2018

Elements

of the

BUSINESS OF CHEMISTRY

American®
Chemistry
Council

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The American Chemistry Council acknowledges the work and research of Dr. T. Kevin Swift conducted prior to joining the American Chemistry Council and upon which this present publication draws. Permission to use this work and research is granted by Dr. Swift for this publication.

Dear Colleagues,

American chemistry will continue to grow substantially over the next decade as abundant energy resources in the United States have tilted the competitive advantage in many types of chemical production toward producers in the U.S. A world leader with $526 billion* in shipments, American chemistry is the second largest chemical producing nation, after China. The industry is making huge investments to capitalize on our advantages. Nearly $200 billion of investments in new shale-advantaged capacity have been announced since 2010, with half of that investment either already completed or under construction. As the U.S. has become a major destination for chemical investment, two-thirds of the announced investment represents foreign direct investment.

As its competitiveness improves, American chemistry is in demand across the world with exports of nearly $130 billion, making us among the largest exporters in the world. In fact, American chemistry produces a large and growing trade surplus, reaching close to $33 billion in 2017. These positive contributions to trade contribute to the broader U.S. economy. Our continued economic growth and job creation is heavily dependent as access to global markets. Free trade and open markets are essential to maintaining our pro-growth, pro-competitiveness agenda.

In fact, American chemistry provides more than half a million high-paying jobs across the U.S. Paying, on average, more than $84,000 per year, jobs in American chemistry are the cornerstone of many local communities. The industry supports a vast supply chain and creates economic activity in the communities where they are located. For every job in chemical manufacturing, more than seven more jobs are created elsewhere in the economy.

It doesn’t end there. With more than $12 billion invested in research & development in 2017, the business of chemistry and its dedicated workforce continue to drive innovation and produce the materials necessary for a healthy and sustainable world. The global economy will face myriad challenges over the next several decades. Global population is expected to expand by another billion people, increasing demands on the Earth’s finite resources. Sustainable solutions from the chemical industry will be required to deliver provide a safe and plentiful food supply, clean air and water, safe living conditions, efficient and affordable energy sources and life-saving medical treatments to communities around the globe.

I hope our *2018 Elements of the Business of Chemistry* will be an invaluable resource for you and your colleagues as you explore the many ways that chemistry is essential to our economy and to our everyday lives.

Sincerely,

Cal Dooley
President and CEO
American Chemistry Council

* Beginning with the 2018 edition, we are now publishing the majority of our data on a chemicals (excluding pharmaceuticals) basis. We’re making this change to align our statistics with those of our global partners and the business community that look at chemicals and pharmaceuticals as separate industries. The pharmaceutical industry remains a key end use market for chemical ingredients.

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Introduction

Elements of the Business of Chemistry is a new publication offered by the American Chemistry Council. This is a sister publication of ACC's premier source of data on the chemical industry, the *Guide to the Business of Chemistry*. This free publication provides a high-level overview of the chemical industry and highlights the importance of the business of chemistry in the U.S. economy and in enhancing society's quality of life.

Elements of the Business of Chemistry segments this business into five types of production: basic chemicals, specialty chemicals, agricultural chemicals, pharmaceuticals, and consumer products. Each of these segments has distinct characteristics, growth dynamics, markets, new developments, and issues.

Elements to the Business of Chemistry was prepared by the American Chemistry Council's (ACC) Economics and Statistics Department, which provides economic analysis of policy initiatives, business trends, and changing industry dynamics. Many of the data published herein are directly from or based on government sources.

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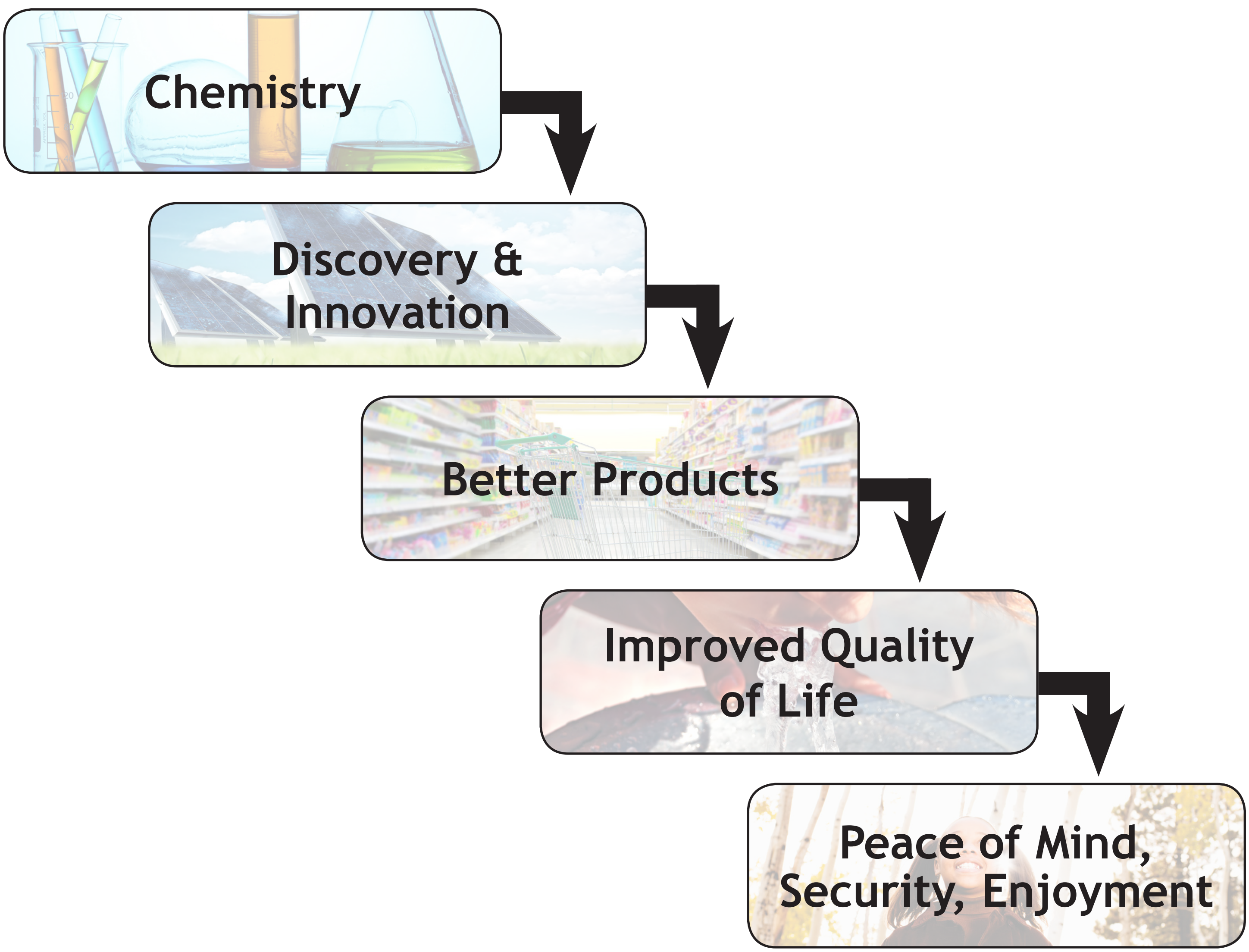
1. CHEMISTRY AND THE ECONOMY

Chemistry: it's in everything and it's everywhere. By its very nature, everything around us—from air and water, to the products and technologies we use every day, even our own living tissue—is chemistry in motion. The business of chemistry transforms more than 275 million tons of natural raw materials obtained from the earth, sea and air into products that we use every day. When the science of chemistry is applied, it helps improve safety, health and productivity. Innovations in chemistry have created countless economic and social benefits: longer and healthier lives through medical advancements; improved standards of living from fertilizers and water treatment; and instant access to information from anywhere, thanks to smartphones and other "smart" devices, to name a few.

Chemistry is essential to our everyday lives. Manufactured fibers and permanent-press clothing, life-saving medicines, technology-enhanced agricultural products, improved foods, protective packaging materials, longer-lasting paints, stronger adhesives, smaller and faster CPUs (central processing units), more durable and safer tires, lightweight automobile parts, and stronger composite materials in aircraft and spacecraft are only a few of the thousands of the innovative products of the business of chemistry. Over 96% of all manufactured goods are directly touched by chemistry, either as a material in processing. Including indirect support, chemistry touches 100% of manufactured goods.



Chemistry in Our Lives

Chemistry contributes in many ways to the products and services that consumers and industries use in their day-to-day activities. The following are just some of the life-enhancing products made possible through chemistry:

AUTOMOBILES - A typical automobile contains over $3,000 worth of chemistry, including 340 pounds of plastics and polymers composites and over 280 pounds of rubber, textiles and coatings. From the urethane foam seat cushioning to nylon airbags to windshield wiper fluids, an automobile's performance and safety depend on thousands of products of chemistry. Supplanting steel in many automotive applications, plastics and polymer composites typically make up 50% of the volume of a new light vehicle but less than 10% of its weight, which helps make cars lighter and more fuel efficient, resulting in lower greenhouse gas emissions.[1] An analysis by the U.S. Department of Energy suggests a 6-8% (with mass compounding) increase in fuel economy for every 10% drop in weight. Thus, not only does the business of chemistry provide better performing and safer vehicles, it also provides solutions leading to improved sustainability.

INFORMATION – This is the Information Age, where there is one smartphone for every three people in the world, and that number is expected to more than double in the next few years. Far beyond the mobile phone of the '90s, or even the smartphones of a decade ago, today people can do everything from streaming live television to shooting and editing a digital film to tracking their heart rate from the convenience of their home, their wrist, or even by using a "virtual assistant." Digital currencies, machine learning, and cloud computing, among other recent developments in how information is stored and shared, is all made possible by chemistry. Chemistry is used to create the electronic circuits; plastics provide the high-impact resistance, strength, and durability needed to protect the device. Indeed, chemistry is essential to information.

LITHIUM BATTERIES are crucial to modern life as they are used in applications ranging from consumer electronics to pacemakers to automobiles. Lithium batteries are used for critical military applications, including remote devices, soldier mobility and improved logistics. The strength and size of lithium batteries make them ideal for consumer use: they are in our smartphones and tablets; they power cordless drills and flashlights. On a larger scale, lithium batteries are used to power everything from wheelchairs to hybrid vehicles to jet fighters and satellites.

PHARMACEUTICALS are central to human health and welfare, and the business of chemistry is central to pharmaceuticals. It is estimated that chlorine chemistry is essential to the manufacture of at least 88% of prescription pharmaceuticals currently sold in the U.S. and Canada; in addition, chlorine is present in the final drug formulation in about 25% of all pharmaceuticals.[2] Drug innovations enable individuals to live with, and manage, diseases that used to be death sentences; for example, diabetics readily test their blood sugar levels with a simple chemical test. Drugs have reduced and eradicated diseases around the world (e.g., smallpox, polio). Currently, scientists in the U.S. are researching how nanotechnology and nanoparticles may be used to fight many diseases, including cancer and Ebola.

1 "Chemistry and Light Vehicles." American Chemistry Council. July 2018.

2 "Chlorine Chemistry: Providing Pharmaceuticals That Keep You and Your Family Healthy." American Chemistry Council's Chlorine Chemistry Division. chlorine.americanchemistry.com/Pharmaceuticals.

RENEWABLE ENERGY & ENERGY EFFICIENCY – Chemistry is essential to renewable energy and energy-efficiency technologies. Wind power turbine blades are made using plastics, such as carbon fiber-reinforced polyurethane, epoxy, and/or unsaturated polyester resins, helping deliver renewable energy to our nation's electricity grid. Building insulation saves up to 40 times the energy used to create it; plastic house wrap that creates a weather resistant barrier saves up to 360 times the energy used to produce it. Chemistry enables compact fluorescent bulbs to "fluoresce" and to use 70 percent less energy than incandescent bulbs; LED lighting could cut global energy demand by 30 percent. Chemistry helps consumers save money and reduces overall energy consumption.

KITCHEN APPLIANCES – Today, most people take for granted that they can grab a cold drink from the refrigerator or microwave a meal in minutes. 100 years ago, food storage consisted of an icebox; now more than 99% of U.S. homes have a refrigerator. Replacing an old refrigerator with a new ENERGY STAR-qualified model—with improved insulation and coolant systems made possible by chemistry—saves enough energy to light an average house for nearly four months.[3] The microwave may be one of the most profound innovations of the last half century; the ease of heating food in a microwave has fostered a revolution in dining habits. The electronics behind the microwave are made possible from silicon chemistry (e.g., the microprocessor), as well as other chemistry that is used to create electronic circuits and protect cable and wiring, plastics that house the microwave, and polysulfone polymers offer resistance to heat, fats, oils and other elements. From the dishwasher to the self-cleaning oven, chemistry has revolutionized our habits in the kitchen.

HEALTH CARE - Modern health care would not be possible without chemistry -- and the future holds new breakthroughs, from shelf stable "plastic" blood that mimics hemoglobin to artificial skin that lets prosthetic wearers sense touch and temperature to nanotechnologies that deliver custom designed drugs based on a patient's DNA. Chemotherapy and other drugs now are delivered more accurately on plastic patches and dissolving discs; polyurethanes are used in medical applications such as catheter tubing and hospital bedding; ethylene oxide is used in the sterilization of medical supplies; and PVC is used in medical blood and intravenous bags and tubing. Polycarbonate, due to its high-impact strength and transparency, is used in a number of medical applications, including syringes, surgical instruments, clear IV components, and kidney dialysis filters. Synthetic latex gloves, sutures, bandages, splints, therapy whirlpools, and hundreds of other modern miracles of health care are all made possible by chemistry.

PROTECTIVE & PERFORMANCE CLOTHING – At the gym, on a construction site or in the line of duty, chemistry helps make what we wear better and safer. Chemistry can protect workers from exposures to hazardous materials, such as lead and asbestos; hard hats are made from high-density polyethylene or other resins. Fabrics coated with polyurethanes are durable and abrasion-resistant; nanotechnology allows apparel to resist stains, add UV protection and can even offer antibacterial properties. High-performance fibers from aromatic polyamides are used to make bulletproof vests. Thanks to chemistry, we are safer (and even smell better).

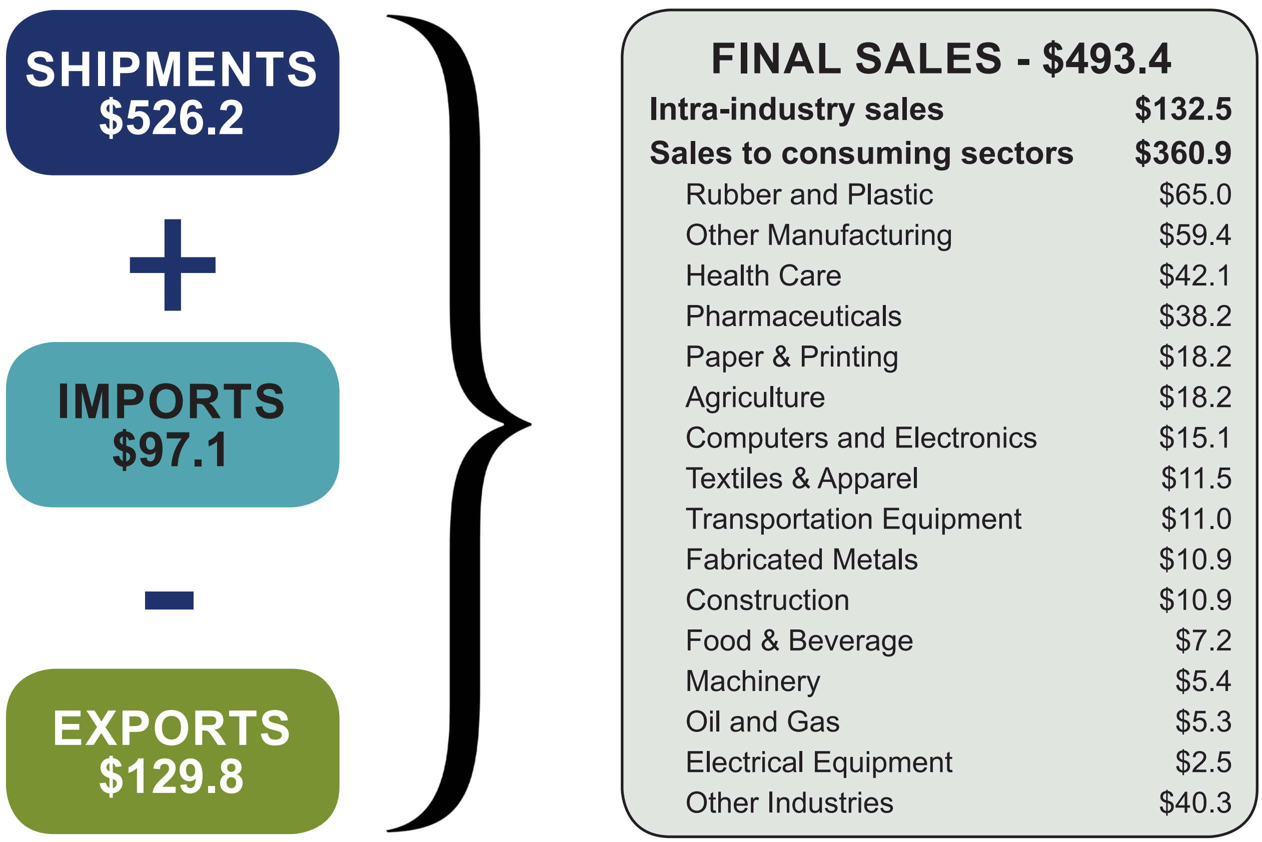
3 https://www.americanchemistry.com/Innovation/Energy/

Economic Contributions of the Business of Chemistry

Chemistry is vital to a strong and vibrant economy. A significant contributor to the gross domestic product (GDP), the business of chemistry is essential to our economy. Every manufacturing industry depends on chemistry in one way or another.

The following flow chart presents estimates of the direct uses of the output of the U.S. business of chemistry. These estimates, based on the IMPLAN input-output model, reflect purchases by the consuming industry or sector. In effect, final sales represent intra-industry sales as well as sales to industries that are consumers of the business of chemistry.

Figure 1.1 - U.S. Business of Chemistry Flow Chart, 2017 ($billion)



Note: Data does not include pharmaceuticals and is not comparable to previous editions of this publication.

Source: ACC analysis based on data from the Bureau of the Census, and the IMPLAN model.

Indirect uses of chemicals incorporated into the outputs of other industries are not included. For example, these data do not reflect the motor vehicle sector's purchase of tires from the rubber and plastics products industry, which purchases synthetic rubber to make tires. The value of this synthetic rubber is not included in the figure for motor vehicles. Thus, on a final demand basis, the total value of chemistry used in products produced by the motor vehicle industry is actually several times larger than indicated in Figure 1.1.

The economic contributions of the chemical industry are numerous, though often overlooked in traditional analyses that consider only the direct jobs and output of the industry. The business of chemistry directly creates hundreds of thousands of jobs. In addition to the jobs created directly by the industry, additional jobs are supported by the purchases made by the chemical industry and by the subsequent expenditure-induced activity. The chemical industry paid its employees' wages and salaries and purchased supplies and services (including transportation, contract workers, warehousing, maintenance, accounting, etc.). These supplier businesses, in turn, made purchases and paid their employees, thus generating several rounds of economic spending and re-spending generated by the chemical industry.

Table 1.1 - U.S. Business of Chemistry Industry Snapshot, 2017

Jobs (in thousands)		Expenditures ($billion)	
Direct Jobs	529	Total Payroll	**$44.5**
Supplier Jobs	1,873	Benefits	**$13.6**
Expenditure-Induced Jobs	1,891	**Total Compensation**	**$58.1**
Total Jobs	**4,293**		
*Multiplier**	*7.1*	Value-Added	$237.5

*Each job in the chemical industry generates an additional 7.1 jobs in other sectors of the economy.

Data on indirect and payroll-induced jobs were calculated using the IMPLAN model.

Sources: Bureau of the Census, Bureau of Labor Statistics, Bureau of Economic Analysis, Internal Revenue Service, and American Chemistry Council analysis.

The impact of chemistry on the U.S. economy is much more extensive than standard output and job multipliers derived using input-output (I-O) analysis indicate. While the former only looks at the jobs directly related to the industry, the latter primarily focuses on supplier relationships rather than downstream customer industries or final end-uses. Looking downstream, the economy depends upon chemistry at four levels:

1. Actual production of chemicals;
2. Industries manufacturing products that purchase chemicals and use them to make raw materials or intermediate inputs for other industries;
3. Industries manufacturing consumer products and other final goods, which purchase chemicals directly or buy industrial parts and components based on chemistry; and
4. Wholesale, retail and service industries based on chemistry-derived products.

The robust network of relationships between the chemical manufacturing industry and the consumer is complex, but chemistry is key to a number of major consumer products, including apparel, appliances, furniture, home furnishings, light vehicles, and sporting goods, as well as agriculture and construction. Many of the products of the business of chemistry in themselves can be classified in some of these other industries. For example, pharmaceuticals and personal care products could very well be classified as industries manufacturing consumer products and other final goods, while agricultural chemicals could be classified as industries manufacturing industrial products used as intermediate inputs for other industries. Services are becoming the means by which chemistry is delivered to the ultimate consumer.

Almost every industry purchases some products and services of chemistry and, therefore, depends on the business of chemistry. Indeed, most manufactured goods are directly touched by chemistry. In addition to examining relationships among industries using the standard I-O analysis, we also examine industries which typically spend more than 5% of their material purchases on chemistry (a rough criterion for dependence).

Table 1.2 - Industries Dependent upon the U.S. Business of Chemistry, 2016

Industry	Employment (thousands)	Payroll ($billion)	Value-Added ($billion)
Business of Chemistry	**526**	**$42.9**	**$237.5**
Agriculture	1,219	45.2	173.4
Oil and Gas Extraction and Metal Mining	623	64.0	209.2
Water and Sewage Treatment	50	3.0	14.6
Textiles and Fabrics	113	5.2	11.4
Engineered Wood Products	78	3.8	9.7
Paper and Paper Products	367	24.5	59.2
Petroleum Products	113	12.7	139.3
Rubber and Plastic Products	714	37.9	84.1
Nonmetallic Mineral Products	410	23.6	55.6
Aluminum	57	3.8	11.7
Windows and Doors	63	3.1	6.3
Metal Coating	136	6.7	15.7
Industrial Machinery	114	9.8	17.0
Commercial and Service Industry Machinery	90	6.6	15.2
Ventilation and HVAC Equipment	131	7.5	21.9
Semiconductors and Electronic Components	362	41.2	46.3
Electrical Equipment and Components	323	22.1	46.7
Total – Intermediate Goods	**4,964**	**$320.7**	**$937.3**
Food, Beverage and Tobacco	1,853	89.4	281.4
Textile Mill Products	115	4.7	11.2
Apparel and Leather Products	148	6.2	9.6
Printing	439	21.4	37.7
Phmarmaceuticals	292	33.6	155.0
Book and Periodical Publishing and Software	145	17	72.9
Computers & Electronics	679	83.8	252.8
Household Appliances	63	3.9	10.6
Mobile homes	25	1.1	2.4
Light Vehicles and Parts	969	60.1	166.7
Aerospace	484	48.8	111.3
Ship and Boatbuilding	134	8.4	20.5
Furniture and Fixtures	393	17.5	30.3
Medical Equipment and Supplies	309	23.1	60.5
Other Miscellaneous Manufacturing	283	14.9	21.4
Total – Consumer and Other Final Products	**6,331**	**$433.6**	**$1,244.4**
Residential Building Contractors	752	41.4	101.3
Nonresidential Building Contractors	788	60.5	146.0
Specialty Trade and Heavy Contractors	5,372	317.9	578.8
Total – Construction	**6,912**	**$419.8**	**$826.1**

Table 1.2 - Industries Dependent upon the U.S. Business of Chemistry, 2016

Industry	Employment (thousands)	Payroll ($billion)	Value-Added ($billion)
Chemical Wholesalers	130	11.1	29.7
Druggist Goods Wholesalers	200	22.7	142.4
Farm Supplies	116	7.0	16.3
Paint Wholesalers	21	1.6	3.5
Total - Wholesale Distribution	**467**	**$42.4**	**$191.9**
Testing Labs	166	12.9	22.1
Specialized Design Services	140	9.6	14.0
Scientific R&D Centers	656	84.8	139.3
Photographic Services	52	1.6	3.4
Veterinary Services	374	14.6	20.9
Facilities Support Services	148	7.3	12.4
Document Preparation Services	47	1.7	3.1
Services to Buildings and Dwellings	2,090	61.4	88.8
Waste Management and Remediation Services	414	24.6	47.1
Health Care Services	15,600	860.6	1,283.3
Auto Repair	921	35.6	85.0
Personal and Laundry Services	1,470	40.6	95.9
Total – Services	**22,078**	**$1,155.3**	**$1,815.4**
Total – Dependent Industries	**40,752**	**$2,372**	**$5,015**
Percent of U.S. Totals	28.3%	29.8%	25.9%
Total U.S. – All Sectors	**143,861**	**$7,966**	**$19,391**

Notes. Total value-added of all sectors of the economy equals GDP.

Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, Census Bureau, and American Chemistry Council analysis.

2. WHAT IS THE BUSINESS OF CHEMISTRY?

The business of chemistry—applying science to support and enhance our quality of life—is one of the oldest American industries: the first U.S. chemical plant was established in 1635.[1] The chemical industry is a dynamic, forward-looking, innovative industry and a keystone of the economy.

The chemical industry is also an enabling and transforming business. U.S. companies engaged in the business of chemistry invest billions of dollars annually in research and development (R&D). These companies continue to be internationally competitive and create new processes and products to solve performance, safety and efficiency problems in a number of industries and arenas. The composition of the business of chemistry is ever-changing, with increasing diversification into high-technology fields such as pharmaceuticals, biotechnology, nanotechnology, and advanced materials that have applications in other industries. The U.S. business of chemistry is the world's second largest, accounting for over 12% of the world's total chemical production.

Table 2.1 - Business of Chemistry Summary, 2013-2017

	2013	2014	2015	2016	2017
			$billions		
Shipments	599.6	588.1	521.6	503.4	526.2
Capital Expenditures	22.5	29.4	29.5	26.4	28.7
Funds for R&D	11.8	13.0	12.8	12.2	12.1
Exports	140.7	139.5	128.3	121.0	129.8
Imports	100.1	102.9	95.1	93.1	97.1
Trade Balance	40.6	36.6	33.2	28.0	32.7
			2012 = 100		
Production Index	99.3	98.5	95.6	95.7	98.2
Price Index	99.7	99.8	93.2	90.0	92.7
Employment (thousands)	517	524	526	526	529
Average Hourly Wage – Production Workers	$20.17	$20.62	$21.04	$22.67	$23.47

Note: Data for chemicals, excluding pharmaceuticals; it is not comparable to the 2017 edition of this publication.

Sources: Bureau of the Census, Bureau of Labor Statistics, and American Chemistry Council.

The business of chemistry is the largest exporting sector in the United States, larger than aerospace products (and parts) and motor vehicles. Chemicals and related products account for more than ten cents out of every dollar of American exports. For more detailed trade information, see the U.S. Trade in the Business of Chemistry chapter.

Americans employed in the business of chemistry are among the most productive in the world. The increasingly complex nature of the business of chemistry requires new and more highly developed skills, better-trained, and educated workers. The need for more technology skills and the increasing productivity has resulted in companies in the business of chemistry paying wages that are typically greater than those paid by manufacturing as a whole. For more information on investment in knowledge and employment trends, see the *Investment in the Future: Knowledge* and *Investment in the Future: Capital* sections.

1 "A Timeline of Chemical Manufacturing." ICIS Chemical Business. May 2008. www.icis.com/resources/news/2008/05/12/9122818/a-timeline-of-chemical-manufacturing.

The business of chemistry is not easily captured by traditional economic nomenclature, such as the North American Industrial Classification System (NAICS) and the Standard Industrial Classification (SIC). The definitional foundations of both are based on the concept of related production activities. In contrast, the business of chemistry is largely market-driven. In addition to production activities, it is also important to consider marketing, distribution, intellectual property, and other capabilities that distinguish industry segments. Rather than statistical classifications, the industry is typically viewed as having five main segments: basic chemicals, specialty chemicals, agricultural chemicals, pharmaceuticals, and consumer products, each with its own structure, growth dynamics, markets, developments, and issues. However, the boundaries dividing these segments are not clearly defined, and some degree of overlapping exists. For example, some specialty products like architectural coatings and packaged adhesives could be considered consumer products; some pharmaceutical products are sold over the counter and marketed to consumers. Key characteristics for each segment are displayed in Table 2.2.

Furthermore, some convergence is occurring among segments, blurring the distinctions even further. For example, the next several decades will see the diffusion of biotechnology into more traditional (basic) chemistry businesses, particularly as bioscience grows in importance. Nanotechnology is used across segments, and the consumer market continues to broaden. Increasingly, the business of chemistry provides more knowledge-intensive solutions for human wants and needs.

Table 2.2 - Characteristics of the Business of Chemistry

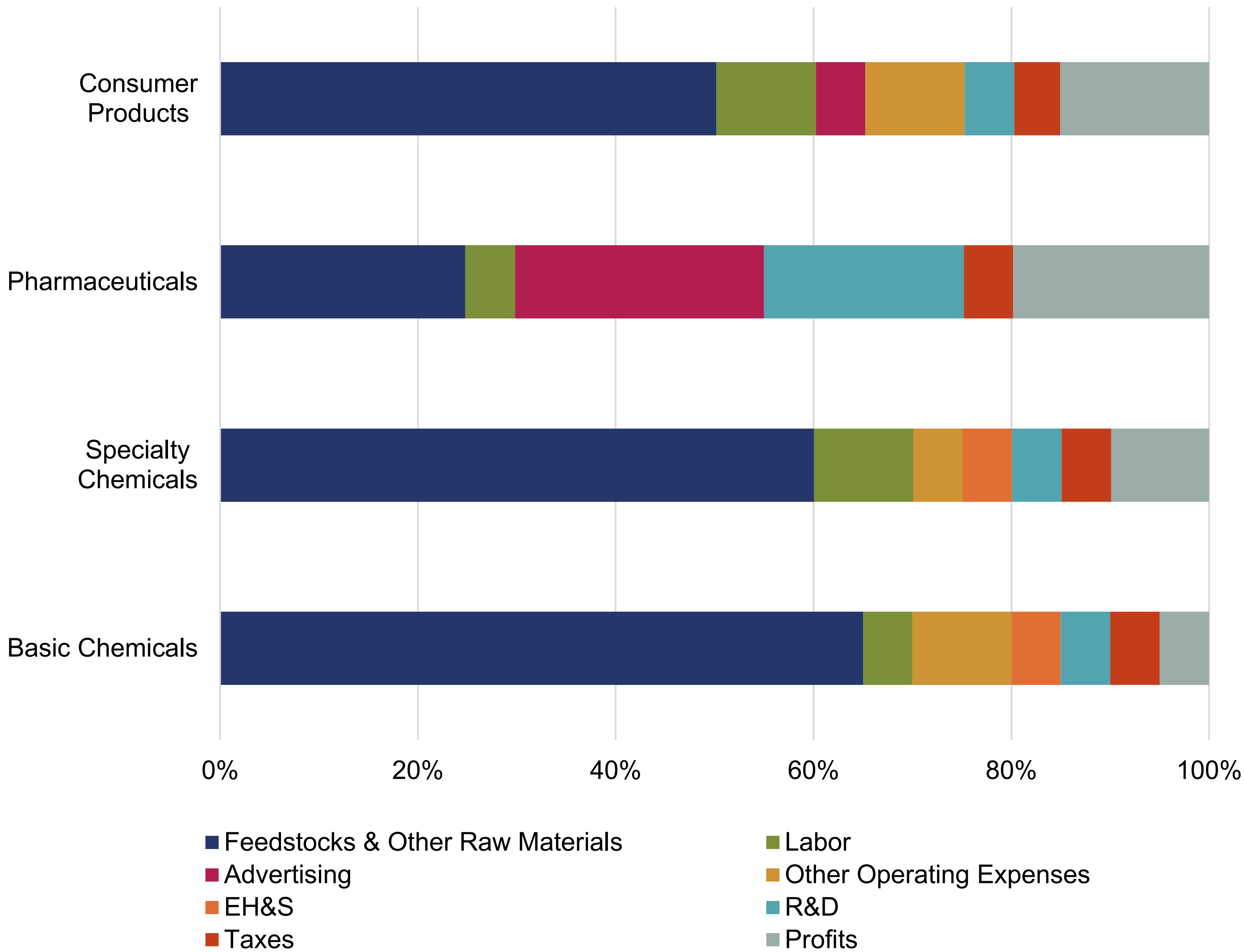
	Basic Chemicals	Specialties	Agricultural Chemicals	Pharma-ceuticals	Consumer Products
Product Price (per pound)*	<$0.80	>$1.75	$0.30-$1.50	>$20.00	>$2.00
Long-Term Growth Prospects (X GDP)	1.6	1.3	1.0	1.4	1.2
Economic Return on Capital Employed (10-Year Average)	7%	12%	5-15%	20%	15%
	As a Percent of Revenues				
Research and Development Spending	1-5%	2-8%	4-11%	33%	2-3%
Plant and Equipment Spending	5-10%	4-9%	5-8%	3-7%	3-6%
EH&S Spending	3-5%	2-4%	1-4%	1-2%	1-2%

*These figures represent typical ranges within chemical categories and are intended to illustrate the variations across categories.
Source: American Chemistry Council analysis.

Cost Structure

The typical cost structures over the business cycle differ between the major segments of the business of chemistry. Basic chemicals are dominated by costs for feedstock and materials: combined, they amount to more than 60% of total costs. On the other hand, pharmaceuticals and consumer products spend much more on advertising, research and development (R&D), and other sales, general, and administrative (SG&A) expenditures. The following figure presents typical cost structures over the business cycle for four of the five major segments of the business of chemistry. Given the disparate nature of agricultural chemicals, this segment is not broken out separately. The fertilizer business tends to reflect the cost dynamics of basic chemicals while the crop protection business more closely resembles pharmaceuticals and specialties.

Figure 2.1 - Typical Cost Structure in the Business of Chemistry by Segment



Production Indices

The Federal Reserve Board (FRB) provides some 295 industrial production index measures of output in the manufacturing, mining and electric/gas utilities industries. This detailed and integrated system of output provides details along market (demand-oriented) groups and industry (supply-oriented) groups, generally all four-digit NAICS industries as well as more detailed sub-industries. These are measures of real output—that is, production, activity (on a volume basis), and the effects of price changes are not included—relative to its level in a base year (in this case, 2012). Weighting factors are published for each of the component production indices to quantify the relative importance of each segment to overall chemical manufacturing. By using these weights, it is possible to calculate unpublished indices for certain industries, segments, or concepts (e.g., chemicals, excluding pharmaceuticals).

Table 2.3 - Business of Chemistry Industrial Production Indices

	2013	2014	2015	2016	2017
			2012=100		
Chemicals	**99.3**	**98.5**	**95.6**	**95.7**	**98.2**
Basic Chemicals	100.3	97.5	94.2	95.8	96.4
Specialty Chemicals	100.4	103.7	102.8	101.2	107.6
Agricultural Chemicals	116.1	108.1	94.6	96.5	116.4
Consumer Products	89.3	93.7	93.8	91.0	90.4
Pharmaceuticals	91.9	90.4	94.1	92.7	91.1
Chemicals + Pharmaceuticals	96.6	95.6	95.2	94.7	95.6

Note. These figures represent typical ranges within chemical categories and are intended to illustrate the variations across categories.
Source: American Chemistry Council analysis.

Price Indices

The Bureau of Labor Statistics (BLS) collects data on domestic prices for a wide variety of goods and services as provided by their producers. These are commonly referred to as the PPI, or producer price indices. Such measures include manufacturer rebates, incentives and surcharges. Prices are adjusted for quality and include intra-company transfers; sales and excise taxes are not included. The indices measure the net revenue to the seller relative to its level in a base year. To make these comparable to the above FRB production indices, ACC has rebased these to where 2012=100. The BLS also collects data and published indices on import and export prices. ACC includes these and rebases them to 2012 as well.

Table 2.4 - Business of Chemistry Producer Price Indices

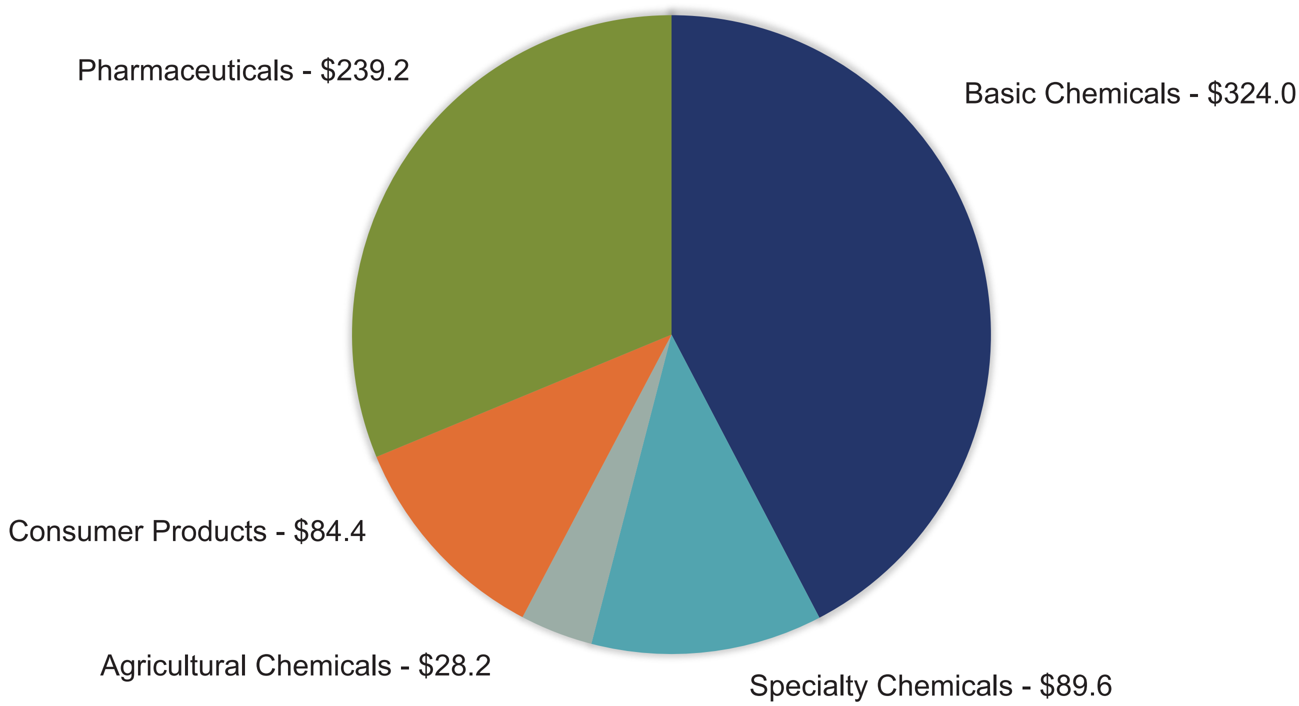
	2013	2014	2015	2016	2017
			2012=100		
Chemicals	**99.7**	**99.8**	**93.2**	**90.0**	**92.7**
Basic Chemicals	99.8	99.7	92.4	89.0	94.1
Specialty Chemicals	100.6	101.3	100.8	100.9	101.9
Agricultural Chemicals	96.6	94.9	93.2	85.6	83.6
Consumer Products	100.3	101.8	102.4	102.9	103.7
Pharmaceuticals	104.6	110.4	118.0	126.7	133.2
Chemicals + Pharmaceuticals	101.4	103.4	101.8	102.7	106.7

Note. These figures represent ranges within chemical categories and are intended to illustrate the variations across categories.
Source: American Chemistry Council analysis.

Shipment Value

In addition to the five major segments (basic chemicals, specialties, agricultural chemicals, pharmaceuticals, and consumer products), the business of chemistry—one of the largest manufacturing enterprises in the U.S.—consists of hundreds of sub-segments. Total volumes of chemicals produced in the U.S. amount to more than one billion tons. The value of this business is measured along the lines of the value of its shipments, as reported by the Bureau of the Census. Shipments measure the nominal value of products shipped from manufacturing establishments (or facilities); they are not adjusted for price changes. Readers should note that these are based upon non-seasonally adjusted data and, therefore, differ from data reported on a monthly basis.

Figure 2.2 - Business of Chemistry Shipments by Segment ($billion), 2017



Source: American Chemistry Council, Bureau of the Census.

Financial Performance

There are many ways to assess the financial health of an industry using metrics derived from financial statements on income, assets, and liabilities. The ratios are calculated on a company basis: that is, for statistical purposes each company is assigned to an industry group based on its largest business segment. As a result, the "company" data presented may include revenues from non-chemical business activities by companies classified as basic chemical companies. On the other hand, the chemical operations of companies not classified as chemical companies would not be included in the sample of companies assigned to other, non-chemical industries. One should note that these figures are not compatible with data presented elsewhere in this section on basic chemicals. Details on the financial performance (solvency and liquidity, profitability, cash flow, etc.), are provided in a spreadsheet of annual data, available for ACC members on MemberExchange. Contact ACC's Economics & Statistics Department for more information.

Table 2.5 - Chemicals: Select Measures of Financial Performance, 2017

Financial Ratio	
Quick Ratio	0.84
Sales/Current Assets Ratio	2.38
Debt Ratio (Total Debt to Total Assets)	0.64
Debt/Equity Ratio	1.75
Inventories as a % of Revenues	12.5%
Operating Margin	9.8%
Return on Equity	15.6%
Return on Net Assets	11.6%
Return on Fixed Capital	24.0%
Return on Working Capital	30.5%
Revenues/Employee	$840,000
Net Income/ Employee	$89,461

Sources: American Chemistry Council, based on Bureau of the Census data.

3. CHEMISTRY 101

In addition to the five market-driven business segments, there are two types of chemistry: organic and inorganic. Organic inputs, such as oil and natural gas, contain hydrocarbons, which form the backbone of final organic chemical outputs. Inorganic inputs are often compounds of two or more natural elements, and do not generally contain carbon as a principal element.

Very few chemicals use oil and natural gas directly as raw materials. Rather, they are first processed into natural gas liquids, such as ethane and propane, or into heavier liquids, such as naphtha and gas oil. In the first stage of processing, these raw materials are refined to produce primary outputs like benzene and ethylene. Primary outputs like these are the building blocks of the business of chemistry. In subsequent stages of processing, chemicals, such as chlorine, are added to the hydrocarbon backbones to give the compounds certain desired characteristics. The final output may, for example, be nylon or polyester fiber, plastic, a pharmaceutical product, or other products.

Basic Chemicals

Basic chemicals, also called commodity chemicals, are produced in large volumes to chemical composition specifications that are homogeneous in nature; that is, there is no product differentiation. Basic chemicals are typically incorporated into a manufactured product or used in processing. One way to think of this segment is that producers of these chemicals are selling molecules (lots of them). Examples of basic chemicals include inorganic chemicals, bulk petrochemicals, organic chemical intermediates, plastic resins, synthetic rubbers, manufactured fibers, dyes and pigments, and printing inks.

Basic chemicals are a mature business. Primary markets include other chemicals and chemical products; other manufactured goods (textile products, automobiles, appliances, furniture, etc.) where they are incorporated into the final product or used to aid in processing (pulp and paper, oil refining, aluminum processing, etc.); and some non-manufacturing industries. Prices are highly correlated with capacity utilization levels and feedstock (or raw material) costs, resulting in low profit margins and a high degree of cyclicality. In some cases, economic returns may be less than the cost of capital.

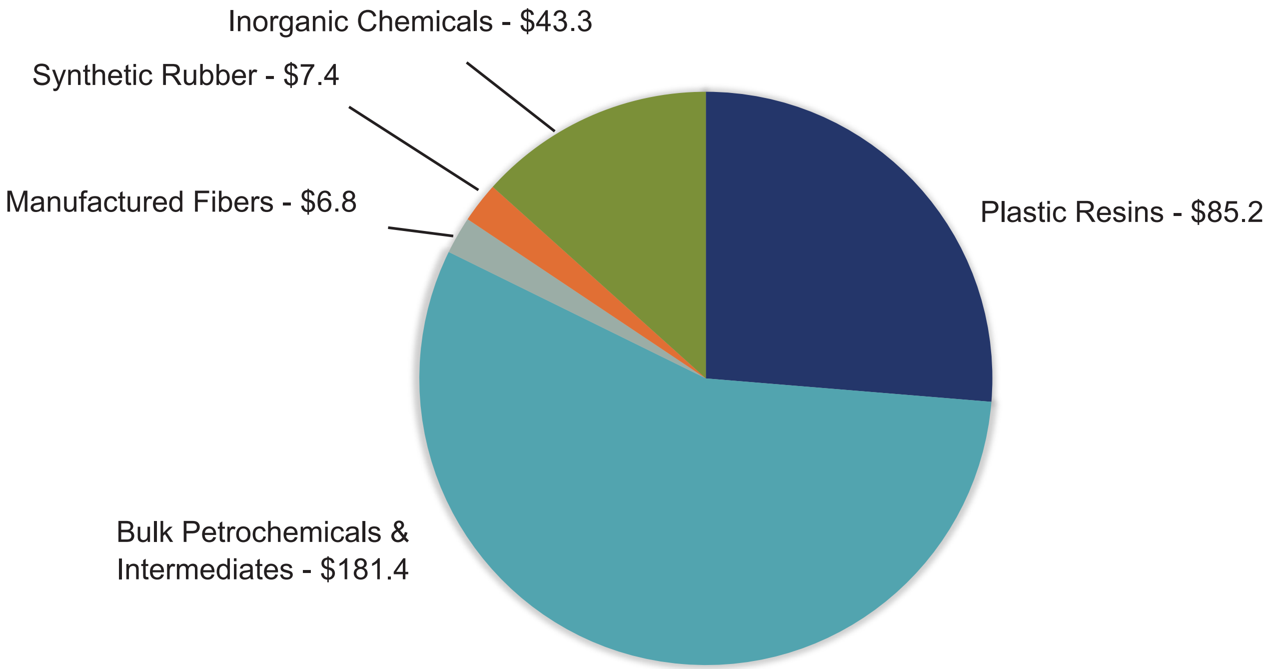
Basic chemicals production is capital intensive. In addition to high capital costs, production of basic chemicals is typically large in scale, with high energy requirements. These factors, coupled with potential environmental liabilities, create high barriers to entry in this market. Also important is the access to hydrocarbon feedstocks, or other raw materials. Plant size (or scale) also drives economics, as well as critical mass in product. Technology requirements are moderate and continuous in nature, with more importance on process technology than product technology.

An ethane cracker utilizing hydrocarbon feedstocks would typify many basic chemicals plant operations. A new natural gas-based ethane cracker could have an annual capacity of 1.5 million metric tons or more, with a price tag of well over $4 billion. These crackers need to be located close to the feedstock, which limits the geography where facilities could be located, as well as access to distribution networks.

Distribution of basic chemicals is largely by rail and water to a limited number of large-volume customers, mostly other manufacturers or farmers (fertilizers). For many basic chemicals, typical customer accounts may generate in excess of $1 million in annual sales. Currently, an important change in focus from products to customers is underway. There has been some consolidation in basic chemicals and joint ventures have also become an important strategic vehicle as companies look to share technologies and reduce costs. A focus

on core chemistry competencies has also become important and there have been de-mergers of companies into separate life science and basic industrial chemical entities. The chemical subsidiaries of oil companies, that can build upon their feedstock advantages, account for a large (and increasing) share of the total. Basic chemicals companies generally employ low-cost leadership strategies (through scale economies or proprietary process technology) and are often reluctant to relinquish market share, particularly when a large number of players exists. The following figure displays a breakdown of basic chemicals shipments by major type.

Figure 3.1 - Basic Chemicals Shipments ($billion), 2017



Inorganic Chemicals

Inorganic chemicals are generally derived from metal and non-metallic minerals such as salt, a simple compound formed from sodium (Na) and chlorine (Cl) that can be broken down by electrolysis to produce chlorine and caustic soda (sodium hydroxide). Other examples of inorganic chemicals include acids (nitric, phosphoric, sulfuric, etc.), aluminum sulfate, industrial gases (e.g., oxygen, nitrogen, argon, hydrogen), lime, soda ash (sodium carbonate), sodium bicarbonate, sodium chlorate, sodium sulfate, and sulfur, among others.

The oldest chemical segment (dating from the 1630s), inorganic chemicals serve both consumer and institutional markets. For example, chlorine, a common inorganic chemical, is used by the paper industry to bleach paper pulp, and consumers may appreciate it as a means of keeping their clothes white and their drinking water safe. Other industries served by inorganic chemicals include oil refining, steel, and other chemical and manufacturing industries (caustic soda is used extensively in manufacturing processes and in the production of soaps and detergents). Also referred to as “air separation gases,” industrial gases serve major markets such steel, other chemical producers, electronics, and health care.

Key economic factors of the industry include very mature demand, high cyclicality and low margins, environmental pressures, and increased consolidation. For industrial gases, in particular, key economic factors include high capital intensity, globalization, high concentration and additional consolidation, increasing service orientation, and impact of innovations in membrane separation.

Bulk Petrochemicals and Organic Intermediates

Bulk petrochemicals, also called primary petrochemicals, are monomers derived from hydrocarbon feedstocks (mostly petroleum and natural gas; small volumes are derived from coal). A distinguishing feature is the carbon molecule. These basic building blocks are used as the starting point for tens of thousands of chemical products. The foundation for a plethora of petrochemical derivatives, bulk petrochemicals include aromatics (which contain a six-carbon ring structure), olefins (short "chain" molecules of two, three or four carbons in length), and methanol (an alcohol). More than 90% of all organic chemistry is derived from seven petrochemicals: benzene, toluene, and xylene (aromatics); ethylene, propylene, and butadiene (olefins); and methanol.

Bulk petrochemicals are then chemically converted, or incorporated with other chemicals (e.g., chlorine, nitrogen or oxygen), into organic intermediates (or petrochemical intermediates). Sometimes, multiple steps are required to produce an intermediate of the desired chemical composition. Examples of bulk petrochemicals include acetic anhydride, acetone, adipic acid, cyclohexane, ethylene oxide, ethylene dichloride, ethylbenzene, cumene, formaldehyde, propylene oxide, phenol, and styrene, among others. These products, in turn, are used in downstream derivatives such as plastic resins, synthetic rubbers, manufactured fibers, surfactants, dyes and pigments, and inks, among others.

Ultimately, over 70% of U.S. petrochemicals end up as plastic resins, synthetic rubbers or manufactured fibers.

Bulk petrochemicals and organic intermediates primarily serve other chemical manufacturers and ultimately automotive, building and construction, consumer/institutional, electrical/electronic, furniture/furnishing, and packaging markets. Key economic factors include maturing demand and technology, volatile margins, environmental pressures, consolidation, globalization, overcapacity, consolidation, the increasing dominance of affiliates of oil companies, and the growing presence of Middle Eastern producers in global markets.

Petrochemical Derivatives and Other Industrial Chemicals

Organic chemicals and other chemical products are derived from bulk petrochemicals, organic intermediates, and other sources of carbon molecules. In many cases, these chemicals are compounded with inorganic chemicals and other materials. These products, in turn, are used in "downstream" derivatives such as plastic resins, synthetic rubbers, manufactured fibers, surfactants, dyes and pigments, and inks. Other products include turpentine and other wood chemicals, carbon black, explosives and other miscellaneous chemical products. Plastic resins are by far the largest segment.

Plastic resins are synthetic, long-chain compounds derived from one or more petrochemical monomers (ethylene, vinyl chloride, styrene, propylene, etc.). They offer excellent molding, mechanical, chemical resistance, and other properties. During the past several decades, the plastic resins industry has achieved remarkable growth, replacing many traditional materials such as metals, glass, and wood in packaging, automotive, building and construction, electronics, and other end-use markets. Plastic resins include commodity thermoplastics, thermosets, engineering resins, and thermoplastic elastomers.

Commodity thermoplastics are polymers that are softened by heat and hardened by cooling in their final state as a finished product. These resins can be resoftened to their original condition by heat, allowing them to be recycled. Examples of commodity thermoplastics include acrylonitrile-butadiene-styrene (ABS), polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). (Some thermoplastics are directly polymerized from bulk petrochemicals.) Major markets for commodity thermoplastics include packaging, building and construction, consumer/institutional, electrical/electronic, and furniture/furnishing. End-use applications include automotive trim and parts, appliance parts, grocery bags, wrap, bottles, drums and containers, toys, pipe, siding, fishing line, carpeting, wire and cable,

medical disposables, egg cartons, insulation, and various other applications. Key economic factors include maturing demand, flat margins, diffusion of metallocene technology, environmental pressures, restructuring, shift of customer industries overseas, overcapacity, and consolidation.

Thermosets are polymers that, in their final state as a finished product, cannot be resoftened by heat (and, thus, cannot be recycled). Examples include epoxy, melamine, phenolic, polyester, polyurethane, and urea resins. Major markets for thermosets include building and construction, furniture/furnishing, appliances, transportation, adhesives, electrical/electronic, ink, and coatings. Thermosets are the oldest plastic resins and are used in end-use applications such as laminates, wiring devices, plywood and other structural panels, carpet, refrigerator insulation, buttons and knobs, flooring, panels, tanks, boat hulls, and shower-stalls. Key economic factors include declining and maturing demand, health of housing and construction activity, environmental pressures, consolidation, shift of customer industries overseas, and increasing scale economies.

Engineering plastics are thermoplastic polymers that have high-performance mechanical, thermal, electrical and chemical properties. Examples include acetal, fluoropolymer, polycarbonate, polyphenylene sulfide, and other resins. Major markets for engineering plastics include automotive, electrical/electronic, and consumer. These resins are often used to replace metals in applications such as valves, faucets, zippers, wire and cable jacketing, non-stick coatings, microwave cookware, appliance and electronics housings, hair dryers, bearings, gears, and myriad other products. Key economic factors include continued supplanting of competing materials (expanding applications), maturing demand, price pressures, globalization, and consolidation.

Figure 3.2 - Plastic Resins Summary, 2017

Manufactured fibers, also known as synthetic fibers, are synthetic cellulosic and polymeric textile fibers that offer favorable, engineered attributes vis-à-vis natural fibers. Cellulosic fibers, such as acetate and rayon, are made from raw materials from plants or trees, such as wood pulp. Meanwhile, polymeric fibers such as acrylic, nylon, polyester, polyolefin, and others are derived from petrochemicals. Manufactured fibers are used in apparel, home furnishing, automotive, construction and some industrial applications. Key economic factors include intense overseas competition, mature demand, loss of apparel markets overseas, and low margins.

Synthetic rubbers are manufactured materials that exhibit a high degree of flexibility. Synthetic rubbers require vulcanization, a process that cross-links the elastomer molecules. Examples include butyl rubber, ethylene-propylene-diene monomer (EPDM) terpolymers, neoprene, nitrile rubber, styrene-butadiene rubber (SBR), and specialty elastomers. These materials are primarily used in the automotive sector and also used in the construction and consumer product manufacturing industries. Major uses are automotive bumpers and fascias. One particularly dynamic segment is thermoplastic elastomers, complex urethane-based synthetic rubbers that can be processed using injection molding and other processes used for thermoplastic resins. Key economic factors include continued supplanting of competing materials, pressures from key customers, globalization and consolidation, price pressures from OEMs, product innovations leading to longer-lasting tires, new grades, mature demand, loss of some end-use markets overseas (e.g., shoes), and low margins.

Colorants are used to impart color into other materials. These organic and inorganic chemicals include dyes (typically organic compounds and liquid in form) and pigments (generally inorganic compounds and in powder form). This segment serves the textile, paper, and plastic products markets. Key economic factors include continued mature demand, fashion trends, very low profit margins in dyes, price pressures in pigments, loss of textile markets overseas, competition from Indian and other Asian producers, environmental pressures, restructuring, and consolidation.

Inks are colored, liquid dispersions of dyes (or pigments) that are suspended in a liquid (referred to as a vehicle) and used to impart text and graphic designs onto plastics, paper, textiles, metals, and glass. This business serves the packaging, greeting card, photocopying, newspaper, book and other publishing/printing industries. Key economic factors include impact of electronic media, environmental pressures (e.g., water-soluble products), globalization, and consolidation.

Other industrial chemicals include turpentine and other wood chemicals, carbon black and explosives, as well as some other miscellaneous industrial chemical products. Key economic factors vary from segment to segment but generally include increased consolidation, declining prices, environmental pressures, and maturing demand.

The American Chemistry Council's Plastics Industry Producers Statistics Group (PIPS) provides relevant, timely, comprehensive and extensive business statistics on the plastic resins industry. Available for subscription on an annual basis, these statistical reports contain production and detailed sales by end use information, and capacity and inventory measures for major plastic resins. With key players and nearly the full industry in North America participating, these surveys have long been considered an authoritative, comprehensive and reliable source of information on the plastic resin industry.

Resin producers and other industry professionals use ACC's PIPS data for making a wide variety of critical business decisions. The data represents an economic indicator used by plastics processing companies, machinery manufacturers, lobbyists and other industry segments to access the business climate. Industry consultants, investment banks and securities firms rely on ACC's PIPS reports for their ongoing market research and analysis (Statistics on the Plastic Resins Industry. American Chemistry Council. plastics.americanchemistry.com/Jobs/EconomicStatistics/Plastics-Statistics/.)

Specialty Chemicals

Specialty chemicals (also called "performance chemicals" or "specialties") are differentiated—and often technologically advanced—products. They are manufactured in lower volumes than basic chemicals and are used for a specific purpose (e.g., as a functional ingredient or as processing aids in the manufacture of a diverse range of products). Specialties enable customers to reduce overall systems costs, enhance product performance and optimize manufacturing processing to increase yield through custom solutions. That is, they are sold for what they do, rather than for what they contain. Examples of specialty chemicals include adhesives and sealants, catalysts, coatings, electronic chemicals, institutional and industrial cleaners, plastic additives, water management chemicals, and other specialties. One feature that distinguishes specialties from basic chemicals is that specialties typically have a large customer-servicing or technical-servicing component.

Long-term growth prospects for specialties are generally more dynamic than basic chemicals. Many specialty markets exist, including manufacturing industries (automobiles, consumer products, electronics, food, foundries, lubricants, paper, plastic products, rubber products, etc.) and non-manufacturing industries such as oil recovery, construction, and electric utilities. More so than other segments, the specialty chemicals segment tends to focus along markets, many of which are maturing and becoming increasingly international. Raw materials for specialty chemicals are derived from petrochemical intermediates and other basic industrial chemicals, which are then processed into higher value-added products. Specialty chemical prices tend to be set by "value-in-use," as opposed to by cost, and historically their earnings have not been impacted as much by demand pressures as other chemical segments. In general, specialty chemicals represent a small portion of a customer's total cost, but are essential to the productivity and performance of the product. That is, the economics are driven by the value to the customer; this raises "switching costs" and offsets the bargaining power of customers. Critical mass in end-markets is also important for specialty chemicals. Traditionally, specialties have higher profit margins (and returns on equity) than basic industrial chemicals and a much lower degree of cyclicality. Earnings, on the other hand, have been less volatile. A rough rule of thumb is that most specialties are priced at more than $1.25 per pound.

Specialty chemical products are higher value-added because they cannot easily be duplicated by other producers or are shielded from competition by patents, resulting in high barriers to entry. In this market, strong technical servicing, marketing, and distribution competencies are a must, as strong customer relationships are paramount. Indeed, the final price of a specialty chemical features a very high service component. Innovation is critical and specialty chemical companies typically spend 4-8% of their revenues on research and development (R&D); these innovations are growth drivers for most companies.

Though capital needs are less important and more flexible with specialty chemicals than they are with basic chemicals, they can still be relatively high. Companies typically spend 4-9% of revenues for new plant and equipment (P&E). While dedicated and continuous operations are also typical in specialties (although at a lower scale), there are also a large number of plants that are general-purpose synthesis operations (with equipment for specific unit operations such as distillation, crystallization, filtration, etc.) or formulating plants. By definition, most specialties are niche businesses and, beyond a certain size, scale does not matter.

Specialty chemical companies are generally fragmented along specialty market lines. Customers, mostly other manufacturers and some non-manufacturing operations, generally purchase relatively low volumes. In some specialty markets, typical customer accounts generate less than $50,000 in sales. Sole-source contracts (e.g., partnership agreements) are also a factor. Consolidation and globalization are occurring, although acquisitions tend to be smaller than in basic chemicals. Motivation includes enhancing leverage from existing platforms, investing in segments that have higher growth potential, cost synergies, or filling a void in product, market, technology or geographic gaps. Alliances to provide scale and scope are becoming important.

External factors influence the specialties industry as well. The growing presence of e-commerce has had a large impact on specialties because it allows smaller firms to have greater customer reach. Government regulation is high, largely for environmental, health and safety concerns (some segments face environmental

pressures, such as “green” products and processes). The Environmental Protection Agency (EPA) is the leading regulator, although the Food and Drug Administration (FDA) the more relevant regulator in some specialty markets such as cosmetics and food additives.

The following further defines specialty chemicals. For each of the main specialty chemical segments, a brief definition, an estimate of market size, key characteristics (economic, manufacturing, etc.), growth dynamics, developments and issues are provided.

Adhesives and Sealants
Adhesives are used to bond two surfaces together, while sealants are used to fill a gap between two objects. Included in this segment are epoxy, hot melt, glues, rubber and other adhesives as well as caulk, joint and other sealing compounds. The adhesives and sealants business is fragmented, serving major markets such as automotive, building and construction, nonwovens, office supplies, and packaging. Pricing is largely driven by raw material costs. Key economic factors include continued supplanting of mechanical fasteners by adhesives, coupled with increasing demand as durable goods shift from metals to greater use of plastics, thus necessitating more adhesives. In addition, environmental pressures (e.g. sustainable products and processes such as water-based adhesives), increasing global competition, the shifting of end-use customer industries overseas, and industry consolidation are occurring.

Catalysts
Catalysts are specialty chemicals that affect the speed of a chemical reaction without changing chemically, or being consumed. This business serves major markets such as oil refining, chemical processing, and automotive emission controls. Key economic factors include environmental regulations for removal of nitrous oxide and other pollutants, declining quality of crude oils used in refining, and an increased number of light vehicles.

Coatings
Coatings are materials applied to surfaces to protect and/or decorate. Included are alkyd, enamel, latex, oil-based, and powder; other coatings used in architectural, automotive and original equipment manufacturer (OEM) applications; and stains, varnishes, lacquers, removers, and thinners. It is a highly fragmented business serving major markets such as building and construction, OEM and other general industrial, packaging, and transportation. A large “do-it-yourself” market exists within architectural coatings. Pricing is largely driven by raw material costs, especially titanium dioxide, which is widely used in the coatings industry. Key economic factors include environmental pressures (e.g., demand for “green” products and processes such as electro-deposition, water-based coatings, etc.), the emergence of large mass retailers, globalization, and industry consolidation. Branding and distribution play important roles in this business.

Cosmetic Additives

Cosmetic additives are functional chemicals used to impart special properties (such as improved performance) in personal care products such as cosmetics, deodorants, perfume, skin care, sun care, and toiletries. Included are such chemical products as antimicrobials, antiperspirant and deodorant salts, emollients, fixative polymers, hair polymers, thickening agents, and UV stabilizers, among others. In addition to these additives, the consumer products industry also uses fragrances, bulk surfactants, and other chemicals. Key economic factors include environmental pressures (e.g., sustainable products, organics, and product safety), globalization, consolidation, product quality and performance, and maturing growth.

Electronic Chemicals
Electronic chemicals are essential in the manufacture of semiconductors, printed circuit boards and other microelectronic devices. Among them are cleaners, developers, dopants, encapsulants, etchants, photoresists, specialty polymers, plating solutions, and strippers. This business serves major markets such as computers, telecommunications equipment, automotive, and medical devices. Long-term growth prospects are driven by the increasing proliferation of electronics in contemporary life. Key economic factors include increasingly

global customers, high technological barriers to entry, device miniaturization, and shortening product life cycles. Service innovation plays a very large role in this business, as does recycling and other environmental considerations.

Fine Chemicals

Fine chemicals are undifferentiated intermediate, medicinal and aroma chemicals that are produced in low volumes—but with very high purity standards—for a small number of customers. This business serves major markets such as pharmaceuticals, crop protection, dyes, flavors and fragrances, food, and electronics. (Fine chemicals used in the latter three categories are included in relevant specialty segment.) Key economic factors include customer consolidation and price pressures, low-cost competition (particularly from Asian producers), increased outsourcing of fine chemical needs by pharmaceutical companies, demand from pharmaceutical and crop protection offsetting soft demand in dyes. Some companies have responded by controlling costs, moving to low-cost regions, and shifting to higher-growth and higher-margin products.

Flavors and Fragrances

These natural and synthetic additives are used to impart flavor and fragrance in finished food and personal care products. Included are aroma chemicals, compounded flavors, compounded fragrances, fixatives, essential oils and other natural extracts, and other odoriferous substances. This business serves major markets such as food and beverage, cosmetics, toiletries and other personal care products. Chemicals in this segment are generally used in other specialty chemical segments such as cosmetic additives and food additives. Key economic factors include environmental pressures (e.g. sustainable products, organics, and product safety), globalization, consolidation, product quality and performance, and maturing growth. It's a fairly research-intensive business. New product introduction is demanded by customers who are continually repositioning their products and is essential to maintaining growth and high margins.

Food Additives

Food additives are used to impart flavor and/or color and other properties (e.g., nutrient value, texture) in finished food products, as well as facilitate food and beverage processing. Included are acidulants (e.g., citric acid), antimicrobials, antioxidants, emulsifiers, enzymes, flavor enhancers, leavening agents, stabilizers and thickeners, artificial sweeteners, and fat replacers, among others. Within the food and beverage industry, this segment serves markets such as baked goods, confections, frozen foods, dairy products, soft drinks and beer, and other food and beverage processing. Key economic factors include environmental pressures (e.g., from "green" products, organics, and product safety), globalization, consolidation, product quality/performance, and maturing growth. The emergence of "nutraceuticals" (food-derived products that provide additional health benefits on top of those innate to the food) will play a growing role in this business.

Functional Fuel and Lubricant Additives

These functional chemicals are added to lubricating oils to impart special properties and to enhance combustion and/or reduce emissions of pollutants. Included are antiknock additives, antioxidants, antiwear additives, corrosion inhibitors, defoamers, deicers, deposit control modifiers, detergents, viscosity modifiers, and other additives. Key economic factors include maturing markets, overcapacity, customer consolidation, increased performance demands, shorter product cycles, and industry consolidation and restructuring. There is a large aftermarket for this segment, and branding can be important.

Institutional and Industrial Cleaners

As the name implies, institutional and industrial cleaners are used to clean and sanitize surfaces, equipment and other applications in institutional and industrial settings, such as food and beverage processing plants, restaurants, schools, hospitals, lodging, and laundries. Included are general-purpose cleaners, alkaline cleaners, floor waxes and polishes, strippers, dishwashing detergents, metal and other acid-type cleaners, soaps, scourers, disinfectants, solvents, hand cleaners, and other janitorial supplies. This business serves major markets such as food service, hospitality, health care, educational institutions, and food processing. Key economic factors include environmental pressures (e.g. sustainable products and

food safety), globalization, consolidation, product quality/performance and reliability, and maturing growth. Other external factors, such as travel and tourism expenditures are important, as is dining outside the home. A large number of players exist, and regional fragmentation is the norm.

Oilfield Chemicals

These functional chemicals—which are used to enhance oil recovery and production—include a variety of acids, biocides, corrosion inhibitors, defoamers, dispersants, emulsions, polymers, surfactants, thickeners, viscosifiers, and other products used in cementing, well stimulation drilling, production, work-over and completion, and enhanced recovery. Key economic factors include drilling activity, globalization of customers, and increased performance demands. The recent increase in domestic chemical production, due in large part to shale gas, has stimulated the need for oilfield chemicals.

Paper Additives

Paper additives are functional chemicals used to facilitate paper manufacture or to enhance the properties of the final paper product. Examples include biocides, coagulants, defoamers, dispersants, flocculants, lubricants, sizing agents, and wet-strength agents, among others. In addition to these additives, the paper industry consumes large quantities of basic chemicals such as chlorine, caustic soda, and titanium dioxide. Key economic factors include maturing markets, customer consolidation, recycling and other environmental regulations, raw material availability, and increased performance demands. The rise of electronic communications has decreased the market for paper in some industries, particularly in the U.S., although other parts of the world are seeing an increased demand for paper and paper products.

Plastics Additives

These functional chemicals are added to plastic resin to aid or facilitate in processing or to enhance, extend or modify the final properties of plastic products. Included are antioxidants, antistatic agents, blowing agents, colorants, flame retardants, heat and other stabilizers, lubricants, plasticizers, reinforcing agents, and UV absorbers, among others. This business, by way of plastics processors, ultimately serves major markets such as light vehicles, building and construction, electronics, and consumer products. Key economic factors include maturing plastics markets in the U.S., faster growth overseas, increased performance demands in plastics, and industry/customer consolidation. As with other specialties, the increased manufacturing activity in the U.S. due to shale gas production is triggering growth in this segment.

Plastics Compounding

Plastics compounding is the physical mixing of resins with performance-enhancing additives (see above) to produce a compounded (or formulated) plastic mixture that is preferable to the base resin(s) alone (e.g., less expensive, has more favorable physical or aesthetic properties). The compounded resin product is marketed to plastic processors that manufacture a wide variety of plastic products for construction, automotive, and other applications. Plastic (or polymer) compounding is a significant market for captive resin producers, independent toll/custom compounders, and plastic processors. It serves major markets such as the plastic processing industry and ultimately light vehicles, building and construction, electronics, and consumer products, among others. Key economic factors include maturing plastics markets in the United States, faster growth overseas, increased performance demands, and industry/customer consolidation.

Rubber Processing Chemicals

These functional chemicals are used to facilitate processing or to improve the properties of the final rubber product. They include accelerators, activators, anti-ozonants, antioxidants, stabilizers, and vulcanizing agents, among others. Key economic factors include maturing markets, customer consolidation, recycling and environmental regulations, and increased performance demands. In addition to these additives, the tire and rubber products industry consumes large quantities of synthetic rubbers and of basic chemicals such as chlorine, caustic soda, and titanium dioxide.

Water Management Chemicals

Formulated and proprietary chemicals are used in the treatment of cooling and boiler water to prevent corrosion and the build-up of scale and also to prevent disease from drinking water. Included are biocides,

coagulants, defoamers, flocculants, scale inhibitors, and corrosion inhibitors, among others. These specialties are also used in process water and wastewater treatment. This business serves major markets such as paper mills, chemical plants, oil refineries, and electric utilities. Key economic factors include consolidation and the rising bargaining power that customers have as they consolidate, declining real prices, the increased popularity of sole-source contracts and partnership agreements, modest account turnover, and maturing demand (largely tied to new plant construction). Additional drivers include economic development outside North America, environmental regulations and end-use customers' desire to reduce waste.

Other Specialties

A number of other diverse—and overlapping—specialty chemical segments also exist, including construction chemicals, foundry chemicals, imaging chemicals, metal plating and finishing chemicals, mining chemicals, paint additives, research chemicals, and textile specialties, among others. Some functional chemical products such as antioxidants, biocides, enzymes, flame-retardants, ion exchange resins, thickeners, and UV absorbers are also included. Growth prospects vary among segments, as do key economic factors, which generally include increased consolidation, declining prices, environmental pressures, and maturing demand.

Agricultural Chemicals

Although closely related to basic chemicals and specialties, a distinguishing feature of agricultural chemicals is that one end-use customer industry -- farming -- clearly dominates demand patterns. The business consists of two major segments: fertilizers and crop protection; and there are both commodity and specialty segments within this business. In addition to farming, a few other businesses, such as construction and utilities, also use agricultural chemicals, as do several institutional segments. It is likely that some undercounting occurs in this business segment; also, the value of seeds and traits based on biotechnology are not included in crop protection.

Fertilizers

Fertilizers are various combinations of three basic elements (nitrogen, phosphorous and potassium) that are added to soil to replace or supplement essential nutrients to promote plant (and especially crop) growth. Phosphorous and potassium are found in phosphate rock and potash, respectively. Fertilizers primarily serve the farm sector. Pricing is largely driven by raw material costs and key economic factors include increasing overseas demand, a high degree of seasonality, volatility in farm incomes, and potentially reduced demand arising from genetically modified crops. With the rise in natural gas resources, nitrogenous fertilizers have experienced renewed competitiveness in recent years.

Crop Protection

Crop protection products include fungicides, herbicides, insecticides, miticides, and pesticides that help control weeds, pests, and diseases, as well as disinfectants, rodenticides, and other products used to control germs. The farm sector is the primary end-use market, although household, hospital, other institutional, electric utilities, telecommunications, and industrial applications are also important. Key economic factors include growing population and the need to increase agricultural productivity, sustainable development, high regulatory barriers, high costs for product development, cost cutting, globalization, and consolidation.

The business is affected by the increased use of GMOs (genetically modified organisms) and other biotechnology innovations. The use of GM crops has increased rapidly over the past two decades; according to the USDA, “in 2012, 88 percent of the corn, 94 percent of the cotton, and 93 percent of the soybeans planted in the U.S. were varieties produced through genetic engineering.” Although agricultural biotechnology offers promise for improving crops and increasing yields and potentially increasing food crop production on existing farmland—all factors which could reduce the need for crop protection products—the crop protection industry has grown in recent years.

Pharmaceuticals

The pharmaceuticals business includes prescription and over-the-counter drugs and vitamins; in vitro (and other) diagnostics; bacterial and viral vaccines; toxoid vaccines; biological products (e.g., serums, plasmas); and other pharmaceutical preparations for both human and veterinary use. This segment also includes biotechnology, a technology platform that cuts across pharmaceuticals and diagnostics with applications in crop seeds, traits and value-added grains; and enzymes, among others.

The pharmaceutical business primarily serves the health care sector (hospitals, physicians and other health care providers, testing laboratories, pharmacies and other retailers, and some service sectors), although household use is also important. Key economic factors include high regulatory barriers, high costs for new drug development, growing R&D funding requirements, the number of new products in the "pipeline," globalization, consolidation, outsourcing of fine chemical operations, intellectual property issues, bargaining power by health care customers, rapid introduction of new product (and potential for "flops"), shorter product life cycles, patent expirations and the role of generics, other low-cost competition, consolidation trends among customers, stocking/de-stocking cycles, cost-cutting, and the impact of biotechnology. There is increasing pressure to introduce new pharmaceutical products faster, cheaper, and in greater quantity. Competition from overseas producers, as well as fewer products in development, has caused some softness in shipment activity. This comes at a time when patent expirations are rising, resulting in pricing pressures associated with an increased market share by generic drugs. Furthermore, low-cost suppliers from India and China are playing an increasingly larger role in the market.

Pharmaceutical prices are often based on cost-effectiveness and value-in-use considerations vis-à-vis other alternatives. Patent and other intellectual property protection is very important, and development costs are high, which influence the economics of the business. As a result, pharmaceuticals have typically enjoyed much higher profit margins than basic chemicals. Competition is largely based on innovation, product development and differentiation, geographical coverage, price, and customer service.

Marketing and channel management competencies are important and rising, as is advertising and branding. Sustainable product differentiation and intellectual property are significant competitive factors. To maximize revenues, it is critical to have strong distribution capabilities in every major region of the world. The rising presence of online pharmacies and business-to-business (B2B) sites is impacting supply chain dynamics. In addition, international competition is rising, as is increasing penetration by generics as patents expire.

Technology advantages are extremely important in pharmaceuticals, and there is increasing convergence between biology and chemistry as biotechnology innovations further diffuse. As a result, R&D spending in pharmaceuticals as a percent of sales is the highest among all industries. Pharmaceuticals have a high value-added component because they cannot easily be duplicated by other producers or are shielded from competition by patents. Capital needs are moderately high, but flexible. Plants are usually batch-oriented synthesis or formulating operations in which quality control and a clean environment are essential. Beyond a certain size, scale does not matter.

Government regulation (primarily the FDA) is extremely high, primarily in the area of product composition and its inherent safety. Indeed, it is a very high barrier to entry, as product approval can be a quite lengthy process.

Strategic acquisitions, alliances and research agreements, as well as investment in internal capabilities are important in pharmaceuticals. Some consolidation is occurring and industry concentration is relatively high. Optimal size in both research and marketing terms has become important, and critical mass has become paramount in a number of these activities. The biotechnology segment includes many start-up ventures and initial public offerings (IPOs).

Consumer Products

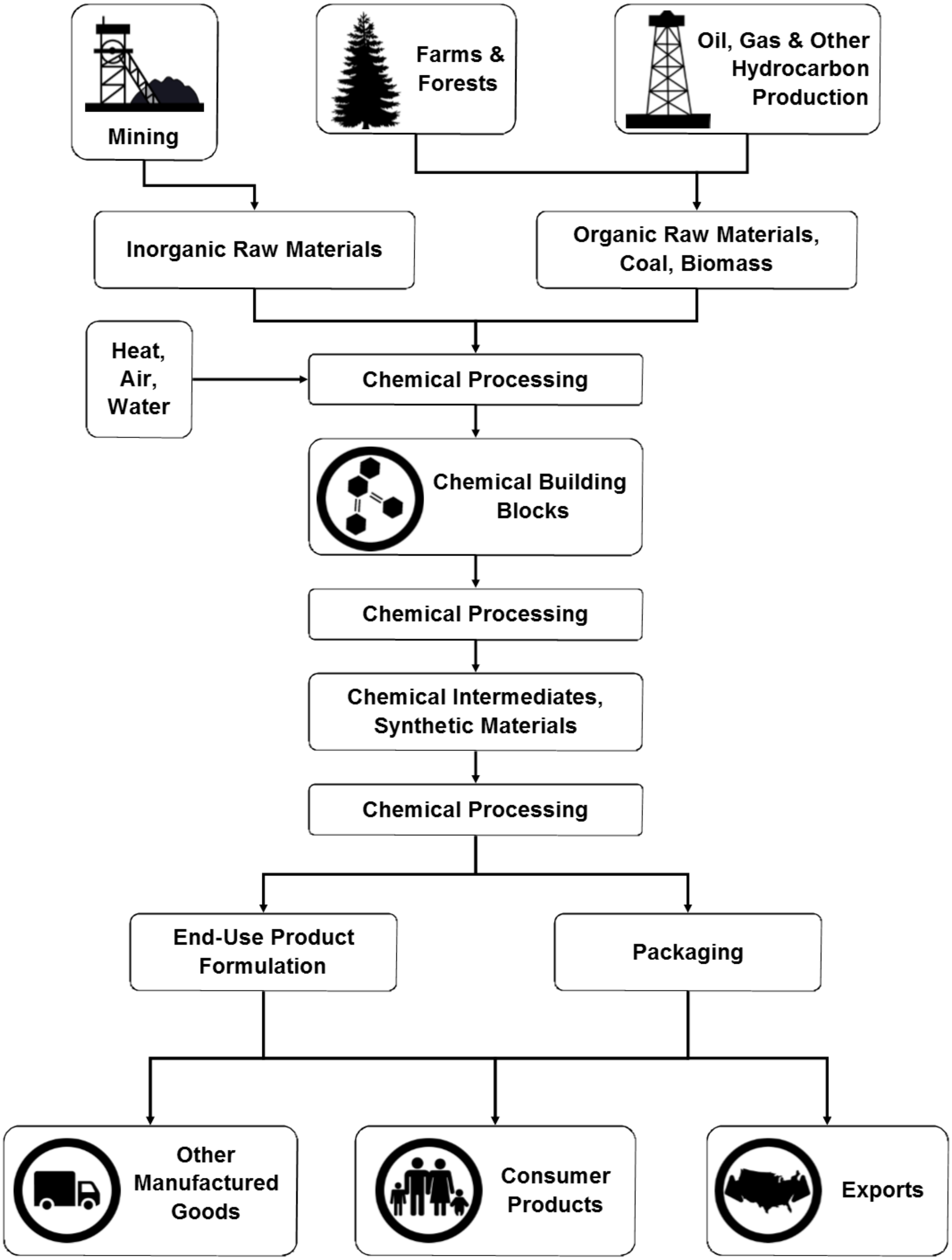
The consumer products business is one of the oldest segments of the business of chemistry, dating back thousands of years (ancient Babylonians were the first recorded makers of soap). Included are soaps; detergents; bleaches; laundry aids; toothpaste and other oral hygiene products; shampoos, conditioners and other hair care products; skin care products; cosmetics; deodorants; perfume and cologne, among other personal care products. A feature that distinguishes consumer products from the other segments is that they are packaged; many companies in this packaged goods segment prefer to be viewed as “household products” companies.

Markets are segmented along distribution channels, price points, and consumer demographic lines. Points-of-sale (POS) include supermarkets, department stores, big-box stores, and specialty stores, among others. The economics of the consumer sector are largely driven by supply chain costs, although differentiation can engender widely different price points for similar products marketed to different consumer groups.
Branding aids in maintaining profit margins that are higher than that for basic chemicals. Brand loyalty is extremely important, as is management of distribution channels. In many segments, the fight for shelf space is paramount, and companies in these areas spend large resources on advertising. Because product life cycles are generally short, product development and brand extension are important. In addition, research and development expenses are rising, and many products are becoming high-tech in nature. The rise of the Internet, and ecommerce, has played a large role in how companies market their products.

Consumer products employ what is often simple chemistry and are generally formulated in batch-type operations although some products (e.g., detergents) are manufactured in large dedicated plants. Raw materials include fats, oils, surfactants, emulsifiers and other additives, and other basic chemicals. Formulating involves mixing, dispersing, and filling equipment rather than reactors for chemical conversions. Most operations, in fact, represent packaging lines. As a result, capital needs tend to be moderate as compared to basic chemicals. Government regulation is moderately high, largely in the area of product composition. The FDA is by far the leading regulator.

Consolidation and globalization are occurring as worldwide brand management continues to grow. Companies usually employ focus or product differentiation strategies, generally along brand lines. Some segments are subject to pressures from customers for environment- and animal-friendly “green” products and, despite brand importance, many consumer products are experiencing increased competition from generic products. Long-term demographic trends are important to growth prospect.

Figure 3.3 - Business of Chemistry Chemical Chain



A simplified overview of the production chain of the business of chemistry, from raw material inputs to valued outputs. Chemical chains for select individual chemicals are in the appendices.

4. GLOBAL BUSINESS OF CHEMISTRY

Dynamic, innovative and technology-based, the business of chemistry is worldwide in scope, applying science to support and enhance the quality of life. It is a large, mature industry, with numerous suppliers and customers. Although the business is—in general—highly fragmented, for some individual products within regions, the concentration can be quite high, with only a few producers. Often, individual companies are simultaneously suppliers, customers, and competitors. Chemical manufacturers in industrialized nations typically produce a wide variety of chemicals ranging from commodity industrial chemicals to specialty chemicals. In developing nations, domestic chemical production tends to be simple chemical products such as fertilizers and inorganic commodity chemicals.

The globalization of the business of chemistry took off in the 1960s when numerous companies, based in various countries, began investing in production facilities in foreign countries, thus the development of world markets, with prices of many chemicals set by global supply and demand. World economic growth, the reduction of tariffs, and other trade barriers that promote world trade, as well as advances in technology, logistics, and distribution, have continued to foster this globalization. Globalization of investments and markets has spread industry capital resources, technology, and managerial capabilities around the world and has resulted in a growing population of multinational chemical companies.

Although a number of large companies had foreign subsidiaries for many years, international investment by American and Western European companies grew at a particularly rapid pace during the 1980s and 1990s. Prior to that time, most developing nations had only moderate domestic chemical production. Rather, they were export markets for the chemical industries of the developed nations and provided little or no competition in other markets. By the 1990s, however, many developing nations embarked on ambitious programs to develop globally competitive chemical industries, including several of the newly industrialized countries (NICs) of Asia (Singapore, South Korea, Taiwan, Thailand) and many of the larger economies of Latin America (Argentina, Brazil, Mexico and Venezuela).

By the 2000s, the Middle East was rapidly emerging as a major player in global petrochemical markets, and U.S. chemical production (particularly Gulf Coast petrochemicals) was essentially being written off, as one of the highest-cost producers. By 2010, however, shale gas production in North America caused a dramatic shift in production costs and ethane supplies in the Middle East became constrained. Today, the U.S. and Canada are among the lowest-cost producers in the world.

World Trade

Chemical manufacturers have developed global supply chains to create and deliver the products of chemistry efficiently. International trade is essential to the global business of chemistry. An increasing amount of international trade in chemicals is actually "related party trade" or intra-company transfers by multinational chemical companies. Market access and minimizing tariff and nontariff barriers has been key to the globalization of the chemical industry and the fluidity of world trade.

Note. The global data presented in the following tables and figures were developed using multiple sources, including: ABIQUIM (the Brazilian Chemical Industry Association), ANIQ (National Association of Chemical Industries, Mexico), Bureau of the Census, Chemistry Industry Association of Canada (CIAC), CEFIC (European Chemical Industry Council), Eurostat, JPIA (Japan Petrochemical Industry Association), Statistics Canada, United Nations, VCI (German Chemicals Industry Association), World Trade Organization, and American Chemistry Council estimates.

Table 4.1 - Global Chemical Shipments* by Region ($billion)

Region	2017
North America	608.7
Latin America	223.2
Europe	736.6
Former Soviet Union	66.0
Africa and Middle East	149.3
Asia-Pacific	2,467.0
Total Global Shipments	4,250.4

*The term "shipments" is equivalent to the term "turnover," or value of output.
Note. The data are expressed in U.S. dollars, with average annual market exchange rates used to convert other currencies into U.S. dollars.

Figure 4.1 - Global Chemical Exports by Region, 2017

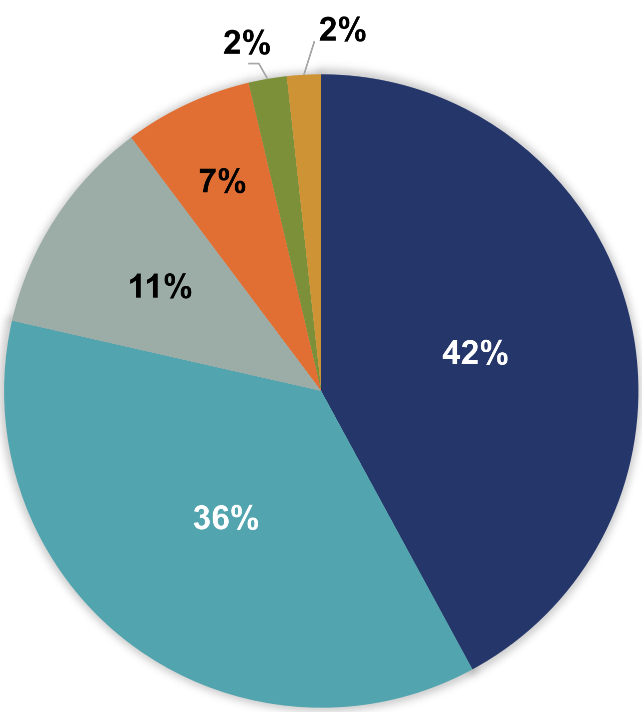


Figure 4.2 - Global Chemical Imports by Region, 2017

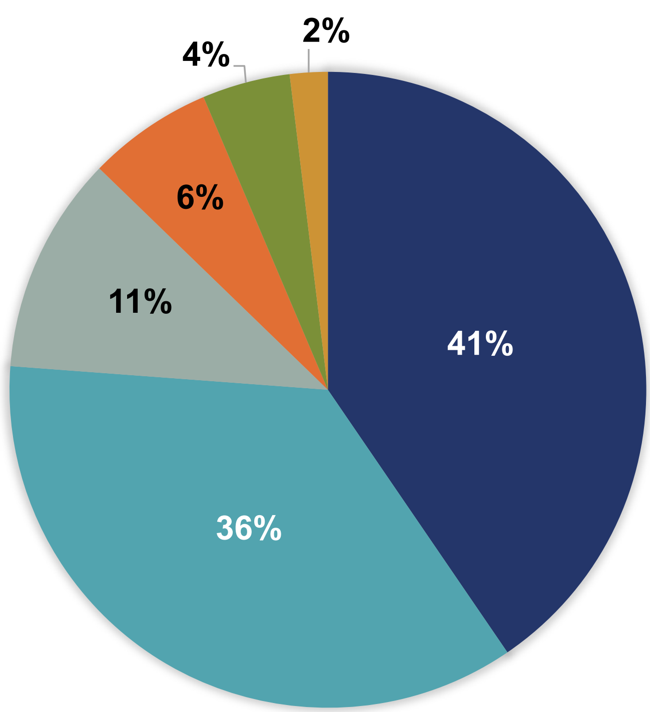
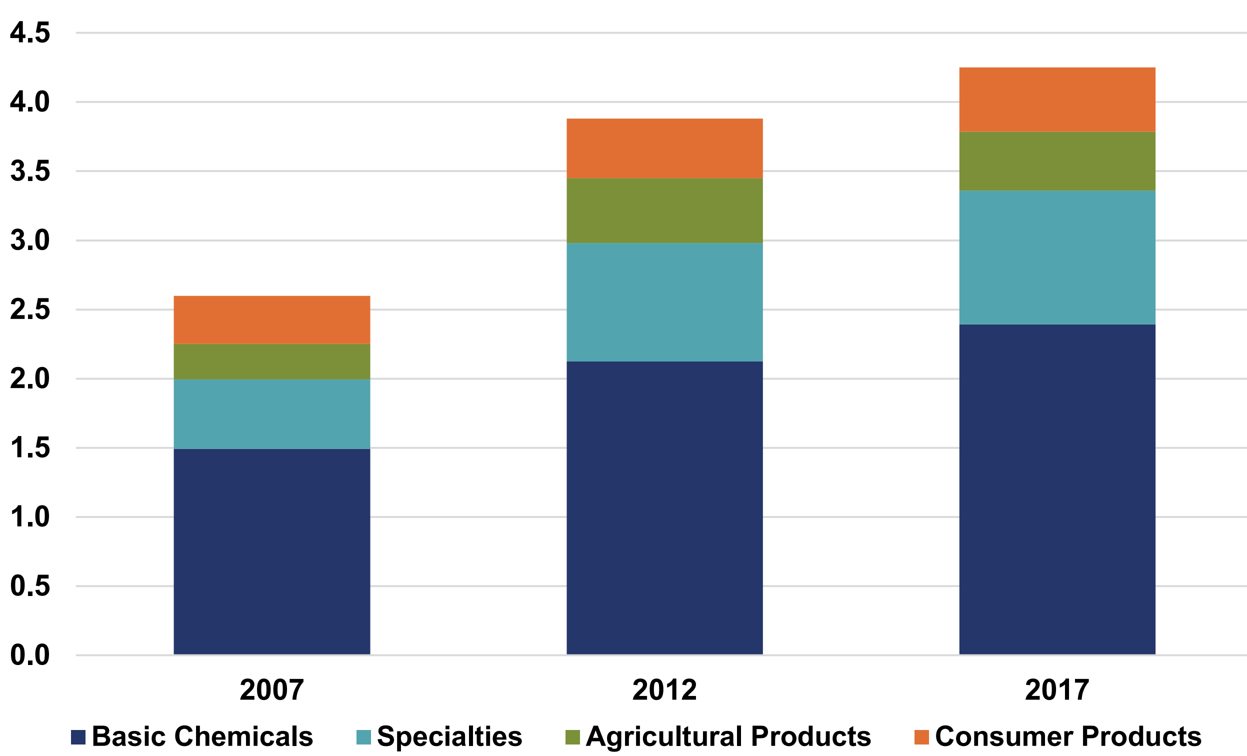


Figure 4.3 - Global Chemical Domestic Sales* by Region, 2017 ($billion)

*Sales data is derived by subtracting shipments from exports and then adding imports; it is equivalent to apparent consumption.

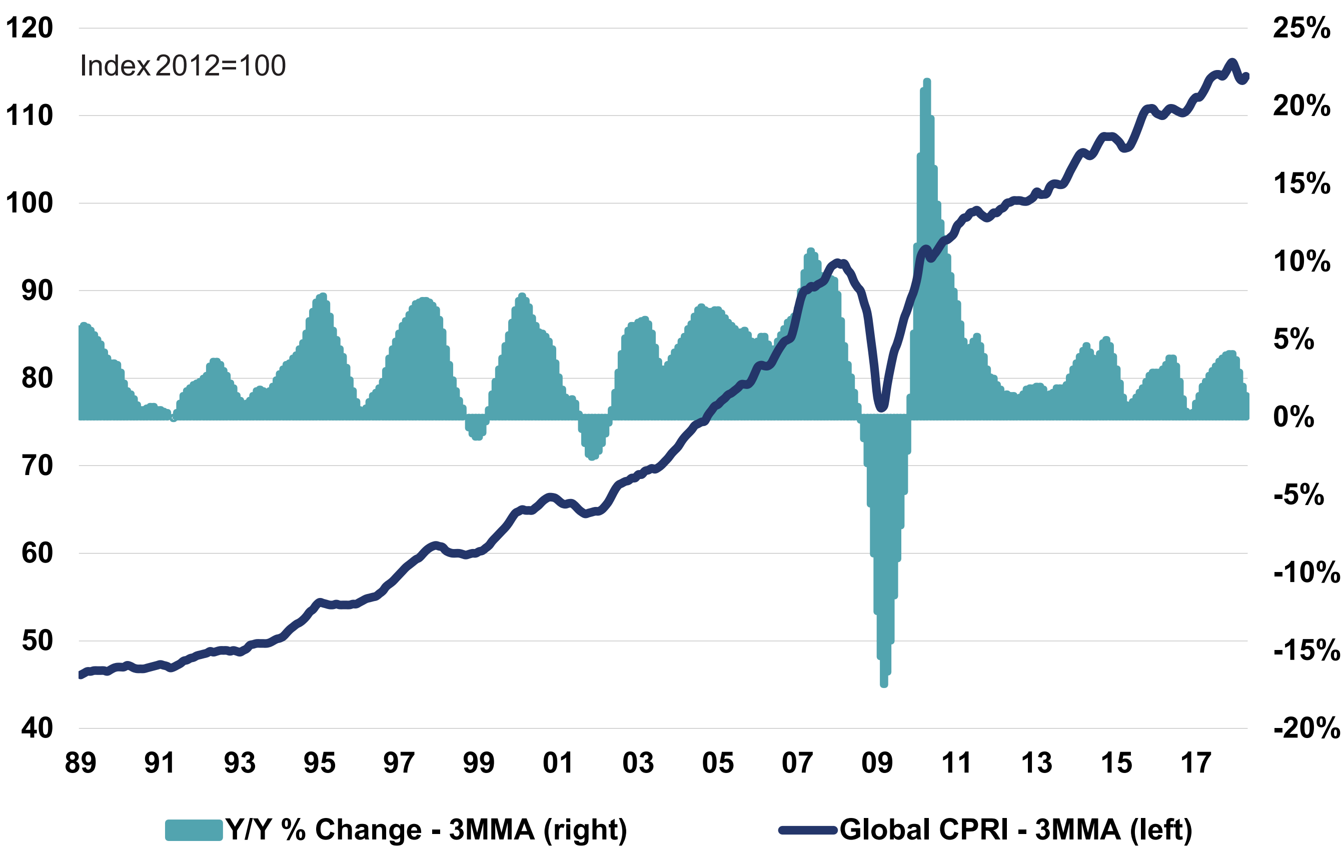
Figure 4.4 - Global Chemical Shipments by Segment ($billion)



Global CPRI

The ACC Global Chemical Production Regional Index (Global CPRI) measures the production volume of the chemical industry for 33 key nations, sub-regions, and regions, all aggregated to the world total. The index is comparable to the Federal Reserve Board (FRB) production indices and features a similar base year where 2012=100. This index is developed from government industrial production indices for chemicals from over 65 nations accounting for about 98% of the total global business of chemistry. Because foreign data are often non-seasonally adjusted or at best working day adjusted, ACC attempts to present the data on a seasonally adjusted basis comparable to that of the United States and Canada. As a result, it will differ from (and hopefully improve upon) official government statistics of some nations. In many cases, ACC created indices of production based on actual production data (weighted according to industry structure) and other data. The Global CPRI measures production activity generally consistent with the overall industry nomenclature of NAICS 325 (less pharmaceuticals) and the EU NACE 20 industries. That is, the index measures production of soaps and detergents, personal care products, fertilizers, and other downstream products in addition to measuring inorganic chemicals, organic chemicals, plastic resins, synthetic fibers, synthetic rubber, adhesives and sealants, coatings, and other specialty chemicals. Production of pharmaceuticals is excluded.

Figure 4.5 - Global Chemical Production Regional Index (Global CPRI)



Total world and regional, monthly, quarterly and annual time series are available back to 1987, as are detailed sub-regional data. The Global CPRI is released on a monthly basis. *Data, charts, and the monthly report are available for ACC members on MemberExchange or by email distribution. Contact ACC's Economics & Statistics Department for more information.*

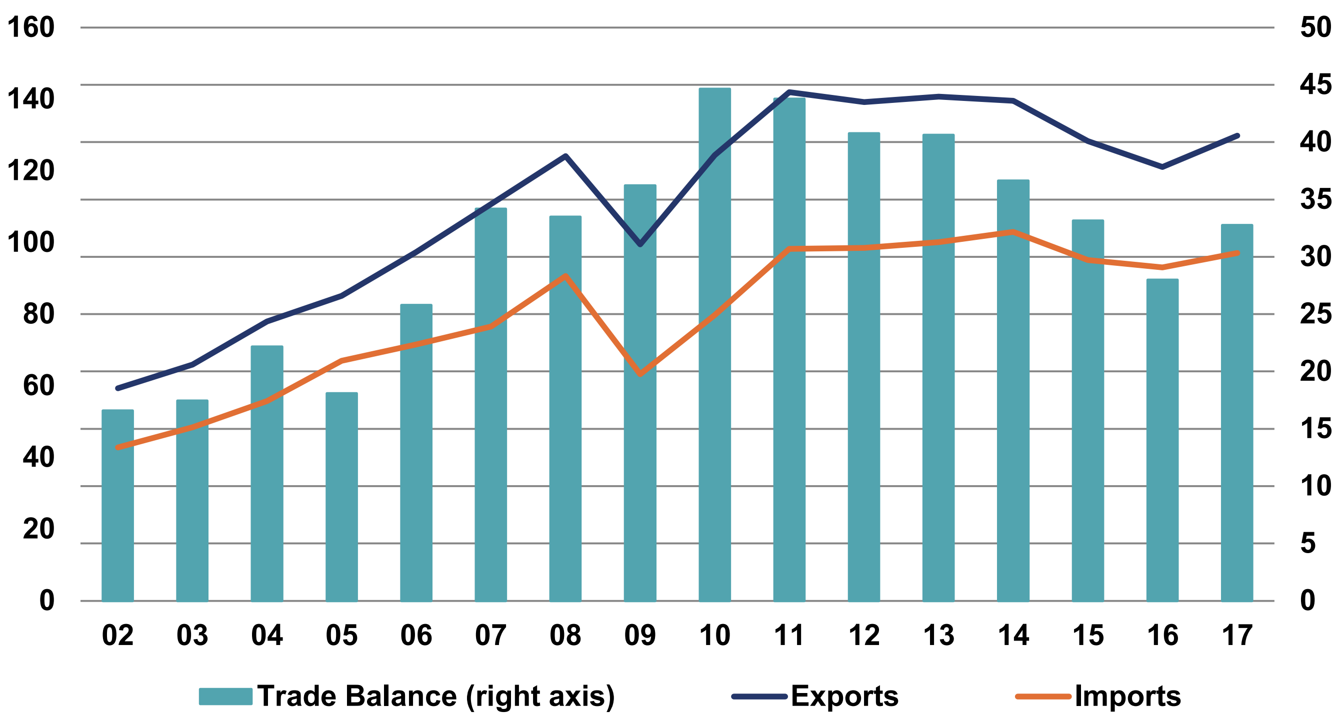
5. U.S. TRADE IN THE BUSINESS OF CHEMISTRY

As the business of chemistry has expanded and become global in nature, international chemicals trade has advanced as well. Chemicals are manufactured in production locations around the globe and prices for chemicals are generally set by global supply and demand. The international trade of chemicals reflects an intensely competitive struggle for markets by the producers in an increasingly global industry. But, at the same time, as the industry has expanded across the globe, a significant portion of international chemicals trade is actually between related parties producing in different nations. Indeed, two-way trade (or total trade) in chemicals between many countries is astounding. U.S. trade in chemicals (both imports and exports) has grown steadily over the years but, on balance, the U.S. chemical industry has maintained a net exporter position.

Table 5.1 - 2017 Top Chemicals Trade Partners ($billion)

Canada	40.0	United Kingdom	5.7
Mexico	26.0	Singapore	4.9
China	24.4	Ireland	4.8
Japan	11.9	Switzerland	4.5
Germany	10.9	Taiwan	3.8
Brazil	8.5	Italy	2.8
South Korea	8.5	Argentina	2.6
France	6.6	Australia	2.3
Netherlands	6.4	Russia	2.0
India	6.0	Thailand	1.8

Figure 5.1 - U.S. Trade in the Business of Chemistry ($billion), 2017



Imports

American manufacturers and chemical producers import chemicals that are essential inputs to their production process. Indeed, imported inputs are an important part of competitive domestic business and represent a significant portion of U.S. trade; more than half of U.S. imports are inputs used for domestic production. Canada has consistently been one of the largest exporters to the United States. Most imports from Canada are plastic resins and commodity chemicals. China is also becoming an increasingly important source of chemical imports to the U.S. Regionally, Western Europe is the largest trade partner in terms of chemical imports into the U.S. and a notable portion of these imports are related party trade reflecting transfers across borders made by multinational firms.

Table 5.2 - Top Chemicals Import Countries of Origin, 2017

	($billion)
Canada	18.0
China	12.9
Germany	7.7
Japan	6.0
Mexico	4.9
France	4.5
Ireland	3.9
Switzerland	3.8
South Korea	3.3
India	3.0

Figure 5.2 - Share of Imports by Sector, 2017

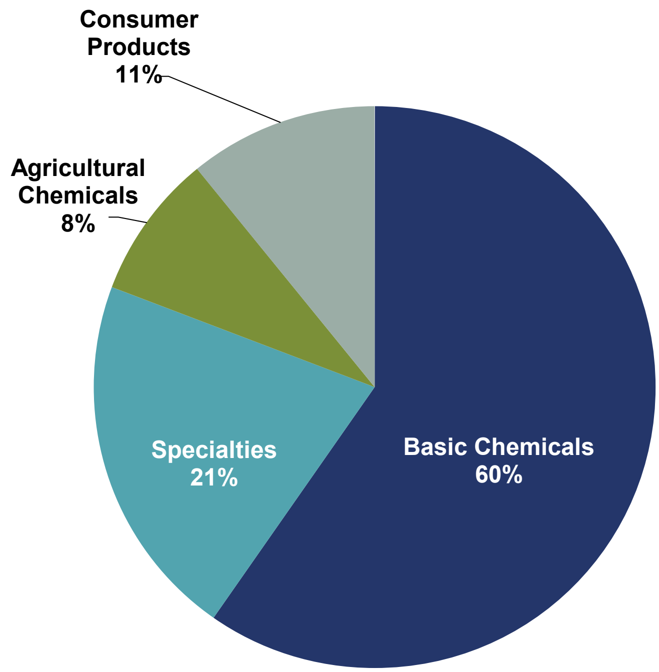
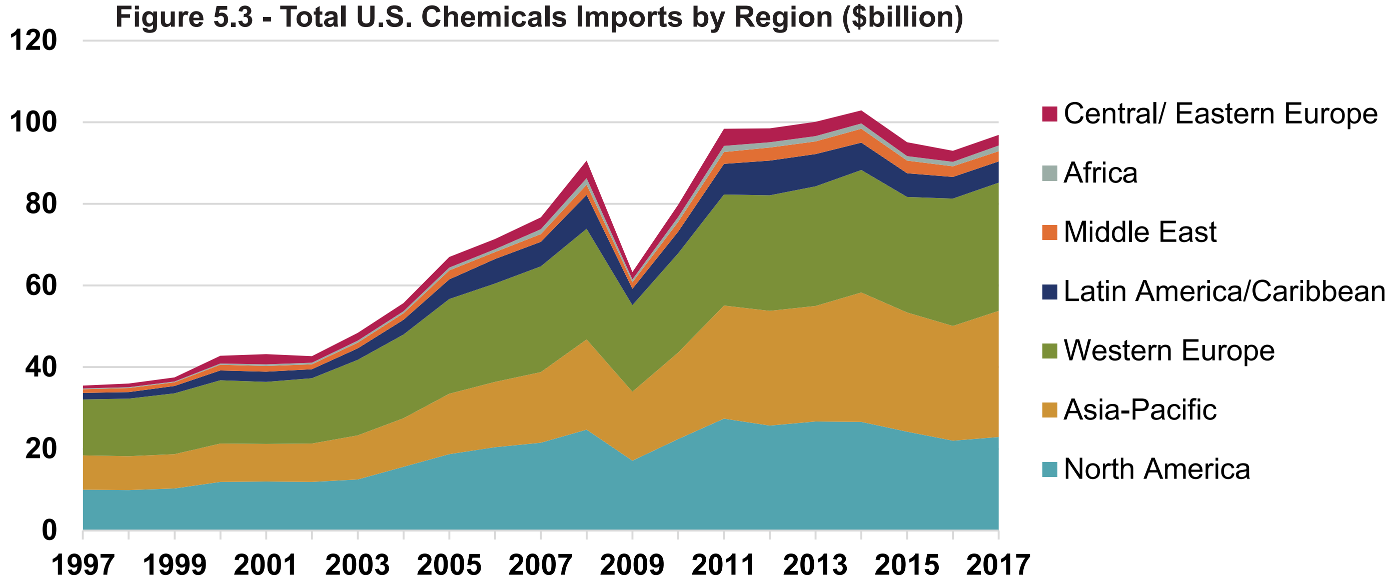


Figure 5.3 - Total U.S. Chemicals Imports by Region ($billion)



Exports

The business of chemistry in the U.S. began with a limited export trade in potash and naval stores with the United Kingdom as early as the 18th century. With abundant natural resources and a highly skilled workforce, American chemistry quickly became a major exporter of chemistry products to markets throughout the world. The chemical industry continues to be one of the top exporting sectors in the United States.

Figure 5.4 - Share of Exports by Sector, 2017

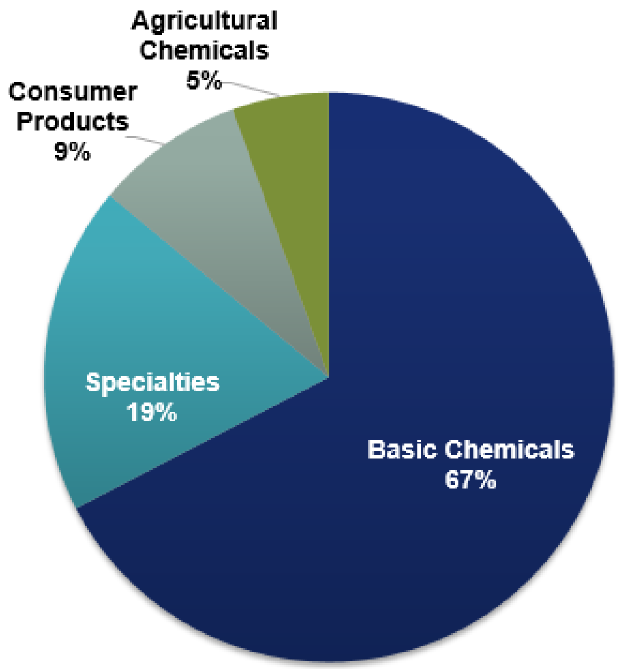
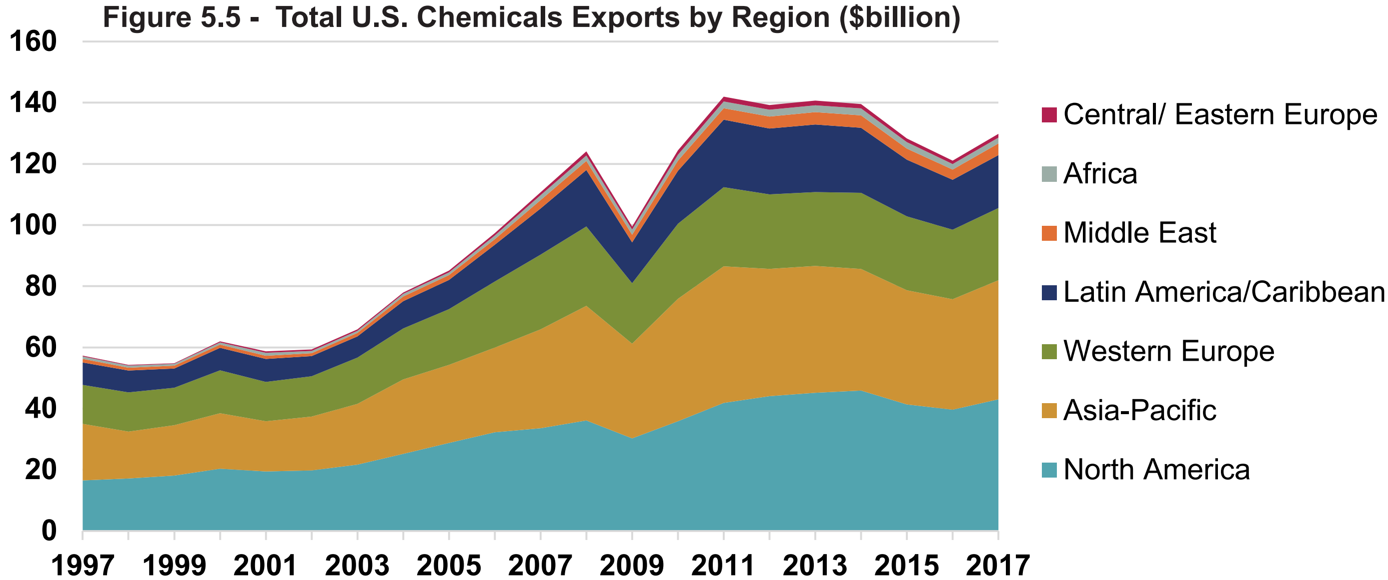


Table 5.3 - Top Chemicals Export Destinations, 2017

	($billion)
Canada	22.0
Mexico	21.1
China	11.5
Brazil	6.6
Japan	5.8
South Korea	5.2
Netherlands	4.3
Germany	3.2
Singapore	3.1
India	3.0

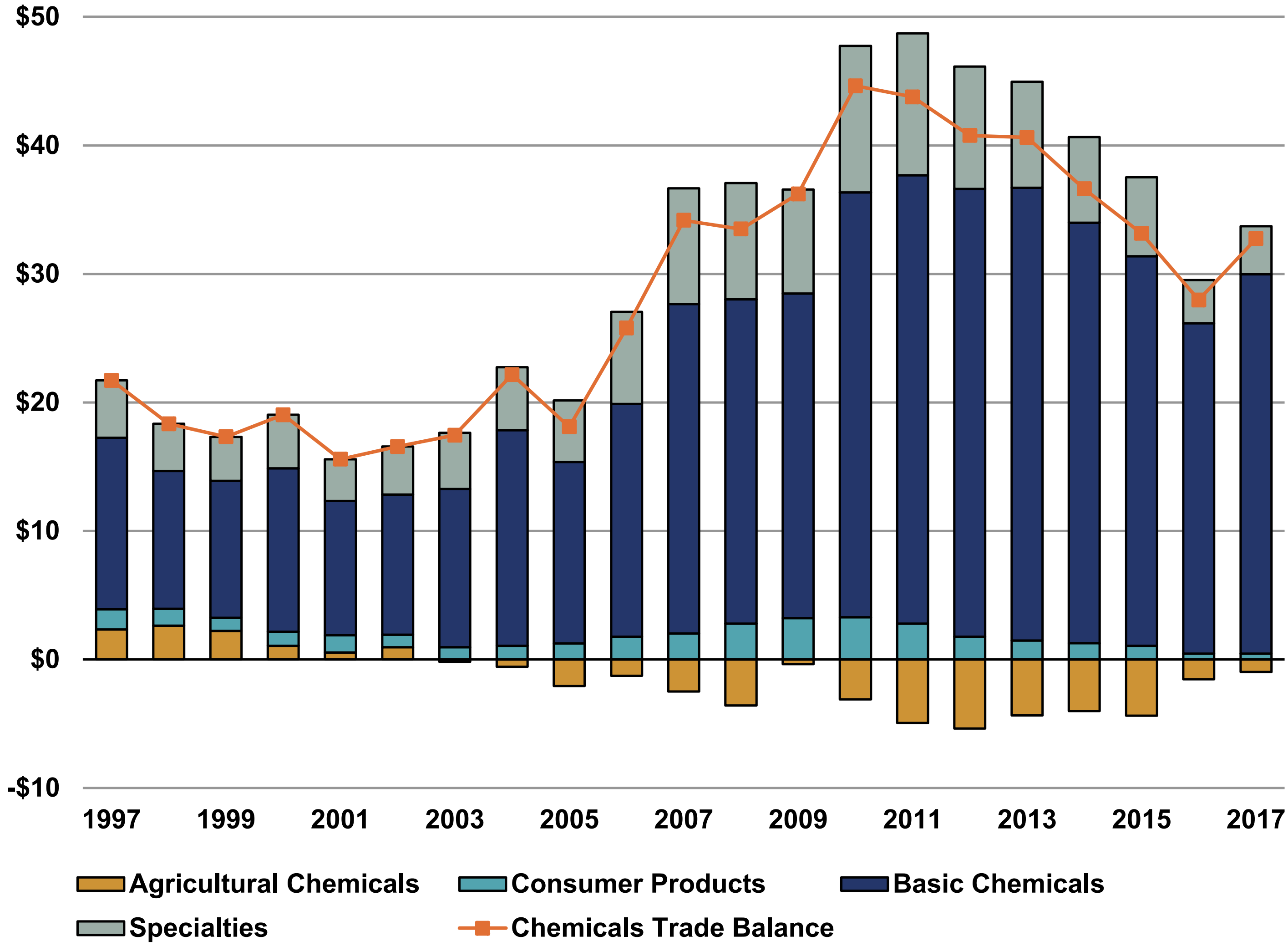
Figure 5.5 - Total U.S. Chemicals Exports by Region ($billion)



Trade Balance

In aggregate, the U.S. chemical industry is a net exporter – a position it has maintained historically. The position can vary from year to year and depends on industry segment and bilateral comparisons. Due to access to abundant and affordable shale gas, U.S. chemical manufacturers face comparatively lower production costs. The increased competitiveness of the industry will lead to a growing trade surplus especially in those segments benefitting the most from the shale gas revolution in the United States.

Figure 5.6 - Chemicals Trade Balance by Segment ($billion)



Note. The U.S. trade data in this section are from by the U.S. Department of Commerce and are presented by chemical segments. The entire business of chemistry is represented by NAICS 325 (Chemical Manufacturing). Exports shown in this section are domestic exports valued free alongside ship (FAS). Imports are general imports at customs value. General imports include imports that are subsequently exported (re-exports).

In previous versions of this publication, certain charts included data for Total Chemicals (including pharmaceuticals). In this publication, charts have been updated to reflect Chemicals, excluding Pharmaceuticals.

6. INVESTMENT IN THE FUTURE: KNOWLEDGE

A powerful engine for innovation and creativity, the business of chemistry is more than a supplier of products and solutions to other industrial sectors; it is an enabling enterprise, imparting technological innovations throughout the value chain. Innovation is at the core of the chemical business; it is found in all aspects of the enterprise, from research and development (R&D) to business processes to customer relationships and knowledge. The leading-edge technologies made possible by the business of chemistry improve functionalities, reduce costs and increase productivity. Indeed, chemistry could be another word for innovation.

In the 1970s, sociologist Daniel Bell was one of the first to recognize the emergence of a post-industrial society in which knowledge plays a dominant role. In his 1976 book, The Coming of Post-Industrial Society: A Venture in Social Forecasting, Bell cited the business of chemistry as the first of the truly modern industries, because its origin lies in the intimate linkage between science and technology.

A key driver of competitiveness and economic growth, innovation is at the core of value-added products and services; new, cleaner and more efficient production processes; and improved business models. Valuation of companies is no longer equivalent to annual sales. It includes recognizing the importance of knowledge and intangible assets such as brand or corporate image, patents, customer relationships, unique skills or knowledge bases, and others. Indeed, physical assets in a number of industries are becoming commodities. It is the intangible assets—employee knowledge, brands, process technology, and data and information about products, customers, and business processes, as well as more traditional intellectual property, such as patents, trademarks, and regulatory licenses— that increasingly define "real value." In an increasingly global business, companies are finding significant advantages in information, relationships, and knowledge versus physical assets.

Research and Development Activities

The business of chemistry in the United States is consistently one of the largest private-sector industry investors in research and development (R&D). R&D spending by companies includes research in the sciences, engineering and the design and development of prototype processes and products. (Spending for product testing, technical servicing, market research, and other non-technological activities is excluded.) Chemists and other scientists, engineers, and technicians are constantly engaged by the business of chemistry: they develop new (and improved) process technologies, new chemical compounds and products, and new applications for existing chemical products, to name a few. And new products and processes are the driving force of the continued competitiveness of the business of chemistry, both domestically and internationally.

Investment in R&D is a commitment of resources in the present in exchange for an anticipated future stream of benefits. It involves allocating resources to people, as opposed to simply increasing manufacturing output. It typically involves a high degree of risk, as there is no guarantee of a return on the investment. Rates of return on successful innovations, however, can be quite high, often in the range of 20 to 30%.

There are two broad categories of research: basic and applied. Basic (fundamental) research can be defined as any planned search for unknown facts and principles of general validity, without regard to commercial objectives. It consists of original investigation for the advancement of scientific knowledge. Applied research, on the other hand, can be defined as any investigation planned with the intent of using known phenomena or substances to accomplish a particular objective. In general, the basic research of today is the foundation for tomorrow's applied research. Once the research has been conducted, the findings (or other general scientific knowledge) must be translated into a form that is designed to meet the needs of customers. This is the "development" part of R&D.

Organized industrial research in the business of chemistry began around 1900. World War I gave new emphasis to research, and marked the beginning of sizable programs. Over the last century, R&D efforts by the business of chemistry have continued to expand, and in even times of lower profit margins, chemical companies have maintained their R&D activity.

Today, most basic and specialty chemical companies typically allocate 2-3% of their annual sales toward R&D. In the pharmaceutical segment, companies allocate anywhere from 10% to 25%. Moreover, unlike many other manufacturing industries that receive government funding for research, the business of chemistry in the U.S. typically funds its own R&D.

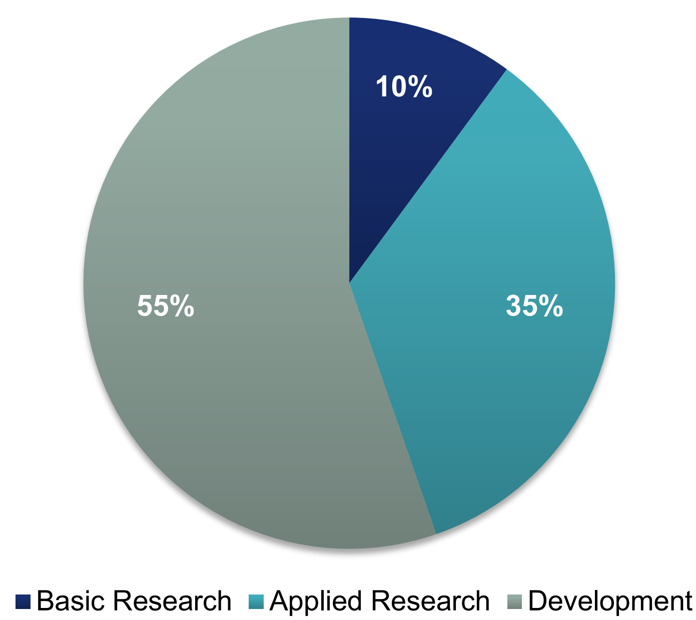
Successful research in the business of chemistry requires intensive effort and major expenditures; it takes years from the time a project is conceived to the time a chemical product is brought to the marketplace. A 2013 McKinsey & Company study (Chemical innovation: An investment for the ages) found that it takes from two to 19 years for a chemical product to reach the market. For each project that successfully leads to a practical application, there may be as many as 100 failures. The successes must yield enough in profits to provide an adequate return on the total investment in R&D.

Major areas of R&D interest, as well as technological developments achieving rapid diffusion, include:

- Nanotechnology
- 3-D printing
- Metallocene and other single-site catalysis
- Sustainability and resource recovery
- Conversion technologies
- Bioprocesses and biocatalysts
- Direct oxidation of alkanes
- Hydraulic fracturing productivity
- New/improved materials for construction applications
- Rare earth elements (technologies, applications)
- Powder coatings, radiation-cured coatings, and water-based coatings
- Advanced materials for high-performance applications (ceramics, metal matrices, etc.)
- Improvements in energy efficiency
- Chemicals and materials for microelectronics (e.g., lithium battery materials)
- New solvent cleaning technologies

In R&D, a number of companies appear to be seeking critical mass via economies of scale and alliances. The role of alliances and other collaborations in innovation is achieving greater recognition as companies seek to "do more with less" in their innovative processes. A number of companies are adopting a more open innovation model, using more ideas from outside. There also appears to be a more direct link between R&D efforts and commercial results, as strategic business units within many companies have become more responsible for defining R&D programs that fit their objectives. Knowledge management and innovations along the entire chemical value chain are now seen as critical areas.

Figure 6.1 - Basic and Specialty Chemical Companies' R&D Spending by Type



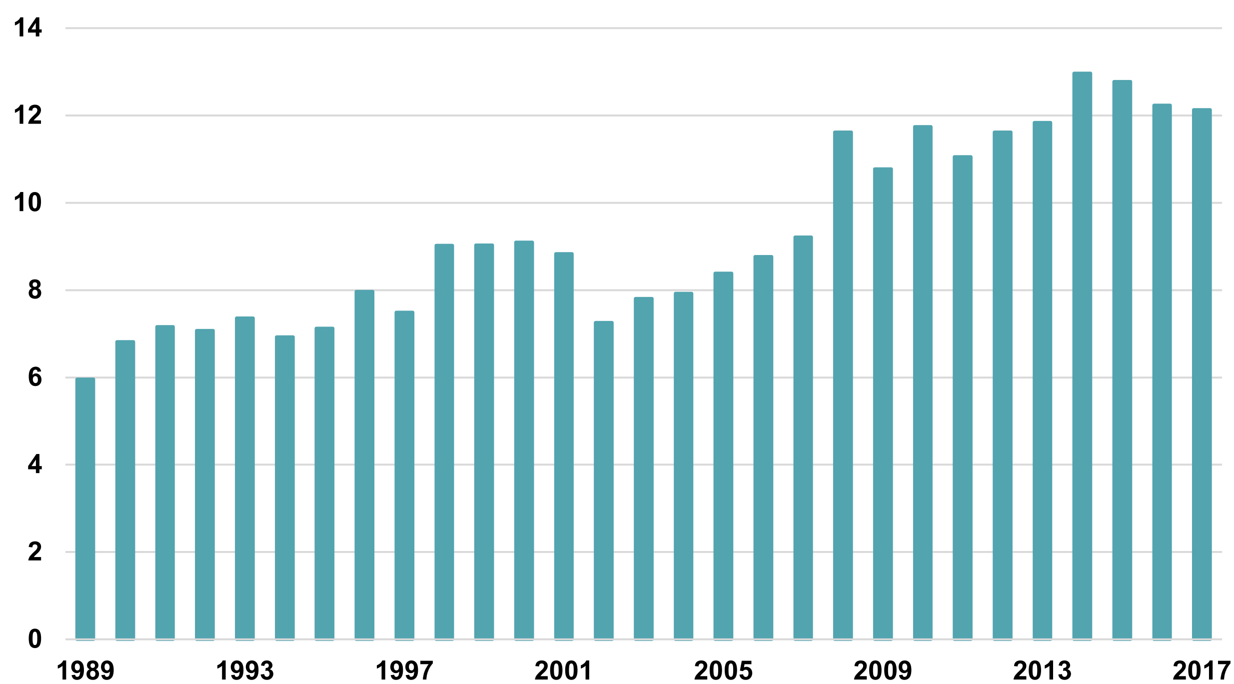
Innovation and Learning

The role of innovation and learning has gained wide recognition as critical to success. For industries and companies, many different measures of the innovation and learning perspective have been proposed and used, but one has found acceptance among stock analysts, academics, and others: the percent share of revenues from new products and services. Two professors at the Harvard Business School, Robert S. Kaplan and David P. Norton, found that a company's ability to innovate, improve, and learn is directly related to its value (part of a concept they developed called the "balanced scorecard"). That is, only through the ability to launch new products and services, create additional value for customers, and improve operating efficiencies can a company—and, by extension, an industry—penetrate new markets and increase revenues and margins. In short, new products and services increase shareholder value.

ACC's Economics and Statistics department collects data on the percent share of revenues from new products and services as part of its annual economic survey. Analysis of these data shows that specialty chemical companies have a slightly higher share compared to basic chemical companies. This follows several years of reduced R&D investment. The data are not entirely comparable from year to year.

Innovation—putting ideas into action through knowledge to create new products and services to meet the needs of current and future customers—is a long-term driver of future financial performance and value creation. It provides business opportunities, as well as the sustainable foundation for continued growth. Innovation can lead to shifts in relative cost relationships, and provide sustained competitive advantages. Indeed, it is at the heart of the business of chemistry, and is crucial to economic growth and improvement in the quality of life.

Figure 6.2 - R&D Spending in the Business of Chemistry ($billion)



Service Innovation

Innovation is not limited to products and processes; it can include a range of endeavors that lead to enhanced value. The service intensity of many products in the business of chemistry is increasing, and service innovations are an increasingly important type of innovation. In a number of segments, companies have added management services to their portfolio, in addition to—and sometimes instead of—chemical products. Specialty chemical and advanced (performance) materials companies—which, by their nature, require extensive technical servicing components with highly-trained service and sales representatives, knowledgeable customer service problem-solvers, and EH&S professionals—demonstrate increasing innovation. Companies are looking beyond traditional technical servicing and utilizing creative solutions to adding value as service companies.

Service innovations in the business of chemistry are especially prominent in the automotive and electronics industries. Automobile manufacturers require specific properties when considering paint and coating applications (e.g., anti-corrosion properties). Rather than purchasing paint by the gallon, automobile companies are engaging with coatings manufacturers to meet individual requirements. The coatings companies are often integrated in the automotive manufacturing, running complete coatings operations at body plants. In the electronics industry, services such as "cradle-to-grave" responsibility for chemicals have become increasingly important. For example, a chemical supplier may "lease" chemicals to a semiconductor company to process the chips, so that the semiconductor company is free from the management of used chemicals. Chemical companies are taking on the role of consultant, solving problems and supplying solutions, best practices, and performance guarantees, while at the same time reducing waste and increasing cost savings.

Service innovation encompasses a new way of thinking in the business of chemistry. As a differentiation strategy, service offerings can lower coordination, transactions, and other costs incurred by the customer, as compared to if the customer were to search out and assemble various products, services and activities (chemicals, equipment, procurement, operations, maintenance, quality assurance, inventories, etc.) on their own. Service innovation allows the customer to concentrate on their core competencies and provides technological flexibility. To suppliers and innovators, these innovations engender a stream of revenues and higher added value. Innovations in service mark a shift from the value of things to the value provided by things.

Figure 6.3 - Percent of Basic and Specialty Chemical Revenues from New Products

7. INVESTMENT IN THE FUTURE: CAPITAL

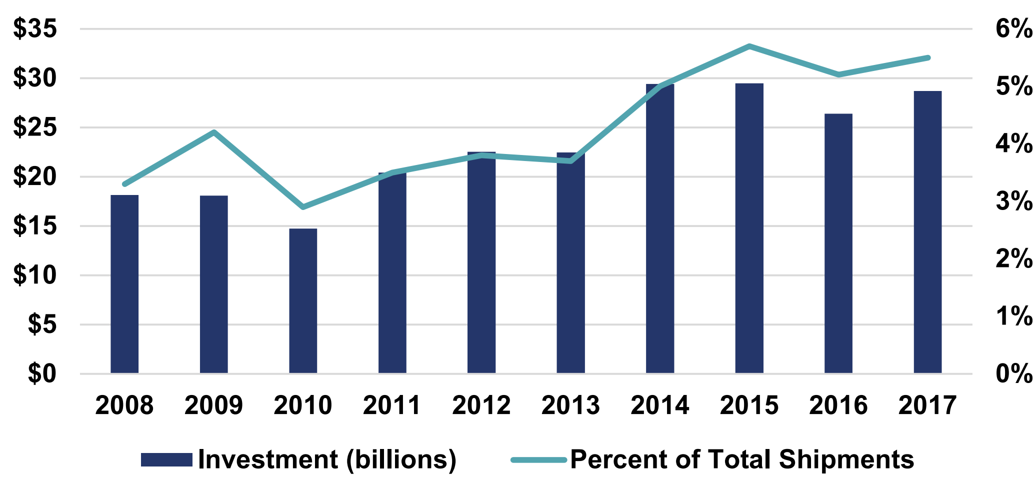
The business of chemistry is, in general, a capital-intensive industry. There are numerous factors that contribute to high capital costs: the large plant capacities often needed to obtain economies of scale in producing chemicals; the intricate nature of the equipment and processes used; the high degree of process automation; the large amounts of equipment needed; technology requirements (and the rapid technological obsolescence); and depreciation of process plants.

Capital intensity (or financial resources employed per worker) is a good indicator of the adequacy of capital formation. Changes in capital formation and employment growth show up in what economists refer to as "capital endowment," that is, the average amount of capital stock that is available to each worker. Increasing levels of capital employed per worker (also called capital deepening) have long been noted as a key to improved productivity, indicating that workers are equipped with the latest technological innovations embodied in the acquisition of new capital (and capacity). Higher productivity is, in turn, typically accompanied by higher real wages for workers. On the other hand, declining capital endowment places the labor force at a clear disadvantage in depriving it of new technological innovations relative to competitors. This tends to reduce real wages for workers. Among manufacturing industries, chemistry is second to petroleum refining in terms of capital employed per worker.

Capital Investment

Capital investment—the investment in new plants and equipment (P&E), also referred to as capital spending—is comprised of two basic components: structures (e.g., buildings) and equipment. The equipment category is composed primarily of traditional process equipment such as fabricated metal products (pressure vessels, storage tanks, heat exchangers, pipe, etc.); general industry machinery (pumps, compressors, etc.); electrical transmission, distribution, and industrial apparatus; and other special industry machinery. A sizable portion of equipment spending in the business of chemistry is for instrumentation, computers, and related automation (or information processing) technologies. To a large degree, structures in the business of chemistry protect chemical processes from the elements, and support process equipment. Investment in structures is mostly for industrial buildings and related structures (loading docks, terminals, etc.), but also includes some minor spending for office buildings. Of the two, equipment is notably more important to long-term growth potential for the manufacturing sector and the business of chemistry. This is because equipment is directly involved in the production process and it embodies the latest in process technologies.

Figure 7.1 - Capital Investment - Chemicals



Source: Bureau of Economic Analysis and ACC analysis (based on Bureau of the Census data)

The business of chemistry has consistently been one of the largest U.S. private-sector investors in new plants and equipment. During much of the post-World War II period, real (that is, adjusted for the effects of inflation) capital investment in structures (or plants) and equipment by the business of chemistry paralleled overall U.S. economic activity. Investment rose during periods of business expansion and fell during periods of economic downturns.

Some differences in P&E spending exist among companies on the basis of their main business focus. Normally, basic chemical companies generally allocate the largest share of their sales for P&E spending. Specialties follow with industrial gases as the most capital-intensive segment. With batch operations tending to predominate, consumer product companies allocate less to P&E spending.

Profits and Other Determinants of Investment

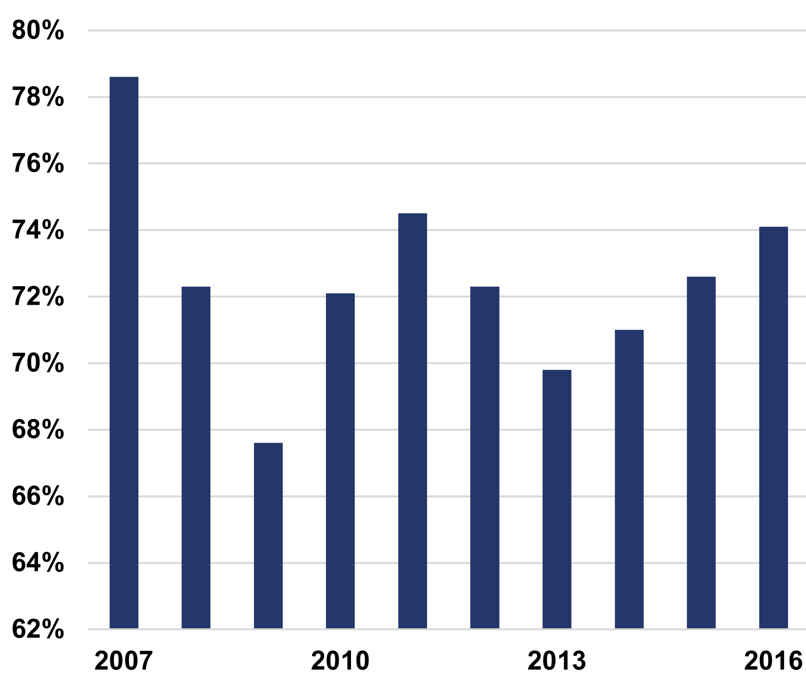
Profit margins (and operating profits) and capacity utilization rates are key drivers for P&E investment. A number of factors drive the magnitude and composition of investment in new plants and equipment. Major determinants that influence the level of capital spending include after-tax profits, the business cycle, long-term business expectations, taxation policies, the cost of capital, the burden of debt, the supply of credit, and mandated expenditures.

The 1990s were a period of slow and steady growth for companies engaged in the business of chemistry. In the early part of the 2000s, chemical companies were especially hard hit, as reduced capacity utilization, rising energy and other raw material costs, falling real prices, a downturn in end-use markets, and oversupply all contributed to declining margins. By 2010, the U.S. business of chemistry began to experience another wave of growth, spurred in part by developments in shale gas, which made the U.S. increasingly more attractive as a place to manufacture chemicals. The business of chemistry can be a volatile industry, in terms of profit margins; however, as a whole, the industry continues to seeing growing profits.

Capacity Utilization

Capacity utilization (or operating rate) measures the extent to which the capital stock of an industry (or nation) is employed in the production of goods. Capacity utilization rises and falls with the business cycle. Historically, there has been a relationship between the capacity utilization rate and the producer price index. The Federal Reserve Board (FRB) publishes a capacity utilization number for the business of chemistry (NAICS 325). Fluctuation between 74% and 85% is typical, but the average (for total chemicals) over the last decade was 73% due to the recession and new capacity. Industrial chemicals tend to feature higher capacity utilization rates; plastic resins are a prime example.

Figure 7.2 - Capacity Utilization



Motivation for Capital Investment

Companies involved in the business of chemistry have a number of reasons for investing in new plants and equipment. New capital needs include expanding production capacity for both new and existing products, replacing worn-out or obsolete plant and equipment, and improving operating efficiencies. It is common for existing plants to undergo complete modernization programs that utilize the latest process technologies, often for "debottlenecking" (i.e., maximizing through-put in an existing plant). Other reasons for P&E investment include energy savings, addressing changing environmental concerns, and other initiatives need to remain competitive.

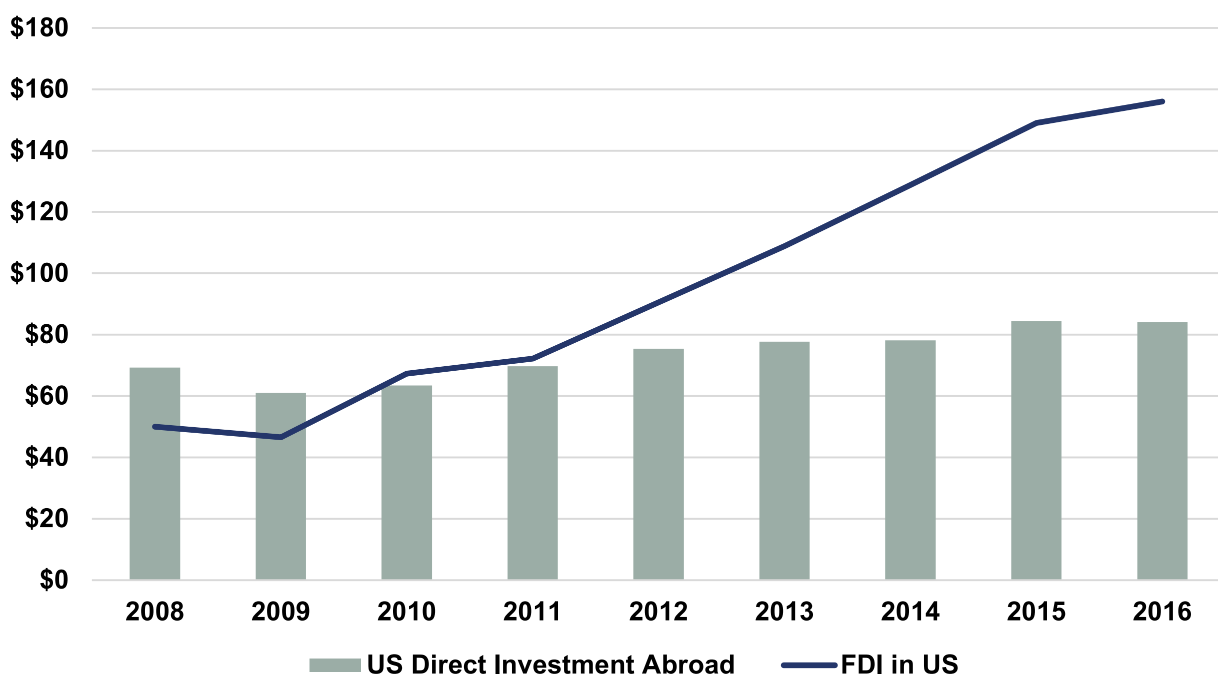
A long lead-time is required for funding, designing, and completing chemical industry capital spending programs. This makes short-run adjustments difficult, as capital investment cannot easily be turned on and off. Given its capital-intensive nature, however, the business of chemistry is highly sensitive to the costs of capital and the level of cash flow.

Foreign Direct Investment

Foreign direct investment (FDI) is the funnel through which exports flow. In conjunction with growing exports, since the early 1980s, the business of chemistry has become increasingly global in scope, with growing U.S. investment abroad and increasing foreign investments in the United States.

American companies have long established a presence in overseas markets, with many "going global" in the 1950s and 1960s. This presence has continued. Western Europe accounts for more than half of the overseas investment by American companies. Canada, Brazil, China, Australia, Singapore, and Thailand are other large destinations for American investment. Because investment positions are measured by book value, investments made by foreign companies in the United States tend to be more recent, and as a result, the position is higher than U.S. investment overseas. In terms of replacement value, however, U.S. investment overseas is higher.

Figure 7.3 - Foreign Direct Investment ($billion)



Maintenance and Repair Spending

Maintenance and repairs require significant capital to keep plant operations efficient and safe. This includes routine maintenance, planned modifications, and other repairs. Of these expenses, about half are for labor and the other half for materials, including supplies and spare parts.

As a share of shipments, spending tends correlate with the operating conditions of the plant: spending is low where service conditions are light and high where severe operating conditions exist. Corrosive materials and the use of special equipment, for example, tend toward higher maintenance costs. As would be expected, basic chemicals engender the most maintenance and repair spending. Other chemicals that engender considerable maintenance and repair include fertilizers and some specialties operations.

Information Technology

Companies in the business of chemistry, like most other sectors of the economy, have become increasingly dependent upon information technology (IT). Both the decision-making process today and the means with which these companies plan, develop and implement information technology are becoming more and more complex. IT investments help companies improve operational efficiencies, innovation, and customer relationships.

The Internet has changed how companies operate. Nearly every aspect of business is touched by IT in some form or another. Today, e-commerce is a common practice, and crucial to competitiveness in the global market. Web-based communications have displaced faxes, and “in-person” meetings no longer require participants to be in the same room. Other major areas of IT spending include security; business process outsourcing, such as payroll, human resource administration, and logistics; portal developments, application integration, cloud computing, and data warehousing.

Advances in information technology are accelerating product and process development. Companies have made significant investments in enterprise resource planning (ERP) systems and are employing advanced supply chain management systems, such as electronic data interchange (EDI) systems, for leverage. Supply-chain integration offers increased organizational flexibility to meet customer’s changing needs, as well as increased speed of decision-making. Companies are increasingly collaborating with customers and suppliers to deliver greater value.

Companies are also looking to leverage intellectual capital resident within their organization. An increasing emphasis is being placed on knowledge management (KM), a means of capturing an organization’s expertise, wherever it exists, and putting this knowledge into action. KM leverages the exchange of knowledge. Technologies such as content management systems, social networking, and decision support systems are critical tools in bringing this expertise to bear.

8. EMPLOYMENT

Innovative, creative, and progressive, the business of chemistry is one of the most knowledge-intensive industries in the manufacturing sector. Despite a high degree of capital intensity, the business of chemistry is one of the largest U.S. industries in terms of employment. Historically, growth in the business of chemistry has been accompanied both by expanding employment and by significant gains in labor productivity (i.e., output per man-hour). Real wages have also increased. Because of the highly technical and rapidly changing nature of the industry's operations and products, R&D and technical services provided to customers are increasingly important factors in companies' ability to compete. This, together with continuing increases in the automation of production processes, has caused some decline in the production worker portion of the industry's workforce over time.

The industry employment data collected by the Bureau of Labor Statistics (BLS) undercounts actual employment by the business of chemistry because it does not include company management, and professional and technical services employees. As a result, actual employment is 10-15% higher than reported by the BLS Current Employment Survey (CES) data.

Table 8.1 - Employment in the Business of Chemistry (thousands of people)

	2013	2014	2015	2016	2017
Employees	517.0	524.1	525.5	525.8	529.3
By Occupation					
Production Workers	329.0	333.2	339.3	341.9	340.5
Other	188.0	190.9	186.2	183.9	188.8
By Sex					
Female	120.4	125.4	128.5	128.0	130.6
Male	396.6	398.7	397.0	397.3	398.7

Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, National Science Foundation, American Chemistry Council analysis.

Total Employment Impact of the Business of Chemistry

The means by which an industry generates employment reaches beyond those directly employed by the industry. The true employment impact of an industry takes into consideration the following:

- **Direct Employment** — the people who work directly for the industry. For example, in the business of chemistry this includes plant operators, R&D engineers, chemists, etc.
- **Indirect Employment** — the people who works in jobs in other industries (such as supplier) that are supported indirectly by the industry being examined. For example, in the business of chemistry this could be third-party truck drivers who transport materials to/from the plant.
- **Expenditure-Induced Activity** — the jobs in the suppliers' suppliers (e.g., truck manufacturers needed to make the trucks that are transporting materials to/from the plant), and in those industries supported by the wages paid to employees (e.g., medical facilities, coffee shops).

Each job in the chemical industry generates an additional 7.1 jobs in other sectors of the economy.

Table 8.2 - Total Jobs Supported by the Business of Chemistry (in thousands), 2017

Industry	Direct	Supply Chain	Payroll-Induced	Total
Chemicals*	529			529
Agriculture		71	36	108
Mining		111	8	119
Utilities		36	6	42
Construction		46	21	68
Manufacturing, excluding Chemicals		223	86	309
Wholesale Trade		206	55	261
Retail Trade		78	255	333
Transportation		165	64	229
Information		34	32	66
Finance and Insurance		145	221	366
Professional, Scientific, Technical Services		203	98	301
Management of Companies and Enterprises		195	21	216
Administrative and Waste Management Services		204	121	324
Health Care and Education		1	390	391
Arts, Entertainment, and Recreation		22	57	80
Accommodation and Food Services		51	222	272
Other Services		45	175	220
Government		37	22	59
Total - All Industries	**529**	**1,873**	**1,891**	**4,293**

Note. Beginning in 2012, the calculation of the job multipliers is based on analysis using the IMPLAN model. The IMPLAN model is a widely accepted and robust input-output model. It calculates industry multipliers using complex output-labor ratios and industry spending patterns. Multipliers generated by this type of model are typically used in assessing the economic impact of projects or plant closures, import substitution analysis, centralized planning, and economic benefit analyses. The results differ significantly from previously published analyses using a somewhat different approach based on data from the Bureau of Economic Analysis. As a result, data published before 2012 are not comparable to data presented herein.ource: Bureau of Labor Statistics and American Chemistry Council analysis.

*In previous publications, jobs in pharmaceuticals were included in the Chemicals category. As such, this number is not comparable to previous data.

Knowledge Workers

The business of chemistry is a powerful engine of innovation and creativity. This results from the knowledge base of its employees. “Knowledge worker” is a term that was originally coined by management guru, Peter Drucker, several decades ago. It refers to employees with university degrees and/or training whose principal tasks involve the development or application of specialized knowledge in the workplace. In the business of chemistry, more than four out of every 10 employees have administration, sales, technical servicing, R&D, and clerical positions. Scientists and engineers comprise about a tenth of the industry workforce.

The American Chemistry Council’s analysis of knowledge workers categorizes employment by the nature and type of occupation (as opposed to education level). Those occupations with analytical, information, organizing, planning, leading, controlling, and technical competencies were deemed to be knowledge workers. It should be noted that due to definitional changes, these results may not be directly comparable to previous analyses. Because the BLS data undercount actual employment (and the undercounting is centered in company management and professional and technical services), the share of knowledge workers is probably much higher than the results reflect.

Wages, Benefits and Other Labor Indicators

The complex nature of the business of chemistry often demands highly-trained, skilled and educated workers. In plant operations, this has resulted in making technicians out of skilled workers (e.g., machinery operators) and skilled workers out of unskilled workers (e.g., laborers). In other areas, the need for chemists, chemical and industrial engineers, and other technically-trained personnel (from agronomists to toxicologists to zoologists) continues to mount.

In addition to high salaries and wages reflecting occupational knowledge intensity, the business of chemistry also provides excellent benefits to its employees. These include legally-mandated expenditures, as well as voluntary programs, including profit-sharing and other compensation, vacation and other leave, health and life insurance, stock purchase plans, pensions, 401(k) contributions, and others. As a share of salaries and wages, these typically add a third or more to the cost of compensation.

Driven by large investments in knowledge and in capital, the business of chemistry has achieved significant gains in productivity over the years. These productivity gains have allowed companies to restrain boosts in unit labor costs, and in some cases, even reduce them. Most plants in the business of chemistry are continuous in nature, often operating around the clock. As a result, shift-work is the norm, and the typical workweek exceeds 40 hours. The average workweek, when compared against the number of production workers, provides an excellent indicator of industry production activity.

Table 8.3 - Occupation/Segment Mix in the Business of Chemistry, 2017

	(thousands of people)
Management	38.2
Managerial Support Positions	18.3
Chemical Engineers	10.3
Other Engineers	15.4
Life Scientists	1.2
Chemists	13.0
Other Scientists	1.2
Information Technology Professionals	5.9
Other Professionals	3.9
Technicians and Other Technical Support	30.9
Marketing and Sales	20.3
Administrative Support	54.2
Knowledge Workers, Total	**212.8**
Knowledge Workers as a % of Total	*40%*
Supervisors	30.3
Trade and Craft	3.3
Plant Operators	231.0
Other	51.9
Other Workers	**316.5**
Business of Chemistry Total	**529.3**

Source: American Chemistry Council analysis based on Bureau of Labor Statistics.

Figure 8.1 - Labor Productivity (2012 = 100)

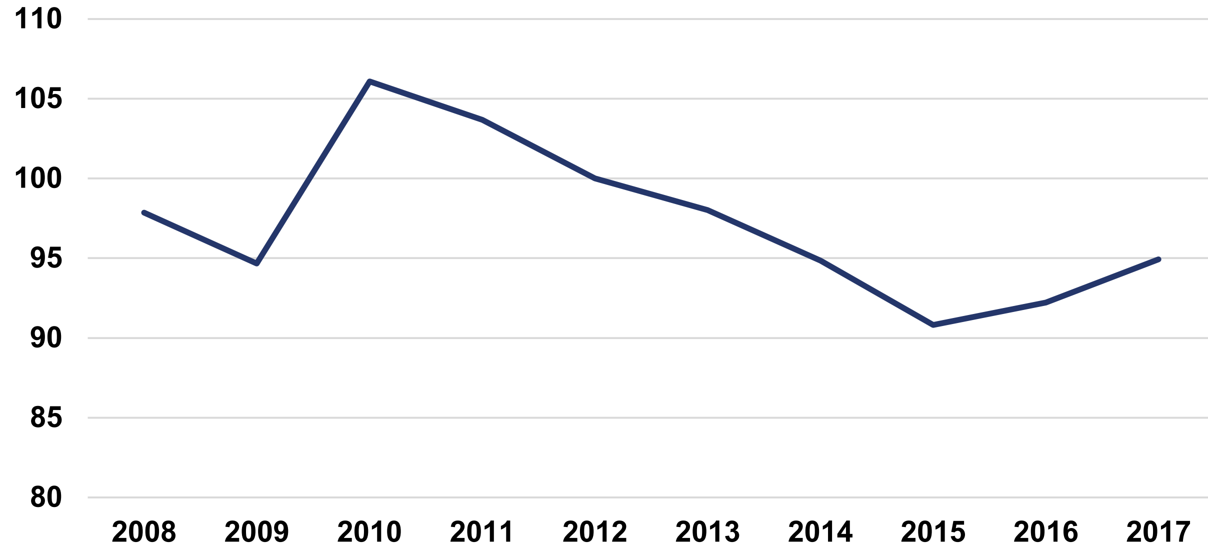
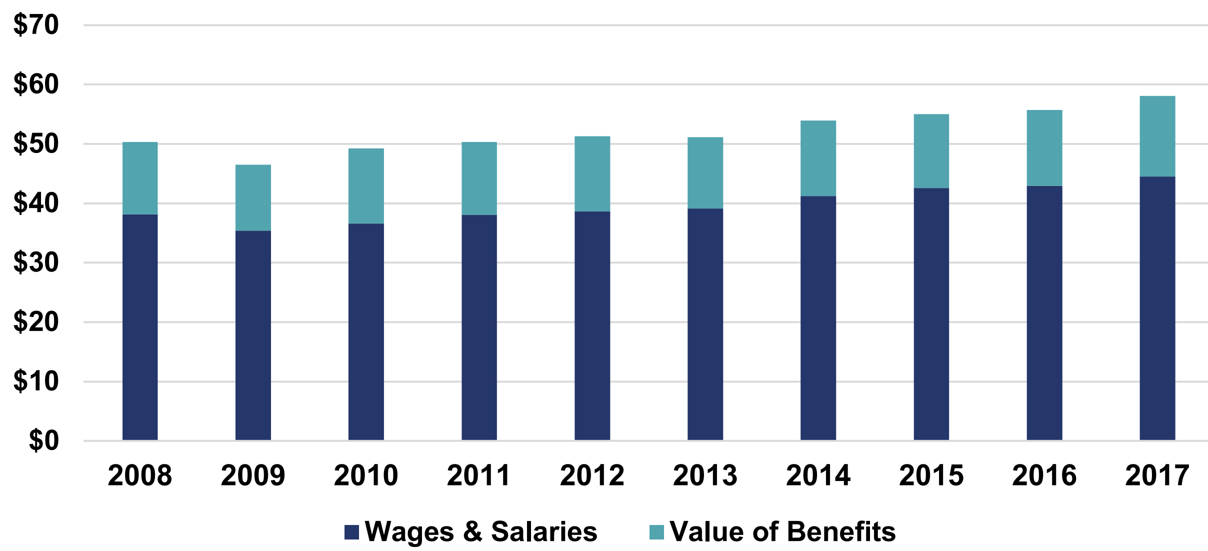


Figure 8.2 - Total Employee Compensation ($billion)



Notes on the Employment Data

The Bureau of Labor Statistics publishes two sets of data on employment by industry. The Current Employment Survey (CES) is the timeliest data available with preliminary national-level estimates available within a week of the end of the month for which data are reported. State-level estimates are usually available within three weeks of the end of the month, however, estimates at the state level are only provided for significant industries within the state. In the case of the chemical industry, the CES data only provides employment data for 21 states. The second data set is the Covered Employment and Wages (CEW) series, which collects data on employment and payroll from state claims for unemployment insurance. These data are the most accurate and detailed for employment and payroll, however, the data are not finalized for the prior year for six to nine months following the end of the calendar year. On a national level, the CES and CEW data on chemical industry employment differ slightly due to their different origins. As a result, ACC presents the CES for national-level employment. At the state level, ACC presents the CEW data, which are lagged by one year due to the fact that the Guide to the Business of Chemistry goes to print before the CEW data are released for the prior year.

9. ENVIRONMENT, HEALTH, SAFETY AND SECURITY

Since the first Earth Day nearly a half century ago, there have been major advances in protecting the environment, and in protecting the health and safety of workers and communities. Efforts to preserve the environment—air, water, land and climate—are made possible in large part thanks to the innovative products of chemistry. America's chemical makers create products that help protect the environment, promote health, and provide safety, and are committed to continuous environmental improvement in their own operations.

Environment

Many environmental improvements are achieved due to the energy efficiency of innovative chemistry products, and less energy used equals fewer energy-related emissions. Products of chemistry are also used directly to clean and protect the environment. For example, absorbents, catalysts and plastic fibers in air filters for automobiles, homes and commercial buildings clean the air, and "scrubbers" at industrial facilities dramatically reduce noxious emissions to the environment and acid rain; landfills are lined with industrial strength plastics to prevent toxic run off into sensitive waterways or drinking water sources; and new chemical compounds protect plants from proliferating pests and disease.

Without fertilizers, the world food supply would shrink by one-third!

Health

The products of chemistry play a key role in the quality of life for a growing global population, through improved health and nutrition, and better materials for a multiplicity of construction, consumer, and industrial applications. Chemistry fosters safe food and water supplies, such as fertilizers that deliver essential nutrients to soil, and chlorine chemistry used to clean and disinfect drinking water around the world. Lifesaving medicines derived from chemistry help us combat disease and live longer.

Safety

Voluntary health, safety, and environmental improvement actions by the chemical industry often go beyond the minimum standards set by government regulations. For example, ACC's Responsible Care® initiative commits members to continuously improve health, safety, security and environmental performance. This commitment is demonstrated by the important contributions made by scientists and engineers in the development of products and technologies that improve health, safety and the environment, as well as the industry's commitment to continuous improvement and health and environmental research.

The World Health Organization estimates that diseases associated with dirty water kill at least 6,000 people every day.

Sustainability

Chemistry is fundamental to understanding the world's most pressing sustainability challenges, and essential to overcoming them. Chemicals must be produced and used in ways that protect the health of people and the environment. Members of the American Chemistry Council hold themselves to this standard and are helping other manufacturers and businesses do the same. Beyond safe chemistry, ACC members are committed to putting the power of chemistry and the industry's best scientific minds to work with experts in other business sectors, at universities and in government to develop new and innovative ways that chemistry can contribute to a sustainable future.

Environmental, Health and Safety Spending

In recent years, Environmental, Health and Safety (EH&S) spending as a share of shipments has declined, largely the result of more rapid gains in revenues. In addition, learning curve effects are playing a role. The period since the early 1970s witnessed increasing gross annual operating costs (depreciation, labor, material and supplies, services, etc.) for pollution abatement and control at manufacturing facilities. In addition to end-of-pipe pollution abatement activities, chemistry companies also made significant outlays for Superfund and other hazardous waste site remediation.

During the past several decades, the industry has constructed an extensive program to reduce emissions of the many types of materials that contribute to air, water, and land pollution. The industry's environmental actions have necessitated capital expenditures for pollution abatement and control that have totaled in the tens of billions of dollars since 1970.

Figure 9.1 - EH&S Spending by Basic and Specialty Chemical Producers

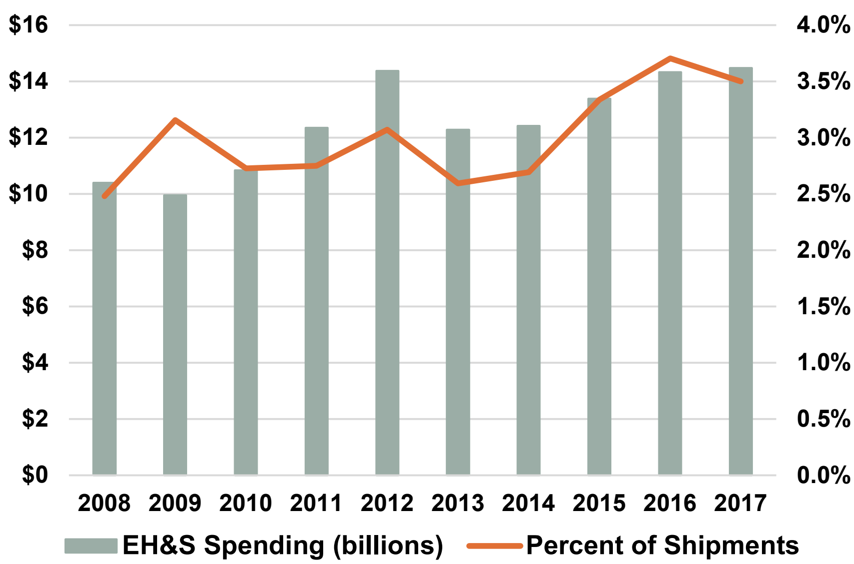
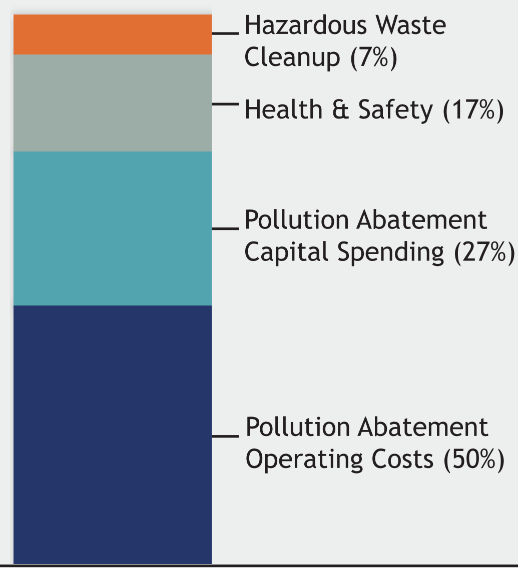


Figure 9.2 - EH&S Spending by Type of Spending



Environmental Performance

Environmental protection has been a national priority for decades. Since the U.S. Environmental Protection Agency (EPA) launched the Toxics Release Inventory (TRI) in 1986, total toxic releases and air emissions of criteria pollutants have fallen sharply. At the same time, the population and real (inflation-adjusted) gross domestic product (GDP) have grown.

Because transforming raw materials into products used by other industries can generate pollution, basic industries such as chemicals are among those most heavily regulated, particularly as it relates to the environment. Nowhere has the environmental performance of the business of chemistry been so positive than in the reduction of emissions of toxic substances. Although the list of TRI chemicals has changed significantly over the past decade, the long-term downward trend in the releases of core chemicals is evidence of the industry's dramatic improvement in environmental performance: since the start of TRI data collection, toxic releases and air emissions of criteria pollutants have declined, while chemical production has increased. The following table shows the long-term progress made in reducing emissions to the air of several key pollutants.

Table 9.1 - Key Pollution Indicators: A Summary of Progress (thousands of short tons)

	1985	1990	1995	2000	2005	2010	2015	2017
Sulfur Dioxide								
Total, All Sectors	23,307	23,077	18,619	16,347	14,546	7,732	3,801	2,815
Business of Chemistry	456	297	286	338	251	146	115	123
As a % of Total	2.0%	1.3%	1.5%	2.1%	1.7%	1.9%	3.0%	4.4%
Nitrogen Oxides								
Total, All Sectors	25,757	25,529	24,956	22,598	20,355	14,846	11,617	10,776
Business of Chemistry	262	168	158	105	61	53	47	47
As a % of Total	1.0%	0.7%	0.6%	0.5%	0.3%	0.4%	0.4%	0.4%
Volatile Organic Compounds								
Total, All Sectors	27,404	24,108	22,041	17,512	17,753	17,835	16,172	16,232
Business of Chemistry	881	634	660	254	235	85	75	77
As a % of Total	3.2%	2.6%	3.0%	1.4%	1.3%	0.5%	0.5%	0.5%
Carbon Monoxide								
Total, All Sectors	176,844	154,188	126,777	114,467	88,546	73,771	61,130	60,109
Business of Chemistry	1,845	1,183	1,223	361	208	173	129	129
As a % of Total	1.0%	0.8%	1.0%	0.3%	0.2%	0.2%	0.2%	0.2%
Coarse Particulates (PM_{10})								
Total, All Sectors	41,324	27,753	25,819	23,747	21,302	20,823	24,472	18,152
Business of Chemistry	58	77	67	55	36	23	20	19
As a % of Total	0.1%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%
Fine Particulates ($PM_{2.5}$)								
Total, All Sectors	n/a	7,560	6,929	7,288	5,592	5,964	6,191	5,343
Business of Chemistry	n/a	47	42	46	29	18	14	14
As a % of Total	n/a	0.6%	0.6%	0.6%	0.5%	0.3%	0.2%	0.3%
Ammonia								
Total, All Sectors	n/a	4,320	4,659	4,907	3,929	4,271	3,864	3,563
Business of Chemistry	n/a	183	183	26	18	22	22	22
As a % of Total	n/a	4.2%	3.9%	0.5%	0.5%	0.5%	0.6%	0.6%

Notes. Business of chemistry emissions do not include emissions from fuel combustion. Particulates include condensibles.

Source: Environmental Protection Agency

Figure 9.3 - Environmental Progress and Economic and Population Growth in the U.S.

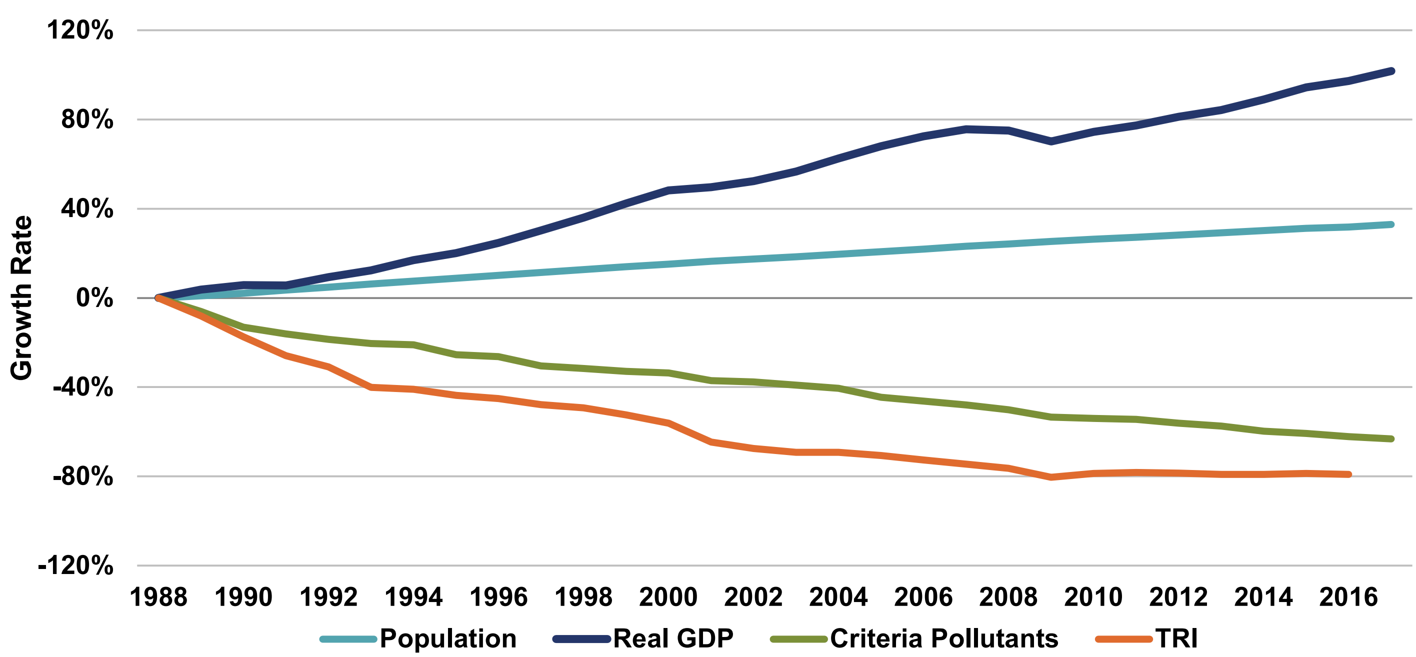


Figure 9.4 - Environmental Progress and Production in the Business of Chemistry

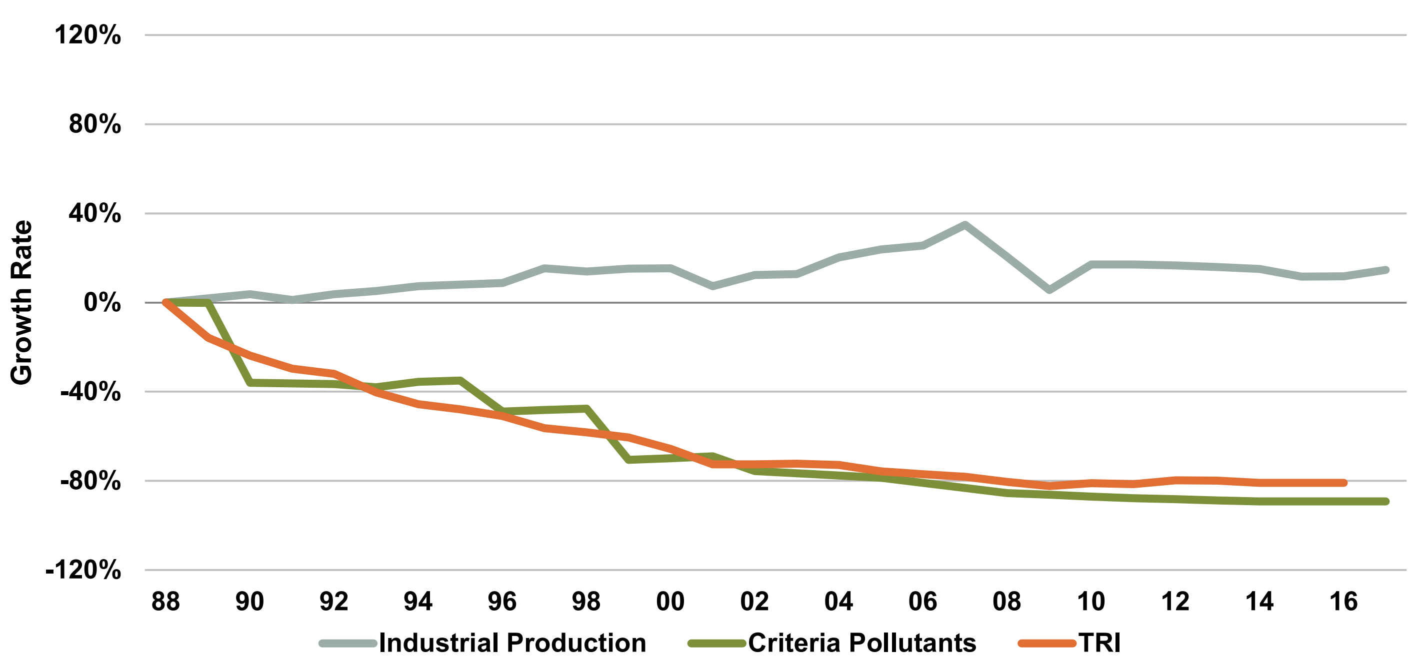


Table 9.2 - Toxics Release Inventory: Business of Chemistry (millions of pounds)

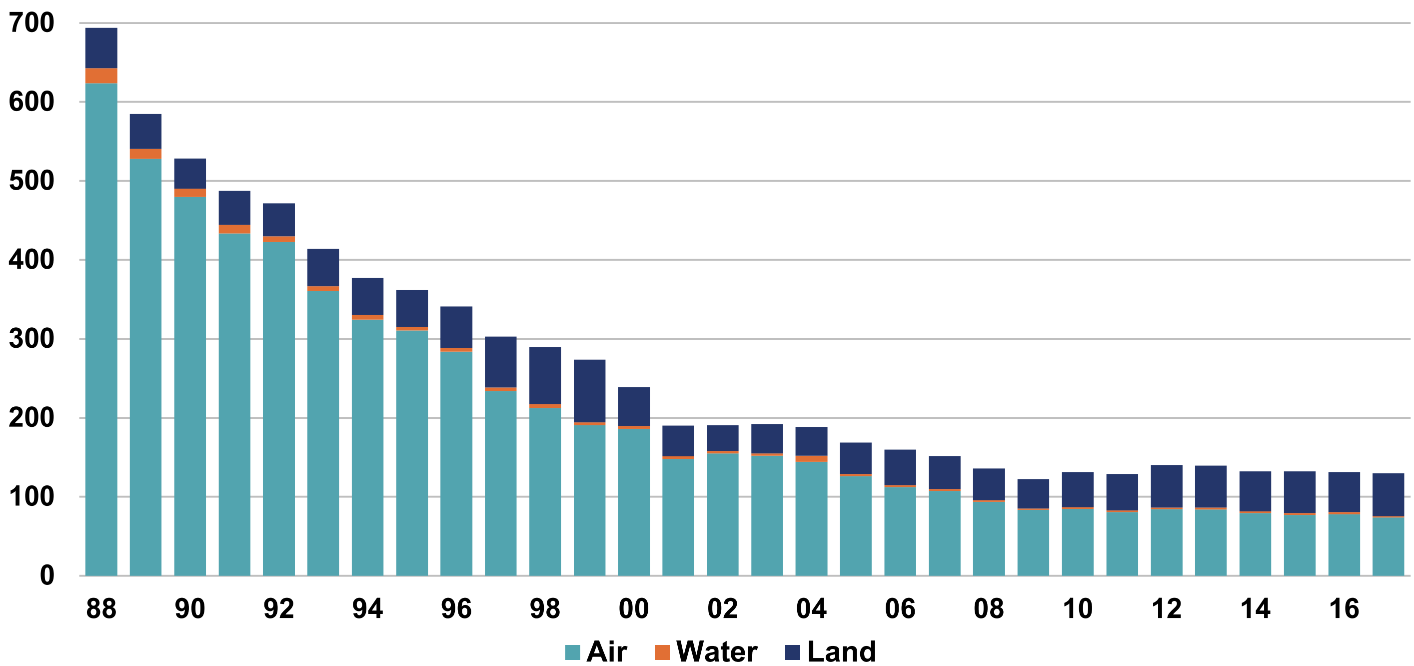
	1988	1990	1995	2000	2005	2010	2015	2016	2017
Total Releases*	694	528	362	239	169	134	132	131	130
Air	624	480	311	186	126	85	77	78	74
Surface Water	19	11	5	4	3	2	2	3	2
Land	51	38	46	49	40	47	53	51	54
Underground Injection	160	156	152	110	94	97	97	99	101
Off-site releases**	76	61	32	54	44	50	61	51	52

*The American Chemistry Council defines total releases to be the sum of total air, surface water, and land. Underground injections are not included in releases to the environment. Includes 1988 core chemicals only (does not include delisted chemicals; chemicals added in 1990, 1991, 1994, 1995; or aluminum oxide, ammonia, hydrochloric acid, or sulfuric acid).

**Off-site releases include metals and metal compounds transferred off-site for solidification/stabilization and for waste water treatment, including to publicly owned treatment works (POTWs).

Sources: Environmental Protection Agency – TRI Public Data Releases via TRI Explorer (www.epa.gov/triexplorer).

Figure 9.5 - TRI Releases by Media: Business of Chemistry (millions of pounds)



*According to the U.S. EPA, "**The Toxics Release Inventory (TRI)** tracks the management of certain toxic chemicals that may pose a threat to human health and the environment. U.S. facilities in different industry sectors must report annually how much of each chemical is released to the environment and/or managed through recycling, energy recovery and treatment. (A "release" of a chemical means that it is emitted to the air or water, or placed in some type of land disposal.) The information submitted by facilities is compiled in the Toxics Release Inventory. TRI helps support informed decision-making by companies, government agencies, non-governmental organizations and the public.*

"There are currently over 650 chemicals covered by the TRI Program. Facilities that manufacture, process or otherwise use these chemicals in amounts above established levels must submit annual TRI reports on each chemical." For more information, visit: https://www.epa.gov/toxics-release-inventory-tri-program

Worker Health and Safety

In addition to its environmental protection activities, the business of chemistry has also achieved a remarkable record of worker safety. This record has continually improved post-World War II, largely as a result of elimination of job hazards and the industry's initiatives in implementing effective safety programs. Basic and specialty chemical companies spend billions of dollars per year improving worker health and safety. The results have been nothing short of phenomenal: data from the Bureau of Labor Statistics indicate that the business of chemistry has illness and injury rates of nearly far below that of manufacturing as a whole, and one of the lowest rates across all manufacturing industries. Furthermore, illness and injury rates for American Chemistry Council member companies are nearly one-third that of the business of chemistry as a whole.

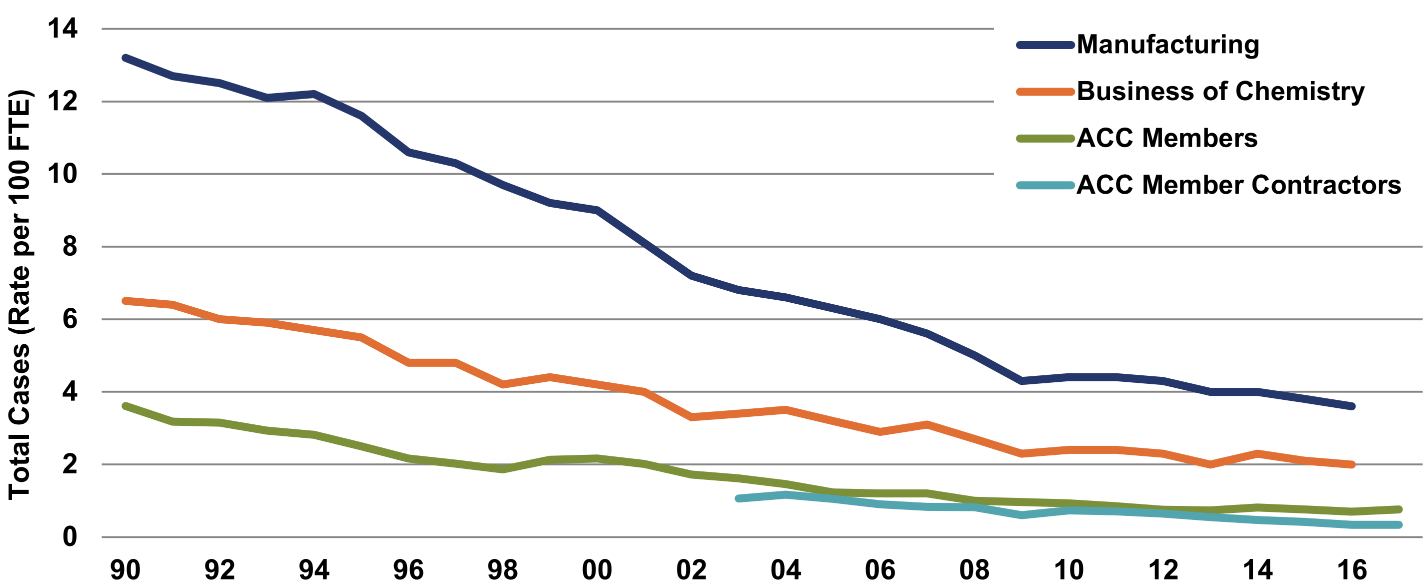
Table 9.3 - Occupational Injury and Illness Rates

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Manufacturing										
Total OIIR Cases	5.0	4.3	4.4	4.4	4.3	4.0	4.0	3.8	3.6	n/a
Lost Workday Cases	1.2	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.9	n/a
Business of Chemistry										
Total OIIR Cases	2.7	2.3	2.4	2.4	2.3	2.0	2.3	2.1	2.0	n/a
Lost Workday Cases	0.8	0.6	0.7	0.7	0.7	0.5	0.7	0.6	0.6	n/a
American Chemistry Council Companies										
Total OIIR Cases	1.01	0.96	0.93	0.85	0.75	0.73	0.82	0.76	0.70	0.76
Lost Workday Cases	0.24	0.23	0.22	0.20	0.17	0.17	0.20	0.20	0.17	0.20
American Chemistry Council Company Contractors										
Total OIIR Cases	0.82	0.60	0.73	0.71	0.65	0.55	0.47	0.42	0.34	0.34
Lost Workday Cases	0.15	0.12	0.13	0.12	0.13	0.09	0.09	0.08	0.06	0.07

Notes. Lost workday cases rate per 100 employees.

Sources: Bureau of Labor Statistics and American Chemistry Council

Figure 9.6 - Trends in Occupational Injury and Illness Incidence Rates



Spending on Security

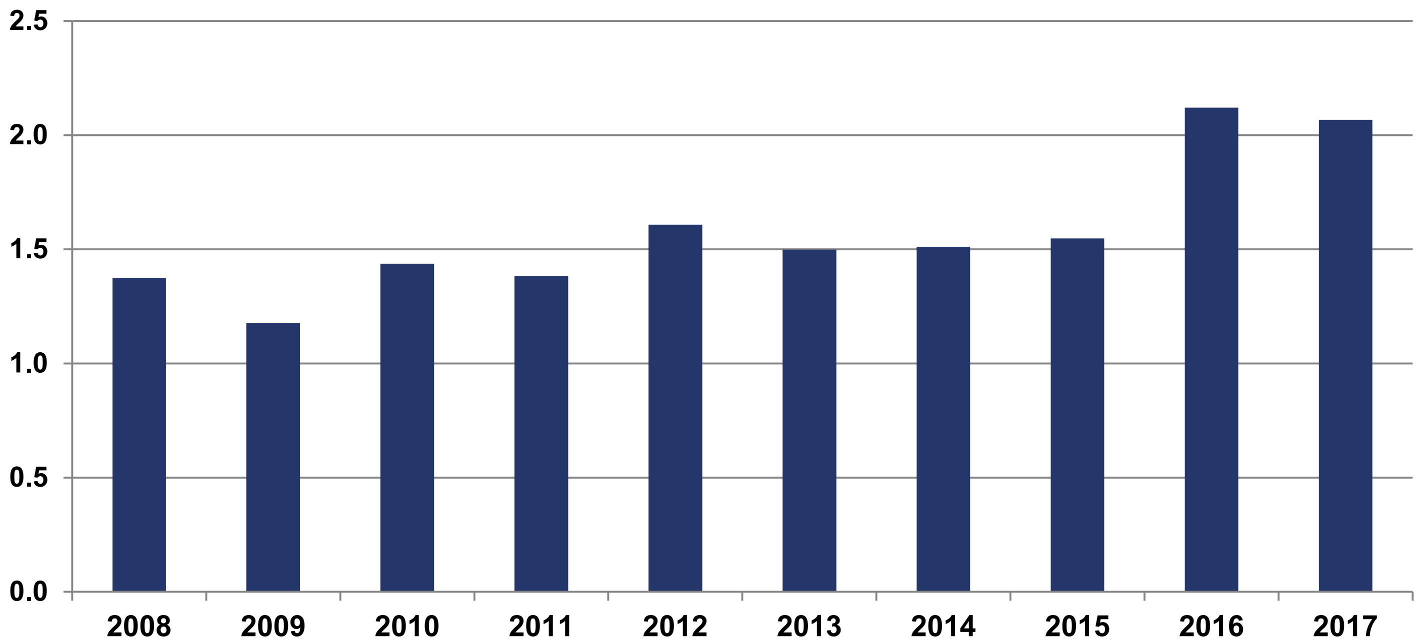
Because of its critical role to the economy, The Department of Homeland Security (DHS) has identified the chemical sector as one of sixteen "critical infrastructure sectors" (defined as "sectors whose assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.").

While facility security has long been a focus of the chemical industry, the events of Sept. 11 lead to heightened security concerns. Within months of the terrorist attacks of 9/11, ACC created a stringent, mandatory security program called the Responsible Care® Security Code. Since 9/11/2001, ACC members have invested more than $17 billion under the Security Code to further enhance site, transportation, and security at their facilities. ACC member companies must also assess cybersecurity vulnerabilities, implement security measures to address them and provide appropriate training and guidance to employees on current and emerging threats.

Business leaders are increasingly investing in the security of their companies' people and information, as well as process plants, equipment, technology, storage facilities and buildings. Companies must also consider the security of other assets such as tank cars and other vehicles, utilities (electric power, steam, natural gas, water, sewer, etc.), railroad lines and roads, cogeneration facilities, hazardous waste processing facilities, supplies, tools, office equipment, and even employees' personal property.

The American Chemistry Council collects data on spending for security via its annual economic survey of member companies. Some companies spend as much as 2% of their sales on security for their business operations. Security spending includes bodyguard, guard dog, patrol and other guard services, other security services, electronic surveillance, remote electronic monitoring of security, and miscellaneous protective services. Security costs also include those traditionally associated with information, computer, network, and related IT security. Other costs not contained in this figure include: security efforts by non-security personnel (e.g., building services); costs of process safety measures; higher freight expenses; inventory control; additional procedures; insurance; and other related expenses. Thus, these costs do not represent the entire cost of security but rather one fraction of it; actual total spending for security could be several times this amount.

Figure 9.7 - Security Spending by ACC Member Companies ($billion)



ACC's Commitment to EHS&S

Responsible Care® is the chemical manufacturing industry's environmental, health, safety and security performance initiative. For the past 30 years, Responsible Care has helped ACC member companies significantly enhance their performance and improve the health and safety of their employees, the communities in which the operate, and the environment as a whole.

Responsible Care is a global initiative that began in Canada in 1984, was enacted by the U.S. chemical industry in 1988, and today is practiced in 68 economies around the world. Participation in Responsible Care is a condition of membership for ACC members and Responsible Care Partner companies, all of which have made CEO-level commitments to uphold the program elements.

The Responsible Care Guiding Principles are at the heart of the Responsible Care commitment—through these principles, members and Partners pledge to improve environmental, health, safety and security performance for facilities, processes and products throughout the entire operating system. Companies also are committed to open and transparent reporting and undergo mandatory headquarters and facility audits to certify their performance. This information is made publicly available at https://responsiblecare.americanchemistry.com/.

Responsible Care companies are working to make the industry even safer for our employees and communities. A summary of 2017 performance reporting shows that Responsible Care companies:

- Have a worker safety rate than is five times better than the U.S. manufacturing sector as a whole, and almost three times better than the business of chemistry overall.
- Improved their worker safety record a significant 79% since 1990.
- Decreased reportable distribution incidents by 70% since 1995.
- Through the period 1992-2015, ACC members have reduced their greenhouse gas intensity by over 24% and improved energy efficiency by 19% during the same time frame

Note: some of the data are preliminary and subject to change.

The Long-Range Research Initiative (LRI) of the American Chemistry Council (ACC) promotes innovations in chemical safety assessment. It invests in science essential for understanding the impact of chemicals on human health and the environment. With a focus on biologically-relevant exposures, LRI adopts an integrated approach to exposure and hazard characterization to promote a shift in focus away from development of safety assessments based solely on hazard or exposure data. Through integration and translation of its research outcomes, LRI transforms this information into knowledge that can inform decisions and policies about the safety of chemicals relevant to current environmental and public health challenges.

Chemistry is fundamental to understanding the world's most pressing sustainability challenges, and essential to overcoming them.

CHEMISTRY: The Science Behind Sustainability

Chemicals must be produced and used in ways that protect the health of people and the environment. Members of the ACC are committed to meeting this core expectation and are helping other manufacturers and businesses along the value chain to do the same. As an industry, we are committed to improve our own sustainability performance and help others to do the same. ACC's Sustainability Principles outlines our commitment to promote the safe use of chemicals, address the environmental impacts of our operations and products and go beyond regulatory requirements to manage, measure and report our progress. As an industry, we will:

- Develop new ways to measure and promote the safe and sustainable use of chemicals.
- Commit to industry sustainability practices, hold ourselves accountable and exceed government regulations.
- Elevate the quality of life for people around the world through technologies that improve health and wellness, enable food security, increase access to clean water and provide comfortable shelter.
- Improve the availability, performance and cost-effectiveness of renewable energy and energy efficient technologies enabled by chemistry.
- Reduce greenhouse gas emissions in the manufacture and use of our products.
- Protect our environment by supporting efforts to reduce and manage waste so oceans and water sources are not polluted with mishandled plastic or other materials.
- Promote innovations in product design, product re-use, repurposing and recycling to extend the useful life and value of all products.

TRANSCAER® (Transportation Community Awareness and Emergency Response) is a voluntary national outreach effort that focuses on assisting communities to prepare for and to respond to a possible hazardous material transportation incident. TRANSCAER members consist of volunteer representatives from the chemical manufacturing, transportation, distributor, and emergency response industries, as well as the government. Union Pacific Railroad and The Dow Chemical Company founded TRANSCAER in 1986.

TRANSCAER is organized into two groups: the National TRANSCAER Task Group (NTTG) and its included Executive Committee, which manages the TRANSCAER program; and the Regional Approach, which implements TRANSCAER and the nine TRANSCAER steps throughout the United States. Members of the NTTG may represent manufacturers, distributors, hazardous materials storage and handling, transporters, emergency response and preparedness organizations, their associations, and related service industries.

For additional information about TRANSCAER, visit www.TRANSCAER.com

TRANSCAER®

A service of the American Chemistry Council, **CHEMTREC®** was established in 1971 as a public service hotline for emergency responders to obtain information and assistance for emergency incidents involving chemicals, hazardous materials and dangerous goods. Today, CHEMTREC is the world's premier call center for emergency hazmat response coordination. Linked to the largest network of chemical and hazardous material experts in the world, CHEMTREC is a cost-effective method for shippers of hazardous materials to offer a world-class public safety service while complying with regulatory requirements.

CHEMTREC® The right information at the right time

For more information, visit www.chemtrec.com.

10. ENERGY

The business of chemistry transforms hundreds of millions of tons of natural raw materials from earth, water, and air into valuable products that enable safer and healthier lifestyles. Chemistry unlocks nature's potential, improving the quality of life for a growing and prospering world population by creating materials used in a multitude of consumer, industrial and construction applications. The transformation of simple compounds into valuable and useful materials requires large amounts of energy.

The business of chemistry is energy-intensive; in fact, it is the second largest user of energy (fuel and nonfuel) in manufacturing sectors (petroleum and coal products is the largest). Within the chemical industry, this is especially the case for basic chemicals, as well as certain specialty chemical segments (e.g., industrial gases). The largest user of energy is the petrochemical and downstream derivatives business. Inorganic chemicals and agricultural chemicals are also energy-intensive.

Unique among manufacturers, the business of chemistry relies upon energy inputs, not only as fuel and power for its operations, but also as raw materials in the manufacture of many of its products. *The term "energy" as used in this publication includes consumption for both feedstocks and as fuel and power for production processes*.

Fuel and Power

The business of chemistry operates by creating complex chemical reactions. Many of these reactions require large amounts of heat, pressure and/or electricity. The industry consumes energy to produce electricity and/or steam onsite and purchases electricity and some steam from electric utilities or other suppliers. The accompanying table provides details on energy consumed for fuel and power uses by the business of chemistry. This illustrates the predominant role of natural gas in meeting the industry's fuel and power needs, over half of which is provided by natural gas.

Feedstocks

In addition to air, water, and metallic and nonmetallic minerals, the business of chemistry uses large quantities of energy such as natural gas, natural gas liquids, and naphtha as raw materials or feedstocks. (A small amount of coal is also used.) Petroleum and natural gas contain vast quantities of hydrocarbon molecules that are split apart during processing and are then recombined into useful chemistry products.

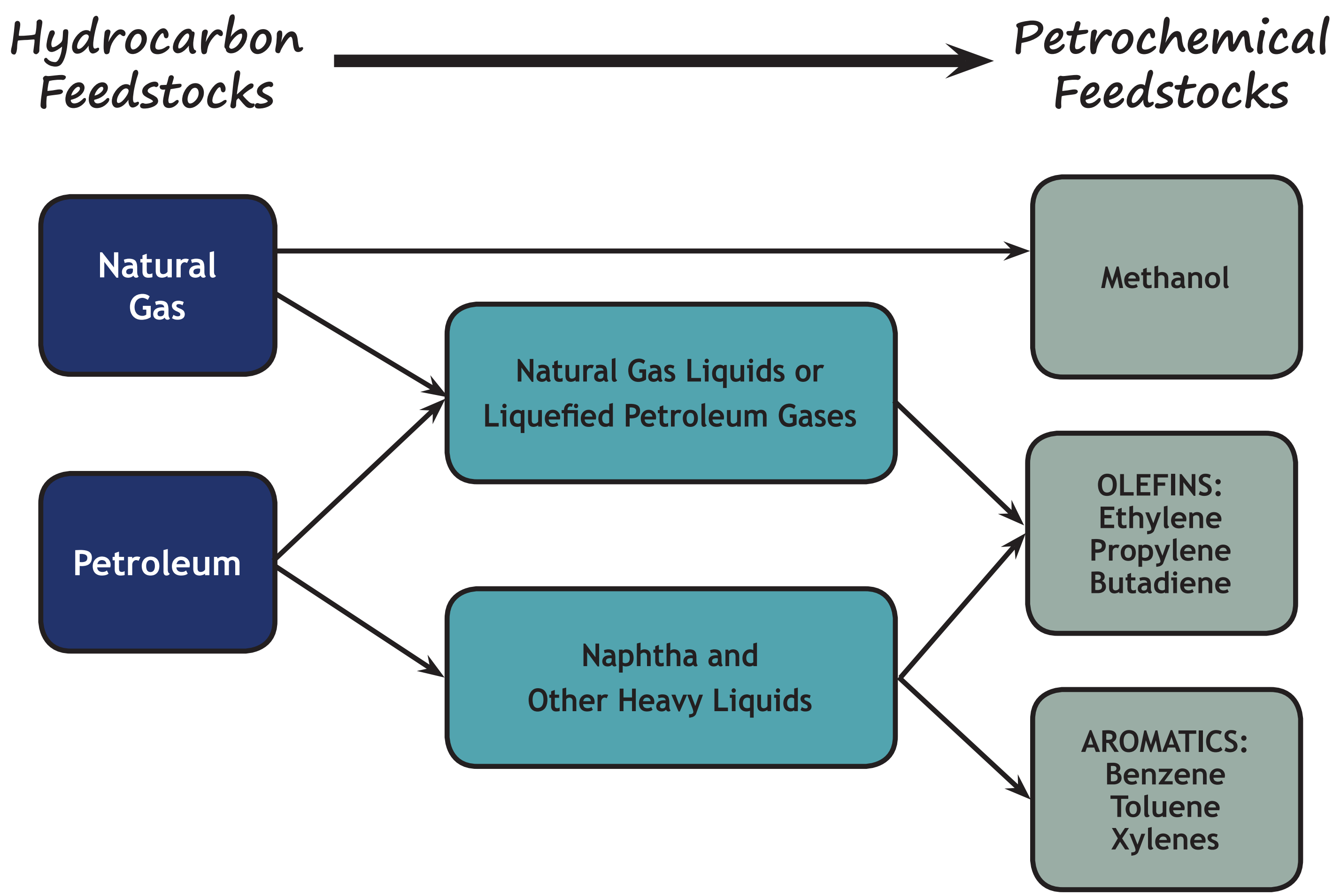
The feedstock data show that natural gas liquids (NGLs), such as ethane, play a large role in meeting the industry's feedstock needs. Combined with natural gas directly used as a feedstock, it accounts for more than half of the total. Heavy liquids, such as naphtha, also play a major role. Although coal and biomass can be used as hydrocarbon feedstocks, petroleum and natural gas account for 99% of feedstocks for the business of chemistry. Natural gas liquids are predominant, and are followed by naphtha and other heavy liquids. Besides methanol, natural gas is directly used as a feedstock for ammonia and carbon black. Once the dominant source of petrochemical feedstocks, the use of coal has dropped dramatically in the U.S. over the past century. Feedstock use is concentrated in bulk petrochemicals and in fertilizers.

There are several methods of separating or "cracking" these chains found in fossil fuels. Natural gas is processed to produce methane and natural gas liquids (NGLs). Natural gas liquids—also called liquefied petroleum gases—include ethane, propane, and butane and can be produced via natural gas processing or through the petroleum refining process. Petroleum is refined to produce a variety of petroleum products, including naphtha and natural gas liquids. Naphtha and NGLs are processed in large vessels called crackers, which are heated and pressurized to crack the hydrocarbon chains into smaller ones. These smaller hydrocarbons are the gaseous petrochemical feedstocks used to make the products of chemistry: olefins (ethylene, propylene, and butylene) and aromatics (benzene, toluene and xylenes). The seventh petrochemical feedstock, methane, is directly

converted from the methane in natural gas and does not undergo the cracking process.

These petrochemical feedstocks are the foundation of chemistry of plastics, pharmaceuticals, electronic materials, fertilizers, and thousands of other products that improve the lives of a growing and prospering population. The product chains for these petrochemical feedstocks can be found in the appendices.

Figure 10.1 - Derivation of Petrochemical Feedstocks

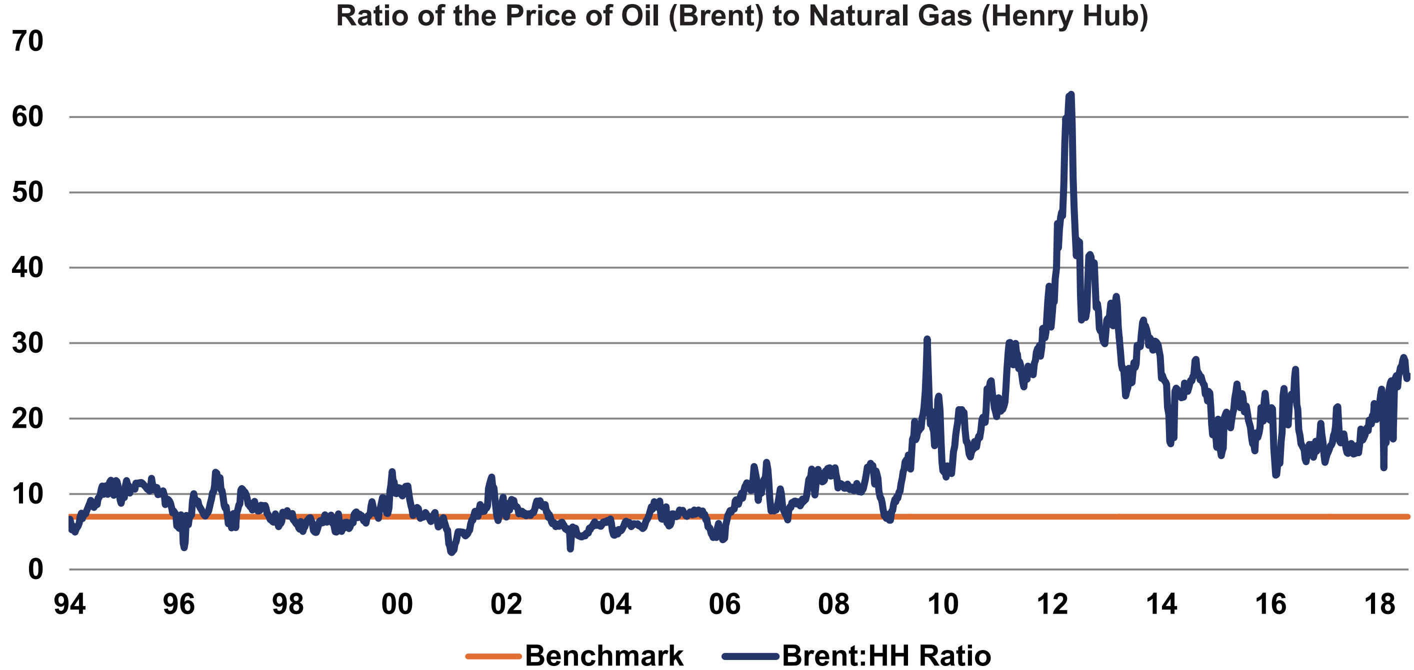


Natural Gas & Petroleum Products

The business of chemistry is a large user of natural gas and petroleum products, The business of chemistry accounts for nearly 9% of all U.S. petroleum products consumption, including distillate and residual fuel oil for fuel and power use, natural gas liquids (or liquefied petroleum gases), such as ethane and propane, and heavy liquids (i.e., naphtha and gas oil) consumed as feedstocks. The business of chemistry is also the largest single industrial user of natural gas. Most natural gas is consumed as fuel: the majority of steam boilers and cogeneration units (units that produce both steam and electricity) are powered by natural gas. The remaining natural gas consumption is directly used as feedstocks to manufacture ammonia, carbon black, and methanol.

Due to the relative abundance of natural gas in the United States, natural gas and natural gas liquids derived from natural gas are vital to the domestic business of chemistry. Around 90% of U.S. olefins production (specifically ethylene) is based on natural gas liquids, while 70% of European and Asian petrochemical production is based on naphtha, a petroleum-based feedstock. Because petroleum is traded on the world market, all countries are subject to the same price. Natural gas markets, however, are regional; in other words, the price in North America affects only North American producers. For this reason, U.S. petrochemicals enjoy a competitive advantage when natural gas prices are low relative to oil prices. In the early 2000s, natural gas prices quadrupled, resulting in the idling or permanent shut down of about 50% of U.S. methanol capacity, 40% of ammonia capacity, and 15% of ethylene capacity, all which depend on natural gas or natural gas derivatives as feedstocks. By 2010, with the advent of abundant supplies of shale gas, the situation had reversed. Closed plants have been restarted, new plants are under construction, and substantial new investments have been announced.

Figure 10.2 - U.S. Based Petrochemical Competitiveness: Ratio of the Price of Oil (Brent) to Natural Gas (Henry Hub)



Source: Energy Information Administration and American Chemistry Council analysis.

A general rule of thumb concerning the competitiveness of U.S. petrochemical production vis-à-vis Western Europe (a primary competitor and largest exporting region) is that when the ratio between the price of oil (as measured in U.S. dollars per barrel, Brent) divided by the price of natural gas (as measured in U.S. dollars per million BTUs, Henry Hub) is above 7.0, U.S.-based petrochemicals production is generally competitive. When it is lower than 6.0, Gulf Coast petrochemicals are relatively disadvantaged. During the 1994-1999 period, the ratio averaged 8.5. As this figure shows, the ratio has been above 7.0 for since late 2009.

Energy Consumption

Petroleum and natural gas are important for both fuel and power in feedstock uses of energy. Table 11.2 provides a summary of historical perspective on energy consumption by the business of chemistry. The year 1974 represents the year of the first oil price shock, and provides a logical base-year for comparison. Similarly, 1990 represents a base-year widely used in evaluating greenhouse gas (GHG) emission trends.

Table 10.1 - Energy Consumption by the Business of Chemistry (trillions of BTUs)

	1974	1980	1990	2000	2010	2014	2015	2016	2017
Total Fuel & Power	3,022	2,786	2,789	3,191	2,688	2,854	2,827	2,816	2,838
Natural Gas	1,612	1,612	1,643	1,804	1,529	1,707	1,692	1,726	1,754
Coal and Coke	311	300	272	303	189	137	127	112	109
Fuel Oil (Petroleum)	285	194	77	59	18	16	15	16	16
Purchased Electricity	437	454	461	522	471	491	485	456	446
Other	377	303	336	503	481	503	508	506	513
Total Feedstock	2,165	2,924	2,852	3,470	2,874	2,903	2,989	3,086	3,408
NGLs/LPGs*	1,483	1,587	1,058	1,562	1,483	1,718	1,770	1,841	2,044
Heavy Liquids	942	873	1,029	1,166	942	685	655	642	696
Natural Gas	430	443	744	709	430	483	547	586	651
Coal	19	18	21	33	19	17	17	17	17

Sources: American Chemistry Council, Federal Reserve Board, Bureau of the Census, EIA

*Natural gas liquids (NGLs) and liquefied petroleum gases (LPGs) include ethane, propane, and butanes.

Figure 10.3 - Composition of Energy Requirements (trillion BTUs), 2017

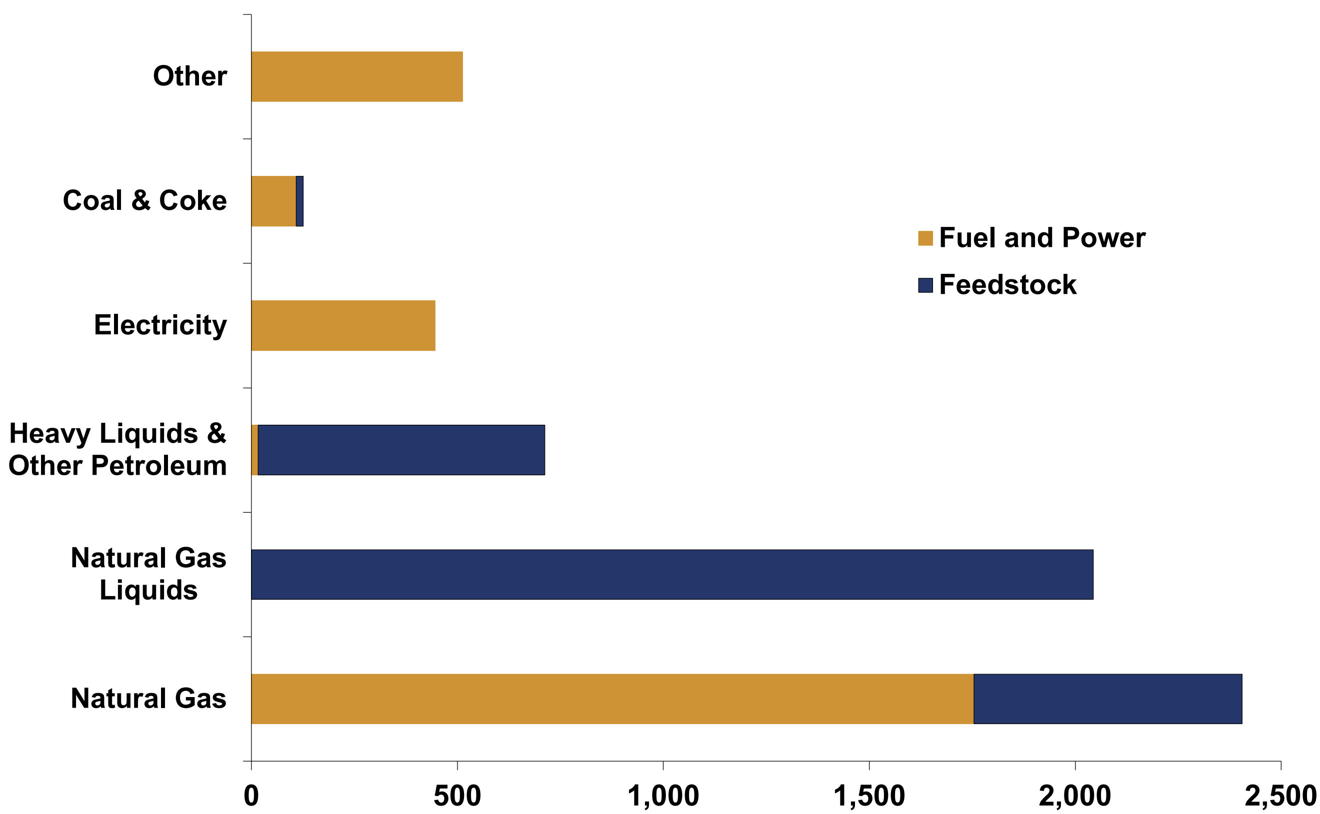
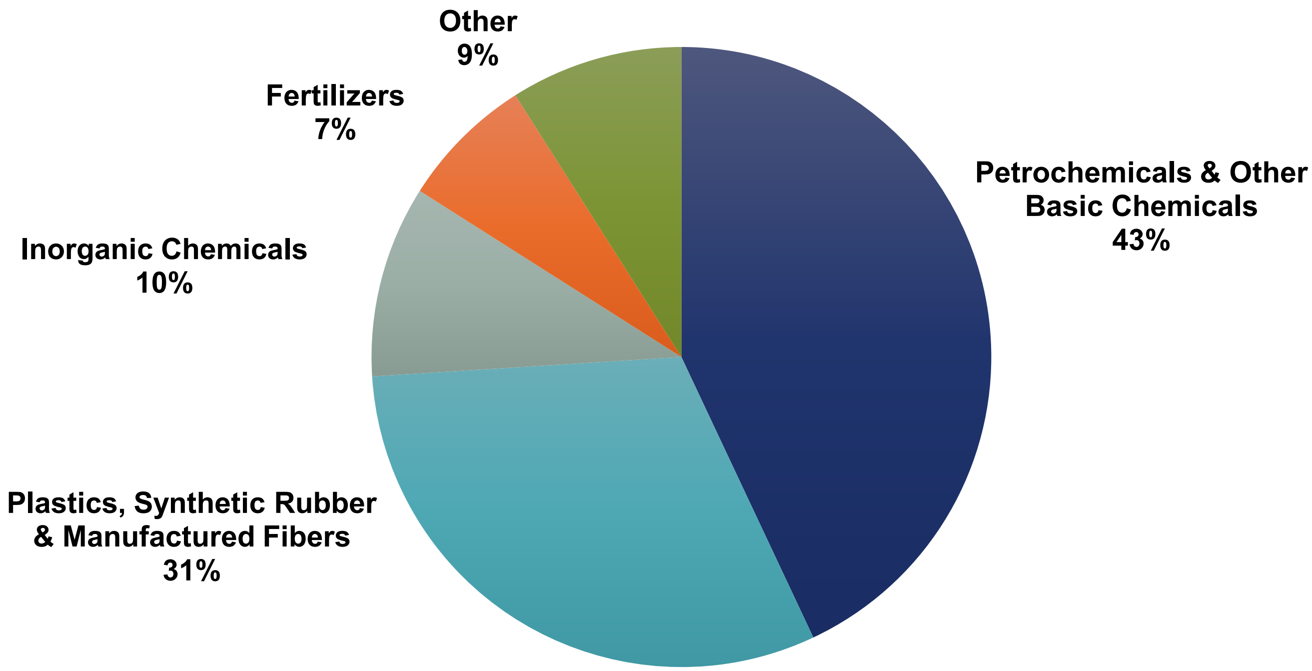
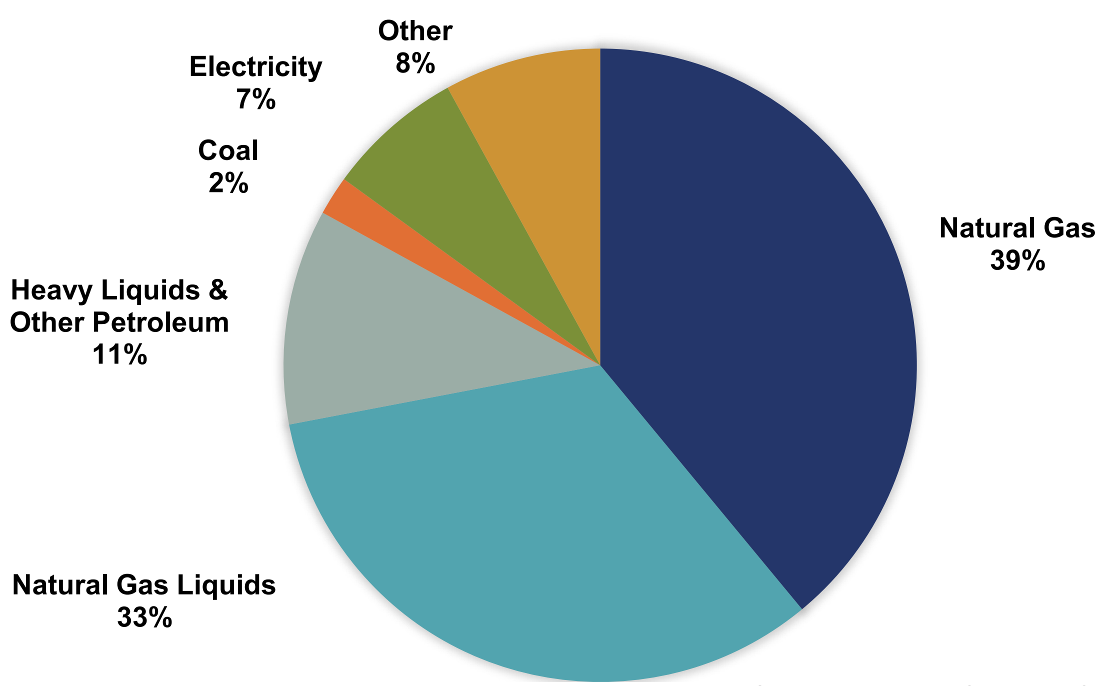


Figure 10.4 - Share of Total Energy Consumption by Segment



Source: U.S. Energy Information Administration, Manufacturing Energy Consumption Survey (MECS)

Figure 10.5 - Share of Total Energy Consumption by Source

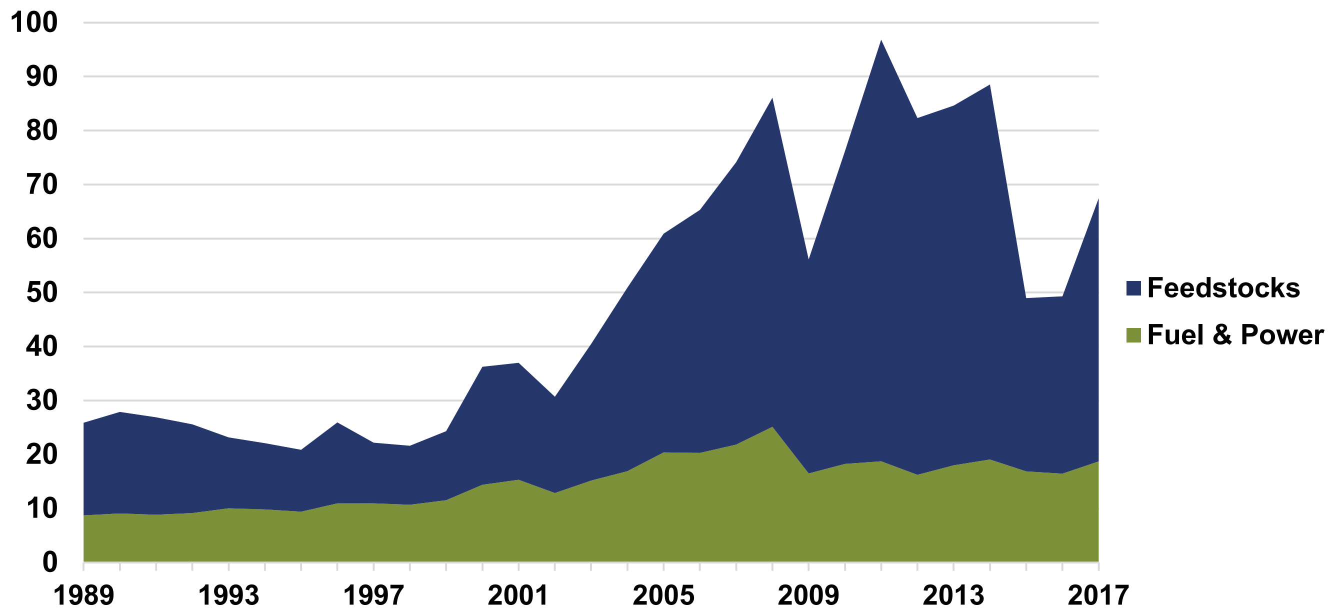


Sources: American Chemistry Council, Federal Reserve Board, Bureau of the Census, EIA

Energy Costs

Energy represents a significant share of manufacturing costs for the U.S. business of chemistry. For some energy-intensive products, energy for both fuel and power needs and feedstocks account for up to 85% of total production costs. Because energy is a vital component of the industry's cost structure, higher energy prices can have a substantial impact on the business of chemistry. Overall energy costs represent around 10% of the value of industry shipments. Moreover, value added by the business of chemistry is equivalent to five times this energy cost, which is just one of many inputs, including other raw materials and services that the business of chemistry purchases from other industries.

Figure 10.6 - Value of Energy Consumed by the Business of Chemistry ($billion)



Sources: American Chemistry Council, Federal Reserve Board, Bureau of the Census, EIA

Chemical Industry Energy Efficiency

The business of chemistry in the United States has achieved significant energy efficiency gains. Since the oil crises of the 1970s, the business of chemistry began a series of energy efficiency improvements that continue today: the fuel and power energy consumed per unit of output is half that of 1974. Improvements in energy efficiency are essential for the business of chemistry to maintain its competitive edge in domestic and world markets. Since energy costs remain a major cost to the industry, providing a clear incentive for energy efficiency efforts.

One way that the business of chemistry is improving its energy efficiency is through the use of combined heat and power (CHP), also known as cogeneration. CHP is the simultaneous generation of electricity and heat from a facility that is located very close to the manufacturing facility. Because most CHP facilities use natural gas and create two forms of energy (electric power and steam) with the same amount of fuel, they are often twice as efficient as older coal-burning electric utilities. These efficiencies are boosted by the fact that the power generation is physically located close to the power consumption, thus avoiding transmission losses associated with consumption of power generated many miles away by large electric utilities. CHP by the business of chemistry accounts for nearly a third of all CHP used in manufacturing. Future federal legislation on electricity restructuring has the potential to impact the business of chemistry's cogeneration.

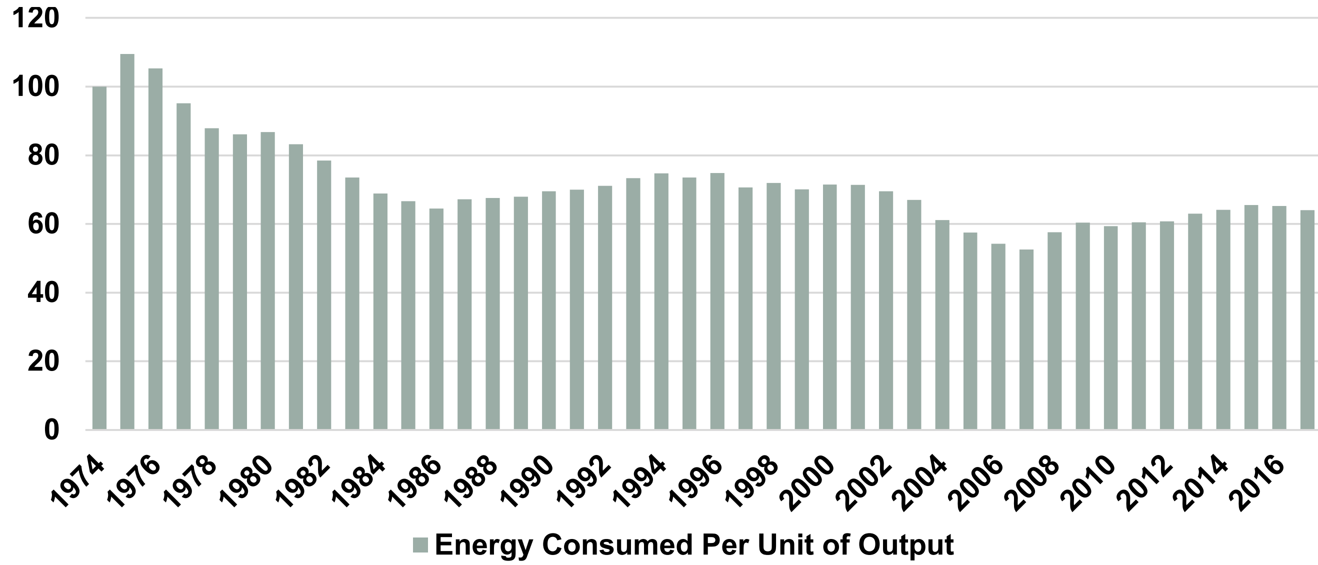
Energy Efficiency from the Products of Chemistry

There are many products of the business of chemistry that help other industries and households save energy and ultimately reduce greenhouse gas emissions (foam insulation, catalysts, etc.). ACC's Economics and Statistics department estimates that the use of chemistry products in various energy-saving applications saves between 8.0 and 10.9 quadrillion British thermal units (BTUs) of energy annually. This represents 8% to 11% of total U.S. energy consumption. To put these energy savings into perspective, the annual savings of 8.0 to 10.9 quadrillion BTUs would be the equivalent amount of energy used to heat, cool, light, and power 41 to 56 million households (about one-third to one-half of all U.S. households). Alternatively, the energy savings is enough to power 98 to 135 million vehicles for a year (between 40-55% of the cars on the road today). Looking at it another way, the energy savings from chemistry products is equivalent to the amount of energy generated by 177,000 to 243,000 windmills operating under typical conditions.

The following are just a few highlights of the energy-saving characteristics of specific chemistry products:

- Chemistry-driven plastic auto parts make up 50 percent of the volume of today's new cars, dramatically reducing vehicle weight to significantly improve gas mileage—by up to seven percent for each 10 percent in weight reduction—while playing a critical role in helping improve vehicle safety.
- Building insulation saves up to 40 times the energy used to create it; plastic house wrap that creates a weather resistant barrier saves up to 360 times the energy used to produce it.
- Innovative material design and technology advancements have resulted in high quality polyurethane insulation products that reduce energy loss. In a one-year study, plastic building and construction materials saved 467.2 trillion Btu's of energy over alternative construction materials. The energy saved by using plastic building and construction materials in one year is enough to meet the average annual energy needs of 4.6 million U.S. households.
- Two pounds of plastic can deliver 10 gallons of a beverage. You'd need three pounds of aluminum, eight pounds of steel, or over 40 pounds of glass to bring home the same amount. Plastic jars can use up to 90 percent less material by weight (approximately) than their glass counterparts. Plastic containers also can use about 38 percent less material than similarly sized steel cans. And extremely lightweight, flexible packaging made from plastic or plastic-and-foil composites can use up to 80 percent less material than traditional bag-in-box packages.
- Chemistry enables compact fluorescent bulbs to "fluoresce" and to use 70 percent less energy than incandescent bulbs—and LED lighting could cut global energy demand by a whopping 30 percent.
- Replacing an old refrigerator with a new ENERGY STAR-qualified model—with improved insulation and coolant systems made possible by chemistry—saves enough energy to light an average house for nearly four months.
- Solar power relies on silicon-based chemistry, and innovative new plastic solar panels are poised to reach the mass residential market.
- Wind power turbine blades are made using plastics and chemical additives, helping deliver renewable energy to our nation's electricity grid.
- Lithium-ion and lithium-polymer batteries employ chemistry to create rechargeable batteries for products such as automobiles, military equipment, laptops, gaming consoles, and smartphones.

Figure 10.7 - Business of Chemistry: Fuel and Power Energy Consumed (1974=100)



Greenhouse Gas Emissions

Radiation from the sun penetrates through the earth's atmosphere and warms its surface. Certain gases in the atmosphere, however, will trap (absorb) some of the outgoing infrared (long-wave) radiation; this radiation is then reradiated back toward Earth. This is similar to the way a greenhouse prevents heat from escaping through its glass panels. As a result, this phenomenon is called the "greenhouse effect." As concentrations of greenhouse gases (GHG) rise, the average temperature of the lower atmosphere will gradually increase. Many greenhouse gases occur naturally, including water vapor, carbon dioxide, methane, nitrous oxide, and ozone; other greenhouse gases are generated in some industrial processes, including hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6). There are certain human activities that add to the levels of most of these naturally-occurring gases:

- Carbon dioxide (CO2) released into the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood or wood products are burned.
- Nitrous oxide (NO2) emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.
- Methane (CH4) emitted during production and transport of fossil fuels (coal, natural gas, and oil), from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock.

Carbon dioxide emissions represent the majority of GHG emissions from the business of chemistry. Nitrous oxide, methane and some other gases account for the balance. Carbon emissions of the business of chemistry, including the indirect carbon value of purchased electricity, account for less than 5% of total U.S. emissions.

Per unit of output, U.S. chemical industry GHG emissions have declined significantly since 1990 due to a range of enhancements and improvements, including [one-time] process changes reducing nitrous oxide emissions; more effective catalysis; upgrades in industrial and process technologies; fuel switching (e.g., natural gas instead of coal); and education and training for employees.

There are two categories of GHG emissions: direct and indirect (or embedded). Direct emissions are emissions from sources that are owned or controlled by the company, such as on-site combustion and process emissions. Indirect (or embedded) emissions also include carbon dioxide emissions from purchased electricity. As such, there are two means of measuring CO2 emissions: one means is to include indirect (or embedded) emissions, which presents somewhat of a life cycle approach and the other means is to exclude indirect emissions, as these emissions are generated by another sector of the economy. *In order to more accurately represent the progress that the U.S. chemical industry has made in reducing its GHG emissions, we report two sets of emissions data: one including indirect emissions, and one excluding indirect emissions.*

Table 10.2 - Business of Chemistry Greenhouse Gas Emissions

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017
	(in million metric tons of carbon dioxide equivalent)									
Fuel and Power CO_2	223.0	238.0	252.5	218.5	203.8	207.2	203.8	196.3	184.7	178.2
Process CO_2	42.3	48.9	50.1	45.7	45.5	45.0	42.0	43.6	43.0	44.2
Total Carbon Dioxide	**265.3**	**286.9**	**302.6**	**264.2**	**249.3**	**252.2**	**245.8**	**239.9**	**227.7**	**222.4**
Nitrous Oxide	27.3	30.8	19.4	18.4	15.7	14.6	16.3	15.9	17.2	17.4
Methane	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
HFCs	46.1	42.9	37.1	20.0	8.0	4.1	5.0	4.3	2.8	2.5
Total GHG Emissions	**338.9**	**360.7**	**359.2**	**302.7**	**273.1**	**271.0**	**267.2**	**260.3**	**247.9**	**242.5**
CO_2 Emissions Embedded in Purchased Electricity	90.3	91.8	102.6	92.9	83.5	82.0	77.9	71.8	60.0	51.7

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017
	(Index where 1990 = 100)									
Performance (including embedded CO_2 emissions):										
Chemical Industry Output	100.0	106.8	121.5	138.0	127.9	122.0	120.7	120.2	119.6	120.7
Energy Efficiency	100.0	103.1	94.2	71.6	75.4	83.1	84.8	84.3	84.4	84.3
GHG Emissions	100.0	106.4	106.0	89.3	80.6	80.0	78.9	76.8	73.2	71.6
GHG Intensity	100.0	99.7	87.3	64.7	63.0	65.6	65.3	63.9	61.2	59.3
Performance (excluding embedded CO_2 Emissions):										
Chemical Industry Output	100.0	106.8	121.5	138.0	127.9	122.0	120.7	120.2	119.6	120.7
Energy Efficiency	100.0	103.1	94.2	71.6	75.4	83.1	84.8	84.3	84.4	84.3
GHG Emissions	100.0	108.2	103.2	84.4	76.3	76.0	76.2	75.8	75.6	76.8
GHG Intensity	100.0	101.3	85.0	61.2	59.7	62.3	63.1	63.1	63.2	63.6

Notes. Process CO2 has been revised to include emissions from phosphoric acid and other processes as well as non-fertilizer consumption of urea (e.g., urea-formaldehyde resin production). Revisions to historical data include nitric acid N2O emissions. In 2013, EPA made revisions to its methodology to calculate process CO2 emissions that resulted in significant upward revisions. The industrial production index (the denominator) was revised as well.

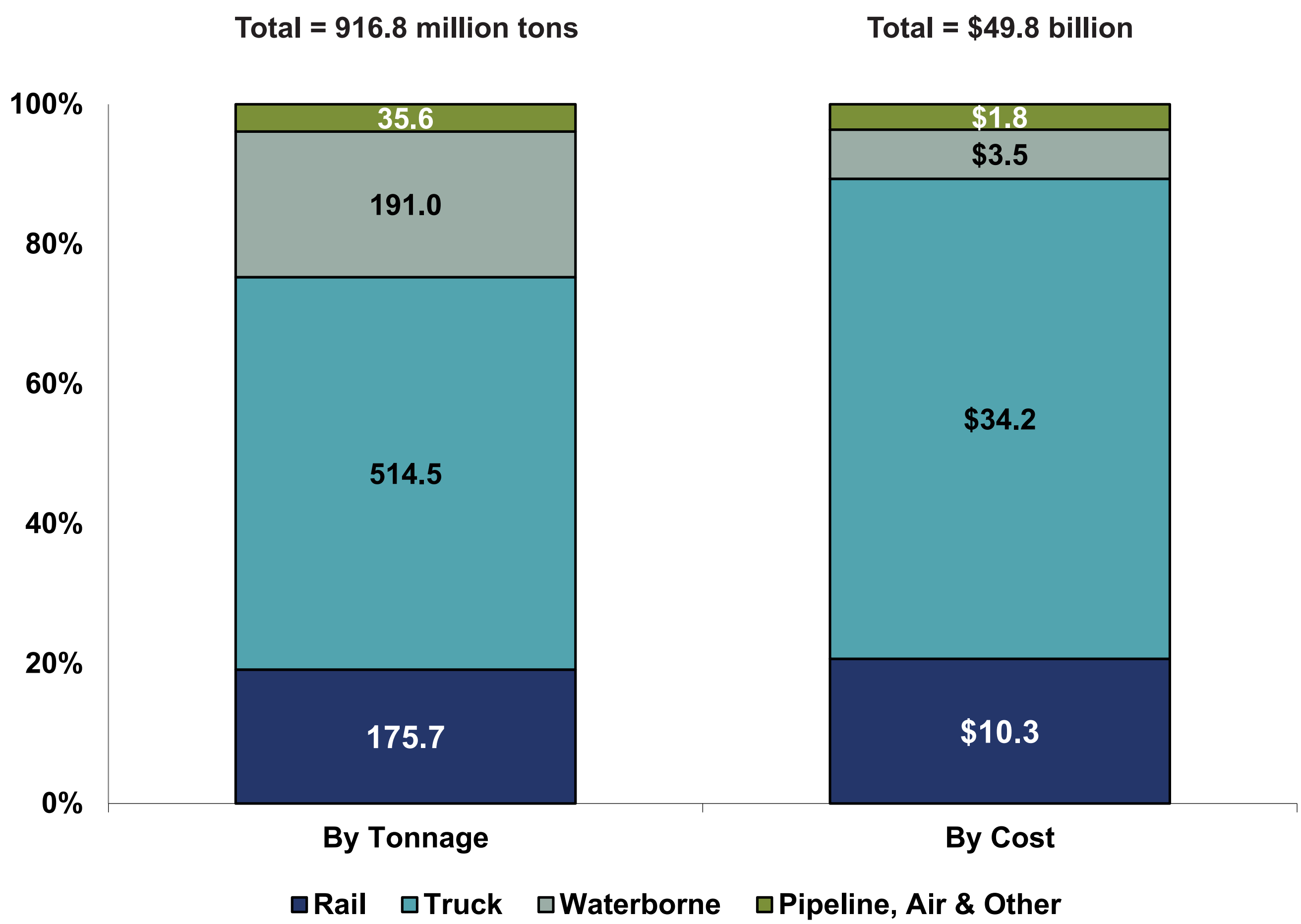
Sources: EPA, American Chemistry Council (Note: fuel and power CO2 revised data on embedded CO2 in purchased electricity)

11. DISTRIBUTION

Much of the U.S. chemical production is concentrated in about a dozen states, but the business of chemistry has customers located throughout the United States and around the world. Thus, a large volume of chemistry products is moved within the U.S. and to foreign destinations every year, playing an important role in the transportation services industry. Chemicals are transported over the road, by rail, by water and by air, generating revenues for trucking companies, railroads, barge operators and other logistics suppliers. More than half of the tonnage of chemical products is transported less than 250 miles from the manufacturing site. This is typical of shipments of bulk, lower value-added commodity chemicals such as fertilizers and industrial inorganic chemicals. On the other hand, high value-added products such as specialty chemicals are often shipped much longer distances.

Because each individual chemical has its own unique physical properties, the transport of chemicals can present unique challenges. Some chemicals, such as chlorine, are gases at normal temperatures and must be liquefied under pressure for transportation. Others, such as hydrochloric acid, are corrosive and require special materials in construction of the shipping containers. Chemicals that require special handling tend to be shipped shorter distances, generally in large containers and high volume. Overall, the cost of transportation accounts for about 10% of the business of chemistry's value of shipments.

Figure 11.1 - Business of Chemistry: Transportation by Mode, 2017



Sources: Association of American Railroads, Bureau of the Census, Bureau of Economic Analysis, Bureau of Labor Statistics, US Army Corps of Engineers, American Chemistry Council analysis. Data do not include pharmaceuticals.

Transportation by Mode

Truck

Over-the-road transportation is typically lower cost than other modes, and offers more flexibility (e.g., is not reliant on set schedules, like trains or airplanes). Companies in the business of chemistry either own their own fleet of trucks, or use for-hire carriers. Shipments through third parties are either Less Than Truckload (LTL), which means that the chemical product is shipped with other products, possibly from multiple manufacturers; or Full Truckload (FT, or FTL), which means the entire truckload is one manufacturer's products, often with a single point of origin.

In the business of chemistry, trucking is most widely used for small-volume packaged chemical products; it is also the most common mode of transport for industrial gases and consumer products and has increasingly been used for bulk shipments of intermediate chemicals.

Rail

According to the U.S. Department of Transportation Federal Railroad Administration, "rail transportation…is recognized to be the safest method of moving large quantities of chemicals over long distances." Chemicals comprise about 7%-10% of rail shipments of commodities (coal is the largest percent, three times that of chemicals). The business of chemistry is one of the top sources of revenue for the railroad industry, accounting for $9.9 billion in 2013, according to the American Associations of Railroads (AAR). Chemicals are generally shipped in tank cars (liquids and liquefied gases), hopper cars (dry commodities), and some boxcars (dry bulk or packaged chemical products).

Waterborne

Transporting chemicals is a significant business for many ocean-going carriers, inland barge operators, and other water freight transportation companies. Waterborne transport is often the least expensive method of transporting chemicals. Depending upon the product and the distance, the savings can be significant, but can only be realized by shipping large volumes and/or long distances. As a result, waterborne transport is primarily used for commodity chemicals, such as basic and intermediate organic chemicals, basic inorganic chemicals, and fertilizers.

Domestic waterborne transport includes coastal, lake, and inland waterway transportation of goods. The vast majority of domestic waterborne transport is via towed barges. Inland waterways include the Mississippi (by far the largest), Tennessee, Ohio, and Missouri waterway systems, among others. The Ohio system and intra-costal system along the Gulf Coast are also major domestic water routes used to transport chemicals.

Other Modes

Other modes of transportation include pipeline, air, and intermodal transportation (the use of multiple modes of transportation). More than three-quarters of this category includes pipeline transportation of ethylene and oxygen, usually for short distances. Small volumes of consumer products are shipped via air transportation and courier service.

12. THE BUSINESS OF CHEMISTRY IN THE STATES AND REGIONS

The states (and regions) in the United States are economically interdependent: each state's economy depends on the continuing availability of goods and services from other states and on the ability to sell its goods and services throughout the nation. This is especially true for the business of chemistry, in that every state is dependent on the products of chemistry to support its manufacturing, agricultural, service and other industries.

While chemical manufacturing of some kind exists in every state, 10 states account for two-thirds of chemical industry shipments.

Nearly every state hosts some form of chemical production; however, most production of basic industrial chemicals occurs in relatively few states. Much of basic chemical production is concentrated in the U.S. Gulf Coast region, where petroleum and natural gas raw materials (or feedstocks) are more readily available than in other parts of the country. In fact, about 70% of all primary petrochemicals are produced in Texas and Louisiana. The business of converting these basic chemicals into plastics, manufactured fibers, rubber, and other chemical products is not as heavily concentrated on the Gulf Coast and tends to be more diffused. For example, the majority of total manufactured fiber production occurs in the Southeast, while production of other chemical products such as plastics, pharmaceuticals, consumer products, and fertilizers is more widely dispersed among the states.

Figure 12.1- Share of Business of Chemistry Shipments by State, 2016

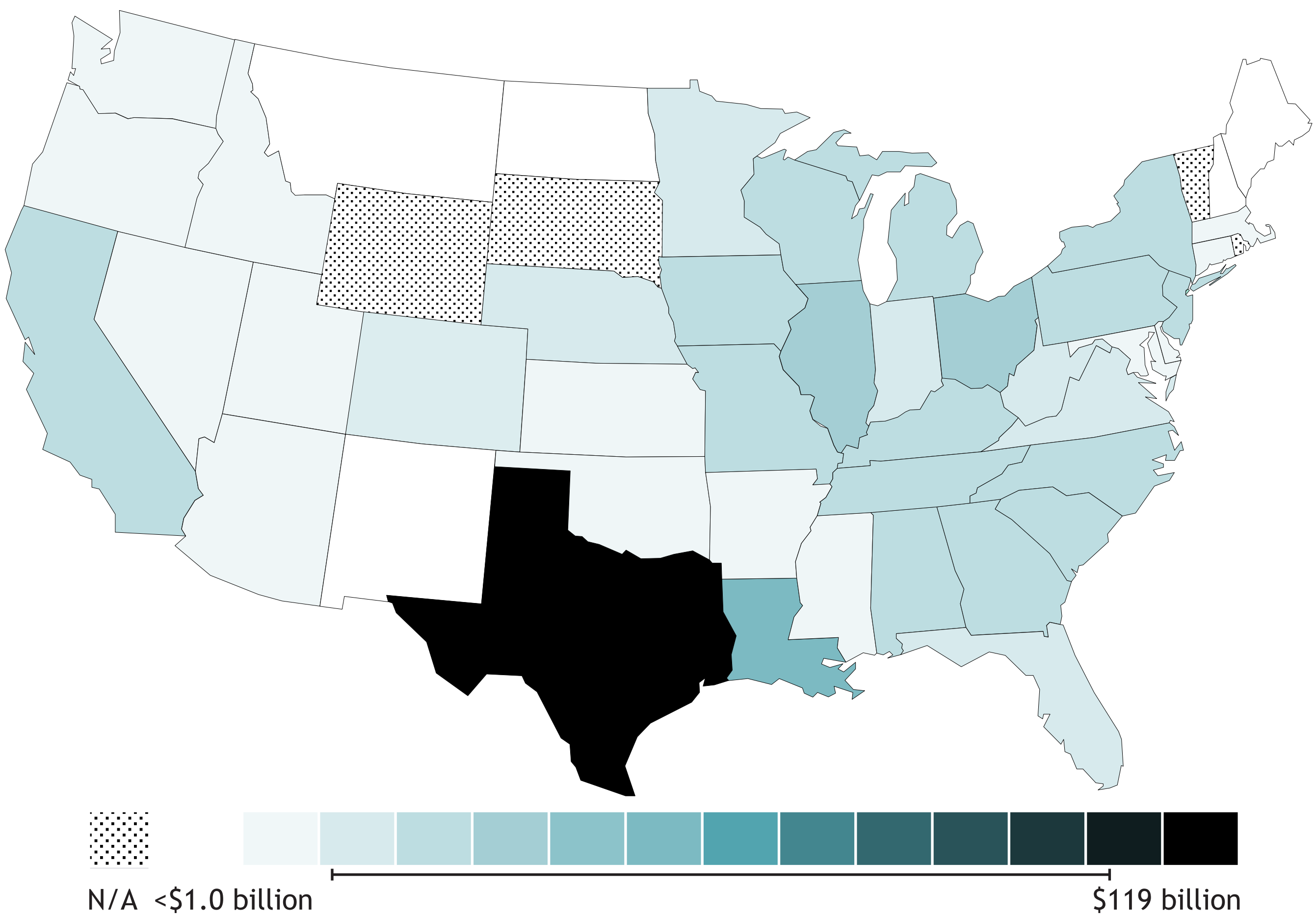


Table 12.1 - State Chemical Statistics (listed in descending order using Value of Shipments), 2017

State	Value of Shipments ($millions)	Employment (thousands)	Average Wages and Salaries ($)	Chemical Exports ($millions)
Texas	117,409	67,708	$113,418	38,287
Louisiana	48,801	25,130	$109,052	9,633
Ohio	29,364	39,155	$85,921	5,624
Illinois	27,471	25,990	$80,336	5,644
North Carolina	18,702	20,484	$71,798	3,683
Iowa	18,146	8,126	$71,963	1,522
California	17,647	32,950	$73,919	6,863
Pennsylvania	15,010	22,510	$69,977	4,703
New York	13,967	17,407	$85,790	3,707
New Jersey	13,424	20,982	$98,274	7,396
South Carolina	13,266	18,377	$71,576	2,407
Georgia	12,889	18,032	$71,462	3,059
Tennessee	12,744	22,928	$81,011	3,852
Michigan	12,178	21,149	$90,405	4,085
Missouri	11,136	13,996	$65,945	1,928
Alabama	10,672	9,021	$86,508	2,244
Wisconsin	10,598	12,824	$79,364	1,203
Kentucky	10,057	10,750	$70,858	2,124
Indiana	9,906	12,547	$68,744	2,083
Florida	8,955	15,109	$69,482	5,409
Virginia	7,021	11,753	$76,580	2,051
West Virginia	6,018	5,887	$92,523	1,557
Nebraska	5,627	3,468	$61,250	378
Minnesota	5,113	7,873	$82,521	1,241
Kansas	4,777	5,135	$76,661	614
Mississippi	4,536	4,717	$68,248	1,181
Maryland	3,703	4,419	$75,947	896
Massachusetts	3,566	6,669	$87,224	1,166
Connecticut	3,027	5,011	$122,926	895
Arkansas	2,967	4,857	$63,694	708
Oregon	2,518	3,543	$64,884	1,612
Washington	2,280	4,067	$75,515	849
Oklahoma	2,278	2,830	$68,675	399
Utah	2,140	2,773	$64,293	834
Delaware	1,968	1,906	$97,018	565
Colorado	1,865	3,265	$61,938	586
Arizona	1,852	3,844	$58,334	738
Idaho	1,429	2,304	$65,033	278
Nevada	1,039	917	$65,998	150
New Mexico	618	642	$91,928	93
North Dakota	513	381	$71,674	303
Maine	409	492	$55,933	33

Sources: Bureau of the Census, Bureau of Economic Analysis, and Bureau of Labor Statistics.

Note. Exports by state are reported on a NAICS basis and do not include exports from unidentified states, Puerto Rico, the Virgin Islands. As a result, they do not sum to exports referenced elsewhere in this publication. Shipment data for 2016.

Table 12.1 - State Chemical Statistics (listed in descending order using Value of Shipments), 2017

State	Value of Shipments ($millions)	Employment (thousands)	Average Wages and Salaries ($)	Chemical Exports ($millions)
New Hampshire	332	728	$60,840	94
Montana	224	510	$64,370	224
Alaska	N/D	65	$52,196	8
District of Columbia	N/D	6	$140,768	7
Hawaii	N/D	306	$45,861	30
Rhode Island	N/D	1,707	$66,390	210
South Dakota	N/D	967	$57,065	71
Vermont	N/D	788	$42,474	65
Wyoming	N/D	1,610	$103,875	980
US Total	**503,404**	**528,612**	**$84,048**	**136,650**

Sources: Bureau of the Census, Bureau of Economic Analysis, and Bureau of Labor Statistics.

Note. Exports by state are reported on a NAICS basis and do not include exports from unidentified states, Puerto Rico, the Virgin Islands. As a result, they do not sum to exports referenced elsewhere in this publication. Shipment data for 2016.

Employment Impact of the Business of Chemistry

The true employment impact of an industry goes well beyond those employees it directly employs. The employment impact also includes jobs in other industries that are supported indirectly by the industry (these include jobs in industries that are in the supply chain of the industry being examined) and the jobs supported by payroll-induced activity (jobs in those industries supported by the wages paid to employees).

The business of chemistry directly employs workers as equipment operators, engineers, sales managers, scientists, safety specialists, environmental protection professionals, and in other occupations. In addition, the business of chemistry generates additional jobs in industries that supply the chemistry business with raw materials, services, equipment, and other non-labor factors of production. These suppliers include equipment manufacturers, wholesalers, contract workers, contract laboratories, engineering and construction workers, energy and raw material producers, transportation operators, etc. In addition, millions of jobs are supported through the indirect purchases of the industry's suppliers and its employees. The suppliers' suppliers and their suppliers make purchases and pay their employees the same way that the business of chemistry does. These subsequent rounds of purchasing generate additional economic activity and jobs. Businesses purchase goods and services and employees spend their wages on housing, food, clothing, furniture, utilities, and a variety of other goods and services.

The business of chemistry is a major employer in a number of states where the industry employs a significant percentage of the state's manufacturing workers. The employment contributions of the business of chemistry are discussed further in the Employment section.

Table 12.2 - Jobs and Payroll Generated by the Business of Chemistry by State, 2017

	in thousands				in $billions			
State	Direct	Supply Chain	Payroll Induced	Total	Direct	Supply Chain	Payroll Induced	Total
Alabama	9.0	14.0	10.5	33.5	0.8	0.6	0.3	1.7
Alaska	0.1	0.1	0.0	0.2	0.003	0.007	0.002	0.013
Arizona	3.8	5.9	4.6	14.3	0.2	0.3	0.2	0.7
Arkansas	4.9	6.3	4.6	15.8	0.3	0.3	0.1	0.7
California	33.0	49.0	38.9	120.9	2.4	3.2	1.7	7.4
Colorado	3.3	4.3	5.4	12.9	0.2	0.2	0.1	0.5
Connecticut	5.0	5.3	17.0	27.3	0.6	0.1	0.2	0.9
Delaware	1.9	2.1	2.0	6.0	0.2	0.1	0.1	0.4
District of Columbia	0.0	-	-	0.0	0.00	-	-	0.00
Florida	15.1	29.7	23.5	68.3	1.0	1.5	0.8	3.3
Georgia	18.0	24.2	21.9	64.1	1.3	1.3	0.8	3.4
Hawaii	0.3	-	-	0.3	0.01	-	-	0.0
Idaho	2.3	3.7	2.5	8.6	0.1	0.2	0.1	0.4
Illinois	26.0	34.6	38.3	98.9	2.1	1.9	1.3	5.2
Indiana	12.5	13.7	16.0	42.2	0.9	0.5	0.4	1.7
Iowa	8.1	11.6	13.8	33.6	0.6	0.3	0.2	1.0
Kansas	5.1	9.6	8.6	23.4	0.4	0.3	0.2	0.8
Kentucky	10.8	13.3	10.3	34.3	0.8	0.6	0.3	1.7
Louisiana	25.1	71.3	51.2	147.6	2.7	3.5	1.6	7.9
Maine	0.5	0.9	0.6	1.9	0.0	0.0	0.0	0.1
Maryland	4.4	3.9	3.4	11.7	0.3	0.3	0.2	0.8
Massachusetts	6.7	7.9	7.6	22.1	0.6	0.6	0.4	1.6
Michigan	21.1	29.5	30.2	80.8	1.9	1.6	1.0	4.5
Minnesota	7.9	11.1	14.7	33.6	0.6	0.4	0.3	1.4
Mississippi	4.7	6.6	4.2	15.5	0.3	0.3	0.1	0.7
Missouri	14.0	18.5	17.8	50.3	0.9	0.8	0.5	2.3
Montana	0.5	1.2	0.7	2.4	0.0	0.1	0.02	0.1

Note. Calculations were made using 2015 IMPLAN model.

Sources: Bureau of Labor Statistics and American Chemistry Council analysis.

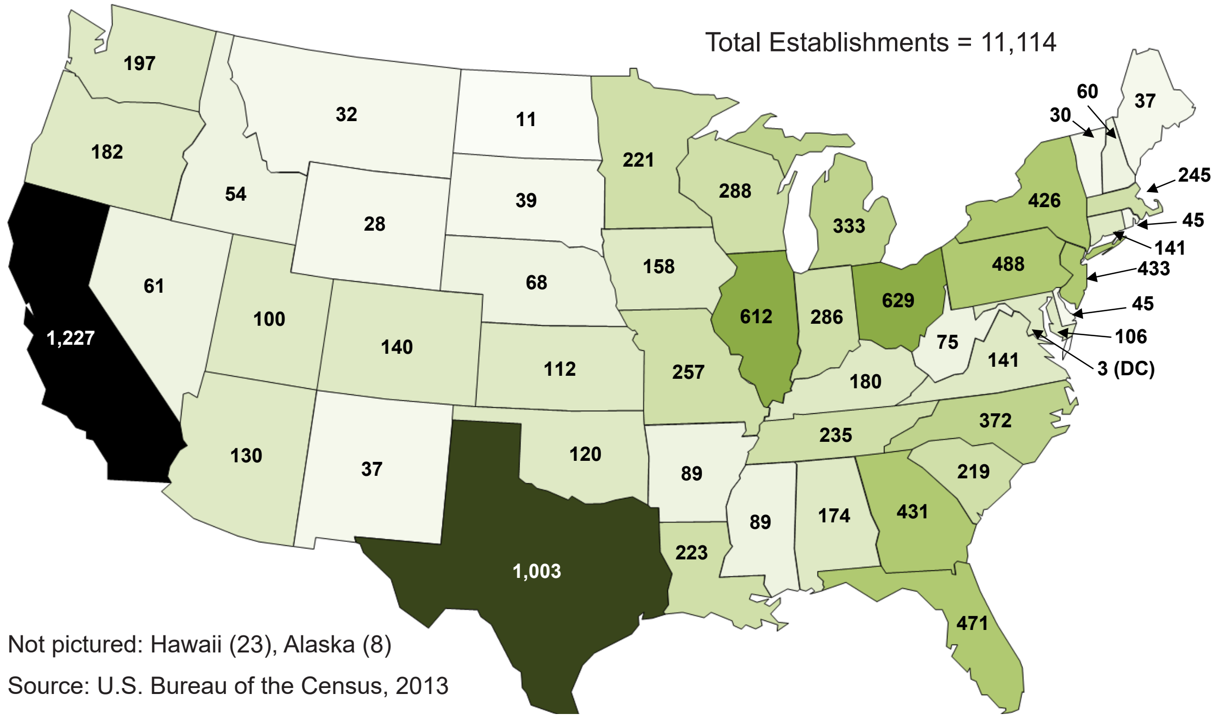
Table 12.2 - Jobs and Payroll Generated by the Business of Chemistry by State, 2017

	in thousands				in $billions			
State	Direct	Supply Chain	Payroll Induced	Total	Direct	Supply Chain	Payroll Induced	Total
Nebraska	3.5	7.2	5.7	16.4	0.2	0.3	0.1	0.6
Nevada	0.9	0.9	0.7	2.5	0.1	0.1	0.0	0.1
New Hampshire	0.7	0.7	0.6	2.0	0.0	0.0	0.0	0.1
New Jersey	21.0	30.8	36.7	88.4	2.1	1.5	1.0	4.6
New Mexico	0.6	0.7	0.6	1.9	0.1	0.0	0.0	0.1
New York	17.4	18.1	16.7	52.2	1.5	1.2	0.7	3.4
North Carolina	20.5	28.5	23.6	72.6	1.5	1.4	0.8	3.7
North Dakota	0.4	0.7	0.6	1.7	0.03	0.02	0.01	0.06
Ohio	39.2	62.6	60.6	162.4	3.4	3.3	2.0	8.6
Oklahoma	2.8	4.6	3.2	10.6	0.2	0.2	0.1	0.5
Oregon	3.5	4.9	3.8	12.2	0.2	0.3	0.1	0.6
Pennsylvania	22.5	27.0	30.3	79.7	1.6	1.4	0.9	3.9
Rhode Island	1.7	1.8	1.6	5.1	0.1	0.1	0.1	0.3
South Carolina	18.4	24.4	18.1	60.9	1.3	1.1	0.6	2.9
South Dakota	1.0	1.7	3.5	6.1	0.1	0.0	0.02	0.1
Tennessee	22.9	28.8	27.0	78.7	1.9	1.5	1.0	4.4
Texas	67.7	312.8	220.9	601.4	7.7	21.7	9.0	38.4
Utah	2.8	3.8	3.3	9.8	0.2	0.2	0.1	0.4
Vermont	0.8	0.7	0.5	2.0	0.03	0.03	0.02	0.1
Virginia	11.8	12.6	11.2	35.5	0.9	0.8	0.4	2.1
Washington	4.1	5.9	4.2	14.1	0.3	0.4	0.2	0.9
West Virginia	5.9	9.9	6.4	22.2	0.5	0.4	0.2	1.2
Wisconsin	12.8	15.8	16.3	45.0	1.0	0.7	0.5	2.2
Wyoming	1.6	1.5	1.2	4.3	0.2	0.1	0.04	0.3

Note. Calculations were made using 2015 IMPLAN model.

Sources: Bureau of Labor Statistics and American Chemistry Council analysis.

Figure 12.2 - Number of Business of Chemistry Establishments by State



U.S. Chemical Production Regional Index

The U.S. Chemical Production Regional Index (US CPRI), which tracks chemical production activity in seven regions of the United States, was developed by Moore Economics for the American Chemistry Council. The US CPRI is comparable to the U.S. industrial production index for chemicals published by the Federal Reserve and the ACC Global Chemical Production Regional Index (Global CPRI). The index is based to where 2012=100. The US CPRI is based on information from the Federal Reserve and is weighted by chemical shipments by region.

Table 12.3 - U.S. Chemical Production Regional Index (US CPRI) (2012=100)

	2012	2013	2014	2015	2016	2017
Gulf Coast	100.0	100.6	98.3	94.8	96.0	96.4
Midwest	100.0	100.0	99.2	96.1	96.5	97.8
Ohio Valley	100.0	98.3	98.8	96.7	96.7	97.6
Mid-Atlantic	100.0	97.5	98.6	97.0	96.6	97.4
Southeast	100.0	99.4	99.1	96.1	96.1	97.3
Northeast	100.0	97.0	98.3	96.4	95.3	95.9
West Coast	100.0	98.9	99.3	96.8	96.6	98.0

Source: American Chemistry Council

APPENDIX A: CHEMICAL CHAINS

Figure A.1 - Chlor-Alkali

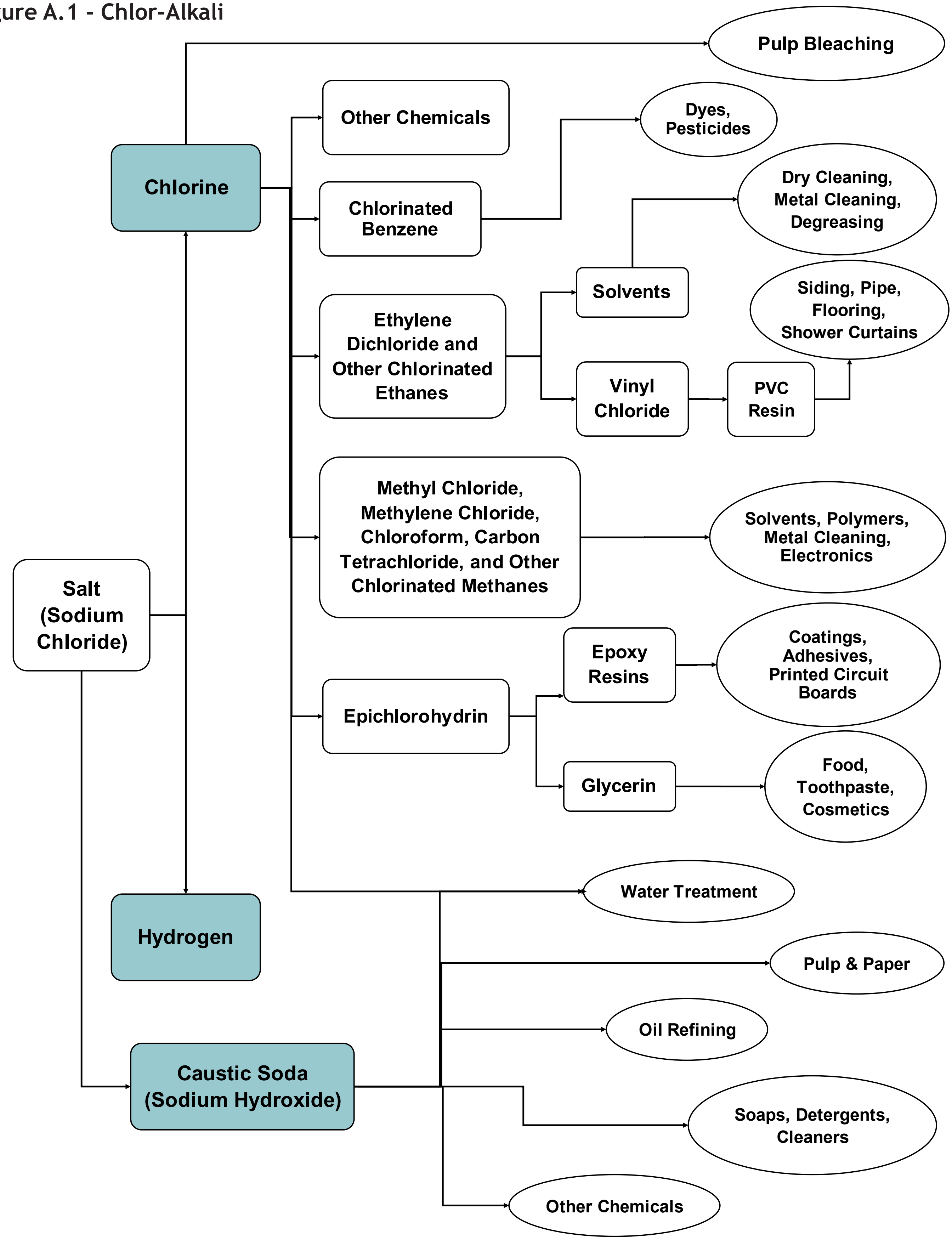
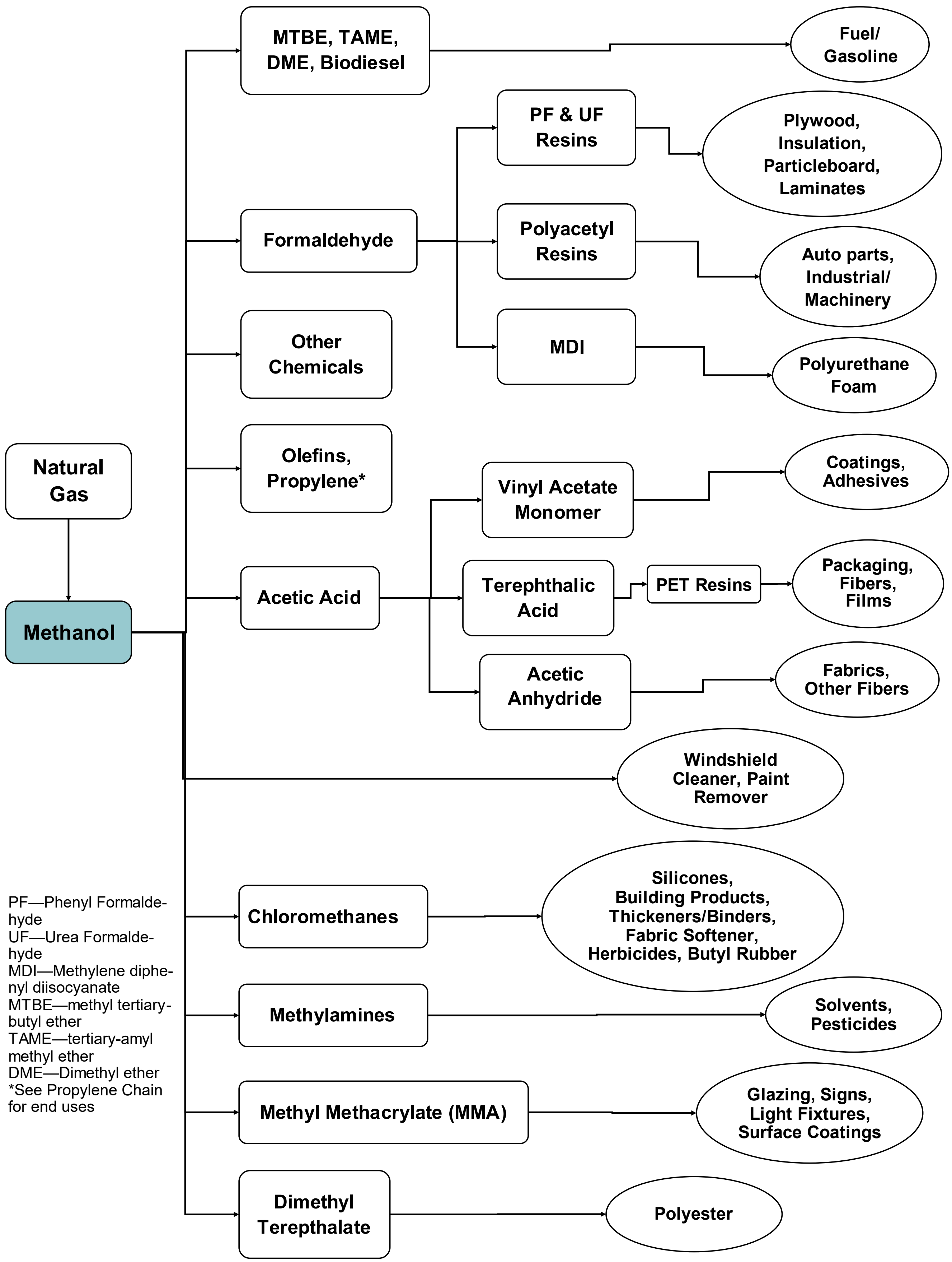


Figure A.2 - Methanol



PF—Phenyl Formaldehyde
UF—Urea Formaldehyde
MDI—Methylene diphenyl diisocyanate
MTBE—methyl tertiary-butyl ether
TAME—tertiary-amyl methyl ether
DME—Dimethyl ether
*See Propylene Chain for end uses

Figure A.3 - Ammonia

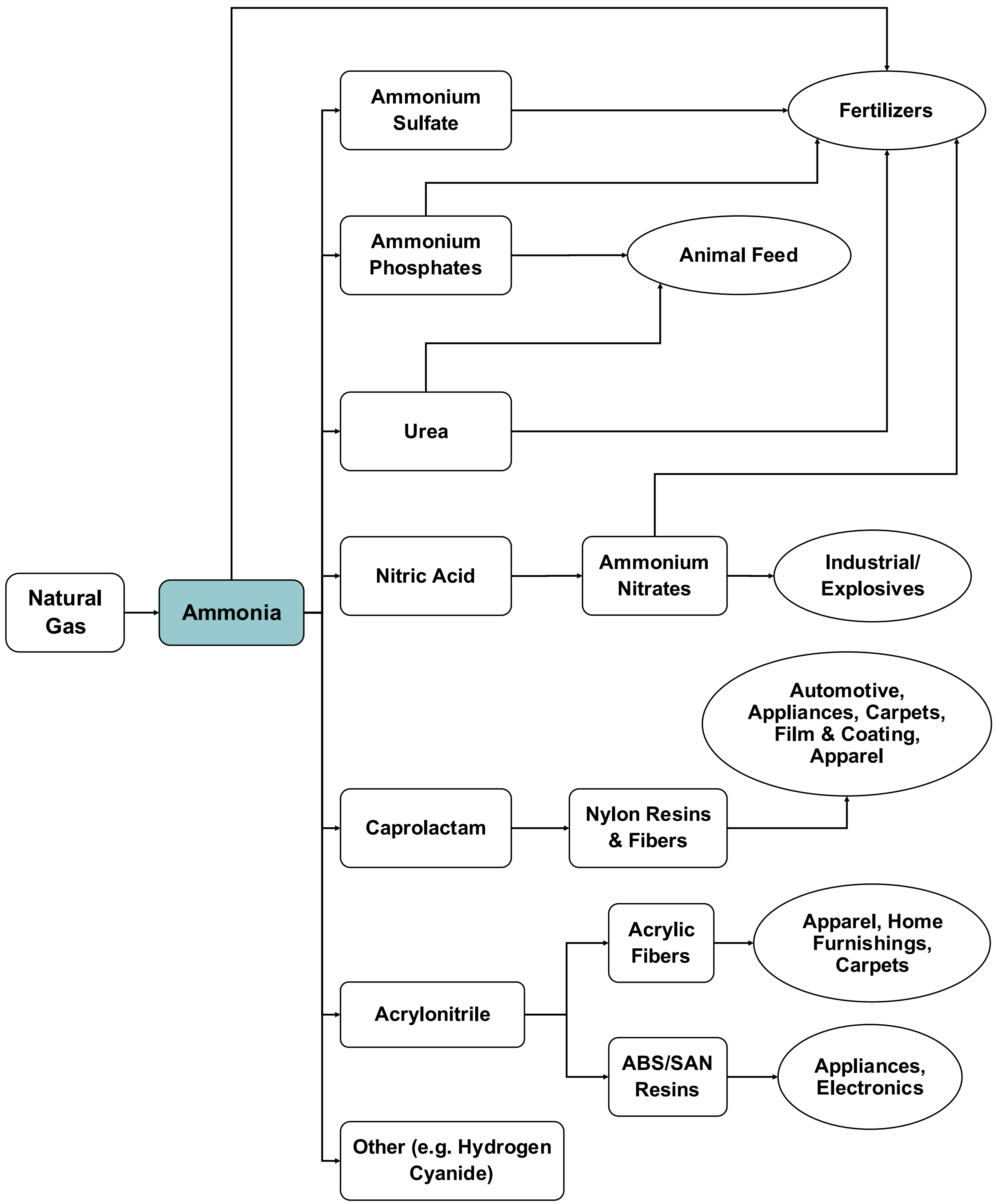


Figure A.4 - Ethylene

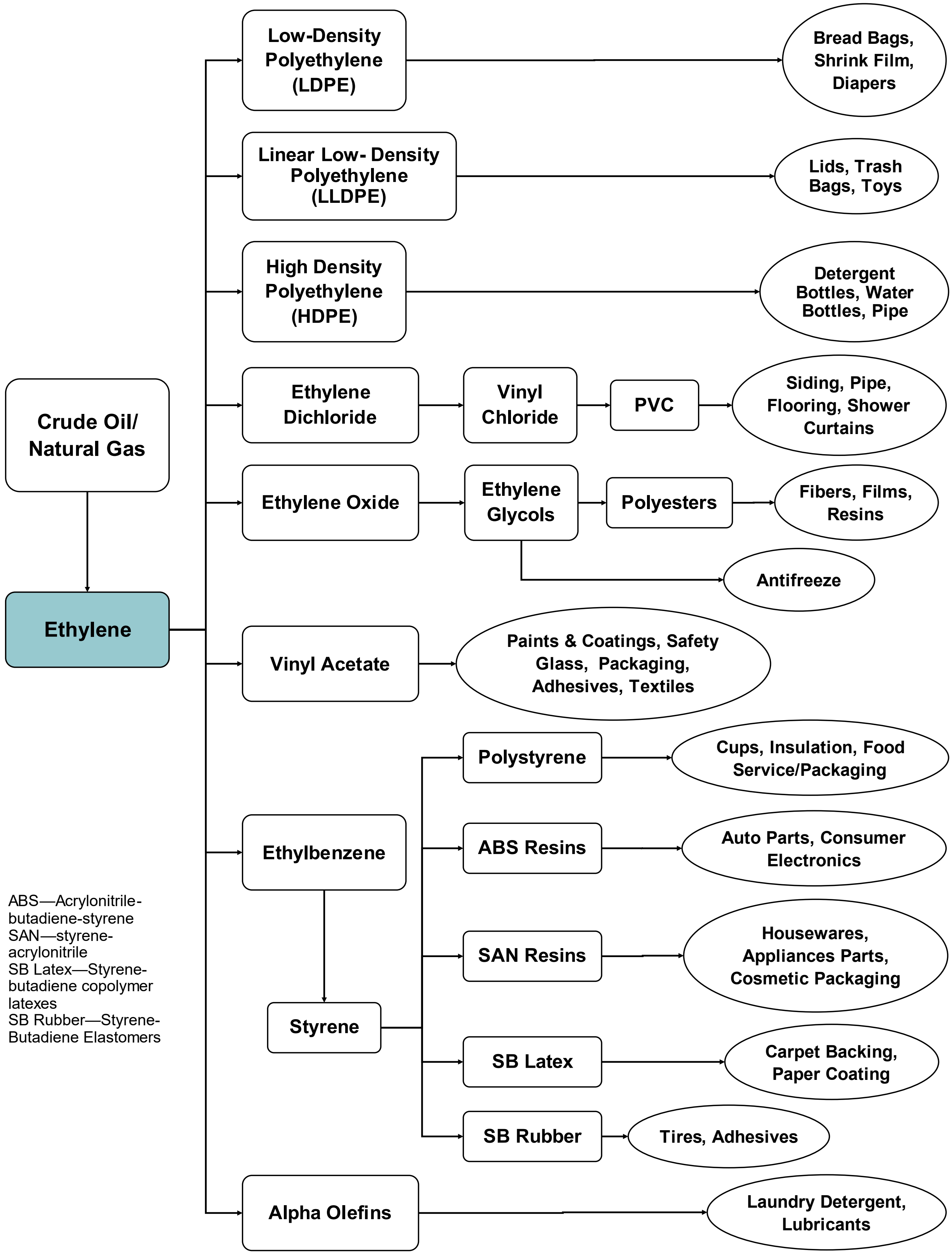


Figure A.5 - Propyylene

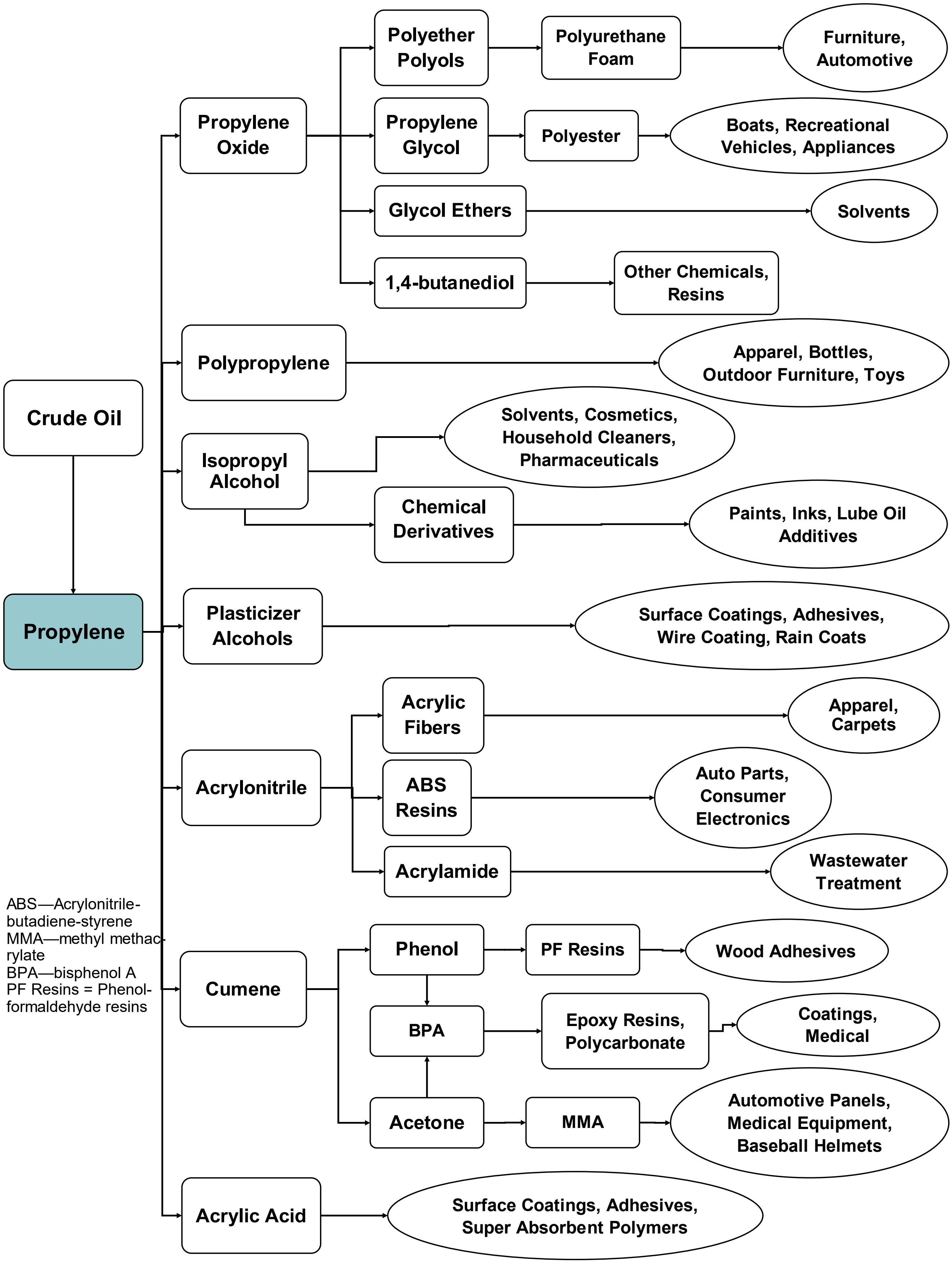
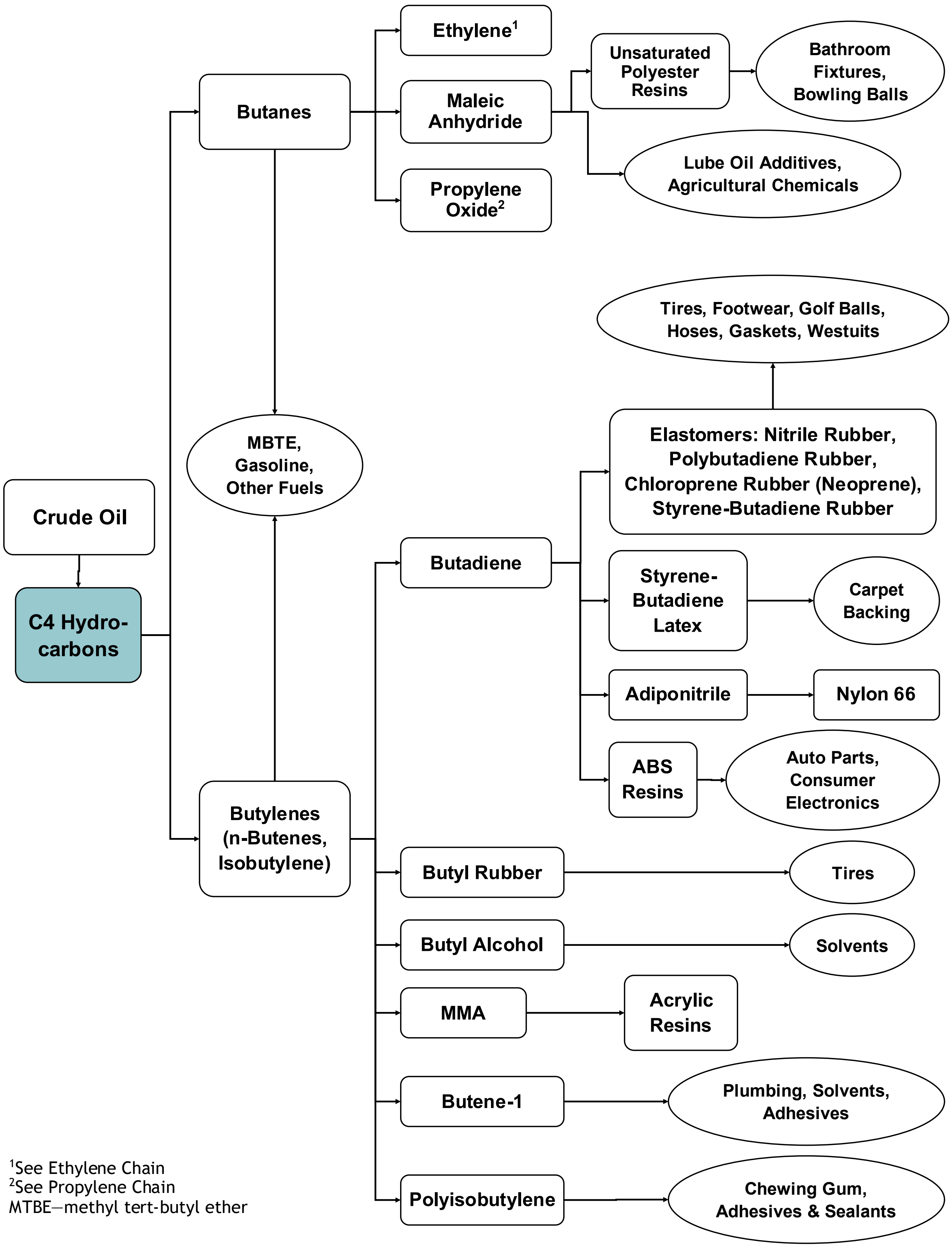


Figure A.6 - C4 Hydrocrarbons



[1]See Ethylene Chain
[2]See Propylene Chain
MTBE—methyl tert-butyl ether

Figure A.7 - Benzene

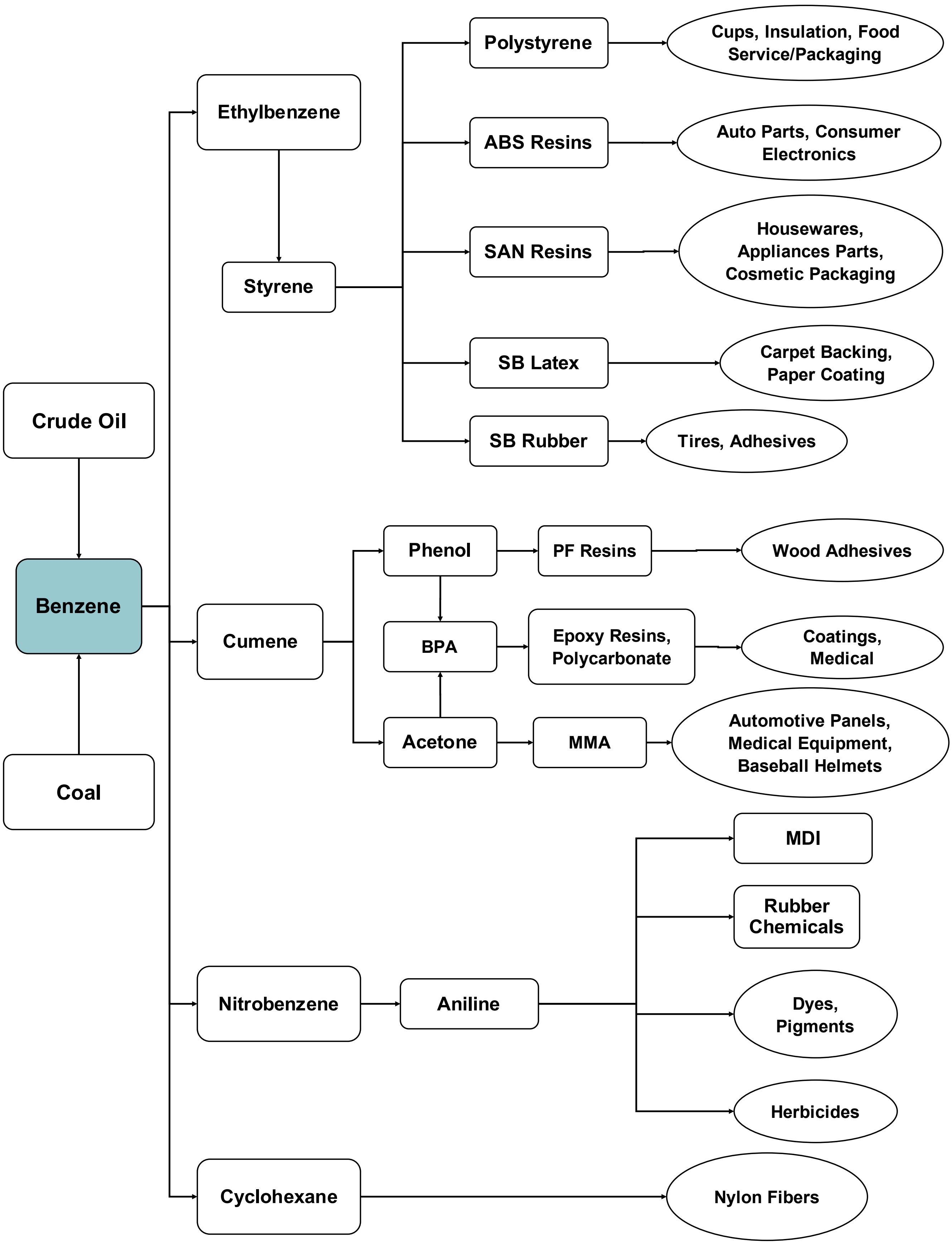
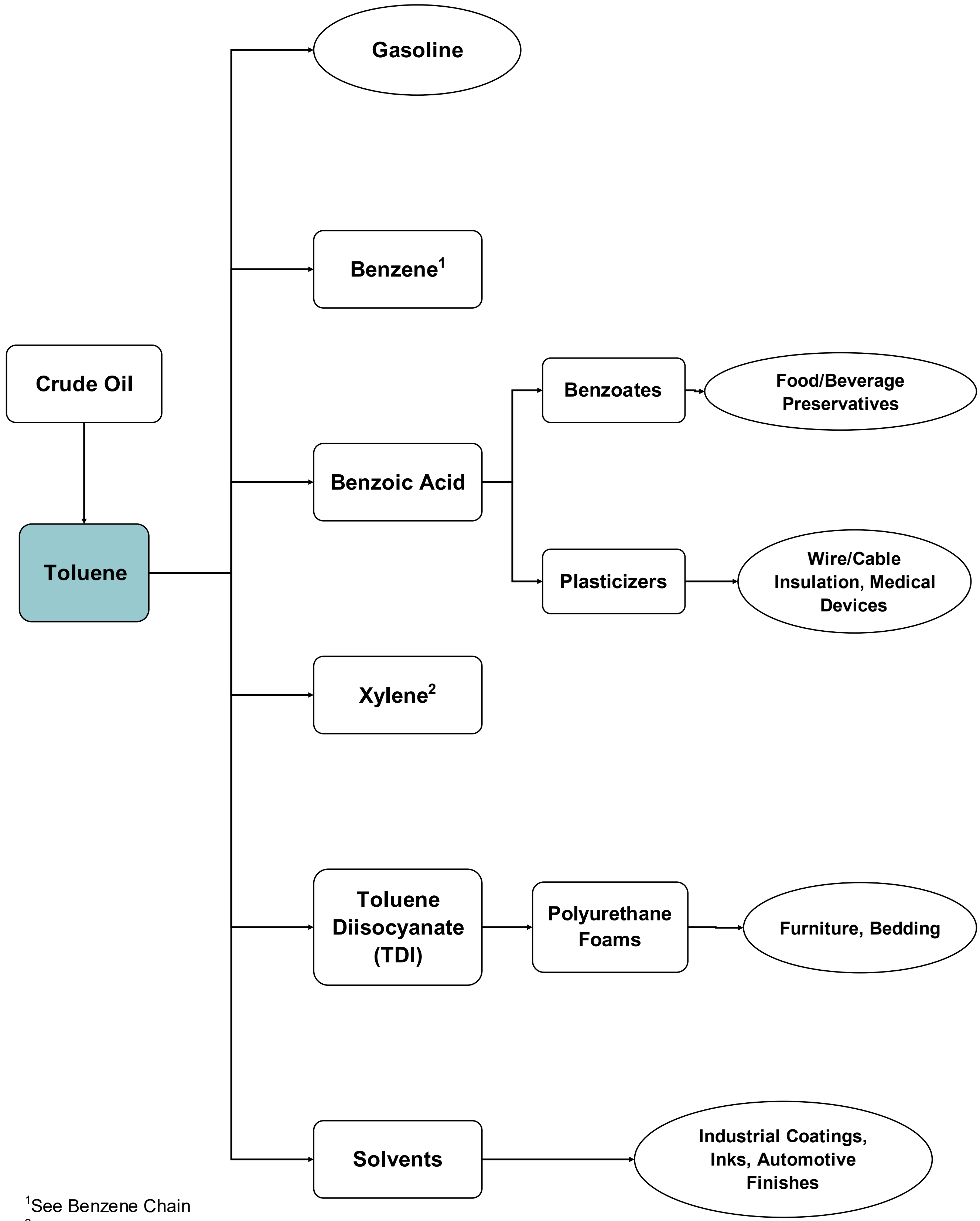
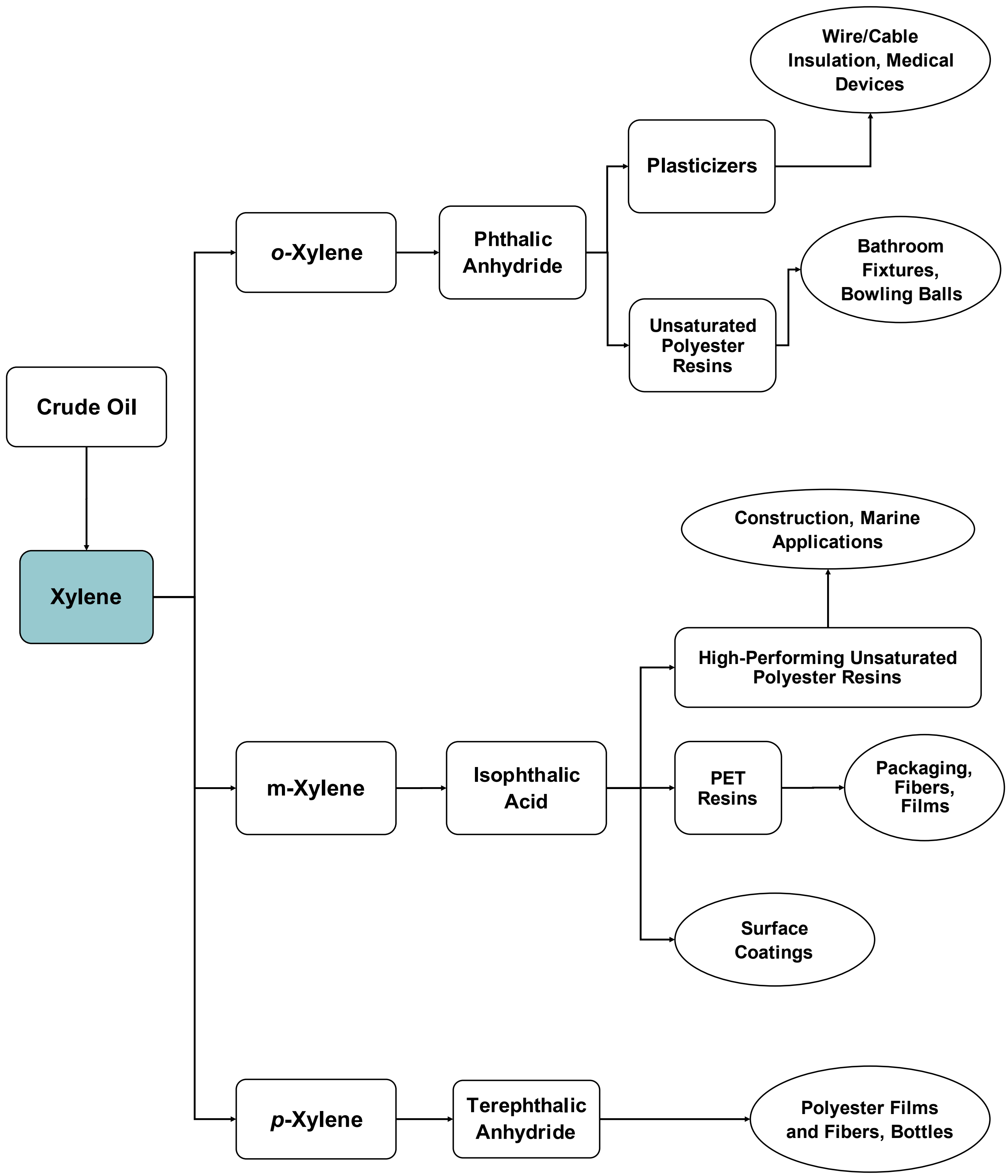


Figure A.8 - Toluene



[1]See Benzene Chain
[2]See Xylene Chain

Figure A.9 - Xylene



APPENDIX B: GLOSSARY

of business and technical terms and acronyms in the Business of Chemistry

ABS - Acrylonitrile-butadiene-styrene

Absorption - A process in which a gaseous stream containing a separable chemical is placed in contact with a liquid solvent flowing down a column containing trays or packing. The solvent absorbs the chemical from the gas. The collection of the compound takes place inside the other substance (e.g., solvent).

Acid - A substance that produces hydrogen ions when dissolved in water.

Acid Test - The ratio of the sum of both cash and short-term securities divided by current liabilities.

Acquisition - The purchase by one company of the assets and obligations of another company.

Active Pharmaceutical Ingredient (API) - The chemical compound in a drug formulation that imparts the desired biological effect.

Adsorption -The adhesion of substances (e.g., gases, liquids) on the surface of solids.

Alcohols - Organic compounds (usually liquids) containing a hydroxyl group (-OH), made of one oxygen and one hydrogen atom, attached to a carbon atom.

Aldehydes - Oxygenated organic compounds (e.g., formaldehyde, acetaldehyde) that have a tail and consisting of carbon/double-bonded oxygen and hydrogen, both attached to the same carbon atom.

Aliphatics - Compounds characterized by having an open-chain structure of carbon atoms.

Alkanes - Straight-chain hydrocarbon without double bonds. These contain single bonds, which makes them less reactive. The simplest alkane is methane. Also referred to as paraffin.

Alkenes - Also referred to as olefins, unsaturated hydrocarbons that contain double bonds, which make them reactive.

Alkylation - This process involves the reaction of hydrocarbons with an olefin by using a catalyst. This can increase the octane number of the compound.

Aromatics - Hydrocarbons containing a 6-carbon ring structure. Benzene is the simplest aromatic. Toluene and xylenes are also aromatics.

Assets - Economic resources (plant, property, inventories, trademarks, patents, etc.) owned by a firm.

Atom - The smallest, most basic unit of an element.

Average Days' Supply in Inventory - In number of days. The ratio of 365 days divided by the inventory turnover ratio. Also referred to as age of inventory.

Barrel – A standard unit of volume for crude petroleum (or oil) and petroleum products equal to 42 US gallons.

Base - A substance that produces hydroxyl ions (OH) when dissolved in water.

Basic Earning Power - Expressed as a percent, this measure is equal to income before income taxes divided by total assets.

Basic Chemicals – Chemicals produced in large volumes to chemical composition specifications that are homogeneous in nature; also called commodity chemicals.

Batch - Chemical processing technology consisting of sequential steps (e.g., extraction) that must be repeated batch after batch. Set-up is required between each batch (versus continuous process). Capital requirements tend to be low but require greater labor input.

Benzene - An aromatic compound in which 6 carbon atoms are structured in a ring. Used to manufacture other chemicals and an important feedstock, it is not used directly by consumers.

Blow Molding – A method of processing plastic resins that uses air to conform molten plastic resin to the shape of the mold. Product examples include bottles and toys.

BPA - Bisphenol A.

BPD (Barrels per Day) – A measurement of production or consumption used for petroleum and petroleum products.

Brand Equity - A combination of factors such as awareness, loyalty, perceived quality, images, and emotions that customers associate with a given brand name.

BTX - Not a mountain bike brand but rather the acronym for benzene, toluene and xylenes.

BTU (British thermal unit) – A unit of heat equal to the amount of heat required to raise one pound of water one degree Fahrenheit at one atmosphere pressure.

Business Cycle – Also called the economic cycle, it refers to sequences of alternating phases of expansion and contraction of economic activity. The cycle involves shifts over time between periods of relatively rapid growth of

output (recovery and prosperity), and periods of relative stagnation or decline (contraction or recession). These fluctuations are recurring but not periodic.

Butane - A straight-chain hydrocarbon containing four carbon atoms.

C4 Hydrocarbons - Hydrocarbons which contain four carbon atoms. These include the butanes, butenes, butadienes, and butylenes.

Capacity – The quantity of a product that can be produced in a plant or other operation.

Capital Employed - Also referred to as operating assets, the dollar value of fixed capital plus the dollar value of working capital less payables. It represents the economic value of cash tied up in the business and is used to calculate economic income.

Capital Expenditures - Major investments in long-term assets such as process equipment, other equipment, buildings, land, etc. Also referred to as capital spending or plant and equipment (P&E) spending.

Cash Flow - This traditional measure of financial performance is equal to net income after taxes plus depreciation and amortization plus (or minus) net change in net working capital.

Catalyst - A substance used in very small quantities to increase the rate of a desirable chemical reaction without itself being changed chemically.

Catalytic Process - A process using a catalyst to increase the rate of a chemical reaction. This can increase overall efficiency, quality and other favorable attributes.

CIF (Cost, Insurance and Freight) - A common term in a sales contract that may be encountered in international trading when ocean transport is used. When a price is quoted CIF, it means that the selling price includes the cost of the goods, the freight or transport costs and the cost of marine insurance.

Coextrusion – A process for plastic film manufacture, with two or more extruders feeding into a single die assembly. The resulting film contains several layers, with each layer having a different functionality.

Commodity Chemicals – High-volume, low-value, homogenous compounds produced in dedicated continuous plants often used in a variety of applications. These are sold on the basis of what they are (the composition), not what they do. Most specialties evolve into commodities.

Compound - A substance composed of two or more different elements that are chemically bound. Water (H2O) is an example of a compound comprised of two atoms of hydrogen (H) and one atom of oxygen (O).

Compounding – The process of mixing two materials together to obtain physical properties in a material that are different than the original materials. For example, glass fibers are sometimes added to plastic resins in order obtain greater strength, rigidity, and creep properties.

Conversion - The portion of raw materials in a chemical process that actually undergoes reaction. That is, the raw material that is consumed or feed that disappears in a chemical reaction. It is usually measured as a percent, primarily around a reaction step, not the whole plant.

Converted Product – in the context of the plastic resins, the term used to refer to products in finished or semi-finished form, which are manufactured using virgin resins. Examples include bags, film, and injection molded parts.

Copolymer - A polymer of two or more different monomers.

Core Competencies - Those functions that the organization can do as well or better than any other organization in the world.

Cost of Goods Sold - A measure of the cost of raw materials, supplies, purchased services, and direct manufacturing costs used for producing the product.

Cost of Capital - Expressed as a percent, this measures the risk-adjusted, after-tax minimum rate of return required to compensate holders of debt and shareholders. It is based on the weighted average of the after-tax cost of debt and equity. The cost of debt is based on the yield prevailing for long-term corporate bonds of equivalent credit risk adjusted by the effective tax rate. The cost of equity is computed by adding a risk premium typical of common equities (with an adjustment for volatility) to the yield for long-term government bonds.

Cracking - A process in which a long-chain molecule (or mixture of longer chain molecules) is broken down into smaller molecules to produce more useful chemicals. High-temperature cracking of hydrocarbons to produce olefins is referred to as steam cracking. When molecules are broken down in the presence of a catalyst, it is sometimes referred to as catalytic cracking.

Crystallinity - A property of polymers in which the molecule attract each other and line up next to the other, thus engendering strength. Crystalline polymers (polyethylene, nylon, etc.) are opaque.

Crystallization - A process in which a mixture of chemicals contained in a solution are separated by chilling and a filter or centrifuge are used to recover solid crystals.

Current Assets - Those assets – cash, time and demand deposits, U.S. government and other short-term securities, trade accounts and trade notes receivable,

inventories, etc. – which can be converted into cash within one year. Also referred to as working capital.

Current Liabilities - Those liabilities – short-term loans from banks, commercial paper, other short-term debt, trade accounts and trade notes payable, etc. – which must be paid within one year. Also referred to as short-term debt.

Current Ratio - The ratio of current assets divided by current liabilities. Also referred to as the working capital ratio.

Custom Manufacturing - An arrangement in which a company produces a product exclusively for a customer.

Cycle - In chemical processing, the complete, repeating sequence of operations in a process; or in part of a process. In plastics molding, the cycle time is the period, or elapsed time, between a certain point in one cycle and the same point in the next.

Dealkylation - A process removing a methyl or ethyl group from an organic compound.

Debottlenecking- After some period of operating a new plant, companies learn more about the process, which allows them to remove bottlenecks in the plant, thus providing additional capacity at little incremental cost.

Dehydrogenation - Chemical processes removing one or more hydrogen atoms from a compound. By adding a hydrogen atom, hydrogenation is the opposite process.

Demand - The quantities of some good or service that consumers desire (or buy) at different prices. The relative value of the marginal unit of some good when different quantities of that good are available.

Depreciation - A systematic financial write-off of the cost of a tangible asset over its estimated useful life.

Distillates - High-volatility molecules separated from refined crude petroleum (or oil). These are generally isolated near the top of a fractional distillation column in an oil refinery.

Distillation - Process in which two or more components of a liquid compound are separated through the use of successive vaporization and condensation. This process is employed to purify or separate the components of a mixture.

DME - Dimethyl ether.

Downstream – The process/processes, products, or industries being fed by the process under consideration. Production of PVC resins, for example, is downstream of chlorine and ethylene production.

Dyes - Synthetic or natural organic chemicals that are soluble in most common solvents, and are used to impart color to fiber, yarn or other fabrics.

EBITDA (Earnings before Interest, Taxes, Depreciation and Amortization) - this is the key profitability metric used by financial analysts.

Economic Capacity - In terms of scale of operations, the minimum requirement for economic operation. That is, the capacity at which producers can still operate with some profit margin.

Economic Income - Cash flow after taxes less a user's charge (cost of capital) on capital employed. This measures "true income" by taking into account the opportunity cost of capital. It is similar to Rutledge & Company's concept of economic profits and Stern Stewart & Company's EVA™ (economic value-added) concept. It is also similar to residual income and economic rent.

Economic Return on Capital Employed - Expressed as a percent, this measure of profitability (or financial performance) is equal to economic income divided by capital employed.

Elastomer - Synthetic polymers with rubber-like properties that can be stretched and will retract to their original form.

Electrochemical Unit (ECU) – The chlor-alkali process produces chlorine and caustic soda in set ratios of one unit of chlorine and 1.1 units of caustic soda. The combination of one unit of chlorine and 1.1 units of caustic soda is an ECU.

Electrolysis - A process in which the passage of electric current through an aqueous solution causes a chemical reaction to occur.

Element - A substance that cannot be decomposed into simpler substances by any chemical or physical reaction. Elements are found on the periodic table. Hydrogen and oxygen are examples of two elements.

Engineering Plastics - High-strength polymers that can be used to replace metals or glass. Favorable properties can include high thermal stability, good chemical and weather resistance, transparency, self-lubrication, or good electrical properties.

Equity Capital - Funds raised from within a company or through the sale of ownership of the company.

Equity Multiplier - The ratio of total assets divided by total shareholder's equity.

Ester - Not your aunt, but a simple oxygenated organic compound usually formed by the chemical reaction between an acid and an alcohol.

Esterification - A process in which an alcohol is reacted with an organic acid to produce an ester.

Ethane - Gaseous straight-chain hydrocarbon (or alkane) containing two carbon atoms.

Ethene - See Ethylene.

Ethyl - A chemical grouping with two carbon atoms attached to an element or group.

Ethylene - An olefin compound with two carbon atoms and one double bond. It is a basic "building block" for other chemicals. Also called ethene.

Exchange Rate - The value of one currency relative to the currency of another nation.

Expenses - Costs incurred in operating a company, such as rent, utilities, and salaries. Usually is separate from cost of goods sold.

EVA Copolymers – The copolymer of ethylene and vinyl acetate that approach elastomeric materials in softness and flexibility yet can be processed like other thermoplastics. It is sometimes classified as a low density polyethylene.

Extraction - A process in which the component in a solution or some other mixture is separated using a liquid (typically a solvent) with selective solvent characteristics.

Factors of Production - Resources used to create wealth. Traditionally defined as land, labor and capital but it also includes knowledge and entrepreneurship.

Fatty Alcohols - Primary alcohols with 6 to 40 carbon atoms. They are manufactured in a variety of ways including synthetically and from natural oils.

Feedstock – In a general sense the physical components that are combined in production to produce a product; but the term is mainly used to refer to a gaseous or liquid hydrocarbon raw material such as ethane, propane, etc. derived from natural gas or naphtha , gas oil, etc. derived from oil refining that used to manufacture petrochemicals.

Finished Goods – The final product of a manufacturing operation produced for commerce.

Fine Chemicals – Low-volume, high-value, homogenous compounds sold on the basis of specific, high-purity composition. Generally used to produce pharmaceuticals and to a lesser extent pesticides and dyes.

Fixed Capital Turnover - The ratio of revenues divided by net fixed capital.

Fixed Costs - Costs and expenses that remain the same no matter what production is. These costs do not vary with output.

FOB (Free On Board) - Commonly used when shipping goods to indicate who pays loading and transportation costs, and/or the point at which the responsibility of the goods transfers from shipper to buyer. FOB shipping is the term used when the ownership/liability of goods passes from the seller to the buyer at the time the goods cross the shipping point to be delivered. FOB destination designates that the seller is responsible for the goods until the buyer takes possession. This is important in determining who is responsible for lost or damaged goods when in transit from the seller to the buyer.

Formulation - The mixing of chemical products by blending, emulsification or other physical means to create new chemical compounds with desired properties, or to perform a desired function.

Fractionation – A chemical process by which a chemical mixture is separated. See also Hydraulic Fracturing.

FRB – Acronym for the Federal Reserve Board.

Free Cash Flow - This measure of financial performance is equal to net income after taxes plus depreciation and amortization less the sum of capital expenditures and dividends.

Free Trade - The movement of goods and services among nations without economic, regulatory or political obstruction.

Gas - Compounds in a vapor state.

Gas Oil - A petroleum distillation faction containing hydrocarbons. It is used as feedstock for steam cracking and as fuel.

Greenfield Plant – Capacity added to a site where none existed. Generally includes items such as roads, sewers, utilities, and other infrastructure that do not have to be added at existing plants.

Gross Margin - The financial definition of gross margin is revenues less variable costs. The chemical industry, however, uses this term slightly differently; the net sales price minus the sum of raw material costs. Byproduct credits are not included, nor are variable production costs. Gross margin is sometimes referred to as the spread over raw materials.

Group - Elements that make up a column in the periodic table.

Henry Hub – Not a 1930s cartoon character but the pricing point for natural gas futures on the New York Mercantile Exchange (NYMEX). This station (located in Louisiana) connects nine interstate and four intrastate gas pipelines. The Henry Hub price is generally viewed as the primary price for the North American natural gas market. The other pricing point is the Alberta Empress.

Hopper Cars – A rail car designed for loading and unloading of plastic resins or other powder or pellet material.

Hydrocarbons - Compounds containing only carbon and hydrogen atoms. Hydrocarbons are the basic raw materials for petrochemicals.

Hydraulic Fracturing – A type of fractionation in which liquid is used to separate chemicals from rock formations. Also calling "fracking."

Income Statement - The financial statement that shows a company's profit after costs, expenses, and taxes. It focuses on a period of time, usually one year and summarizes all of the resources coming into the company (revenues), all of the resources that have left the company, and the resulting net income (or loss).

Industrial Gases – Gases used in industrial and manufacturing processes such as steel production, semiconductor manufacture, food processing, and other industrial activities. The most common industrial gases are oxygen, nitrogen, and argon.

Inflation - A general rise in the prices of goods and services over time caused by a prolonged rise in the supply of money.

Injection Molding – A plastic processing technique in which molten plastic resin is injected in molten form into a mold. The plastic is then cooled and solidifies. Common uses include plastic models and cups.

Intangible Assets - Items of value such as patents, copyrights, knowledge, and brand that have no real physical form.

Intermediate - Obtained from bulk petrochemicals as the middle step in a series of chemical reactions, intermediates can be transformed into different end products.

Intellectual Capital - Knowledge that can add value. It consists of the human capital of individuals (experience, know-how, skills, and creativity) as well as intellectual assets of the firm. The latter can include codified knowledge (processes, databases, programs, methods, designs, etc.) and intellectual property.

Intellectual Property - Intellectual assets such as patents, copyrights, trademarks and trade secrets that are legally protected.

Inventory Turnover - The ratio of cost of goods sold, divided by average inventory.

Ion - An atom or group of chemically bound atoms that have either a positive or negative electrical charge.

Joint Venture (JV) - A partnership between companies to undertake a major project or business.

Ketones - Not a 1950s male vocal group but oxygenated organic compounds (e.g., acetone) derived from secondary alcohols. These compounds contain carbonyl groups that are bonded to alkyl groups.

Leverage - Raising funds through borrowing (including issuing bonds) to raise a company's rate of return.

Liabilities - What a company owes to others.

Licensing - The sale of technology to an unrelated organization using a license that allows the buyer to use the technology.

Liquefied Natural Gas (LNG) - Natural gas that has been cooled to -259˚ Fahrenheit (-161˚ Celsius) and at which point it is condensed into a liquid which is colorless, odorless, non-corrosive and nontoxic. LNG is characterized as a cryogenic liquid and in this form can be transported via specialized tankers.

Liquefied Petroleum Gases (LPG) – A group of hydrocarbon–based gases derived from crude petroleum (or oil) refining or natural gas fractionation. These gases include ethane, ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene. For convenience in transportation, these gases are liquefied through pressurization.

Liquidity – A measure of how quickly an asset can be converted into cash.

Logistics - The physical movement (or distribution) of goods from producers to industrial and consumer users.

Long-Term Debt & Other Liabilities - These are liabilities such as loans from banks, leases, other long-term debt, etc. that must be paid after one year.

Loss - When a company's costs and expenses are more than its revenues.

Market Research - The analysis of markets to determine opportunities and challenges.

MDI - Methylene diphenyl diisocyanate

Merchant Wholesalers - Independently-owned companies that take title to (or own) the goods they handle on behalf of manufacturers.

Metallocene - A compound in which a metal atom is suspended between two five-membered carbon rings that are typically joined together behind the metal atom. Metallocenes are used as catalysts in the polymerization of olefins.

Methane - A gaseous straight-chain hydrocarbon containing one carbon atom.

Methyl - A chemical grouping with one carbon atom attached to an element or group.

MMA - Methyl methacrylate.

Molecule - Atoms of the same element or a combination of elements that are chemically bound together in a fixed proportion.

Monomer - A molecule or groups of molecules that may be reacted by itself or with other chemicals to form various types and molecular chains known as polymers or co-polymers. Monomers tend to be rather simple, low weight molecules.

Monopoly - A market in which there is only one seller. Do not pass Go.

MTBE - Methyl tertiary-butyl ether.

Nameplate Capacity – The capacity to produce a product based on annual design capacity, excluding scheduled turnarounds and maintenance.

Naphtha - Derived from crude oil, naphtha is a basic building block in the petrochemical industry. In addition to being the basis for gasoline, it is used as feedstock for steam cracking.

Natural Gas – A gaseous mixture of hydrocarbon compounds, the primary one being methane. Other compounds include ethane, propane, and other hydrocarbons.

Natural Gas Liquids – Those hydrocarbons in natural gas that are separated from the gas as liquids through the process of absorption, condensation, adsorption, or other methods in gas processing or cycling plants. These liquids consist of propane and heavier hydrocarbons and are commonly referred to as condensate, natural gasoline, and liquefied petroleum gases. Natural gas liquids include ethane, propane, butane, isobutene and condensate (primarily pentanes).

Net Assets - The value of total assets less cash and other equivalent short-term assets.

Net Fixed Capital - Depreciable and amortizable fixed assets (including construction in progress), plus land and mineral rights, less accumulated depreciation. It is also referred to as fixed capital.

Net Working Capital - Current assets less current liabilities.

Net Worth - The value of total assets less total liabilities.

Non-operating Income - The income (or loss) received from investments either from earnings (or loss) on the investment or from capital gains (or losses) on the investment.

Nonwoven - Textiles which are neither woven nor knit, non-woven fabric is typically manufactured by putting small fibers together in the form of a sheet or web, and then binding them either mechanically, with an adhesive, or thermally.

Nylon - A generic name for a family of long-chain polyamides having recurring amide groups as an integral part of the main polymer chain.

OECD – Acronym for the Organization for Economic Cooperation and Development.

OEM – Acronym for Original Equipment Manufacturer.

Olefins - Hydrocarbons containing one double bond in its structure. Double bonds are more reactive than the than the single bonds found in most fractions of crude oil and natural gas. Ethylene is the simplest olefin, with two carbon atoms. It is followed by propylene, with three carbon atoms and one double bond and then butylenes with four carbon atoms and one double bond.

Oligomers - Short chain polymers consisting of less than 10 monomer units.

Operating Margin - Expressed as a percent. This measure of profitability is equal to income (or loss) from operations (revenues less depreciation, amortization, and other operating costs and expenses) divided by revenues.

Operating Rate – The ratio between actual production and nameplate capacity during a certain period of time, for a chemical plant.

Organic Chemicals - Chemical compounds that contain carbon. The petrochemical industry relies on organic chemicals.

Outsourcing - The practice of assigning various functions or work such as accounting or plant maintenance, to outside organizations.

Oxidation - A chemical reaction in which a substance combined with oxygen loses one or more electrons.

pH - A measure of the acidity and alkalinity of a solution. A pH of 7 is said to be neutral. The pH decreases as the solution become more acidic. Conversely, pH will increase as the solution becomes more basic.

Patent - A legal document giving its owner/inventor exclusive rights to the invention for 17 years.

Pesticides - Substances used to kill or control living things that are considered pests. Pesticides include insecticides,

fumigants, fungicides, herbicides, bactericides, rodenticides, etc.

Petrochemical - Substance derived from petroleum or natural gas.

PF Resins - Phenol-formaldehyde resins

Plasticizer - Chemical compounds used to make polyvinyl chloride (PVC) and other polymers flexible.

Polyethylene (PE) - A plastic resin made from many ethylene molecules linked together.

Polymer - Generally composed of smaller molecules or monomers that are linked in chains. They are derived from simple monomers and feature a higher molecular weight.

Polymerization - A process in which very large polymer molecules are formed from smaller molecules. A catalyst is generally used.

Polyolefins - Polymers (or plastic resins) made from light olefins (linear unsaturated hydrocarbons). The most common polyolefins are polyethylene and polypropylene.

Polypropylene (PP) - A polymer (or plastic resin) made from many propylene molecules linked together.

Polystyrene (PS) – A polymer (or plastic resin) made from polymerizing styrene. Polystyrene can form either a clear, hard, crystalline plastic as seen in CD/DVD cases, or it can be expanded into a foam product commonly seen in coffee cups used in fast food operations. Expandable polystyrene is known as EPS.

Polyvinyl Chloride (PVC) - A polymer (or plastic resin) made from the polymerization of vinyl chloride, its uses include vinyl siding, pipe and fittings, conduit, window profiles, and vinyl shower curtains. Most PVC is used in building and construction applications.

Product - Any physical (or tangible) good, service or idea that satisfies a want or need.

Product Differentiation - The creation of real or perceived differences between what are basically the same products.

Product Life Cycle - A theoretical model of what happens to sales and profits for a product or class of products over time.

Production - The creation of finished goods and services using land, labor and capital, knowledge and entrepreneurship.

Profit - Earnings above what a company spends on salaries, other expenses and the cost of the goods sold.

Propane - A gaseous hydrocarbon containing three carbon atoms and derived from natural gas and petroleum.

Propylene - An olefin compound derived from cracking petroleum hydrocarbons, it has three carbon atoms and is a basic “building block” for other chemicals. Also referred to as propene.

Quick Ratio - The ratio of total current assets net of inventories divided by current liabilities.

Reduction - A chemical reaction that involves the gain of electrons.

Resin – General term for polymerized synthetics or chemically modified natural resins used in making plastics.

Restructuring - A process whereby an industry is strengthened by being reshaped into a smaller number of stronger producers. In this process, weaker players divest their positions or shut down uneconomical capacity.

Retained Earnings - Income after taxes, less the dividends paid.

Return on Assets - Expressed as a percent. This measure of profitability is equal to net income after taxes (or loss), divided by total assets.

Return on Equity - Expressed as a percent. This measure of profitability is equal to net income after taxes (or loss) divided by shareholders’ equity.

Return on Fixed Capital - Expressed as a percent. This measure of profitability is equal to net income after taxes (or loss) divided by net fixed capital.

Return on Net Assets - Expressed as a percent. This measure of profitability is equal to net income after taxes (or loss) divided by net assets.

Return on Revenues - Expressed as a percent. This measure of profitability is equal to net income after taxes (or loss), divided by revenues.

Return on Working Capital - Expressed as a percent. This measure of profitability is equal to net income after taxes (or loss), divided by working capital.

Revenues - The value of cash received during a year from the normal course of business. It is equivalent to net sales, receipts, and operating revenues and can include other sources.

Rotomolding - A process for manufacturing plastic finished goods. The resin is first placed inside a heated mold, and as the resin melts, the mold is rotated in three dimensions. The melted resin flows over all the surfaces of the mold, coating the mold and forming a hollow plastic shape.

ROW – Acronym for Rest of the World.

Salts - Compounds formed by the reaction of acids and bases.

SAN - Styrene-acrylonitrile.

SB Latex - Styrene-butadiene copolymer latexes.

SB Rubber - Styrene-butadiene elastomers.

SBU - Acronym for Strategic Business Unit.

Shareholders' Equity - The value of capital stock and other paid-in capital (less treasury stock) and retained earnings. Also referred to as net worth (total assets less total liabilities).

Services - Intangible products such as insurance, electronic funds transfer, and legal or strategic advice.

Shipments - The net selling values, f.o.b. plant to the customer, after discounts and allowances and exclusive of freight and taxes) of all products shipped from an establishment. Includes miscellaneous receipts. Also referred to as turnover.

Solution - Homogeneous mixture of two or more components, such as a gas dissolved in a gas or liquid, or a solid in a liquid. The term is also used to refer to a low pressure polyethylene production process that can manufacture both LLDPE and HDPE polymers.

Solvent – A substance that dissolves another substance.

Specialty Chemicals – Low-volume, high-value compounds sold on the basis of what they do, not what they are. That is, their performance criteria. For this reason they are often referred to as performance chemicals. These are generally blended with other compounds according to proprietary formulations.

Supply Chain Management - The comprehensive process of minimizing inventory and moving goods through the channels of distribution most effectively and efficiently using information technology (IT).

Surfactants - Also referred to as surface-active agents, these compounds reduce the surface tension of water or the solvents that they are dissolved or the tension at the interface between liquids or a liquid and a solid surface. Surfactants include detergents, emulsifiers, wetting agents, etc.

Synthetic Fibers – Fibers that are not of natural origin but are prepared or made artificially. Also called manufactured fibers.

Synthesis Gas - Mixtures of carbon monoxide and hydrogen used for manufacturing some petrochemicals. It is generally produced by steam reforming of hydrocarbons such as methane.

TAME - Tertiary-amyl methyl ether.

Thermoplastics - Long-chained polymers that soften without chemical change when heated. As a result, they can be recycled. The long chained molecules slip if pushed or pulled. They are generally more flexible than thermosets.

Thermosets - A type of plastic; polymers that once formed by heat and pressure, cannot be resoftened or reshaped. As a result, they aren't generally recycled.

Toll Manufacturing - An arrangement in which a company produces a product for a customer using the customer's process.

Toluene - This liquid compound contains seven carbon atoms, is an aromatic and is a "basic building block" for industrial chemicals.

Total Asset Turnover - The ratio of revenues divided by total assets.

UF Resins - Urea-formaldehyde resins.

USGC – Acronym for the United States Gulf Coast. It encompasses the states of Texas, Louisiana, Mississippi, Alabama, and Florida.

Upstream – The process or processes that feeds the process, product, or industry under consideration. For example, benzene and caprolactam are all upstream of nylon. In energy operations, this refers to the exploration and production of crude oil and natural gas.

Utilization Rate – The production volume as a percent of (or relative) to capacity. It is also referred to as the operating rate.

Value Added - Total revenues of a company, less the cost of raw materials, components, and services. It measures the value which the company has added to these brought-in materials and services by its productive activities.

Value Chain - The sequence of linked activities that must be performed by various organizations to move goods from the source of raw materials to the ultimate customers.

Variable Costs - Those costs that vary according to the level of production/output.

Wholesaler - A marketing and distribution intermediary that sells to other organizations.

Working Capital – Measured in dollars, this is equal to current assets and includes cash, time and demand deposits, U.S. government and other short-term securities, trade accounts and trade notes receivable, and inventories.

Working Capital Turnover - The ratio of revenues divided by working capital (or current assets).

World-Scale Plant - A plant the size (or designed capacity) of which achieves full economies of scale. That is, the minimum efficient scale (MES) a term used in industrial organization to denote a plant that can produce such that its long run average costs are minimized.

Xylenes - This liquid compound is an aromatic, contains 8 carbon atoms, and takes on the three following forms: para-xylene, ortho-xylene, and meta-xylene.

Yield - The portion of raw materials in a chemical process that ends up in the prime product rather than as lower value-added by-products or waste. It's usually measured as percent but is sometimes measured as ratio (e.g., pounds of ethylene per pound of ethane).