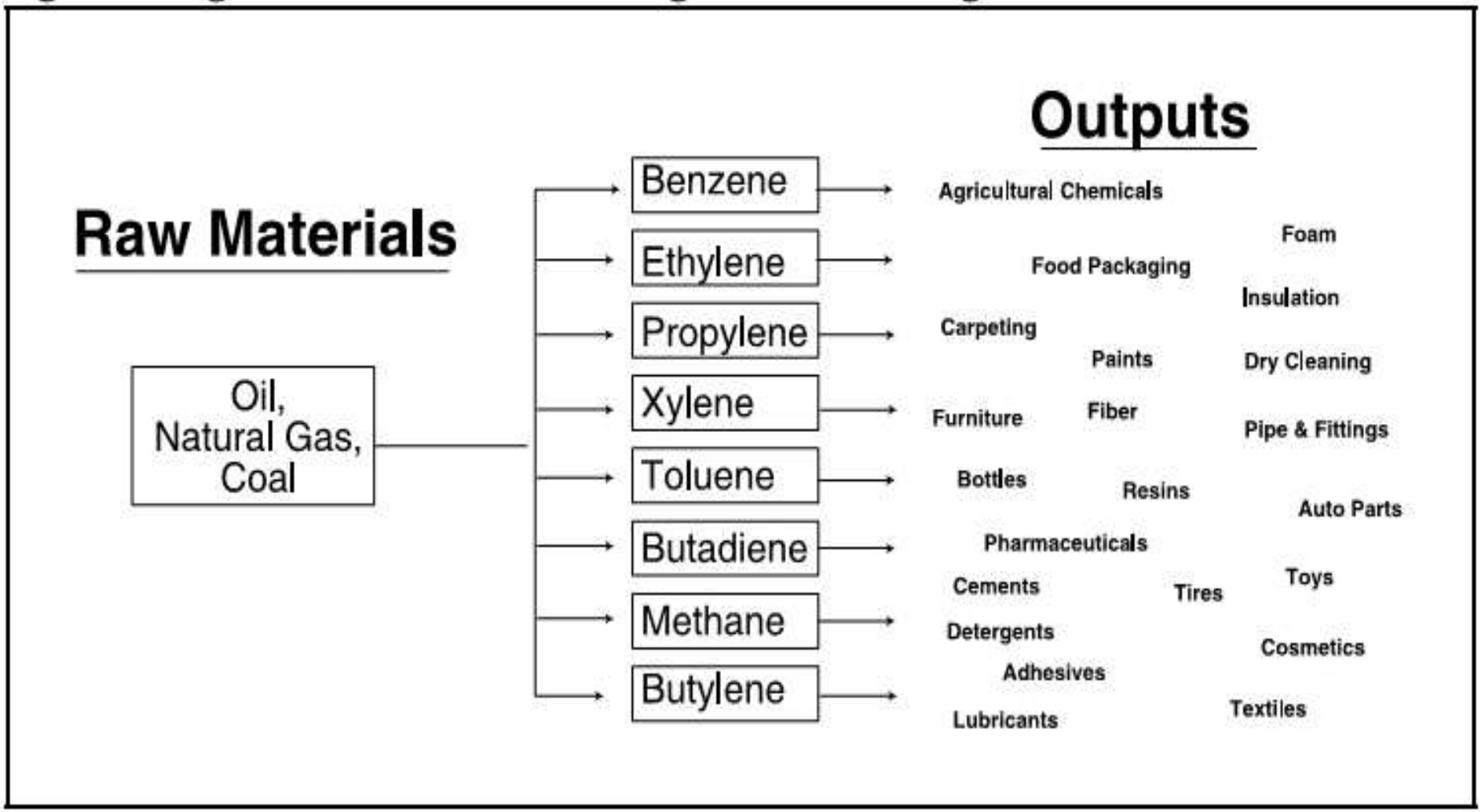
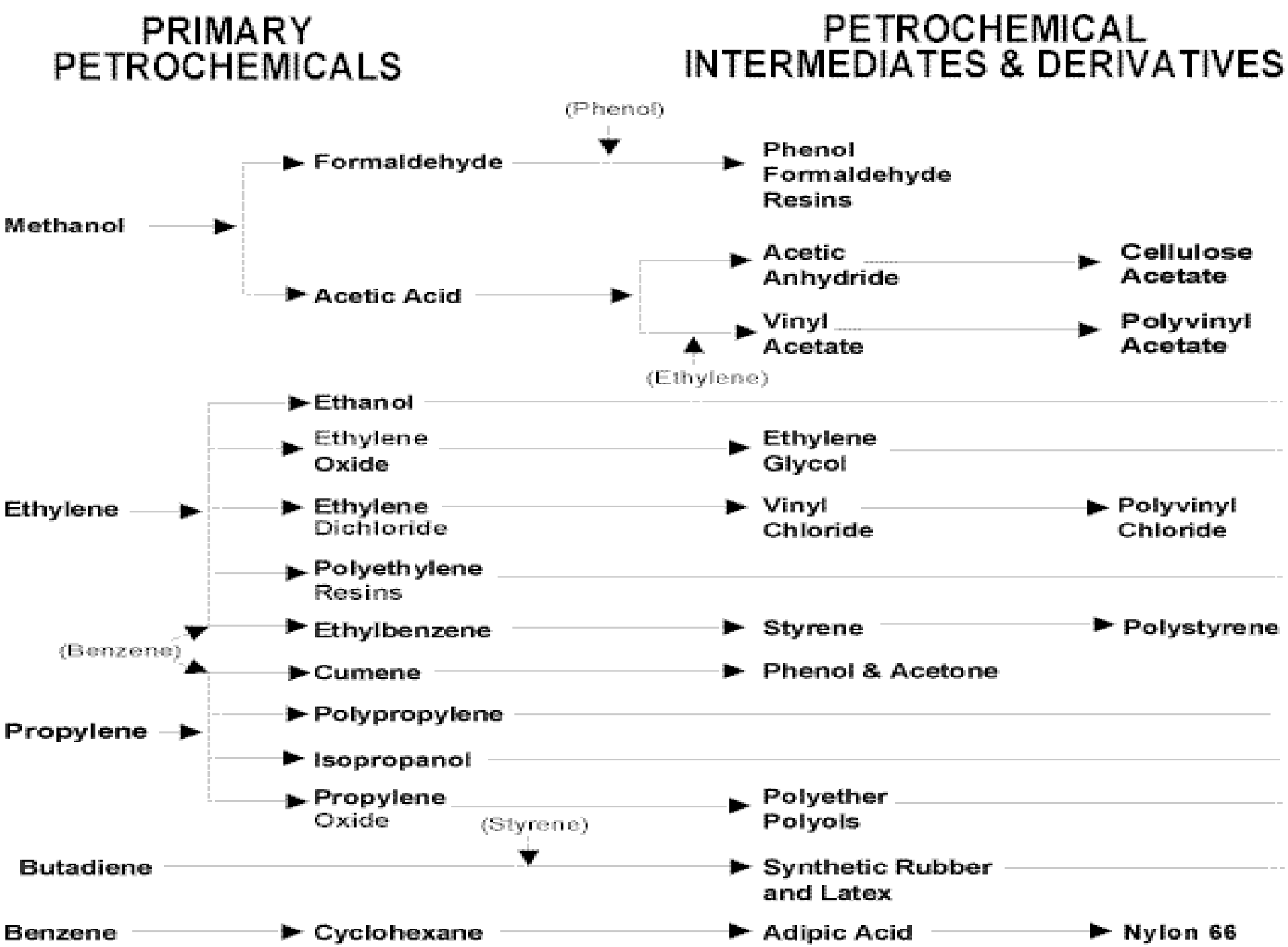
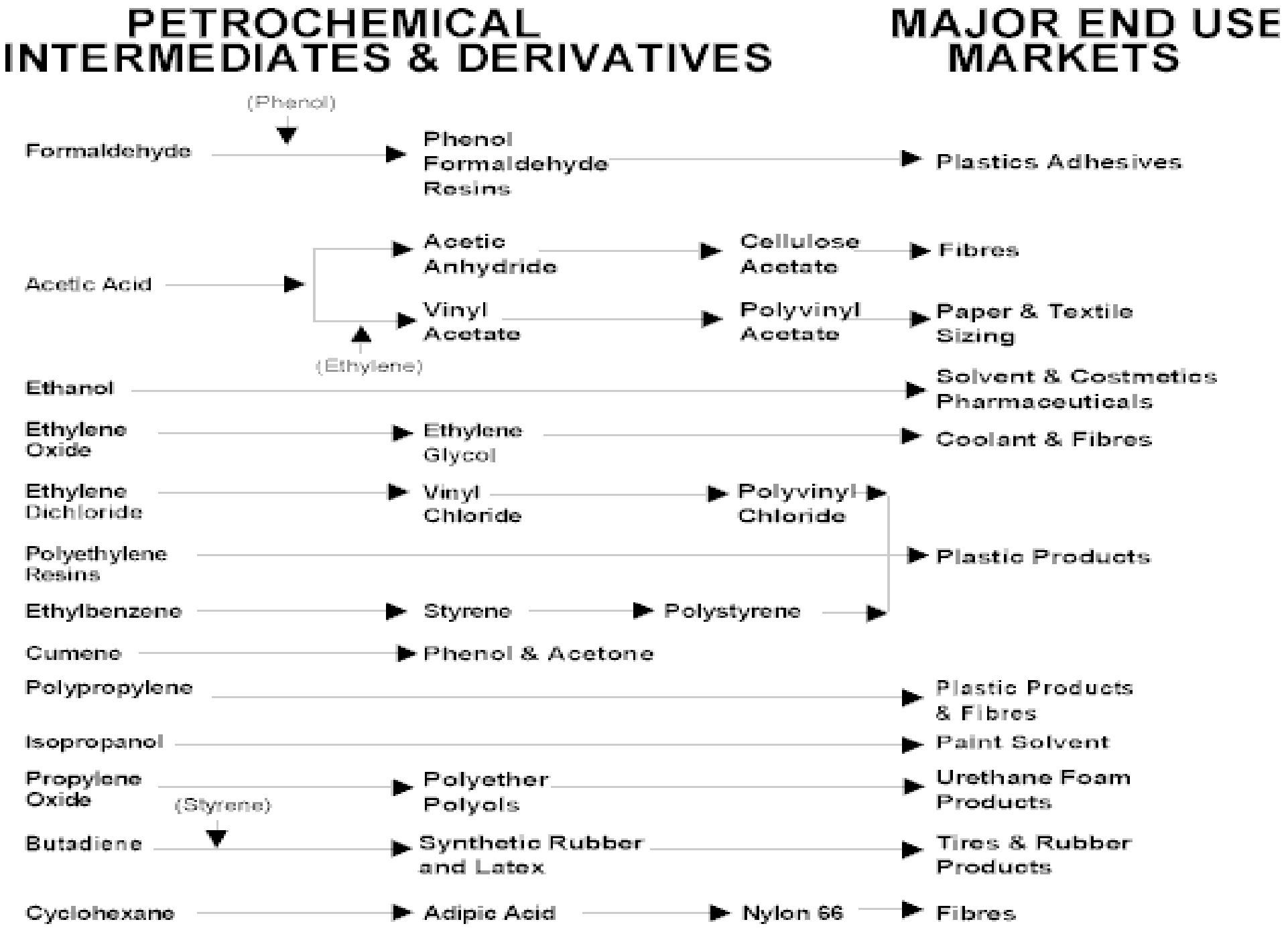
The Petrochemical Industry

In The World

Figure 3: Organic Chemicals and Building Blocks Flow Diagram




PRIMARY PETROCHEMICALS
PETROCHEMICAL INTERMEDIATES & DERIVATIVES
(Phenol)
Formaldehyde
Phenol Formaldehyde Resins
Methanol
Acetic Anhydride
Cellulose Acetate
Acetic Acid
Vinyl Acetate
Polyvinyl Acetate
(Ethylene)
Ethanol
Ethylene Oxide
Ethylene Glycol
Ethylene
Ethylene Dichloride
Vinyl Chloride
Polyvinyl Chloride
Polyethylene Resins
Ethylbenzene
Styrene
Polystyrene
(Benzene)
Cumene
Phenol & Acetone
Polypropylene
Propylene
Isopropanol
Propylene Oxide
Polyether Polyols
(Styrene)
Butadiene
Synthetic Rubber and Latex
Benzene
Cyclohexane
Adipic Acid
Nylon 66


PETROCHEMICAL INTERMEDIATES & DERIVATIVES
MAJOR END USE MARKETS
(Phenol)
Formaldehyde
Phenol Formaldehyde Resins
Plastics Adhesives
Acetic Acid
Acetic Anhydride
Cellulose Acetate
Fibres
Vinyl Acetate
Polyvinyl Acetate
Paper & Textile Sizing
(Ethylene)
Ethanol
Solvent & Costmetics Pharmaceuticals
Ethylene Oxide
Ethylene Glycol
Coolant & Fibres
Ethylene Dichloride
Vinyl Chloride
Polyvinyl Chloride
Polyethylene Resins
Plastic Products
Ethylbenzene
Styrene
Polystyrene
Cumene
Phenol & Acetone
Polypropylene
Plastic Products & Fibres
Isopropanol
Paint Solvent
Propylene Oxide
Polyether Polyols
Urethane Foam Products
(Styrene)
Butadiene
Synthetic Rubber and Latex
Tires & Rubber Products
Cyclohexane
Adipic Acid
Nylon 66
Fibres

MAJOR END USE MARKETS

END USE	US MARKET 2000 (kTons)	Percent of Total Market
PACKAGING (Bottles, Film, Cups, etc.)	9683	25%
BUILDING & CONSTRUCTION (Pipe, Siding, insulation, etc.)	8554	22%
CONSUMER & INSTITUTIONAL (Toys, Housewares, Medical, etc.)	5290	13%
TRANSPORTATION	1846	5%
FURNITURE & FURNISHINGS	1694	4%
ELECTRICAL/ELECTRONICS (W&C, Computers, Appliances, etc.)	1461	4%

Specific Petrochemicals & Polymers

Methanol

METHANOL MANIA

The U.S. may see more than 30 million metric tons of new capacity

	LOCATION	CAPACITY (THOUSANDS OF METRIC TONS PER YEAR)	COST ($ MILLIONS)	START-UP YEAR[a]
Celanese	Bishop, Texas	1,300	na	na
Celanese/Mitsui	Clear Lake, Texas	1,300	$800	2015
Fund Connell	Texas City, Texas	7,200	4,500	na
Lake Charles Clean Energy[b]	Lake Charles, La.	1,000	2,600	2016
LyondellBasell Industries[c]	Channelview, Texas	720	150	2013
Methanex[d]	Geismar, La	2,000	1,100	2014
NW Innovation Works	Kalama & Tacoma, Wash.; Port Westward, Ore.	10,500	5,400	2019
OCI	Beaumont, Texas	1,750	na	2016
South Louisiana Methanol	St. James, La.	1,750	1,300	2016
Valero	St. Charles, La.	1,700	700	2018
Yuhuang	St. James, La.	3,000	1,850	2018

a Year of the earliest production for multiphase projects. **b** Project entails the gasification of petroleum coke to make methanol and hydrogen. **c** Project is a restart of a plant that has been shuttered since 2004. **d** Company is moving two plants from Chile to the U.S. **na** = not available.
SOURCE: Companies

Ethylene

Table 6: Distribution of Uses for Ethylene

Product	Percent of Ethylene Use
Polyethylene	54
Ethylene dichloride	16
Ethylene oxide-glycol	13
Ethylbenzene-styrene	7
Linear olefins-alcohol	3
Vinyl acetate	2
Ethanol	1
Other	4

Source: *Kirk-Othmer Encyclopedia of Chemical Technology.*

Figure 1: A Simplified Ethylene Flow Chart

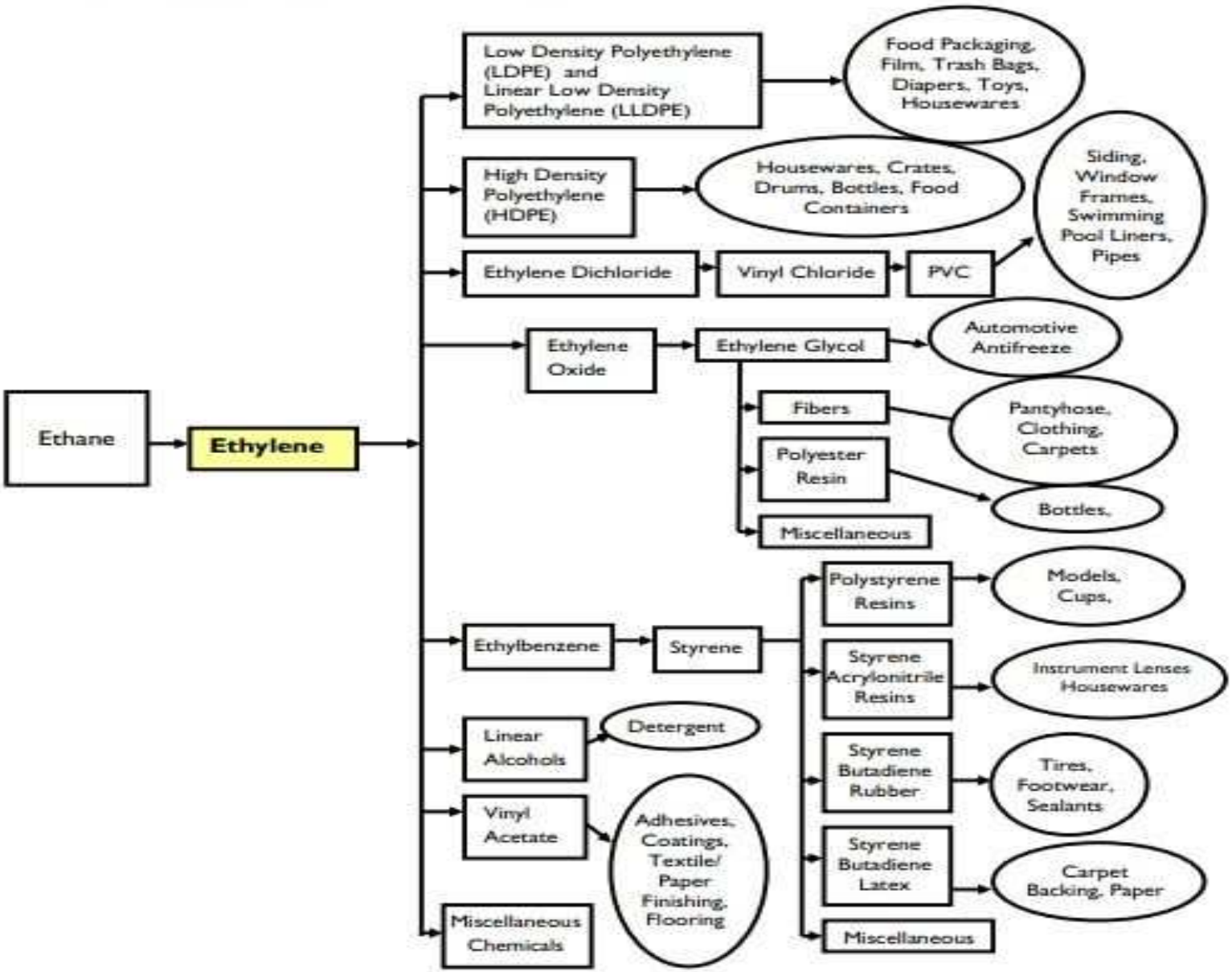
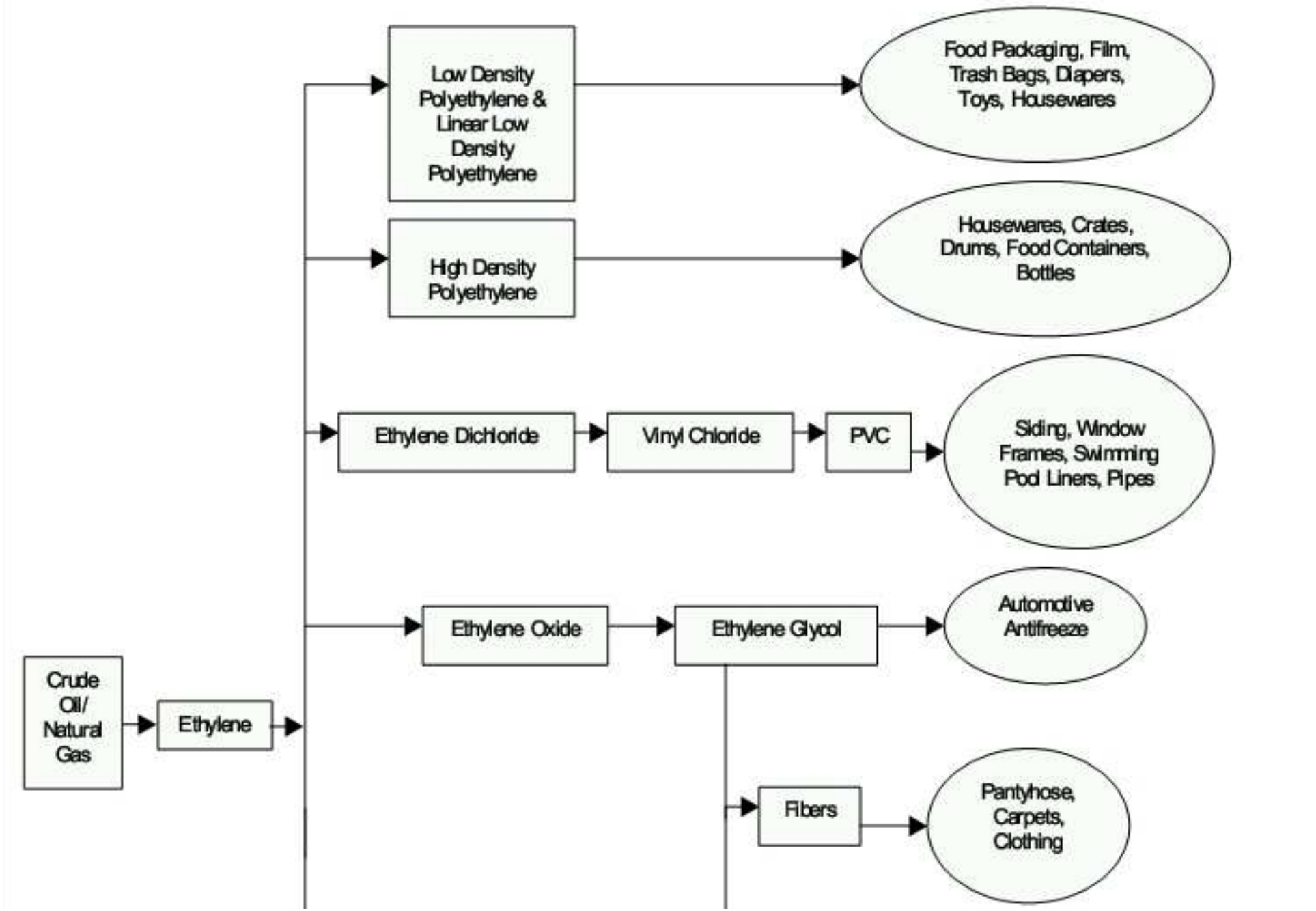
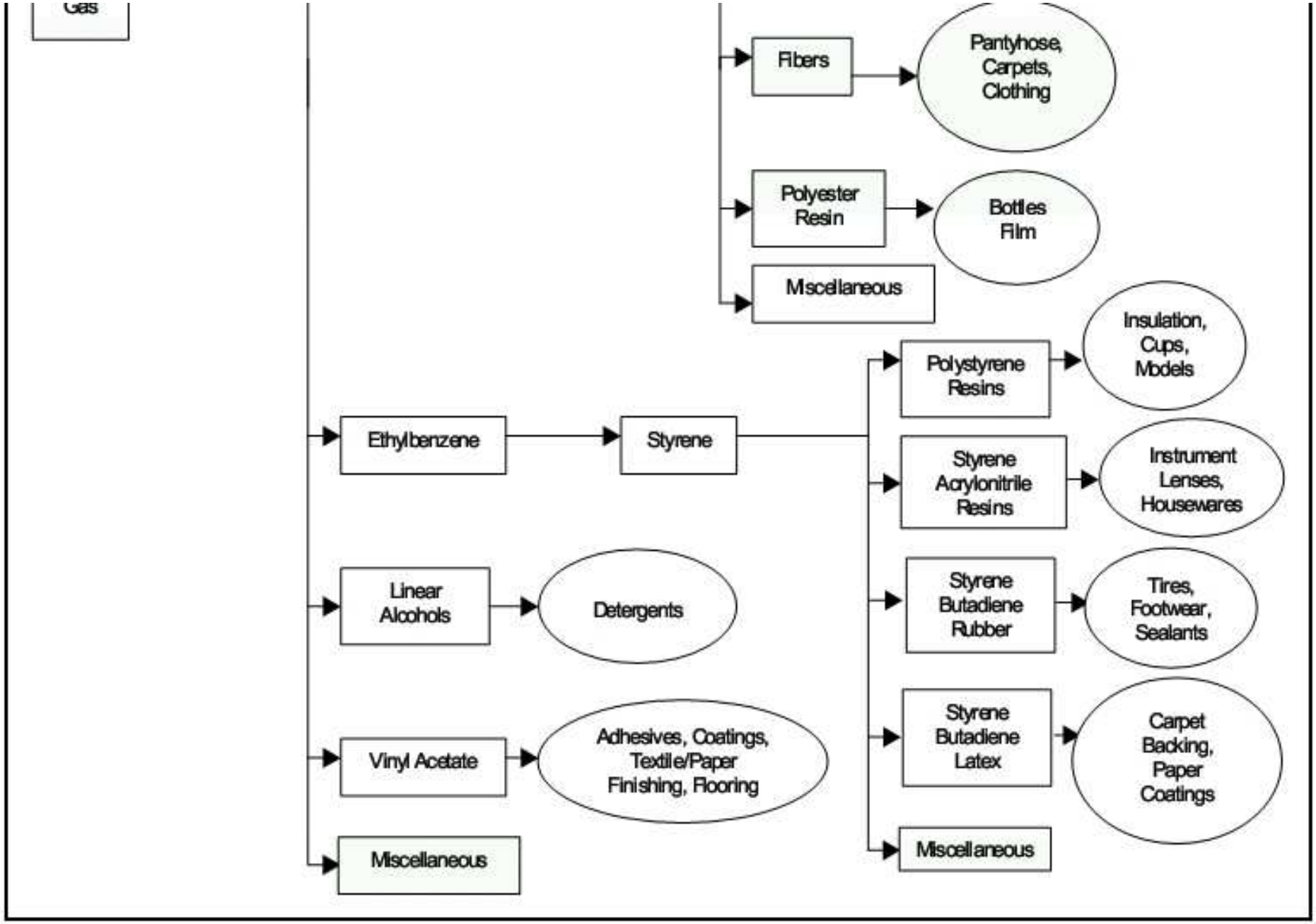
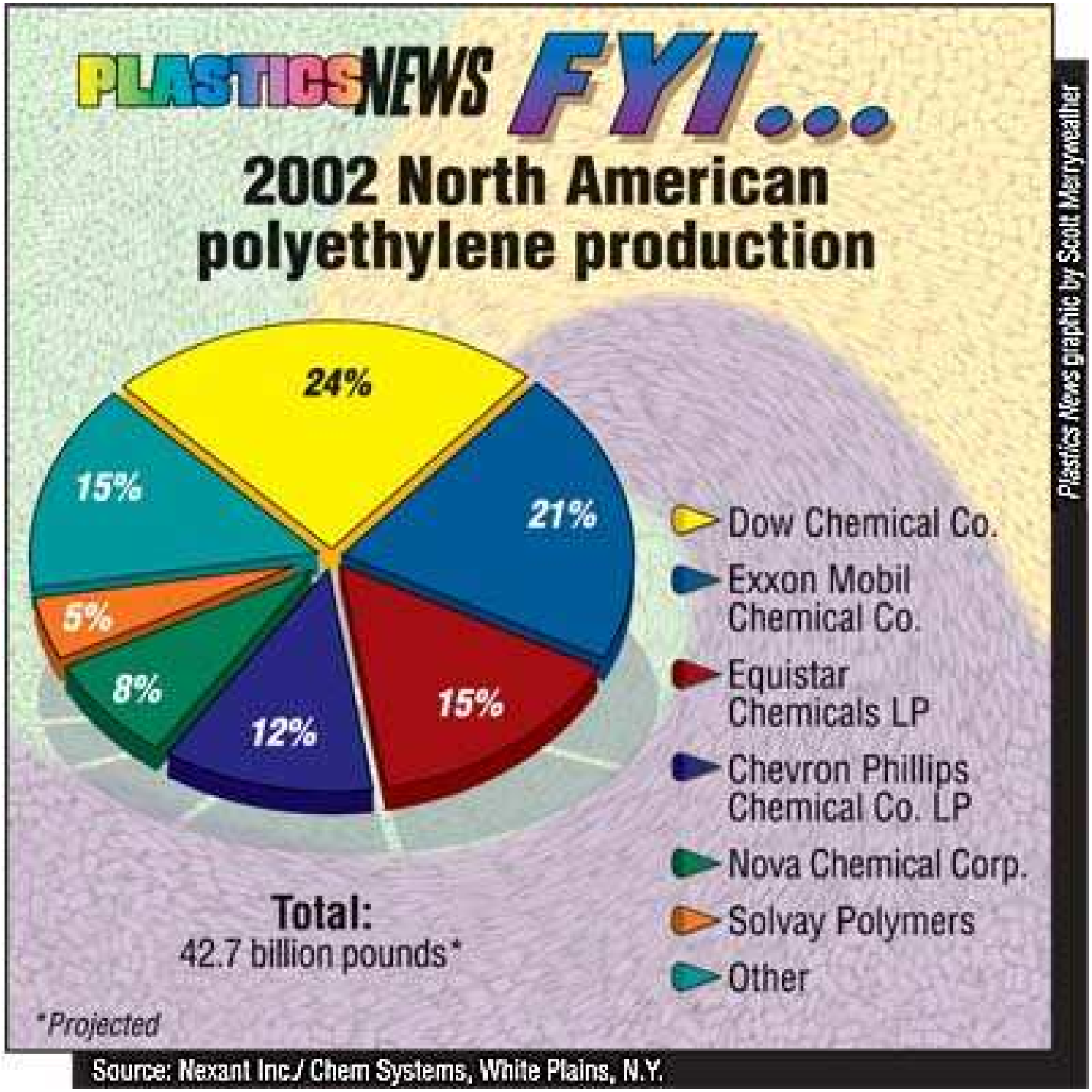


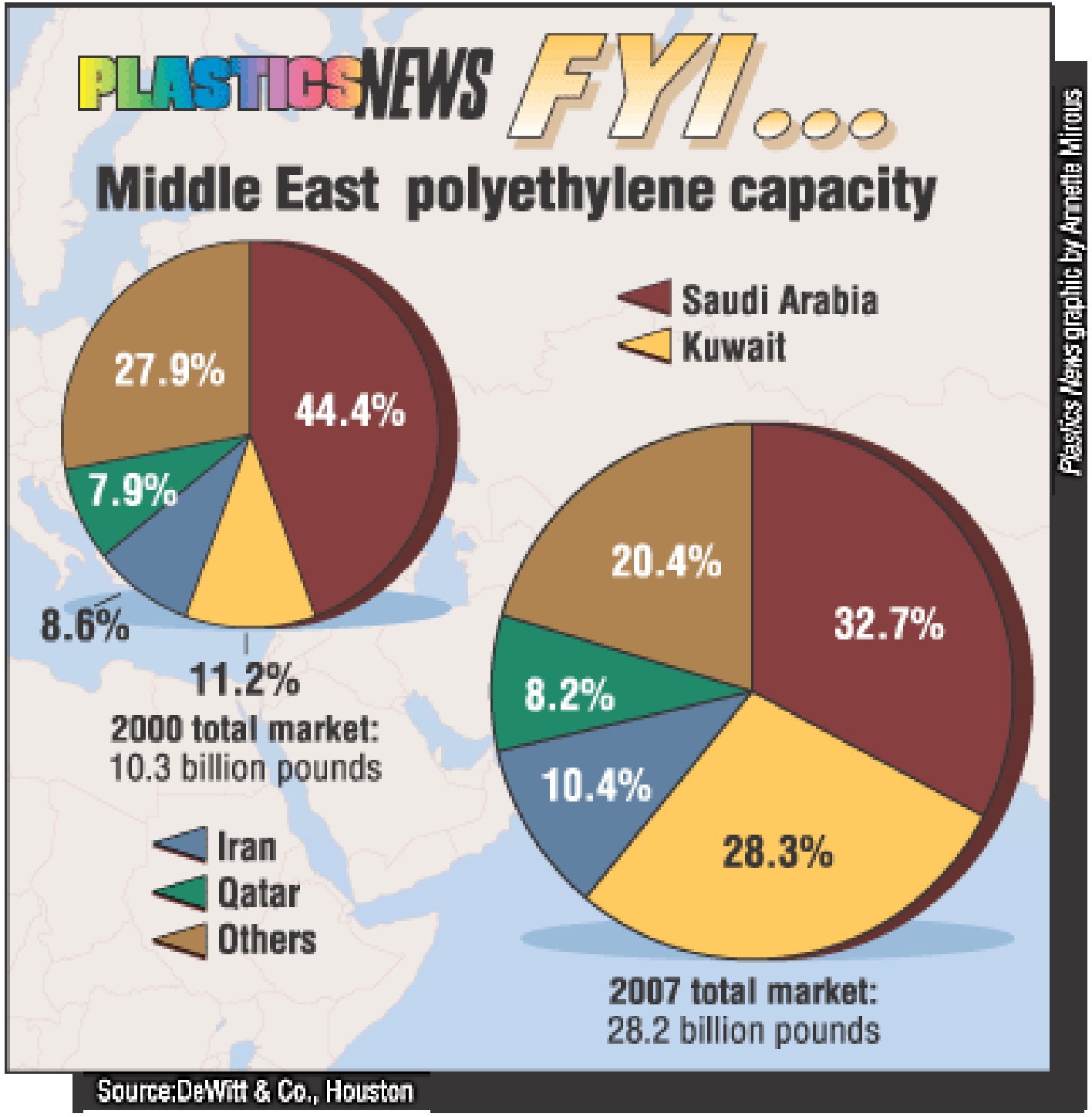
Figure 4: Ethylene Products



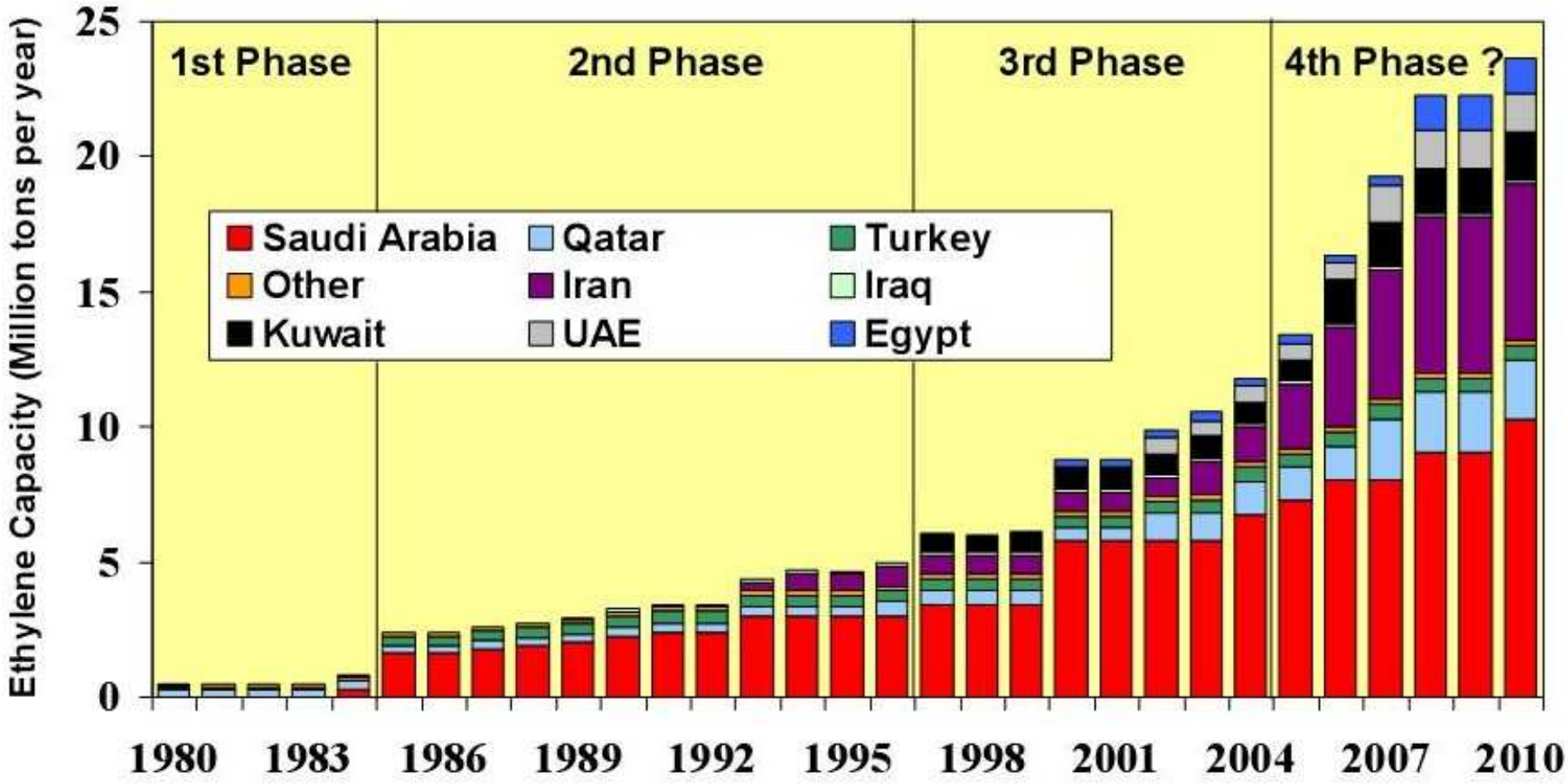


Source: American Chemistry Council, 2001.

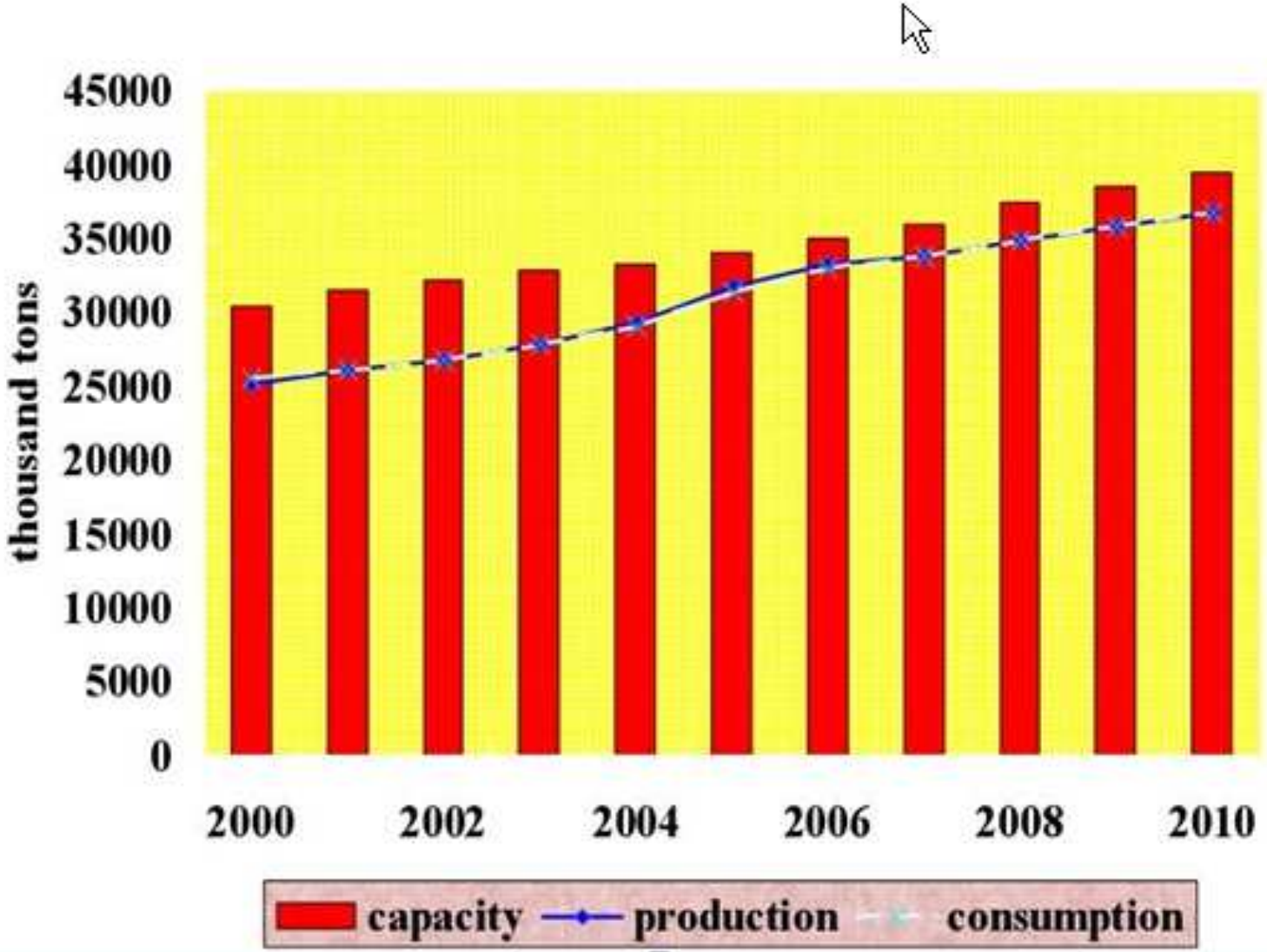

PLASTICSNEWS FYI...
2002 North American polyethylene production
24%
21%
15%
12%
8%
5%
15%
Dow Chemical Co.
Exxon Mobil Chemical Co.
Equistar Chemicals LP
Chevron Phillips Chemical Co. LP
Nova Chemical Corp.
Solvay Polymers
Other
Total:
42.7 billion pounds*
*Projected
Source: Nexant Inc./ Chem Systems, White Plains, N.Y.
Plastics News graphic by Scott Merryweather


PLASTICSNEWS FYI...
Middle East polyethylene capacity
Saudi Arabia
Kuwait
Iran
Qatar
Others
27.9%
44.4%
7.9%
8.6%
11.2%
2000 total market:
10.3 billion pounds
20.4%
32.7%
8.2%
10.4%
28.3%
2007 total market:
28.2 billion pounds
Source:DeWitt & Co., Houston
Plastics News graphic by Annette Mirous

GROWTH OF ETHYLENE CAPACITY IN THE MIDDLE EAST



PVC


45000
40000
35000
30000
25000
20000
15000
10000
5000
0
thousand tons
2000
2002
2004
2006
2008
2010
capacity
production
consumption

Propylene

Table 7: Distribution of Propylene Use

Product	Percent of Propylene Use
Polypropylene	36
Acrylonitrile	16
Propylene oxide	11
Cumene	9
Butyraldehydes	7
Oligomers	6
Isopropyl alcohol	6
Other	9

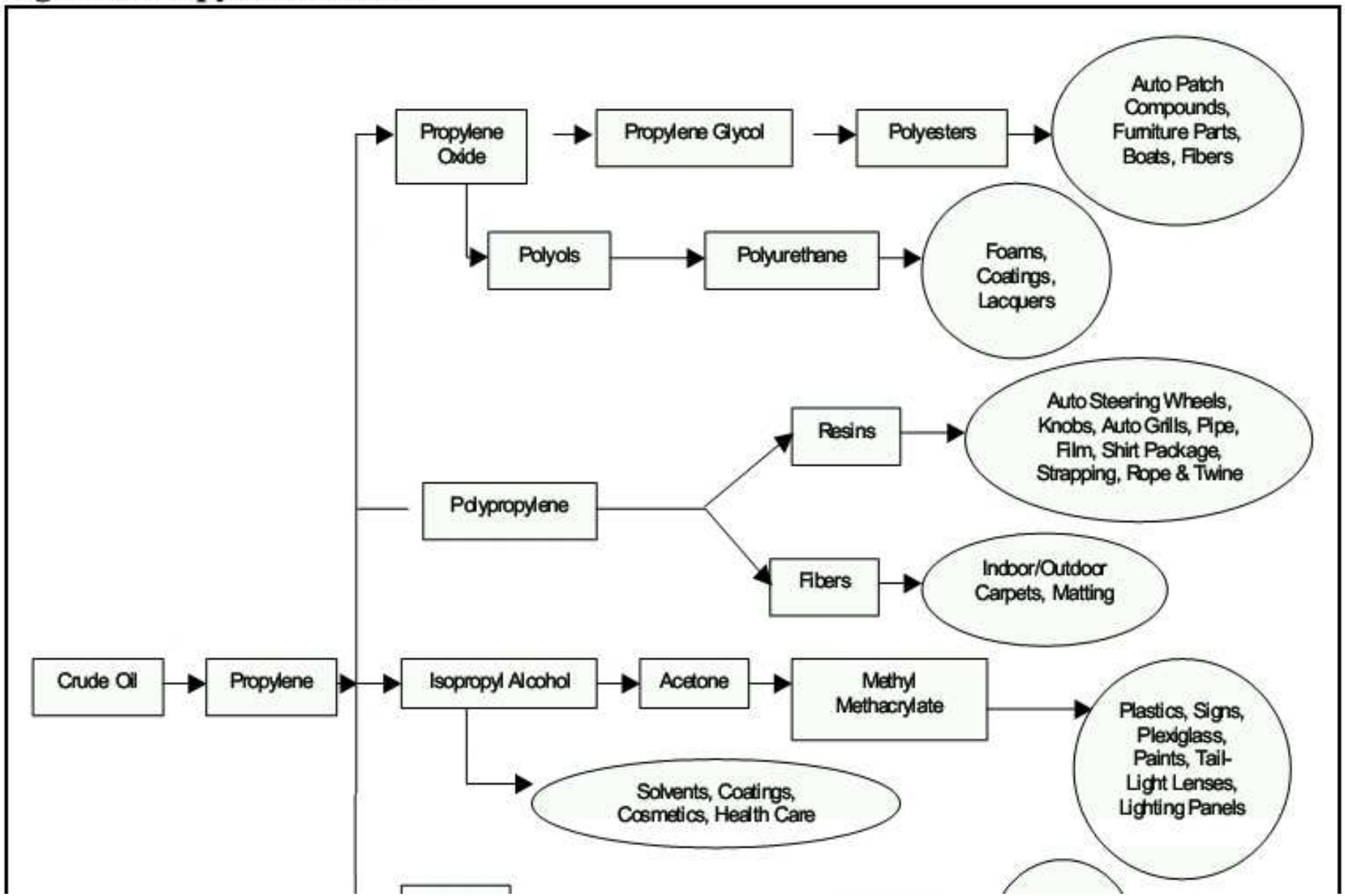
Source: Szmant.

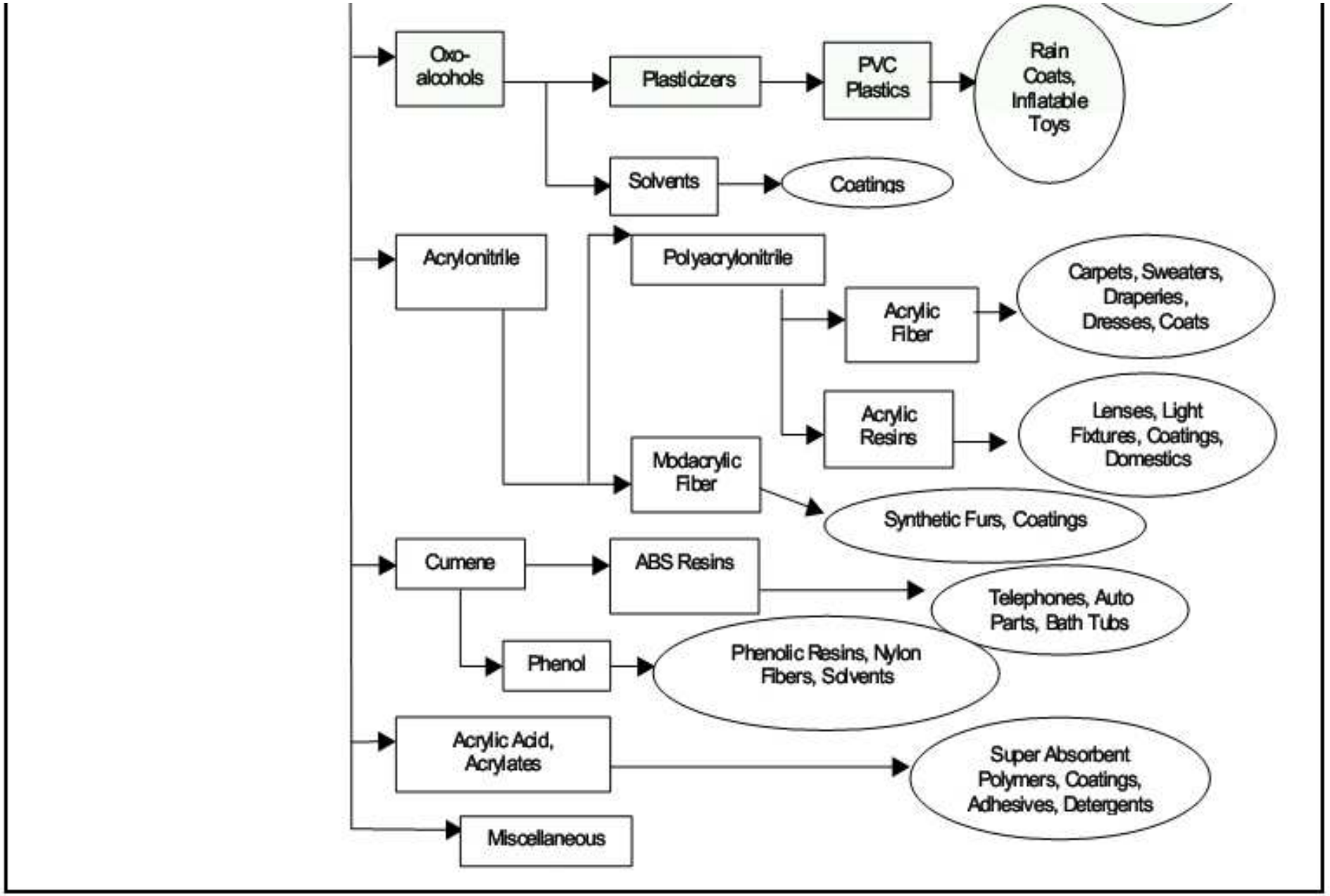
PROPYLENE MARKETS

PRODUCT	Percentage of Total Production 2000	2000-2004 Forecasted Growth Rate (1)
POLYPROPYLENE	57%	6.7%
ACRYLONITRILE	11%	4.3%
OXY ALCOHOL	8%	6.2%
CUMENE	6%	4.4%
PROPYLENE OXIDE	7%	4.3%
OTHER PRODUCTS	11%	--
TOTAL - 2000	51.2 MM Tons	5.6%

(1) Petroleum Technology Quarterly 2001, page 132

Figure 5: Propylene Products





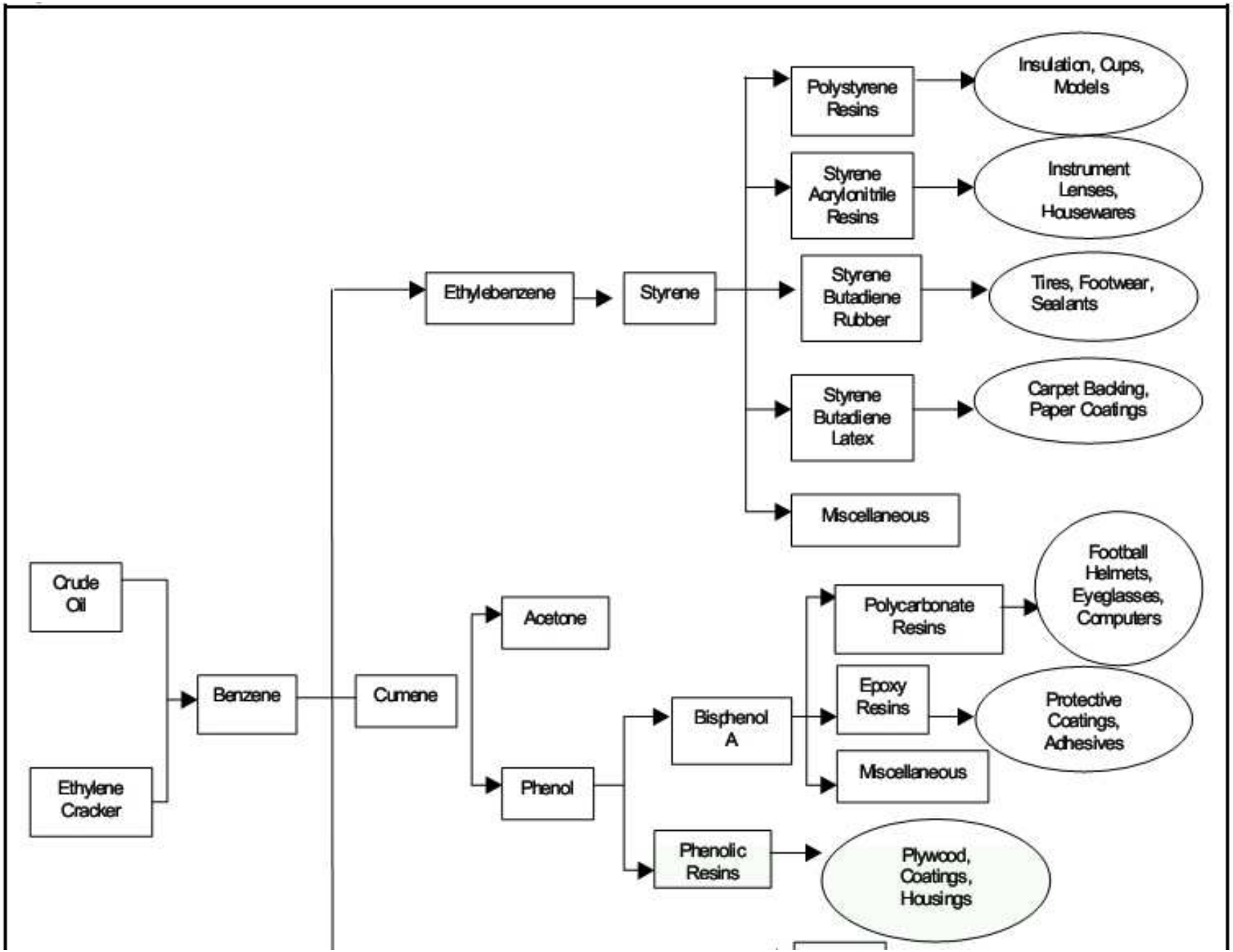
Source: American Chemistry Council, 2001.

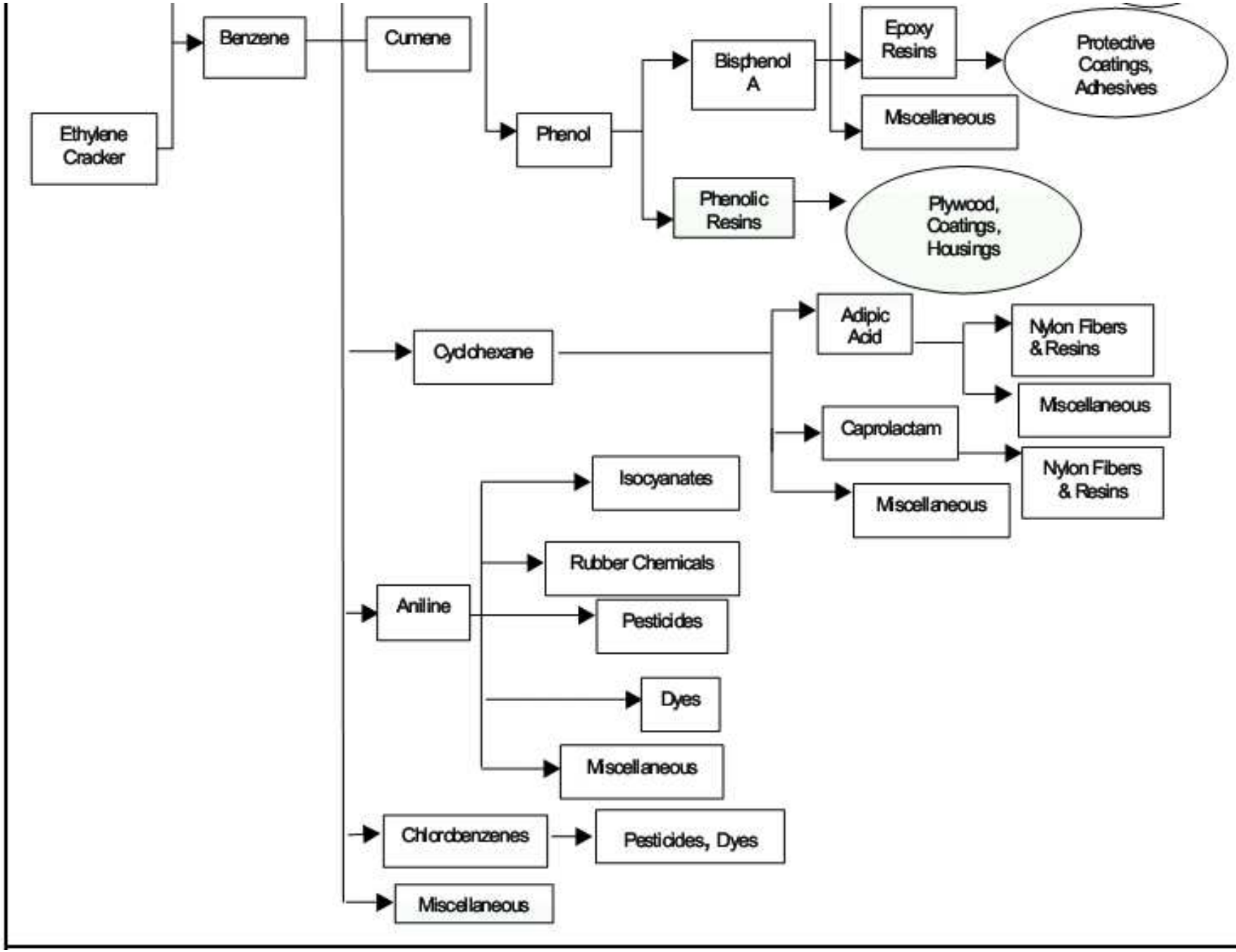
Benzene

Table 8: Distribution of Benzene Use

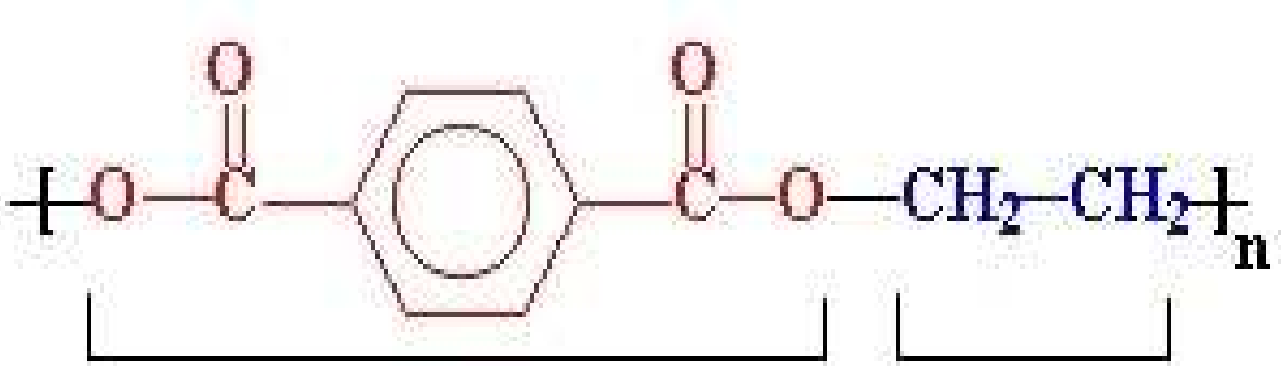
Product	Percent of Benzene Use
Ethylbenzene	52
Cumene	22
Cyclohexane	14
Nitrobenzene	5
Chlorobenzenes	2
Linear detergent alkylate	2
Other	3

Source: *Kirk-Othmer Encyclopedia of Chemical Technology*.


Crude Oil
Ethylene Cracker
Benzene
Cumene
Ethylebenzene
Styrene
Polystyrene Resins
Insulation, Cups, Models
Styrene Acrylonitrile Resins
Instrument Lenses, Housewares
Styrene Butadiene Rubber
Tires, Footwear, Sealants
Styrene Butadiene Latex
Carpet Backing, Paper Coatings
Miscellaneous
Acetone
Phenol
Bisphenol A
Polycarbonate Resins
Football Helmets, Eyeglasses, Computers
Epoxy Resins
Protective Coatings, Adhesives
Miscellaneous
Phenolic Resins
Plywood, Coatings, Housings


Ethylene Cracker
Benzene
Cumene
Phenol
Bisphenol A
Epoxy Resins
Protective Coatings, Adhesives
Miscellaneous
Phenolic Resins
Plywood, Coatings, Housings
Cyclohexane
Adipic Acid
Nylon Fibers & Resins
Miscellaneous
Caprolactam
Nylon Fibers & Resins
Miscellaneous
Aniline
Isocyanates
Rubber Chemicals
Pesticides
Dyes
Miscellaneous
Chlorobenzenes
Pesticides, Dyes
Miscellaneous

PET



terephthalate group

ethylene group

FIVE YEAR DATA

PET - usa

Year	Demand Millions of Pounds	Aver. Annual Price container-grade, contract Gulf, dlvd. $/Pound
1997	8,590	0.52
1998	8,780	0.52
1999	8,835	0.51
2000	9,220	0.61
2001	9,450	0.65
2002	9,780	0.60

Nylon

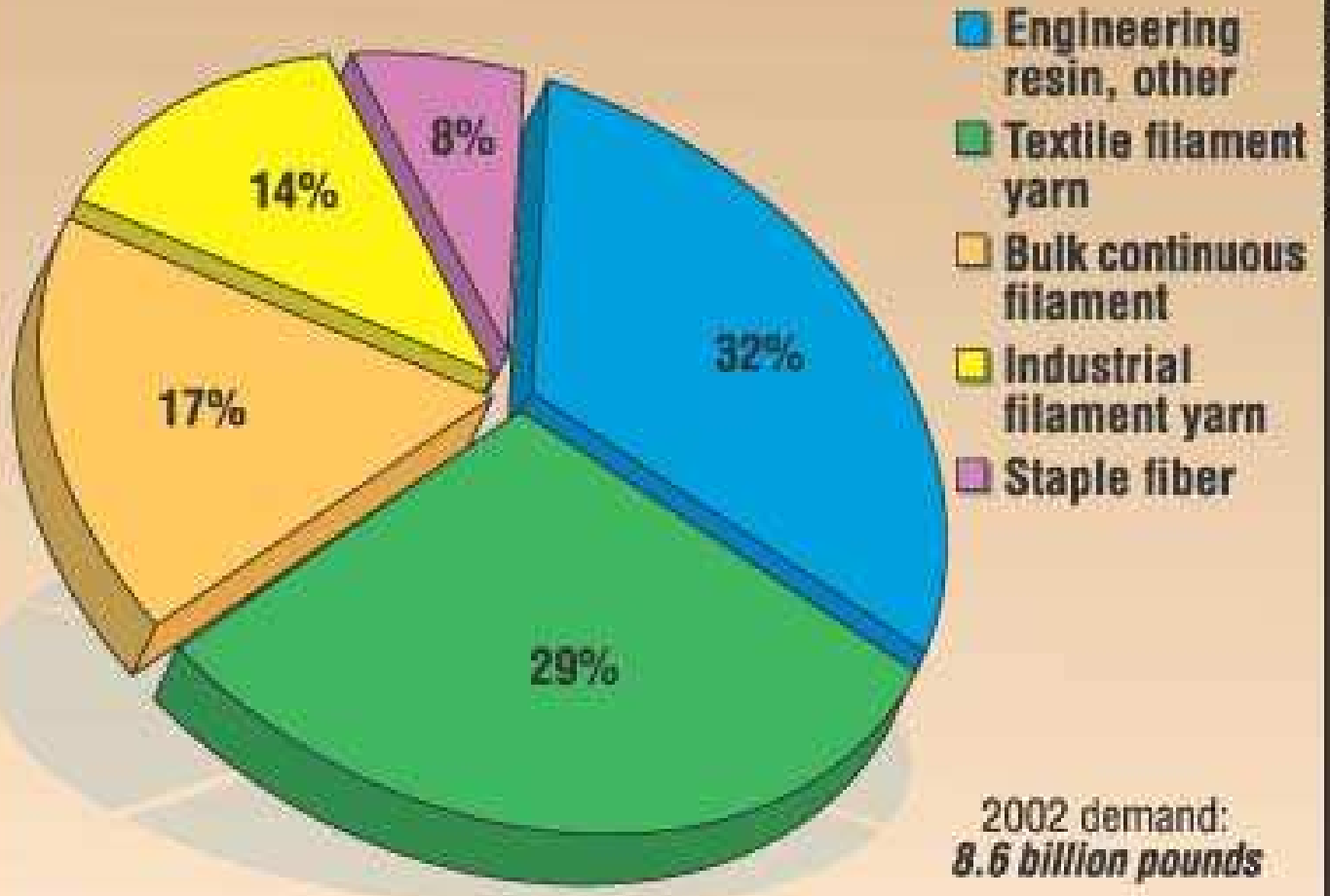
Uses

- carpet fiber
- clothing
- fishing lines
- footwear
- nylon fiber
- pantyhose
- windpants
- toothbrush bristles
- velcro
- airbag fiber
- auto parts: intake manifolds, gas (petrol) tanks
- slings and rope used in climbing gear and slacklining
- machine parts, such as gears and bearings
- parachutes
- metallized nylon balloons
- classical and flamenco guitar strings
- paintball marker bolts
- racquetball,badminton, squash, and tennis racquet strings
- Strings for String instruments
- Drumstick heads
- As filter media in sterlizing grade filters
- Flexible tubing
- Basketball netting
- Sutures
- flags

PLASTICS NEWS **FYI...**

Global demand for virgin nylon fiber

By market segment



2002 demand:
8.6 billion pounds

Source: Chemical Market Associates Inc., Houston

Plastics News graphic by Scott Merryweather

Synthetic fibers

Common synthetic fibers include:

- Rayon (1910) (artificial, not synthetic)
- Acetate (1924) (artificial, not synthetic)
- Nylon (1939)
- Modacrylic (1949)
- Olefin (1949)
- Acrylic (1950)
- Polyester (1953)
- PLA (2002)

Specialty synthetic fibers include:

- Vinyon (1939)
- Saran (1941)
- Spandex (1959)
- Vinalon (1939)
- Aramids (1961) - known as Nomex, Kevlar and Twaron
- Modal (1960's)
- PBI (Polybenzimidazole fibre) (1983)
- Sulfar (1983)
- Lyocell (1992)
- Dyneema/Spectra (1979)

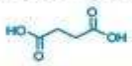
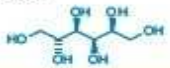
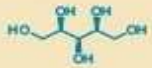
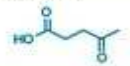
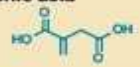
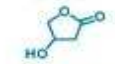
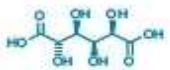
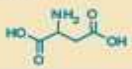
USA syn fiber statistics

Key Industry Statistics

Key Industry Figures	2007	2008	
Industry Revenue	8,470	XXXX	$Mil
Revenue Growth	-2.8	XXXX	%
Industry Gross Product	*3,850	XXXX	$Mil
Number of Establishments	*100	XXXX	Units
Number of Enterprises	*82	XXXX	Units
Employment	*15,650	XXXX	Units
Exports	2,252.9	XXXX	$Mil
Imports	2,470.8	XXXX	$Mil
Total Wages	675	XXXX	$Mil

Where Are They Now?

In 2004, the Energy Department identified a set of biomass-derived compounds best suited to replace petroleum-derived chemicals.

DOE's Top 15	Source	Downstream chemicals and materials	Key uses and products	Commercial biobased products: Now	Commercial biobased products: Likely in 10 years	Bio-scorecard grade[a]
Succinic acid (plus fumaric and malic acids) 	Bacterial fermentation of glucose, chemical oxidation of 1,4-butanediol	1,4-Butanediol, tetrahydrofuran, γ-butyrolactone, maleic anhydride, pyrrolidones	Solvents, polyesters, polyurethanes, nylon, food and beverage acidity control, fabrics, inks and paints, much more	Yes	Yes	A
2,5-Furandicarboxylic acid 	Chemical dehydration of glucose, oxidation of 5-hydroxymethylfurfural	2,5-Dihydroxymethylfuran, 2,5-bis(aminomethyl)tetrahydrofuran	Polyethylene terephthalate analogs, polyamides such as nylon, plastic bottles and containers, fabrics, carpet fiber	Coming soon	Yes	B
3-Hydroxypropionic acid 	Bacterial fermentation of glycerol or glucose	1,3-Propanediol, acrylic acid, methyl acrylate, acrylamide	Polytrimethylene terephthalate, acrylate polymers, carpet fiber, paints and adhesives, superabsorbent polymers for diapers, contact lenses	No	Yes	B
Glycerol 	Chemical or enzymatic transesterification of vegetable oils	Propylene glycol, ethylene glycol, 1,3-propanediol, glyceric acid, lactic acid, acetol, acrolein, epichlorohydrin	Polyesters, butanol, soaps, cosmetics, foods and beverages, antifreeze/deicing fluids, pharmaceuticals, coatings, carpet fiber	Yes	Yes	B
Sorbitol 	Hydrogenation of glucose from corn syrup, bacterial fermentation (under development)	Isosorbide, propylene glycol, ethylene glycol, glycerol, lactic acid, alkanes	Sweeteners, mouthwash and toothpaste, sugar-free chewing gum, polyethylene terephthalate analogs, fuel ingredients, antifreeze/deicing fluids, water treatment	Yes	Yes	B
Xylitol (plus arabinitol) 	Hydrogenation of xylose, extraction from lignocellulose, bacterial fermentation (under development)	Propylene glycol, ethylene glycol, glycerol, xylaric acid, furfural	Sweeteners, sugar-free chewing gum, cough drops and medicines, antifreeze/deicing fluids, new polyesters	Yes	Yes	C
Levulinic acid 	Acid-catalyzed dehydration of sugars	2-Methyltetrahydrofuran, γ-valerolactone, 1,4-pentanediol, acetylacrylic acid, diphenolic acid, caprolactam, adiponitrile, pyrrolidones	Fuel ingredients, solvents, acrylate polymers, BPA-free polycarbonates, polyesters, polyamides, pharmaceuticals, herbicides, plastic bottles and containers	No	Maybe	C
Itaconic acid 	Fungal fermentation of glucose	4-Methyl-γ-butyrolactone, 3-methyltetrahydrofuran, pyrrolidones	Styrene-butadiene copolymers, polyitaconic acid, rubber, plastics, paper and architectural coatings	No	Maybe	C−
3-Hydroxybutyrolactone 	Multistep chemical synthesis from starch	3-Hydroxytetrahydrofuran, acrylate-lactone, 3-aminotetrahydrofuran	Solvents, synthetic intermediates for pharmaceuticals, polyurethane fiber analogs, new polymers	No	Maybe	C−
Glutamic acid 	Bacterial fermentation of glucose	1,5-Pentanediol, glutaric acid, 5-amino-1-butanol	Polyesters, nylon analogs, glutamate flavor enhancers, fabrics, plastics	No	Maybe	D+
Glucaric acid 	Oxidation of starch or glucose by nitric acid or bleach	Lactones, polyhydroxypolyamides, adipic acid	Solvents, nylon analogs, branched polyesters, fabrics, plastics, detergents	No	Maybe	D
Aspartic acid 	Enzymatic amination of fumaric acid, fermentation route (under development)	2-Amino-1,4-butanediol, 3-aminotetrahydrofuran, aspartic anhydride, amino-γ-butyrolactone	Aspartame, polyaspartate, sweeteners, chelating agents for water treatment, superabsorbent polymers for diapers	No	No	D−

NOTE: Other platform chemicals that are doing well or poised to do well as feedstock chemicals: ethanol, butanediols, acetic acid, acrylic acid, adipic acid, lactic acid, farnesene, p-xylene, isobutanol, fatty acid esters, isoprene, furfurals, γ-valerolactone, triacetic acid lactone, and isosorbide. a Scorecard grade based on assessments by biobased chemicals experts and compiled by C&EN: A = being commercialized, B = significant activity, C = actively pursued by researchers, D = limited activity, F = no activity.

SOURCES: Government and industry reports, company information