.[25] Western Europe has been slow to follow the U.S. trend towards increased linear low-density production. Linear low-density accounts for approximately 41 percent of

[17] "World: Polyolefin Capacity Will Be Added in Traditional Importing Countries in the 1990s, Keeping Global Operating Rates at Under 90%," *Oil & Gas Journal*, Sept. 30, 1991, p. 38.

[18] Mary Heathcote, "Far East PE Ambitions Unsettle Trade Balance," *European Chemical News*, Feb. 10, 1992, p. 15.

[19] Helen Berg, Wang Guopei, and Ian Young, "China Keeps to Its Plan," *Chemical Week*, Feb. 12, 1992, p. 29.

[20] Heathcote, "Far East PE Ambitions Unsettle Trade Balance," p. 15.

[21] Ibid.

[22] Geraint Roberts, "PE Capacity Must Force Rethink Among Producers," *European Chemical News*, Feb. 17, 1992, p. 14.

[23] Martin Todd, "Grim Outlook for Polymers," *European Chemical News, European Review Supplement*, Dec. 1991, p. 17.

[24] Roberts, "PE Capacity Must Force Rethink," p. 14.

[25] "APME: W. European Plastics Production," *European Chemical News*, July 8, 1991, p. 9.

Table 7
Polyethylene: World capacity, production, consumption, imports, and exports by countries, 1990

(1,000 metric tons per year)

Country	Capacity	Production	Consumption	Imports	Exports
Austria	(1)	294	159	112	247
Brazil	970	870	720	80	230
Canada	1,554	1,510	788	118	840
China[2]	624	(1)	(1)	(1)	(1)
Germany, West	(1)	1,476	(1)	(1)	(1)
Iraq	90	(1)	(1)	(1)	(1)
Italy[3]	(1)	(1)	1,255	(1)	(1)
Japan	3,456	2,888	2,621	68	335
Korea, South	(1)	816	836	111	141
Mexico	(1)	524	(1)	(1)	(1)
Poland[4]	(1)	159	(1)	(1)	(1)
Quatar	150	(1)	(1)	(1)	(1)
Romania	434	(1)	(1)	(1)	(1)
Saudi Arabia	870	(1)	(1)	(1)	(1)
Spain	815	685	628	161	220
Soviet Union	1,735	1,210	1,160	(1)	(1)
Taiwan[3]	(1)	370	504	164	30
Thailand	280	(1)	355	(1)	(1)
United Kingdom	(1)	(1)	1,080	(1)	(1)
United States	10,780	9,071	8,673	719	1,117
Yugoslavia	(1)	234	188	23	69

[1] Not available.
[2] Estimate.
[3] 1989 data.
[4] 1988 data.

Source: Compiled from numerous trade publications by USITC staff.

Table 8
Major international producers of polyethylene resins in primary forms

Company	State ownership	Country
Atochem	No	France
Asahi	No	Japan
BP	No	United Kingdom
BASF	No	Germany
Dow	No	United States
DSM	No	Netherlands
EniChem	Yes	Italy
Exxon	No	United States
Hoechst	No	Germany
Huls	No	Germany
ICI	No	United Kingdom
Mitsubishi Petrochemical	No	Japan
Mitsui Petrochemical	No	Japan
Neste	Yes	Finland
Phillips	No	United States
Repsol Quimica	Yes	Spain
SABIC	Yes	Saudi Arabia
Solvay	No	Belgium
Sumitomo	No	Japan
Union Carbide	No	United States

Source: Compiled by USITC staff.

low-density polyethylene production in the United States, but in Europe the figure is much lower, around 15 percent. Linear low-density polyethylene's market share is predicted to increase in Europe during the upcoming years as new plants are constructed to produce this resin. Dow and a Shell-BASF joint venture are reported to bring about 200,000 tons of linear low-density capacity on stream in 1992.[26]

[26] Roberts, "PE Capacity Must Force Rethink ," p. 14.

U.S. TRADE MEASURES

Table 9 shows the rates of duty as of January 1, 1992, for imports of polyethylene resins in primary forms under the Harmonized Tariff Schedule (HTS). The table shows the column-1 rates of duty for countries that have most-favored-nation (MFN) status, as well as rates of duty for countries qualifying for special tariff programs. The 1992 column-1 U.S. general rate of duty for the majority of the products covered in this summary is 12.5 percent ad valorem. However, duty rates range from free for elastomeric materials to 12.5 percent for low, medium, and high-density polyethylene resins.[27]

Table 10 lists the amount of imports that entered the United States under the Generalized System of Preferences (GSP) provisions, U.S.-Israel Free-Trade Agreement, and the U.S.-Canada Free-Trade Agreement for polyethylene resins in primary forms.

There are no known domestic nontariff import restrictions. No statutory investigations involving these products have been instituted during the past 5 years.

FOREIGN TRADE MEASURES

The duty rates for polyethylene resins in primary forms vary considerably for the various countries throughout the world. The tabulation below lists the corresponding duty rates for U.S. trading partners (in percent):[28]

Nation	*Average rate of duty on polyethylene resins in primary forms*	
Canada	10.2	(MFN)
	2	(U.S. 1992 rate, 5-year duty elimination)
Colombia	5-10	
China	35-45	
European Communities	12.5	
Korea, South	11	
Mexico	Free to 15	

There are no known nontariff barriers that affect U.S. exports of polyethylene resins in primary forms.

U.S. MARKET

Consumption

U.S. consumption of polyethylene resins in primary forms is shown in table 11. The United States has the highest per capita consumption of polyethylene in the world. In 1990, per capita consumption was 34.0 kg in the United States, 23.8 kg in Western Europe, 4.5 kg in the former Soviet Union, and 5.7 kg for the rest of the world.[29]

U.S. consumption of polyethylene is almost totally accounted for by U.S. production. The only imports of significance are from Canada and are believed to be intracompany transfers to U.S. parents. Dow, Union Carbide, and DuPont account for the majority of Canadian polyethylene production capacity. In 1991, imports accounted for 6.4 percent of consumption.

Production

U.S. production of polyethylene resins in primary forms during 1986-90 is depicted in table 12. In 1990, U.S. production reached an all-time high of 9.1 billion kg, 19 percent higher than in 1989. Linear low-density polyethylene resins, the newest of the large-volume polyethylenes, continue to grow rapidly in the polyethylene family of resins. This trend is predicted to continue because of linear low's superior properties—high strength and elongation in relation to volume.

Imports

Although accounting for only a small percent of consumption, U.S. imports of polyethylene resins in primary forms have increased in each of the previous 5 years with the exception of 1991. Imports remain small compared with exports. Table 13 shows the principal sources of U.S. imports. The majority of U.S. imports came from Canada and, as stated above, are believed to be transferred by U.S. subsidiaries to the parent company in the United States. Imports from Korea and Singapore have increased from a base of zero in 1987 to a value of 33 and 25 million dollars, respectively, in 1991.

FOREIGN MARKETS

Foreign Market Profile

Traditionally the United States has exported its excess production to developing countries that do not have enough domestic production to meet demand. This trade flow is expected to change within the decade as these countries develop their own production facilities. Multinational plastics producing companies and state-owned enterprises are planning production facilities in developing countries. Most of these operations are joint ventures. Some countries have restrictions against foreign investment.

U.S. Exports

During 1987-91 U.S. exports of polyethylene resins in primary forms increased by 82 percent, as shown in table 14. The United States has exported an average of 14 percent of production during the last 5 years. The largest increase in exports has been to Canada, Belgium, and China. Exports to those three countries increased from $250 million in 1989 to $392 million in 1991. Typical export markets for U.S. polyethylene are developing countries in East Asia and South America.

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[27] See appendix B for explanation of tariff and trade agreement terms.

[28] Information obtained from country tariff schedules and U.S. Department of Commerce.

[29] "Eastern Europe Has Potential, but Growth Overstated," *European Chemical News*, July 22, 1991, p. 14.

Table 9
Polyethylene resins in primary forms: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jan. 1, 1992; U.S. exports, 1991; and U.S. imports, 1991

HTS subheading	Description	Col. 1 rate of duty as of Jan. 1, 1992: General	Col. 1 rate of duty as of Jan. 1, 1992: Special[1]	U.S. exports, 1991	U.S. imports, 1991
				— Million dollars —	
3901.10.00	Polyethylene having a specific gravity of less than 0.94:				
3901.10.0010	Linear low-density polyethylene	12.5%	Free (A,E,IL,J) 2.5% (CA)	244	176
3901.10.0020	Low-density polyethylene, except linear low density polyethylene.	12.5%	Free (A,E,IL,J) 2.5% (CA)	368	53
3901.10.0030	Medium-density polyethylene	12.5%	Free (A,E,IL,J) 2.5% (CA)	74	2
3901.20.00	Polyethylene having a specific gravity of 0.94 or more	12.5%	Free (A,E,IL,J) 2.5% (CA)	513	163
3901.30.00	Ethylene-vinyl acetate copolymers	5.3%	Free (A,E,IL,J) 1% (CA)	114	31
3901.90	Other:				
3901.90.10	Elastomeric	Free		10	14
3901.90.50	Other	2.2¢/kg + 7.7%	Free (A,E,IL,J) 0.4¢/kg + 1.5% (CA)	9	138

[1] Programs under which special tariff treatment may be provided, and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn, are as follows: Generalized System of Preferences (A); Automotive Products Trade Act (B); Agreement on Trade in Civil Aircraft (C); United States-Canada Free-Trade Agreement (CA); Caribbean Basin Economic Recovery Act (E); United States-Israel Free Trade Area (IL); and Andean Trade Preference Act (J).

Source: U.S. exports and imports compiled from official statistics of the U.S. Department of Commerce.

Table 10
Special tariffs for imports of polyethylene resins in primary forms, 1987-91

(1,000 dollars)

Type	1987	1988	1989	1990	1991
Duty free under GSP	([1])	([1])	17,520	20,467	2,399
Duty free under Israel Free-Trade Area	([1])	([1])	1,572	137	67
Special tariffs under U.S.-Canada Free-Trade Agreement[2]	([1])	([1])	318,152	367,187	345,434

[1] Country detail provided only for years in which there are actual import data under the HTS—suppressed for years in which data were derived from TSUS using a concordance.

[2] In 1989 polyethylene subject to 10% duty rate; ethylene-vinyl acetate, 4.2%; other ethylene in primary form (HTS 3901.90.5000), 1.7¢/kg+6.1%; all others, free. In 1990 polyethylene subject to 7.5% duty rate; ethylene-vinyl acetate, 3.1%; other ethylene in primary form (HTS 3901.90.5000), 1.3¢/kg+4.6%; all others, free. In 1991 polyethylene subject to 5% duty rate; ethylene-vinyl acetate, 2.1%; other ethylene in primary form (HTS 3901.90.5000), 0.8¢/kg+3%; all others, free.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 11
Polyethylene resins in primary forms: U.S. producers' shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1987-91

Year	Production	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	Million dollars				*Percent*
1987	6,180	803	220	5,597	3.9
1988	9,421	1,083	380	8,718	4.4
1989	8,201	1,140	408	7,469	5.5
1990	8,588	1,106	528	8,010	6.6
1991	[1]7,990	1,460	448	6,978	6.4

[1] Estimated by USITC staff; based on USITC, "Preliminary Report on U.S. Production of Selected Synthetic Organic Chemicals," Series C/P-91-5, Feb. 22, 1992.

Source: Production data obtained from U.S. International Trade Commission, *Synthetic Organic Chemicals, U.S. Production and Sales, 1987-1990.* Import and export data obtained from official statistics of the U.S. Department of Commerce.

Table 12
Polyethylene resins in primary forms: U.S. production by major categories, 1986-90

(Million kilograms (dry basis[1]))

Description	1986	1987	1988	1989	1990
Low-density polyethylene (LDPE) resins	([2])	([2])	3,718	3,029	3,281
Linear low-density polyethylene (LLDPE) resins[3]	([2])	([2])	717	1,092	1,394
Total, specific gravity 0.940 and below	4,026	4,295	4,436	4,121	4,675
Specific gravity over 0.940	3,224	3,586	4,044	3,198	4,116
Ethylene-vinyl acetate and other copolymer resins	186	238	301	294	280
Total, polyethylene resins	7,435	8,119	8,780	7,613	9,071

[1] Dry weight basis is the total weight of the materials including resin and coloring agents, extenders, fillers, plasticizers, and other additives, but excluding water and other liquid diluents unless they are an integral part of the materials.

[2] Data for LDPE and LLDPE were aggregated for 1986 and 1987.

[3] Data shown for LLDPE resins are incomplete because several of the leading producers of LLDPE still continue to aggregate these data with that of LDPE.

Note.—Because of rounding, figures may not add to the totals shown.

Source: U.S. International Trade Commission, *Synthetic Organic Chemicals, U.S. Production and Sales, 1986-90.*

Table 13
Polyethylene resins in primary forms: U.S. imports for consumption, by principal sources, 1987-91

Source	1987	1988	1989	1990	1991
			Quantity *(1,000 kilograms)*		
Canada	([1])	([1])	512,283	556,870	555,539
South Korea	([1])	([1])	5,230	63,663	38,114
Singapore	([1])	([1])	1,006	47,092	25,639
Japan	([1])	([1])	11,252	6,242	4,622
Italy	([1])	([1])	1,144	4,072	5,972
West Germany	([1])	([1])	1,652	2,346	3,241
Belgium	([1])	([1])	2,597	3,305	2,152
France	([1])	([1])	3,638	2,934	2,005
United Kingdom	([1])	([1])	647	2,088	565
Israel	([1])	([1])	1,579	1,002	453
All other	([1])	([1])	24,042	29,850	1,537
Total	377,599	420,127	565,070	719,464	639,837
			Value *(1,000 dollars)*		
Canada	([1])	([1])	338,802	370,465	347,779
South Korea	([1])	([1])	3,734	48,711	33,101
Singapore	([1])	([1])	703	40,212	24,623
Japan	([1])	([1])	24,406	14,752	11,500
Italy	([1])	([1])	1,924	6,258	9,934
West Germany	([1])	([1])	3,100	4,549	6,911
Belgium	([1])	([1])	4,805	6,776	4,903
France	([1])	([1])	4,291	3,624	3,044
United Kingdom	([1])	([1])	1,885	5,390	2,304
Israel	([1])	([1])	3,234	3,318	1,340
All other	([1])	([1])	20,628	23,668	2,365
Total	219,885	380,447	407,512	527,723	447,804
			Unit value *(per kilogram)*		
Canada	([1])	([1])	0.66	0.67	0.63
South Korea	([1])	([1])	0.71	0.77	0.87
Singapore	([1])	([1])	0.70	0.85	0.96
Japan	([1])	([1])	2.17	2.36	2.49
Italy	([1])	([1])	1.68	1.54	1.66
West Germany	([1])	([1])	1.88	1.94	2.13
Belgium	([1])	([1])	1.85	2.05	2.28
France	([1])	([1])	1.18	1.24	1.52
United Kingdom	([1])	([1])	2.91	2.58	4.08
Israel	([1])	([1])	2.05	3.31	2.96
All other	([1])	([1])	0.86	0.79	1.54
Average	0.58	0.91	0.72	0.73	0.70

[1] Country detail provided only for years in which there are actual import data under the HTS—suppressed for years in which data were derived from the TSUS using a concordance.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 14
Polyethylene resins in primary forms: U.S. exports of domestic merchandise, by principal markets, 1987-91

Market	1987	1988	1989	1990	1991
			Quantity *(1,000 kilograms)*		
Mexico	([1])	([1])	165,774	149,049	150,753
Canada	([1])	([1])	109,598	122,914	134,614
Belgium	([1])	([1])	78,184	89,573	127,000
China	([1])	([1])	61,532	59,963	130,035
Taiwan	([1])	([1])	45,716	39,319	103,264
Hong Kong	([1])	([1])	51,461	25,392	84,491
Colombia	([1])	([1])	22,295	22,584	53,947
South Korea	([1])	([1])	53,573	32,483	32,045
Indonesia	([1])	([1])	24,859	21,248	52,980
Ecuador	([1])	([1])	19,654	26,928	52,049
All other	([1])	([1])	507,522	527,826	685,360
Total	910,374	865,954	1,140,170	1,117,278	1,606,538
			Value *(1,000 dollars)*		
Mexico	([1])	([1])	172,470	149,588	156,438
Canada	([1])	([1])	102,858	143,037	149,474
Belgium	([1])	([1])	95,438	97,666	148,191
China	([1])	([1])	51,772	47,455	93,836
Taiwan	([1])	([1])	48,082	40,615	87,219
Hong Kong	([1])	([1])	36,632	20,236	55,698
Colombia	([1])	([1])	23,928	22,515	46,942
South Korea	([1])	([1])	44,998	38,535	40,506
Indonesia	([1])	([1])	19,125	16,954	36,687
Ecuador	([1])	([1])	19,402	20,301	34,029
All other	([1])	([1])	525,201	509,052	611,056
Total	802,906	1,082,602	1,139,906	1,105,954	1,460,076
			Unit value *(per kilogram)*		
Mexico	([1])	([1])	1.04	1.00	1.04
Canada	([1])	([1])	0.94	1.16	1.11
Belgium	([1])	([1])	1.22	1.09	1.17
China	([1])	([1])	0.84	0.79	0.72
Taiwan	([1])	([1])	1.05	1.03	0.84
Hong Kong	([1])	([1])	0.71	0.80	0.66
Colombia	([1])	([1])	1.07	1.00	0.87
South Korea	([1])	([1])	0.84	1.19	1.26
Indonesia	([1])	([1])	0.77	0.80	0.69
Ecuador	([1])	([1])	0.99	0.75	0.65
All other	([1])	([1])	1.03	0.96	0.89
Average	0.88	1.25	1.00	0.99	0.91

[1] Country detail provided only for years in which there are actual export data under the HTS—suppressed for years in which data were derived from the TSUS using a concordance.

Source: Compiled from official statistics of the U.S. Department of Commerce.

U.S. TRADE BALANCE

The United States has traditionally had a substantial trade surplus for polyethylene resins in primary forms. Table 15 depicts the balance of trade for polyethylene in the top 10 countries. The United States has a trade deficit with Canada and Singapore and a trade surplus with all other countries. Figure 12 shows the trends in imports and exports over the 5-year period. The difference between exports and imports has widened since 1990; the declining U.S. dollar has probably contributed to this trend.

Table 15
Polyethylene resins in primary forms: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1987-91[1]

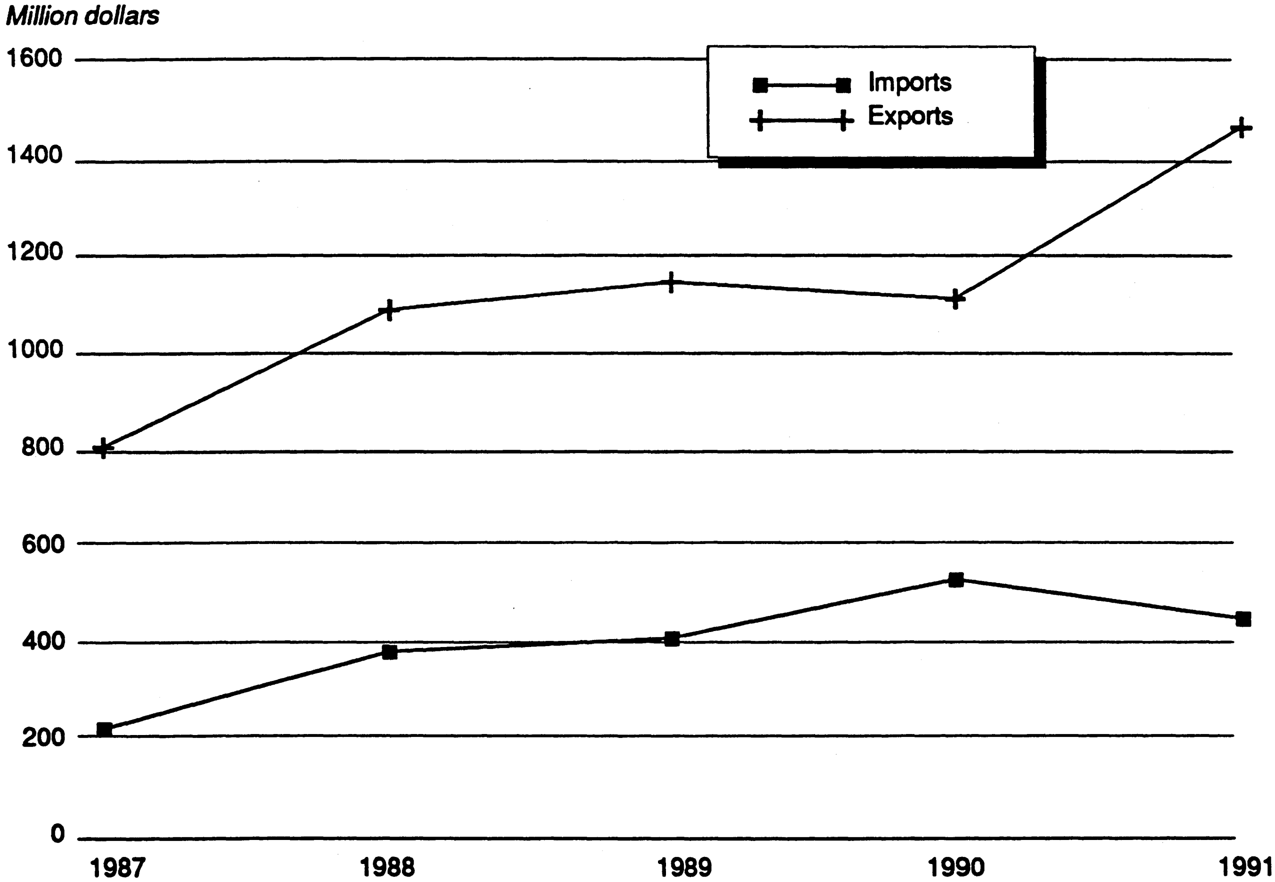
(Million dollars)

Item	1987	1988	1989	1990	1991
U.S. exports of domestic merchandise:					
Canada	71	94	103	143	149
Mexico	75	131	172	150	156
Belgium	32	41	95	98	148
China	62	144	52	47	94
Taiwan	48	40	48	41	87
Korea	56	59	45	39	41
Hong Kong	56	87	37	20	56
Singapore	9	16	27	16	23
Colombia	26	33	24	23	47
Indonesia	21	14	19	17	37
All other	348	422	518	514	622
Total	803	1,083	1,140	1,106	1,460
EC-12	88	100	204	209	246
OPEC	75	92	102	76	143
ASEAN	50	53	77	62	100
CBERA	75	119	105	113	111
Eastern Europe	1	1	2	1	1
U.S. imports for consumption:					
Canada	188	329	339	370	348
Mexico	2	3	0	1	1
Belgium	4	10	5	7	5
China	0	0	0	0	0
Taiwan	0	0	0	0	0
Korea	0	0	4	49	33
Hong Kong	0	0	0	0	0
Singapore	0	0	1	40	25
Colombia	0	0	0	0	0
Indonesia	0	0	0	0	0
All other	25	39	59	60	36
Total	220	380	408	528	448
EC-12	13	22	17	27	27
OPEC	0	0	3	5	0
ASEAN	0	0	1	41	25
CBERA	0	0	0	0	0
Eastern Europe	0	0	0	4	0
U.S. merchandise trade balance:					
Canada	-117	-235	-236	-227	-199
Mexico	73	128	172	149	155
Belgium	28	31	90	91	143
China	62	144	52	47	94
Taiwan	48	40	48	41	87
Korea	56	59	41	-10	8
Hong Kong	56	87	37	20	56
Singapore	9	16	26	-24	-2
Colombia	26	33	24	23	47
Indonesia	21	14	19	17	37
All other	323	383	459	454	586
Total	583	703	732	578	1,012
EC-12	75	78	187	182	219
OPEC	75	92	99	71	143
ASEAN	50	53	76	21	75
CBERA	75	119	105	113	111
Eastern Europe	1	1	2	1	1

[1] Import values are based on customs value; export values are based on f.a.s. value, U.S. port of export. U.S. trade with East Germany is included in "Germany" but not "Eastern Europe."

Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 12
U.S. trade balance: Polyethylene resins in primary forms, 1987-91



Source: Compiled from official statistics of the U.S. Department of Commerce.

APPENDIX A
GLOSSARY OF INDUSTRY TERMS

GLOSSARY OF TERMS

α–Olefins — A subgroup of the Olefin group of unsaturated hydrocarbons of the general formula C_nH_{2n} in which the number of carbon atoms ranges from 5 to 20.

Blow Molding — The process of forming hollow articles by expanding a hot plastic element against the internal surfaces of a mold.

Catalyst — A substance that causes or accelerates a chemical reaction when added to the reactant in minor amount, without being permanently affected by the reaction.

Chain Transfer Agent — An agent capable of stopping the growth of a molecular chain by yielding an atom to the active radical at the end of the growing chain, but also in turn being left as a radical that can initiate the growth of a new chain.

Cold Forming — A group of processes by which sheets or billets of thermoplastic materials are formed into three-dimensional shapes at room temperature by processes used in the metalworking industry such as forging, brake press bending, deep drawing, stamping, heading, and coining.

Colorant — Dyes or pigments that import color to plastics.

Copolymer — This term usually denotes a polymer of two chemically distinct monomers.

Density — Mass per-unit volume of a substance, usually expressed in grams per cubic centimeter.

Dielectric — A material with electrical conductivity less than one millionth of a reciprocal ohm per centimeter, thus so weakly conductive that different parts of its surface can have a different electrical charge.

Environmental Stress Cracking — The formation of external or internal cracks in a plastic caused by tensile stresses less than that of its short-time mechanical strength, when such strength has been reduced by aging or exposure to some environmental condition.

Ethylene — A colorless, flammable gas derived by cracking of petroleum and natural gas.

Ethylene-Vinyl Acetate — Copolymers of major amounts of ethylene with minor amounts of vinyl acetate, that retain many of the properties of polyethylene but have considerably increased flexibility, elongation and impact resistance.

Extender — A substance added to the mixture to reduce its cost.

Extrusion — The process of forming continuous shapes by forcing a molten plastic material through a die.

Filler — A relatively inert substance added to a plastic compound to reduce its cost and/or to improve physical properties, particularly hardness, stiffness, and impact strength.

Film — Film is distinguished from sheet in the plastic and packaging industries only according to thickness. A web under 10 mils thick is usually called a film.

Flame Retardant — Materials that reduce the tendency of plastics to burn.

High Molecular Weight-High-Density — These polymers are linear copolymer or homopolymer resins with average molecular weights between 200,000 and 500,000.

Homopolymer — The polymer resulting from the polymerization of a single monomer: a polymer consisting substantially of a single type of repeating unit.

Impact Strength	The ability of a material to withstand shock loading.
Initiator	An agent that causes a chemical reaction to start and becomes a part of the resultant compound.
Injection Molding	The method of forming objects from granular or powdered plastics, most often of the thermoplastic type, in which the material is fed from a hopper to a heated chamber in which it is softened, after which a ram or screw forces the material into a mold.
Intrinsic Viscosity	In dilute solution viscosity measurements, intrinsic viscosity is the limit of the reduced and inherent viscosities as the concentration of the polymeric solute approaches zero and represents the capacity of the polymer to increase viscosity.
Linear Polymer	A polymer in which the molecules form long chains without branches or crosslinked structures.
Melt Index	The amount, in grams, of a thermoplastic resin that can be forced through an orifice of 0.0825 inch diameter when subjected to a force of 2160 grams in 10 minutes at 190 °C. The test is performed by an extrusion rheometer described in ASTM D 1238.
Molecular Weight	The sum of the atomic weights of all atoms in a molecule.
Monomer	A relatively simple compound, usually containing carbon and of low molecular weight, that can react to form a polymer by combination with itself or with other similar molecules or compounds.
Plasticizer	A substance or material incorporated in a material (usually a plastic or an elastomer) to increase its flexibility, workability, or distensibility.
Polyethylene	A family of resins obtained by polymerizing ethylene gas. Those polymers with densities greater than 0.94 (g/cc) are considered high-density, whereas those with densities 0.94 and below are low-density.
Polymer	The product of a polymerization reaction.
Polymerization	A chemical reaction in which the molecules of a simple substance (monomer) are linked together to form large molecules whose molecular weight is a multiple of that of the monomer.
Resins	The term resin is defined by ASTM (D 883-75a) as a solid or pseudosolid material, often of high molecular weight, that exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. A note added to this ASTM definition explains that in a broad sense, the term is used to designate any polymer that is a basic material for plastics.
Sheet	Sheet is distinguished from film in the plastic and packaging industry only according to thickness. A web over 10 mils is usually called a sheet.
Shore D Hardness	The hardness of a material as determined by either the size of an indentation made by an indenting tool under a fixed load, or the load necessary to produce penetration of the indenter to a predetermined depth.
Tensile Strength	The maximum tensile stress sustained by the specimen during a tension test. The result is usually expressed in pounds per square inch, the area being that of the original specimen at the point of rupture rather than the reduced area after break.
Thermoforming	The process of forming a thermoplastic sheet into a three-dimensional shape by clamping the sheet in a frame, heating it to render it soft and flowable, then applying differential pressure to make the sheet conform to the shape of a mold or die positioned below the frame.

Ultrahigh-Molecular-Weight Polyethylene	Those polyethylenes having molecular weights in the 1.5 to 3.0 million range.
Very Low-Density Polyethylene	Polyethylenes that are linear ethylene copolymers with densities below 0.915 g/cc.

Source: *Whittington's Dictionary of Plastics* and *Modern Plastics Encyclopedia.*

APPENDIX B
EXPLANATION OF TARIFF AND TRADE AGREEMENT TERMS

TARIFF AND TRADE AGREEMENT TERMS

The ***Harmonized Tariff Schedule of the United States*** (HTS) replaced the *Tariff Schedules of the United States* (TSUS) effective January 1, 1989. Chapters 1 through 97 are based on the internationally adopted Harmonized Commodity Description and Coding System through the 6-digit level of product description, with additional U.S. product subdivisions at the 8-digit level. Chapters 98 and 99 contain special U.S. classification provisions and temporary rate provisions, respectively.

Rates of duty in the ***general*** subcolumn of HTS column 1 are most-favored-nation (MFN) rates; for the most part, they represent the final concession rate from the Tokyo Round of Multilateral Trade Negotiations. Column 1-general duty rates are applicable to imported goods from all countries except those enumerated in general note 3(b) to the HTS, whose products are dutied at the rates set forth in ***column 2***. Goods from the People's Republic of China, Czechoslovakia, Hungary, Poland, and Yugoslavia are among those eligible for MFN treatment. Among articles dutiable at column 1-general rates, particular products of enumerated countries may be eligible for reduced rates of duty or for duty-free entry under one or more preferential tariff programs. Such tariff treatment is set forth in the ***special*** subcolumn of HTS column 1.

The ***Generalized System of Preferences*** (GSP) affords nonreciprocal tariff preferences to developing countries to aid their economic development and to diversify and expand their production and exports. The U.S. GSP, enacted in title V of the Trade Act of 1974 and renewed in the Trade and Tariff Act of 1984, applies to merchandise imported on or after January 1, 1976, and before July 4, 1993. Indicated by the symbol "A" or "A*" in the special subcolumn of column 1, the GSP provides duty-free entry to eligible articles the product of and imported directly from designated-beneficiary developing countries, as set forth in general note 3(c)(ii) to the HTS.

The ***Caribbean Basin Economic Recovery Act*** (CBERA) affords nonreciprocal tariff preferences to developing countries in the Caribbean Basin area to aid their economic development and to diversify and expand their production and exports. The CBERA, enacted in title II of Public Law 98-67, implemented by Presidential Proclamation 5133 of November 30, 1983, and amended by the Customs and Trade Act of 1990, applies to merchandise entered, or withdrawn from warehouse for consumption, on or after January 1, 1984; this tariff preference program has no expiration date. Indicated by the symbol "E" or "E*" in the special subcolumn of column 1, the CBERA provides duty-free entry to eligible articles the product of and imported directly from designated countries, as set forth in general note 3(c)(v) to the HTS.

Preferential rates of duty in the special subcolumn of column 1 followed by the symbol "IL" are applicable to products of Israel under the ***United States-Israel Free-Trade Area Implementation Actof 1985***, as provided in general note 3(c)(vi) of the HTS. When no rate of duty is provided for products of Israel in the special subcolumn for a particular provision, the rate of duty in the general subcolumn of column 1 applies.

Preferential rates of duty in the special duty rates subcolumn of column 1 followed by the symbol "CA" are applicable to eligible goods originating in the territory of Canada under the ***United States-Canada Free-Trade Agreement***, as provided in general note 3(c)(vii) to the HTS.

Other special tariff treatment applies to particular ***products of insular possessions*** (general note 3(a)(iv)), goods covered by the ***Automotive Products Trade Act*** (general note 3(c)(iii)) and the ***Agreement on Trade in Civil Aircraft*** (general note 3(c)(iv)), and ***articles imported from freely associated states*** (general note 3(c)(viii)).

The ***General Agreement on Tariffs and Trade*** (GATT) (61 Stat. (pt. 5) A58; 8 UST (pt. 2) 1786) is the multilateral agreement setting forth basic principles governing international trade among its more than 90 signatories. The GATT's main obligations relate to most-favored-nation treatment, the maintenance of scheduled concession rates of duty, and national (nondiscriminatory) treatment for imported products. The GATT also provides the legal framework for customs valuation standards, "escape clause" (emergency) actions, antidumping and countervailing duties, and other measures. Results of GATT-sponsored multilateral tariff negotiations are set forth by way of separate schedules of concessions for each participating contracting party, with the U.S. schedule designated as schedule XX.

Officially known as "The Arrangement Regarding International Trade in Textiles," the ***Multifiber Arrangement*** (MFA) provides a framework for the negotiation of bilateral agreements between importing and producing countries, or for unilateral action by importing countries in the absence of an agreement. These bilateral agreements establish quantitative limits on imports of textiles and apparel, of cotton and other vegetable fibers, wool, manmade fibers, and silk blends, in order to prevent market disruption in the importing countries—restrictions that would otherwise be a departure from GATT provisions. The United States has bilateral agreements with more than 30 supplying countries, including the four largest suppliers: China, Hong Kong, the Republic of Korea, and Taiwan.