

2022 GUIDE TO THE BUSINESS OF CHEMISTRY



150
YEARS

GUIDE TO THE BUSINESS OF CHEMISTRY



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Dear Colleagues,

The United States business of chemistry is a world leader, with \$517 billion in shipments in 2021, and is the second-largest chemical producing nation, after China. Amidst disruption in global energy markets and rising costs for many goods and services, both domestically and abroad, American chemistry continues to contribute significantly to the U.S. economy. American chemistry provides more than half a million jobs, with average pay of more than \$92,000 per year. Our industry supports a vast supply chain and creates economic activity in the communities where facilities are located. For every chemical manufacturing job, more than seven are created elsewhere in the economy.

American chemistry remains in demand around the globe, despite ongoing trade tensions, global supply chain constraints, historically high inflation, and COVID-related disruptions in some parts of the world. In 2021, the U.S. chemical industry was one of the world's largest exporters, at \$153 billion, accounting for 10% of all U.S. goods exports. The industry has a large and growing trade surplus, reaching \$25 billion last year. Trade is essential to the success of the U.S. chemical industry, and it benefits the broader economy as well. Access to global markets is critical for continued economic growth and job creation.

The chemical industry is also a leader in capital investment, with more than \$30 billion in new spending in 2021. These investments include projects to expand capacity to meet growing demand and make industry operations more sustainable. Our industry is expanding technological frontiers, with \$11.4 billion in R&D investment in 2021. These investments in innovation are the key to developing new materials, applications, and processes to ensure a safe and plentiful food supply, clean air and water, safe living conditions, efficient and affordable energy sources, and life-saving medical treatments.

The chemical industry is a key provider of materials used to fight COVID-19, including vaccine supplies, personal protective equipment (PPE), hand sanitizer and disinfectant ingredients, to name a few. Our industry is committed to reducing greenhouse gas emissions in the manufacture and use of our products, and companies are exploring and developing a host of new technologies to do so. Chemistry and plastics are used to create a variety of solutions that help society save energy and reduce emissions, including energy-efficient building products, lightweight vehicle parts, materials for EVs and charging stations, solutions for solar and wind power, and many more.

Companies across the plastics value chain are continuing their work to develop advanced recycling systems — new technologies, innovations, and business models to recover and create value from plastic waste and help prevent it from entering the environment. In the past several years, the private sector has announced billions of dollars in U.S. investments to dramatically modernize plastics recycling, including innovative advanced recycling technologies to convert post-consumer plastics into feedstocks to promote a circular economy.

I hope our *2022 Guide to the Business of Chemistry* will be a valuable resource for you and your colleagues as you explore the many ways that chemistry is essential to our economy and everyday lives.

Sincerely,

A handwritten signature in black ink, appearing to read 'Chris Jahn', with a long horizontal flourish extending to the right.

Chris Jahn
President and CEO
American Chemistry Council

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LIST OF ABBREVIATIONS AND ACRONYMS

Chemicals and other Industry Terms

ABS - Acrylonitrile butadiene styrene	NAICS - North American Industry Classification System
BPA - Bisphenol A	NGLs - Natural gas liquids
BPD - Barrels per day	OEM - Original equipment manufacturer
BTU - British thermal unit	PC - Polycarbonate resins
BTX - Benzene, toluene and xylenes.	PDH - Propane dehydrogenation
CIF - Cost, Insurance and Freight	PE - Polyethylene
DME - Dimethyl ether	PET - Polyethylene terephthalate
DMT - Dimethyl terephthalate	PF Resins - Phenol formaldehyde resins
EBITDA - Earnings before Interest, Taxes, Depreciation and Amortization	PMMA - Polymethyl methacrylate
EDC - Ethylene dichloride	PO - Propylene oxide
EG - Ethylene glycol	PP - Polypropylene
EO - Ethylene oxide	PS - Polystyrene
EPDM - Ethylene propylene diene monomer	PTA - Purified terephthalic acid
EPS - Expandable polystyrene	PP&E - Property, plant, and equipment
EV - Electric vehicle	PVC - Polyvinyl chloride
EVA - Ethylene-vinyl acetate	PX - Paraxylene
EVOH - Ethylene-vinyl alcohol	ROW - Rest of the world
FOB - Free On Board	SAN - Styrene acrylonitrile
GHG - Greenhouse gas	SB Latex - Styrene-butadiene latex
GMO - Genetically modified organisms	SBR - Styrene-butadiene rubber
HDPE - High-density polyethylene	TAME - Tertiary-amyl methyl ether.
HMDA - Hexamethylene diamine	TPE - Thermoplastic elastomer
JV - Joint Venture	UF Resins - Urea formaldehyde resins
LDPE - Low-density polyethylene	USGC - United States Gulf Coast (includes the states of Texas, Louisiana, Mississippi, Alabama, and Florida)
LLDPE - Linear low-density polyethylene	VAM - Vinyl acetate monomer
LNG - Liquefied natural gas(es)	VCM - Vinyl chloride monomer
LPG - Liquefied petroleum gas(es)	
MDI - Methylene diphenyl diisocyanate	
MEG - Monoethylene glycol	
MMA - Methyl methacrylate	
MTBE - Methyl tertiary butyl ether	

Government Agencies and other Acronyms

ABIQUIM - Associação Brasileira da Indústria Química (Brazilian Chemical Industry Association)

ANIQ - La Asociación Nacional de la Industria Química (The National Association of the Chemical Industry), Mexico

BEA - U.S. Bureau of Economic Analysis

BLS - U.S. Bureau of Labor Statistics

CCPA - The Canadian Chemical Producers' Association

Cefic - The European Chemical Industry Council

EIA - U.S. Energy Information Administration

EPA - U.S. Environmental Protection Agency

FDA - U.S. Food and Drug Administration

FRB - Federal Reserve Board

JCIA - Japan Chemical Industry Association

OECD - Organization for Economic Cooperation and Development

USITC - United States International Trade Commission

VCI - Verband der Chemischen Industrie e.V. (Association of the Chemical Industry), Germany

WTO - World Trade Organization

INTRODUCTION

The *Guide to the Business of Chemistry* is a premier source of data on the chemical industry. The publication characterizes the chemical business in ways that are familiar to the industry, as well as its observers. The *Guide to the Business of Chemistry* segments the business into several types of production: basic chemicals, specialty chemicals, agricultural chemicals, and consumer products. Each of these segments has distinct characteristics and markets. A number of industries, such as steel, pulp and paper, glass, and oil refining, are essentially based on chemical processes, but are not included here.

In government classification systems, pharmaceuticals is also considered a segment of the chemical industry. However, ACC does not include pharmaceuticals in its definition of the chemical industry. In most segments of this publication, the data is focused on basic and specialty chemicals or chemicals excluding pharmaceuticals.

The *Guide 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. As these government sources revise historical data, ACC revises its data as well. For this reason, some numbers may be different from data published in previous editions of the *Guide to the Business of Chemistry*.

In addition to the data presented in the *Guide to the Business of Chemistry*, the full spreadsheet containing detailed time-series data is available to ACC members on MemberExchange (ACC member platform) or from the ACC Store at <https://store.americanchemistry.com>.

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CHAPTER 1

CHEMISTRY IN OUR LIVES



Innovations and technologies made possible by chemistry touch nearly all of the products we use every day. There are countless economic and societal benefits made possible by chemistry: 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. Thanks to chemistry, groundbreaking products are improving the world all around us by making it healthier, safer, more sustainable, and more productive.

Chemistry is essential to modern life. From home and personal care products, to clothing and sports equipment, to automobiles and electronics, chemistry helps make possible thousands of products we rely on every day. Following are just some of the areas which benefit from products made possible through chemistry:

COVID-19 Response

The coronavirus pandemic has shone a spotlight on the positive role that chemistry can play in everyday life. From manufacturing crucial inputs for N95 face masks and personal protective equipment (PPE) to producing hand sanitizer and disinfectants, the chemical industry continues to play a critical role in the global battle against COVID-19. In March 2020, as part of the federal government response to COVID, the U.S. Department of Homeland Security identified the U.S. chemical industry as Essential Critical Infrastructure, an industry sector critical to public health and safety, economic and national security. When products such as masks and hand sanitizer were in short supply, many American Chemistry Council member companies responded by altering manufacturing operations and working around the clock to provide the essential materials needed to those who needed them most.

Cleaning and Disinfection

Chemistry contributes 75% of the value of material inputs in cleaning compounds such as hand sanitizers, surface cleaners, bleach, dish soap, and laundry detergent, to name a few. Chlorine bleach is critical to combating the spread of COVID as it effectively disinfects surfaces that inactivate the virus SARS-CoV-2. Chlorine disinfectants are also used to help destroy food-borne germs on kitchen surfaces, as well as to sanitize bathrooms and other household surfaces. Antimicrobials, also known as biocides, prevent the growth and spread of unwanted microbes; a class of antimicrobial products known as disinfectants to kill many disease-causing viruses.

Medical Supplies and Equipment

Chemistry contributes 27% of the value of material inputs used to make medical equipment, and 25% of the value of material inputs used to make medical supplies. 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, chemistry plays a key role in the future of health care. 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 Gear

Chemistry helps make what we wear better and safer. Football, baseball, hockey, lacrosse, skateboarding—nearly every popular sport relies on plastic pads, helmets and other protection. Plastic fibers make our workout clothing breathe and wick away sweat. Modern swimsuits help athletes glide through the water. Cyclists, skiers, hikers, mountain climbers and other outdoor enthusiasts all rely on carbon fiber-reinforced plastic gear, safety equipment and clothing, from skis to helmets to goggles to ropes to insulating fibers. At the gym, on a construction site or in the line of duty, chemistry helps to 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 maybe even smell better).

Modern Communications

Nearly every aspect of communication in today’s society involves some sort of chemistry. From video conferencing to smartphones, chemistry makes communication possible across a wide range of platforms. According to the American Chemical Society, “of the 83 stable (nonradioactive) elements, at least 70 of them can be found in smartphones!”

Touchscreens, enabled by plastics, adhesives and other products of chemistry are employed on smartphones, computer screens, and more. Even the use of a touchscreen involves a tiny chemical reaction: a tiny bit of stored electrical charge enters your finger from the chemical reaction between your skin and the glass on your phone, transfers to detect it on the screen and then traces the movement of your finger across the phone.

Energy

Both renewable energy and energy-efficient technologies would not be possible without chemistry. 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. Continuous rigid or spray foam plastic insulation can help achieve up to 50% energy savings. Spray foam and sealants block energy-wasting air-loss, saving on heating and cooling energy costs. Plastic housewrap and sealants can reduce the infiltration of outside air into the average home by as much as 50%, reducing energy needs. Chemistry enables compact fluorescent bulbs to “fluoresce” and to use 70 percent less energy than incandescent bulbs; LED lighting could cut global electricity demand for lighting by 30 percent. Chemistry helps save money and reduces overall energy consumption.

Electronics

In addition to smartphones and computers, numerous other electronics products, like speakers, home security systems, video doorbells, and more, rely on the products of chemistry to enhance their functionality and performance. A wide variety of chemistry materials, from fluoropolymers and flame retardants to silicones, polycarbonate plastics, phthalates and more, are used in the manufacture of electronics products, to help make them lightweight, durable and functional to meet the technology needs of today's consumers.

Plastic components are essential to advances in weight reduction and miniaturization in many electronic products, helping to make electronics strong and durable, protecting vital technological components while also using less material in production. Silicon microprocessor chips, which are produced using chlorine chemistry, can be found in every day electronics such as alarm clocks and microwave ovens.

Transportation

A typical automobile contains over \$3,200 worth of chemistry, including more than 400 pounds of plastics and polymers composites, over 240 pounds of rubber, and 82 pounds of textiles and coatings. From impact-resistant, polycarbonate-blend bumpers to high-strength 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 (*Chemistry and Light Vehicles*, American Chemistry Council). 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 contribute to the performance and safety of vehicles, it also provides solutions leading to improved sustainability.

Electric vehicles (EVs) account for an increasing share of automobile purchases and also rely on chemistry. EVs are powered by electricity, stored in the vehicle's battery (often a lithium-ion battery) and many are operated (in part or in whole) by computers. Plastics, among other products of chemistry, are critical ingredients in the creation of EV battery housings, closures, encasements, connectors and EV charging stations.

Lithium Batteries

While lithium is often a key component of the cathode materials in a lithium battery, various other chemistries are used in lithium battery components, such as polyethylene or polypropylene memberane separators and elctrolytes. In addition to EVs, lithium batteries are used in numerous products such as personal electronics; medical devices; wireless headphones; smoke, fire, and carbon monoxide detectors and more. Lithium batteries are also 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 smartwatches, power cordless drills, and flashlights. On a larger scale, lithium batteries are used to power everything from wheelchairs to jet fighter controls and satellites.

Pharmaceuticals

An important end-use market for many chemicals, pharmaceuticals are central to human health and welfare. According to PhRMA, childhood vaccines are now able to prevent 16 diseases in the U.S. Pharmaceutical innovations enable people to live with and manage diseases such as high blood pressure, diabetes, and some cancers. At any given time, thousands of medicines and vaccines are in development, aiming to help those who suffer from countless diseases.

Residential Spaces

Chemistry has revolutionized our homes. In recent years, homes have seen a number of chemistry-enabled advancements, such as video doorbells, robot vacuum cleaners and wi-fi enabled smart plugs. Beyond smartphones, chemistry makes “smart homes” possible. In the kitchen, chemistry touches nearly everything. Today, most people take for granted that they can grab a cold drink from the refrigerator or microwave a meal in minutes. Replacing an old refrigerator with an 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. 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.

Environmental Solutions

Efforts to preserve the environment—our air, water, land and climate—are made possible in large part thanks to the innovative products of chemistry. Many environmental improvements are achieved due to the energy efficiency of innovative chemistry products; less energy used equals fewer energy-related emissions. The products of chemistry benefit the environment in many other ways: Lightweight plastic packaging allows more products to be shipped, lightening the load and producing fewer discards. After delivering the goods, many plastics can be recycled and become new packaging or long-lasting products such as plastic lumber. Absorbents, catalysts and plastic fibers in air filters for automobiles, homes and commercial buildings clean the air we breathe, and “scrubbers” at industrial facilities dramatically reduce noxious emissions to the environment and acid rain. Modern landfills are lined with industrial strength plastics to prevent toxic run off into sensitive waterways or drinking water sources. Chemistry produces fertilizers that nurture crops, new compounds that protect plants from proliferating pests and disease, water saving and delivery devices such as plastic sheeting and pipes—resulting in more food for more people.

Building & Construction

Buildings play a central role in all of our lives. And materials made possible by chemistry are used throughout buildings—from rooftops to wall and floor coverings, to insulation, to countertops and surfaces. Chemicals are used in virtually every facet of building construction and maintenance, from roof membranes that reflect light and keep roofs cool, to silicone sealants and caulks used to keep basements dry.

Advances in chemistry and materials science have helped the building and design sector provide many high-performance materials and products that can help address a number of challenges—from helping mitigate climate impacts, to improving occupant health and wellness, to enhancing energy efficiency, to increasing a building’s resilience to natural disasters.

CHAPTER 2

CHEMISTRY AND THE ECONOMY



The business of chemistry is a key element of the nation's economy. The industry contributes significantly to the U.S. gross domestic product (GDP) and creates more than half a million skilled, good-paying American jobs. Chemistry supports a vast supply chain and generates economic activity in local communities around the country.

Table 2.1 - U.S. Business of Chemistry Industry Snapshot, 2021

Jobs (in thousands)		Expenditures (in billions)	
Direct Jobs	537	Total Payroll	\$49.4
Supplier Jobs	1,892	Benefits	\$15.6
Expenditure-Induced Jobs	1,737	Total Compensation	\$65.0
Total Jobs	4,165		
Multiplier*	6.8	Value-Added	\$255.2

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

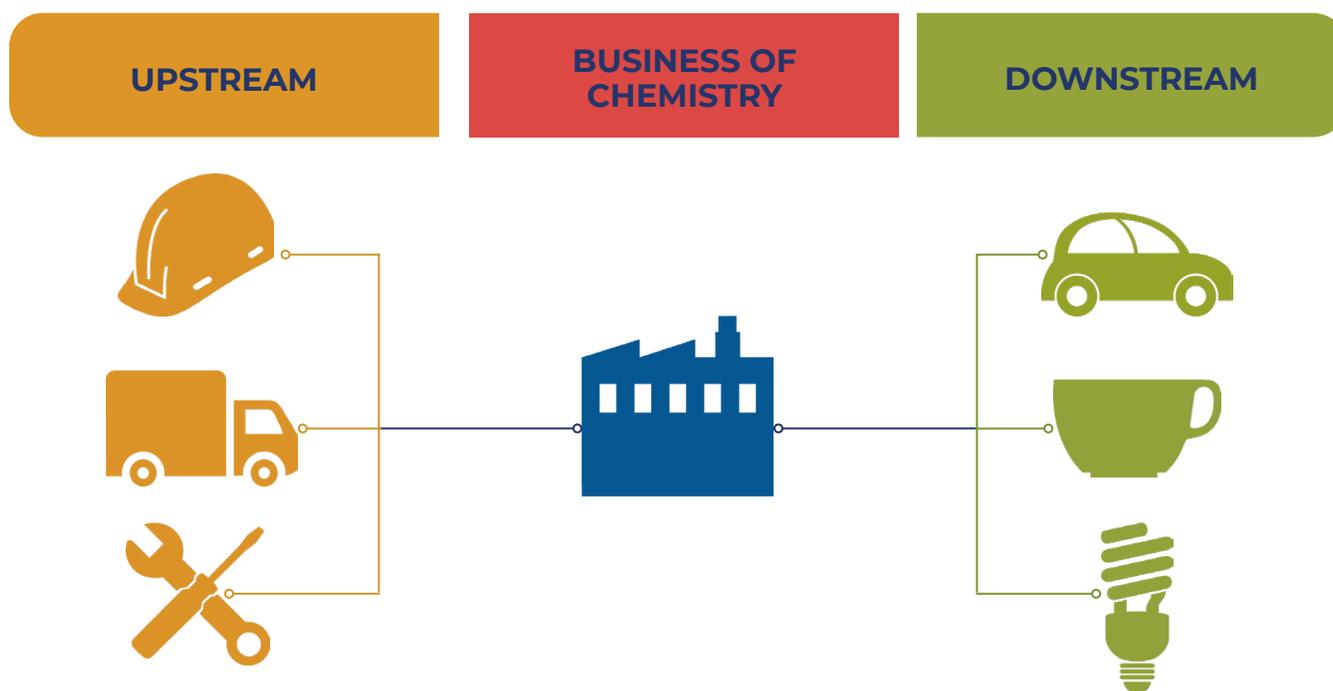
Data on indirect and payroll-induced jobs were calculated using the IMPLAN model.

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

UPSTREAM IMPACTS

The chemical industry's supply chain extends beyond the manufacturing process. To support ongoing operations, the chemical industry purchases of supplies (i.e., raw materials) and services (such as delivery services, contract workers, warehousing, and maintenance). These supplier businesses generate more jobs, in addition to the hundreds of thousands of jobs created directly by the chemical industry. The chemical industry employees, as well as the employees of the supplier businesses, receive wages and salaries which are then spent on products and services in the local communities where the employees live. Those purchases ("expenditure-induced activity") support additional businesses, thus generating several rounds of economic spending and re-spending.

Figure 2.1 - Upstream and Downstream Operations



DOWNSTREAM IMPACTS

The impact of chemistry on the U.S. economy is much more extensive than standard output and job multipliers derived using input-output 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:

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

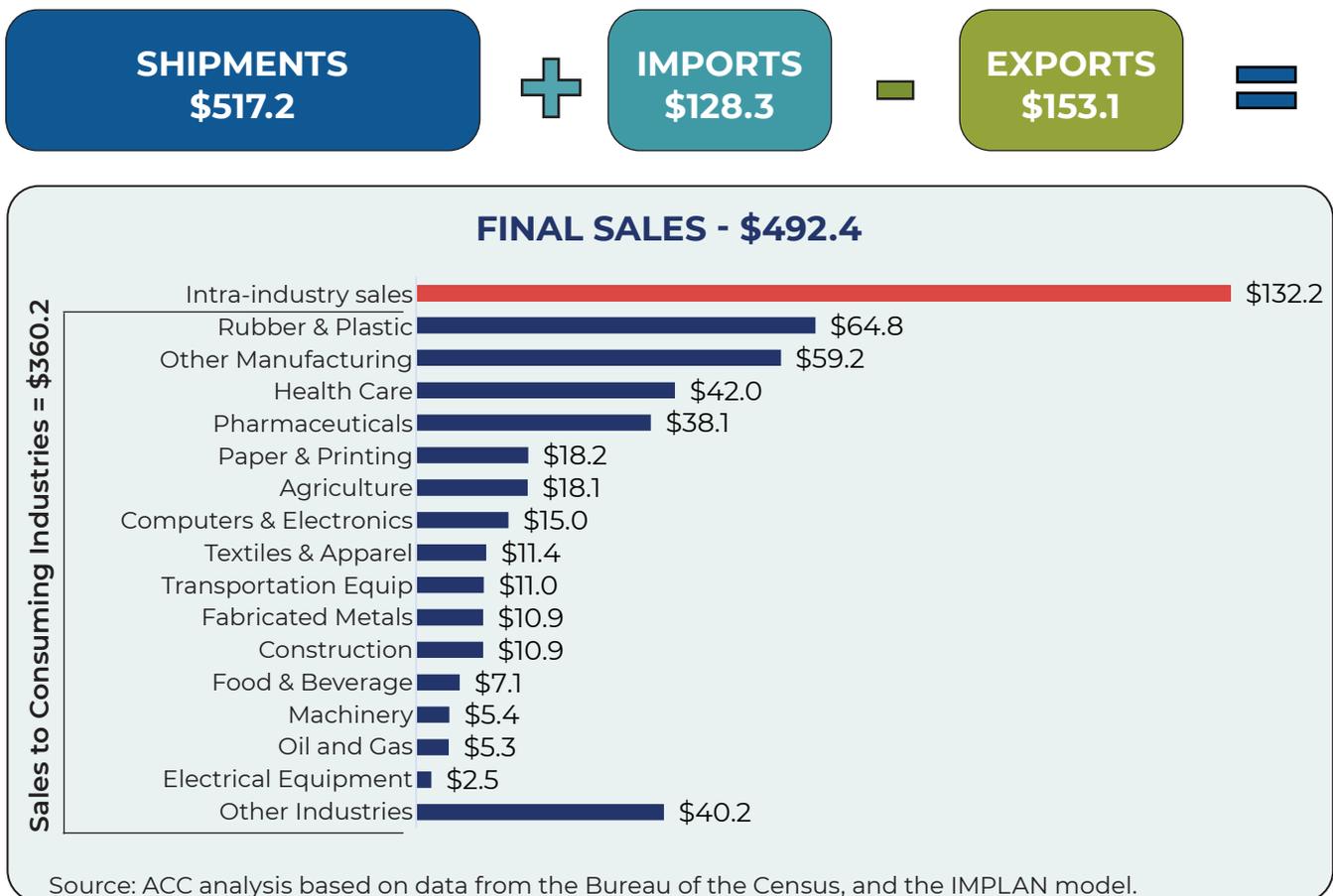
The robust network of relationships between the chemical manufacturing industry and the consumer is complex, but chemistry is key to a number of major consumer products, including apparel,

appliances, furniture, home furnishings, light vehicles, and sporting goods, as well as agriculture and construction.

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

The following 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,¹ 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 chemistry.

Figure 2.2 - U.S. Business of Chemistry Flow Chart, 2021 (in billions)



¹IMPLAN is used by government agencies include the Army Corp of Engineers, U.S. Department of Defense, U.S. Environmental Protection Agency, and over 20 others, and by over 250 colleges and universities, local governments, non-profits, consulting companies, and other private sector companies.

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 2.2.

Table 2.2 - Industries Dependent on the Business of Chemistry, 2021

Industry	Employment (in thousands)	Payroll (in \$billions)	Value-Added (in \$billions)
Business of Chemistry	529	\$47.7	\$255.2
Intermediate Goods			
Agriculture	809	23.5	203.0
Oil & Gas Extraction and Mining	513	56.1	196.2
Water and Sewage Treatment	54	3.7	16.8
Textiles & Fabrics	97	5.1	8.0
Engineered Wood Products	82	5.0	9.7
Paper & Paper Products	350	26.0	61.1
Petroleum Products	104	12.8	208.8
Rubber & Plastic Products	721	44.2	89.1
Nonmetallic Mineral Products	402	26.6	71.0
Aluminum	57	4.2	13.4
Windows & Doors	67	3.7	6.7
Metal Coating	125	7.0	17.4
Industrial Machinery	120	12.1	19.4
Commercial & Service Industry Machinery	87	7.3	14.4
Ventilation & HVAC Equipment	137	8.6	23.5
Semiconductors & Electronic Components	367	50.3	52.5
Electrical Equipment & Components	321	25.0	58.0
Total – Intermediate Goods	4,411	\$321.1	\$1,069.0
Consumer and Other Final Products			
Food, Beverage & Tobacco	1,929	107.2	310.5
Textile Mill Products	103	5.0	8.6
Apparel & Leather Products	116	5.8	11.6
Printing	368	20.1	41.1
Pharmaceuticals	332	42.3	183.7
**Book & Periodical Publishing and Software	160	27	58.6
Computers & Electronics	685	105.1	287.9
Household Appliances	68	4.6	11.4
Mobile homes	30	1.7	1.9
Light Vehicles & Parts	956	64.4	169.4
Aerospace	478	51.9	140.0
Ship & Boatbuilding	146	10.0	19.0
Furniture & Fixtures	372	19.1	29.8
Medical Equipment & Supplies	321	26.5	62
Other Miscellaneous Manufacturing	51	17.2	45.0
Total – Consumer & Other Final Products	6,114	\$507.6	\$1,380.5

Table 2.2 - Industries Dependent on the Business of Chemistry, 2021

Industry	Employment (in thousands)	Payroll (in \$billions)	Value-Added (in \$billions)
Construction			
Residential Building Contractors	866	57.2	117.6
Nonresidential Building Contractors	787	68.9	169.4
Specialty Trade and Heavy Contractors	5,761	392.0	671.8
Total - Construction	7,413	\$518.1	\$958.8
Wholesale Distribution			
Chemical Wholesalers	144	14.4	28.4
Druggist Goods Wholesalers	244	35.0	149.7
Farm Supplies	116	8.4	9.6
Paint Wholesalers	22	1.6	1.4
Total - Wholesale Distribution	526	\$59.4	\$189.1
Services			
Testing Labs	173	14.6	30.1
Specialized Design Services	142	11.4	19.1
Scientific R&D Centers	822	132.7	149.2
Photographic Services	41	1.6	4.7
Veterinary Services	439	21.1	28.4
Facilities Support Services	155	8.6	16.4
Document Preparation Services	39	1.7	4.1
Services to Buildings and Dwellings	2,140	79.3	135.8
Waste Management & Remediation Services	456	30.7	64.4
Health Care Services	15,905	1,039.0	1,521.0
Auto Repair	932	42.8	88.3
Personal and Laundry Services	1,355	45.7	141.4
Total - Services	22,599	\$1,429.2	\$2,202.8
Total – Industries Dependent on Chemistry	41,064	\$2,835	\$5,800
Total U.S. – All Sectors	143,759	\$9,719	\$20,937
<i>Industries Dependent on Chemistry, as a Percent of U.S. Totals</i>	28.6%	29.2%	27.7%

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.

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CHAPTER 3

WHAT IS THE BUSINESS OF CHEMISTRY?



The U.S. business of chemistry is the world's second largest (after China), accounting for nearly 11% of the world's total chemical production.

The chemical industry is a dynamic and innovative industry and are fundamental to the economy. The business of chemistry is the largest exporting sector in the United States, larger than aerospace products (and parts) and motor vehicles, and accounting for nearly ten cents out of every dollar of American exports.

Table 3.1 - Business of Chemistry Summary, 2017-2021

	2017	2018	2019	2020	2021
	<i>in billions</i>				
Shipments	\$523.1	\$548.8	\$510.4	\$464.8	\$517.2
Capital Expenditures	\$29.5	\$25.0	\$28.5	\$26.9	\$30.7
Funds for Research & Development	\$10.9	\$11.3	\$10.5	\$10.1	\$11.4
Exports	\$130.1	\$140.1	\$135.5	\$125.2	\$153.1
Imports	\$97.1	\$109.0	\$101.9	\$96.7	\$128.3
Trade Balance	\$33.1	\$31.1	\$33.7	\$28.6	\$24.8
Production Index (2017=100)	100.0	99.6	94.0	90.7	92.2
Price Index (2017=100)	100.0	104.9	104.3	101.7	119.5
Employment (thousands)	531	538	544	531	537
Average Hourly Wage – Production Workers	\$23.55	\$24.20	\$25.40	\$26.70	\$27.39

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

Electronic data tables, including historic data (back to 1989) are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

The chemical industry is typically viewed as having four main segments: basic chemicals, specialty chemicals, agricultural chemicals, and consumer products, each with its own structure, growth dynamics, markets, developments, and issues. However, the distinction among these segments is not clear and some degree of overlapping exists. For example, products such as architectural coatings and packaged adhesives could be considered specialty chemicals or consumer products. Furthermore, some convergence is occurring among segments, blurring the distinctions even further. Nanotechnology is used across industry segments, and the consumer market continues to broaden.

The business of chemistry is not easily captured by traditional economic nomenclature, such as the North American Industrial Classification System (NAICS). These definitional foundations 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.

Cost Structure

The typical cost structures over the business cycle differ among the major segments of the business of chemistry. Basic chemicals are dominated by costs of raw materials, which can account for as much as two-thirds of total costs, whereas specialty chemicals tend to spend more on research and development. Consumer products tend to spend a higher percentage on marketing and advertising. Profit margins for consumer products tend to be higher than specialties, which are higher than basic chemicals. For agricultural chemicals, the fertilizer business tends to reflect the cost dynamics of basic chemicals while the crop protection business more closely resembles specialties.

HISTORY OF THE U.S. CHEMICAL INDUSTRY

The business of chemistry is one of the oldest American industries and also one that is ever changing. More than 75 years ago, an article in *The American Economic Review* noted that the chemical industry's "technology undergoes rapid and continuous change" and the same could be said today.

The North American Industry Classification System (NAICS) is a classification system that was developed by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadística y Geografía. According to the Bureau of Labor Statistics (BLS), "classification systems are ways of grouping and organizing data so that they may be compared with other data." NAICS was implemented in 1997 and replaced the Standard Industrial Classification (SIC) system. NAICS "is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy." (U.S. Census Bureau).

There is no consensus as to the exact timing of the establishment of the U.S. chemical industry. The American Chemical Society (ACS) attributes the establishment of the American chemical industry to Colonial Virginia in the early 1600s, according to ICIS, the first American chemical plant was started by John Winthrop, Jr., Governor of the Colony of Connecticut, in Boston in 1635. Others would argue that the chemical industry existed in America before the European settlers arrived, as Native Americans had developed methods for crop fertilization and early forms of medicine.

The modern chemical industry, however, really took hold during (and after) World War I. Prior to the start of the war, there was a small chemical manufacturing presence in the U.S. that was mostly based on inorganic chemicals. Other products of chemistry were imported from European manufacturers. When the War disrupted the supply chain, the U.S. had to start manufacturing its own chemicals, and the industry grew from there. In addition to manufacturing chemical products, chemicals became increasingly integrated in the manufacturing processes of other industries (Weisberger, 1946).

SHIPMENT VALUES

In addition to the major segments, the business of chemistry consists of hundreds of sub-segments. 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; they are not adjusted for price changes. *Note: these are based on non-seasonally adjusted data and, therefore, differ from data reported on a monthly basis.*

Table 3.2 - Business of Chemistry Shipments by Segment, 2017-2021

	2017	2018	2019	2020	2021
	in \$millions				
Chemicals	\$523,110	\$548,807	\$510,424	\$464,762	\$517,223
Basic Chemicals	319,503	340,379	303,328	266,341	302,618
Specialty Chemicals	90,333	90,652	86,875	82,637	91,623
Agricultural Chemicals	31,449	32,590	33,609	32,438	36,137
Consumer Products	81,825	85,186	86,612	83,345	86,846
Pharmaceuticals	233,299	209,256	221,183	231,284	251,637
Chemicals & Pharmaceuticals	756,409	758,063	731,607	696,046	768,860

Source: Bureau of the Census (from the ASM-1 report)

Electronic data tables, including historic data (back to 1989) are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

Figure 3.1 - Business of Chemistry Shipments by Segment, 2021



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, 2017). Weighting factors are published for each of the component production indices to quantify the relative importance of each segment to overall chemical manufacturing.

Table 3.3 - Industrial Production Indices, 2017-2021

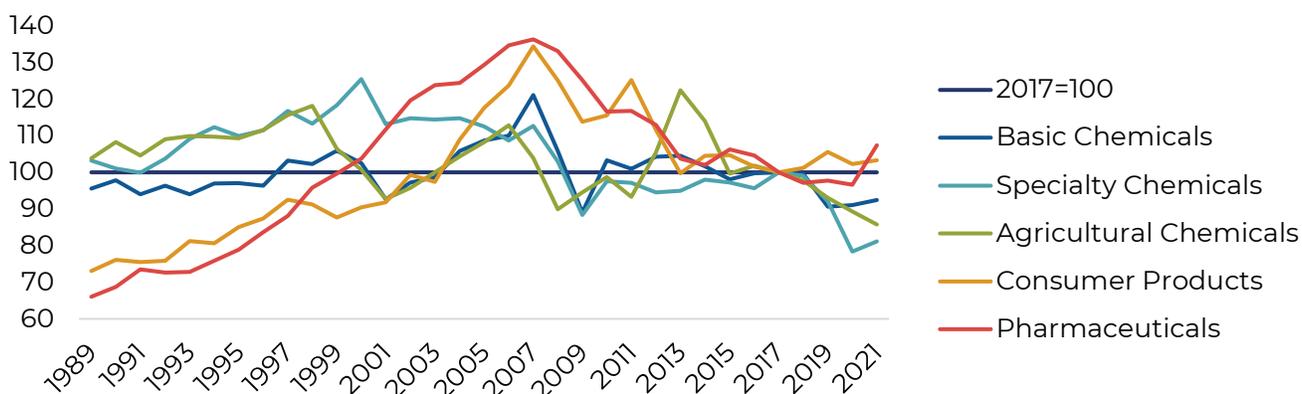
	2017	2018	2019	2020	2021
	<u>2017=100</u>				
Chemicals	100.0	99.6	94.0	90.7	92.2
Basic Chemicals	100.0	99.5	90.6	91.0	92.4
Inorganics	100.0	95.4	87.3	86.1	88.7
Bulk Petrochemicals & Intermediates	100.0	100.6	91.4	92.3	93.3
Specialty Chemicals	100.0	99.0	92.1	78.3	81.1
Agricultural Chemicals	100.0	97.7	93.0	89.3	85.7
Consumer Products	100.0	101.2	105.5	102.2	103.3
Pharmaceuticals	100.0	97.1	97.7	96.6	107.4
Chemicals & Pharmaceuticals	100.0	98.6	95.5	93.0	97.8

Source: Federal Reserve Board, supplemental American Chemistry Council analysis.

Note: For many years, ACC has had reservations concerning the quality of the Federal Reserve Board's industrial gases production index. In addition, the May 2021 annual benchmark to base year 2017 included recalculations of previously published data that create concerns about the quality of the estimates, especially for organic chemicals and plastic resins.

Electronic data tables, including historic data (back to 1989) and additional sub-industry breakouts, are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

Figure 3.2 - Industrial Production Indices, 1989-2021



PRICE INDICES

The Bureau of Labor Statistics (BLS) collects data on domestic prices for a wide variety of goods and services as provided by producers. These are commonly referred to as producer price indices, or PPI. 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 FRB production indices, ACC has rebased these to where 2017=100. The BLS also collects data and publishes indices on import and export prices. ACC includes these and rebases them to 2017 as well.

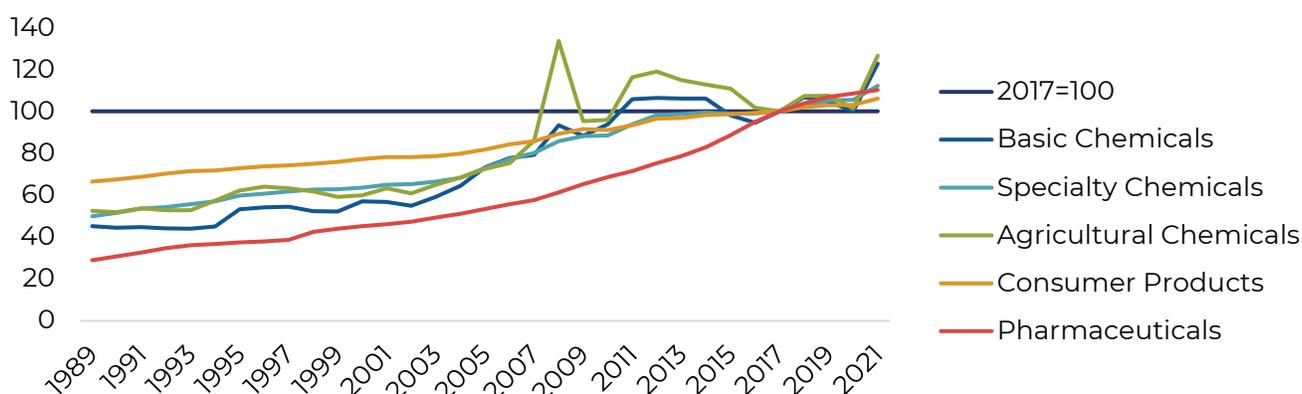
Table 3.4 - Producer Price Indices, 2017-2021

	2017	2018	2019	2020	2021
	2017=100				
Chemicals	100.0	104.9	104.3	101.7	119.5
Basic Chemicals	100.0	106.7	104.6	100.0	122.9
Inorganics	100.0	110.3	113.5	109.7	121.4
Bulk Petrochemicals & Intermediates	100.0	106.3	102.5	97.2	121.6
Specialty Chemicals	100.0	102.7	105.2	105.6	112.2
Agricultural Chemicals	100.0	107.3	107.5	101.5	126.6
Consumer Products	100.0	102.0	102.9	103.1	106.2
Pharmaceuticals	100.0	103.8	106.9	108.6	110.3
Chemicals & Pharmaceuticals	100.0	104.5	105.2	104.1	116.3
Feedstocks	100.0	129.2	79.3	68.7	169.7
Chemical Exports	100.0	104.8	104.1	101.9	118.6
Chemicals Imports	100.0	103.7	102.5	100.9	109.2

Source: Bureau of Labor Statistics, American Chemistry Council analysis.

Electronic data tables, including historic data (back to 1989) and additional sub-industry breakouts, are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

Figure 3.3 - Producer Price Indices, 1989-2021



FINANCIAL PERFORMANCE

There are many ways to assess the financial health of an industry using metrics derived from financial statements such as revenue, assets and liabilities, inventory, operating expenses, and shareholders' equity, among others.

The following tables show key financial ratios for the chemical industry as a whole, as well as two segments of the chemical industry: (1) basic chemicals, resins, and synthetics; and (2) all other chemicals (pharmaceuticals are not included). The data are further segmented by company size, based on total assets.

Types of Financial Ratios

Liquidity ratios examine a company's ability to pay off current (or short-term) debt. The current ratio, quick ratio, and cash ratio are all examples of liquidity ratios. These financial metrics compare the company's assets to the company's current liabilities (debt). The current ratio considers all current assets; the quick (or acid test) ratio considers assets that can be more easily converted to cash and excludes assets such as inventory; the cash ratio considers a company's most liquid assets, cash and marketable securities.

Table 3.5 - Chemical Industry: Select Measures of Financial Performance, 2012-2021

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Current Ratio	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.2	1.2
Quick Ratio	0.8	0.8	0.9	0.8	0.9	0.8	0.8	0.7	0.9	0.8
Cash Ratio	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Debt-to-Equity Ratio	1.6	1.5	1.5	1.7	1.7	1.6	1.4	1.4	1.5	1.4
Inventory Turnover	7.3	7.2	7.0	6.5	6.6	6.5	6.3	6.1	6.3	7.0
Operating Margin	9.9%	9.7%	10.9%	11.2%	10.7%	10.0%	10.0%	9.2%	9.0%	12.5%
Profit Margin	9.0%	10.6%	9.8%	8.9%	9.7%	11.2%	9.0%	6.0%	7.9%	14.5%
Inventory as a % of Revenue	11.9%	12.1%	12.2%	13.0%	12.9%	13.1%	13.6%	14.2%	13.7%	11.9%
Inventory Days of Supply	50.0	50.7	52.1	56.0	55.3	55.9	57.8	60.3	58.1	52.4
	in thousands of dollars									
Revenues/Employee	999	1011	958	879	855	872	884	845	858	1,075
Net Income/Employee	90.1	107.2	94.3	78.4	83.4	97.3	79.6	51.0	67.9	156.2
Total Assets/Employee	1,228	1,198	1,175	1,185	1,202	1,198	1,192	1,194	1,246	1,263

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

Chemical Industry includes NAICS 3251 (Basic Chemical Manufacturing), 3252 (Resin, Synthetic Rubber, and Synthetic Fibers Manufacturing), NAICS 3253 (Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing), NAICS 3255 (Paint, Coating, and Adhesive Manufacturing), NAICS 3256 (Soap, Cleaning Compound, and Toilet Preparation Manufacturing), and NAICS 3259 (Other Chemical Product and Preparation Manufacturing). Pharmaceuticals (NAICS 3254) are not included.

Electronic data tables, including historic data (back to 1989) are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

Leverage (or solvency) ratios examine a company's level of debt in relation to other financial metrics. The debt-to-equity ratio, which compares total debt to equity (the difference between assets and liabilities), is an example of a leverage ratio.

Efficiency (or activity) ratios examine the efficiency of a company's operations, particularly the management of assets. Some efficiency ratios assess a company's ability to turn assets, such as inventory or accounts receivable into cash.

Profitability ratios examine a company's ability to generate profit in relation to other factors, such as revenue, shareholders' equity, or assets. The operating margin considers a company's operating income (revenue, less operating expenses and cost of goods sold, plus interest and income tax) as a percent of total revenue; the profit margin considers a company's revenue, less all expenses, as a percent of total revenue.

**Table 3.6 - Basic Chemicals, Resins, and Synthetics:
Select Measures of Financial Performance, 2012-2021**

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Large Firms (total assets \$25 million and over)										
Current Ratio	1.1	1.2	1.3	1.3	1.3	1.1	1.0	1.0	1.1	1.1
Quick Ratio	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.8	0.8
Cash Ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Debt-to-Equity Ratio	2.5	2.2	2.2	2.3	2.3	1.6	1.4	1.5	1.6	1.5
Inventory Turnover	1.8	1.8	1.7	1.6	1.6	1.5	1.5	1.5	1.7	1.9
Operating Margin	7.2%	7.5%	9.0%	9.1%	9.0%	7.8%	8.2%	7.5%	6.1%	13.1%
Profit Margin	6.8%	9.8%	9.5%	8.5%	6.6%	7.7%	7.0%	5.3%	1.9%	15.0%
Inventory as a % of Revenue	12.6%	12.6%	12.6%	13.8%	13.4%	14.3%	14.4%	14.2%	13.1%	10.6%
Inventory Days of Supply	51.6	51.6	52.5	57.9	56.9	59.8	60.5	59.5	54.8	47.0
Small Firms (total assets under \$25 million)										
Current Ratio	1.8	1.8	1.8	2.1	2.5	3.0	2.2	2.2	3.7	3.4
Quick Ratio	1.2	1.2	1.2	1.5	1.7	2.2	1.4	1.4	2.6	2.4
Cash Ratio	0.4	0.4	0.4	0.5	0.6	1.0	0.5	0.5	1.2	1.2
Debt-to-Equity Ratio	1.2	2.2	2.0	0.9	0.8	0.7	1.0	0.9	0.4	0.4
Inventory Turnover	1.9	2.1	2.5	2.3	2.0	2.1	1.4	1.5	1.9	1.7
Operating Margin	2.3%	3.9%	4.5%	6.1%	8.5%	7.3%	6.9%	8.4%	11.1%	7.0%
Profit Margin	0.2%	2.8%	2.9%	4.1%	7.4%	5.4%	6.0%	5.8%	10.4%	7.3%
Inventory as a % of Revenue	12.8%	11.3%	9.5%	10.1%	11.4%	11.0%	15.7%	14.9%	11.6%	25.9%
Inventory Days of Supply	49.2	43.8	37.2	40.0	46.7	44.1	63.1	60.9	49.3	105.8

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

Basic Chemicals, Resins, and Synthetics include NAICS 3251 (Basic Chemical Manufacturing) and NAICS 3252 (Resin, Synthetic Rubber, and Synthetic Fibers Manufacturing).

Table 3.7 - All Other Chemicals: Select Measures of Financial Performance, 2012-2021

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Large Firms (total assets \$25 million and over)										
Current Ratio	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.1
Quick Ratio	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8
Cash Ratio	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.3
Debt-to-Equity Ratio	1.1	1.1	1.2	1.3	1.3	1.3	1.3	1.4	1.3	1.3
Inventory Turnover	1.9	1.8	1.7	1.7	1.7	1.7	1.7	1.5	1.5	1.6
Operating Margin	13.9%	13.4%	13.9%	14.3%	13.0%	12.2%	12.2%	10.4%	12.2%	11.9%
Profit Margin	14.1%	15.6%	13.8%	12.0%	15.0%	13.9%	13.1%	7.2%	14.5%	16.4%
Inventory as a % of Revenue	11.0%	11.6%	11.9%	12.4%	12.5%	12.7%	12.7%	14.1%	13.9%	17.2%
Inventory Days of Supply	48.1	50.4	52.5	55.3	54.6	55.1	55.0	60.3	60.6	74.4
Small Firms (total assets under \$25 million)										
Current Ratio	2.0	2.0	2.1	2.2	2.1	2.2	2.3	2.7	2.9	2.6
Quick Ratio	1.2	1.3	1.3	1.4	1.3	1.4	1.4	1.7	1.9	1.7
Cash Ratio	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.8	0.7
Debt-to-Equity Ratio	1.2	1.3	1.3	1.0	1.0	0.9	0.7	0.6	0.5	0.6
Inventory Turnover	1.9	1.9	1.9	1.9	1.9	1.8	1.7	1.4	1.3	1.4
Operating Margin	6.3%	6.3%	7.8%	5.7%	6.4%	9.3%	10.6%	9.3%	13.0%	12.7%
Profit Margin	4.9%	4.5%	6.3%	4.4%	5.3%	7.8%	8.3%	8.2%	11.9%	12.9%
Inventory as a % of Revenue	12.0%	12.3%	11.9%	12.1%	12.1%	12.6%	13.2%	16.2%	16.1%	15.2%
Inventory Days of Supply	47.5	48.7	47.7	47.8	48.2	51.9	54.9	66.9	69.4	65.5

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

All Other Chemicals include NAICS 3253 (Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing), NAICS 3255 (Paint, Coating, and Adhesive Manufacturing), NAICS 3256 (Soap, Cleaning Compound, and Toilet Preparation Manufacturing), and NAICS 3259 (Other Chemical Product and Preparation Manufacturing).

CHAPTER 4

CHEMISTRY 101



*Across all four categories of chemicals, chemicals are classified as one of two types, **organic and inorganic**, based on the structural makeup of the compound. In general, organic compounds contain carbon and the chemical products derived from these compounds are classified as organic chemicals. Inorganic compounds, in general, do not contain carbon and the chemical products derived from these compounds are classified inorganic.**

Organic compounds are generally derived from resources such as natural gas, plants, petroleum, and coal. Hydrocarbons, compounds composed of only carbon and hydrogen, are the simplest organic compounds and form the backbone of many final organic chemical outputs. Inorganic compounds are often naturally-occurring elements, such as salts, metals, and even water.

Very few chemicals use natural gas or petroleum directly as raw materials; these resources often contain multiple compounds and must first be processed in order to obtain the relevant compound (or compounds). For example, natural gas is comprised of natural gas liquids, such as ethane and propane, as well as gases such as methane and carbon dioxide. In the first stage of processing, these raw materials are refined to produce primary outputs like ethylene and propylene. Primary outputs like these are the building blocks of the business of chemistry.

In subsequent stages of processing, other chemicals may be added to the hydrocarbon backbones to give the compounds certain desired characteristics. These compounds may go through multiple rounds of processing before becoming a final product of chemistry. These variable outputs are generally classified into the four major market-driven business segments: basic chemicals, specialty chemicals, agricultural chemicals, and consumer products.

*Some compounds, including carbonates, bicarbonates, carbon dioxide and carbon monoxide, contain carbon but are classified as inorganic.

BASIC CHEMICALS

Basic chemicals, also called commodity chemicals, tend to be produced in large volumes and have little to no product differentiation among producers. Basic chemicals are further classified into segments such as inorganic chemicals, bulk petrochemicals and intermediates, plastic resins, synthetic rubbers, and manufactured fibers.

Basic chemicals are used in a wide range of industries and applications; they can be used to make other chemicals and other manufactured goods or used to aid in processing. Pricing for basic chemicals is highly correlated with the costs of raw materials, as well as capacity utilization, which can result in low profit margins. In some cases, economic returns may be less than the cost of capital.

The manufacture of basic chemicals tends to be capital intensive, with large-scale production facilities and high energy requirements. Access to hydrocarbon feedstocks, or other raw materials, is critical. 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 in the billions of dollars.

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.

Figure 4.1 - Basic Chemicals Shipments, 2021



Source: Bureau of the Census (from the ASM-1 report)

Inorganic Chemicals

Inorganic chemicals are generally derived from metal and non-metallic minerals such as salts. Inorganic chemicals serve both consumer and institutional markets including oil refining, chemical manufacturing, and other manufacturing industries.

Chlorine and caustic soda (sodium hydroxide) are produced when salt, a simple compound formed from sodium and chlorine, is broken down by electrolysis. Chlorine and caustic soda are used in a multitude of industries and applications. For example, chlorine helps provide thousands of essential products, including clean drinking water, energy-efficient building materials, electronics, pharmaceuticals, crop protection compounds, and much more. Chlorine is also used in the manufacture of other chemical products and intermediates, such as vinyls and propylene oxide. Caustic soda is used extensively in manufacturing processes and in the production of soaps and detergents.

Industrial gases, also referred to as “air separation gases,” include oxygen, nitrogen, argon, hydrogen, and carbon dioxide, among others. Major markets for industrial gases include steel and other metals production, chemical manufacturing, petroleum refineries, and healthcare.

Inorganic dyes and pigments are used to impart color into other materials. Inorganic pigments tend to in powder form and contain metals, such as cobalt blue and ultramarine violet. 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. Dyes and pigments are used in a multitude of consumer and industrial applications. *Note: not all dyes and pigments are inorganic.*

Other examples of inorganic chemicals include acids (nitric, phosphoric, sulfuric, etc.), aluminum sulfate, lime, soda ash (sodium carbonate), sodium bicarbonate, sodium chlorate, sodium sulfate, and sulfur, among others.

Bulk Petrochemicals and Intermediates

Bulk petrochemicals (or primary petrochemicals) are simple molecules (or monomers) derived from hydrocarbon feedstocks (and, thus, are considered organic chemicals). These basic building blocks are used as the starting point for tens of thousands of other chemical products. 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 combined with other chemicals to make into organic intermediates (or petrochemical intermediates). Sometimes, multiple steps are required to produce an intermediate of the desired chemical composition. Bulk petrochemicals and intermediates primarily serve other chemical manufacturers and ultimately are used in industries including automotive, building and construction, consumer products, electronics, and packaging. Bulk petrochemicals and intermediates are used in downstream derivatives such as plastic resins, synthetic rubbers, manufactured fibers, surfactants, dyes and pigments, and inks.

Plastic resins are synthetic, long-chain compounds derived from one or more petrochemicals (ethylene, vinyl chloride, styrene, propylene, etc.). They offer excellent molding, mechanical, chemical resistance, and other properties. There are various types of plastic resins:

Thermosets are polymers that, in their final state as a finished product, cannot be resoftened by

heat (and, thus, cannot easily be recycled). Examples include epoxy, melamine, phenolic, polyester, polyurethane, and urea resins. Major markets for thermosets include building and construction, furniture/furnishing, appliances, transportation, electrical/electronic, ink, and coatings. End-use applications include adhesives and sealants, electrical casting, surface coatings, building insulation, and automotive components.

Thermoplastics are polymers that are softened by heat and hardened by cooling in their final state as a finished product. These resins can often be re-used and/or recycled. Emerging recycling and recovery technologies often referred to as “advanced recycling” (or, “chemical recycling”), as well as traditional mechanical recycling methods, allowing more types of used plastics to be recaptured and remanufactured into new plastics and products. Examples of commodity thermoplastics include acrylonitrile butadiene styrene (ABS), polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). Major markets for commodity thermoplastics include packaging, building and construction, consumer products, automotive, and electronics. End-use applications include automotive trim and parts, appliance parts, bags and film, medical equipment, bottles, and toys, among many others.

Engineering resins are thermoplastic polymers that have high-performance mechanical, thermal, electrical, and chemical properties. Examples include acetal, fluoropolymer, polycarbonate, polyphenylene sulfide, and other resins. These resins are often used to replace metal or glass in industrial applications. They are also 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. Major markets for engineering plastics include automotive, electrical/electronic, and consumer.

Table 4.1 - Plastic Resins Summary, 2017-2021

	2017	2018	2019	2020	2021
Shipments (in millions)	\$90,209	\$94,853	\$82,768	\$76,186	\$91,126
Production Index (2017=100)	100.0	102.2	90.6	95.7	95.3
Production (in million pounds)*	112,974	119,559	121,457	123,147	123,955
Capital Expenditures (in millions)	\$5,893	\$5,056	\$8,805	\$5,510	\$6,698
Price Index (2012=100)	100.0	104.8	100.5	96.9	129.2
Employment (in thousands)	57.8	59.6	60.3	57.7	57.0
Exports (in millions)	\$28,574	\$32,025	\$31,712	\$28,875	\$37,092
Imports (in millions)	\$13,670	\$15,586	\$13,696	\$11,950	\$19,533
Trade Balance (in millions)	\$14,904	\$16,440	\$18,016	\$16,925	\$17,559

*Data for plastic resin production is reported in pounds, rather than metric tons, and reflects some Canadian and Mexican production.

Sources: Bureau of the Census, Bureau of Labor Statistics, National Science Foundation, ACC Plastics Industry Producers Statistics (PIPS) Group, and American Chemistry Council.

The ACC Plastics Industry Producers' Statistics Group makes available detailed reports (including monthly production and end-use sales data for major thermoplastic and thermoset resins) to subscribers of its various services. For more information on subscriptions to the resin reports please visit: <https://www.americanchemistry.com/chemistry-in-america/data-industry-statistics/statistics-on-the-plastic-resins-industry/resin-report-subscriptions>

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 thermoplastic elastomers. These materials are primarily used in the automotive sector and also used in the construction and consumer product manufacturing industries. Major uses include tires, automotive bumpers and fascias.

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 (e.g., 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.

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.

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, some plastic additives, water management chemicals, and other specialties.

Long-term growth prospects for specialties historically were more dynamic than basic chemicals but growth in the latter due to shale gas has become dynamic as well. 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 are less impacted by demand pressures than 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 cyclicity. Earnings, on the other hand, tend to be less volatile.

Specialty chemical often cannot easily be duplicated by other producers due to high barriers to entry (technology, patents, market and customer knowledge, etc.). In this market, strong technical servicing, marketing, and distribution competencies are a must and strong customer relationships are paramount. Innovation is critical and specialty chemical companies typically spend 3-6% 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, tend to purchase relatively low volumes. In some specialty markets, customer accounts may generate less than \$50,000 in annual 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.

External factors influence the specialties industry as well. The growing presence of online sales and digital chemical marketplaces 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.

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.

Other Specialties

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 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.

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 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 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 include 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 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 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.

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.

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.

Oilfield chemicals are used to enhance oil recovery and production and 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 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 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 has triggered growth in this segment.

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 U.S., faster growth overseas, increased performance demands, and industry/customer consolidation.

Rubber processing chemicals are functional chemicals 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 are formulated and proprietary chemicals 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 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 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 2020 “U.S. corn, upland cotton, and soybeans are produced using [genetically engineered] varieties.” 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.

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 industry 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.

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.

Characteristics of Pharmaceuticals

Historically, pharmaceuticals have been considered part of the broader chemical industry. While ACC no longer includes pharmaceuticals in its definition of the chemical industry, pharmaceuticals are included in the NAICS 325 definition of the broader chemical industry used in many government statistics. For this reason, we continue to include the discussion below.

An important end-use market for many chemicals, the pharmaceutical industry includes prescription and over-the-counter drugs and vitamins; in-vivo diagnostic substances; vaccines; biological products; and other pharmaceutical preparations for both human and veterinary use.

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 important and development costs are high, which influence the economics of the business. 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. 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.

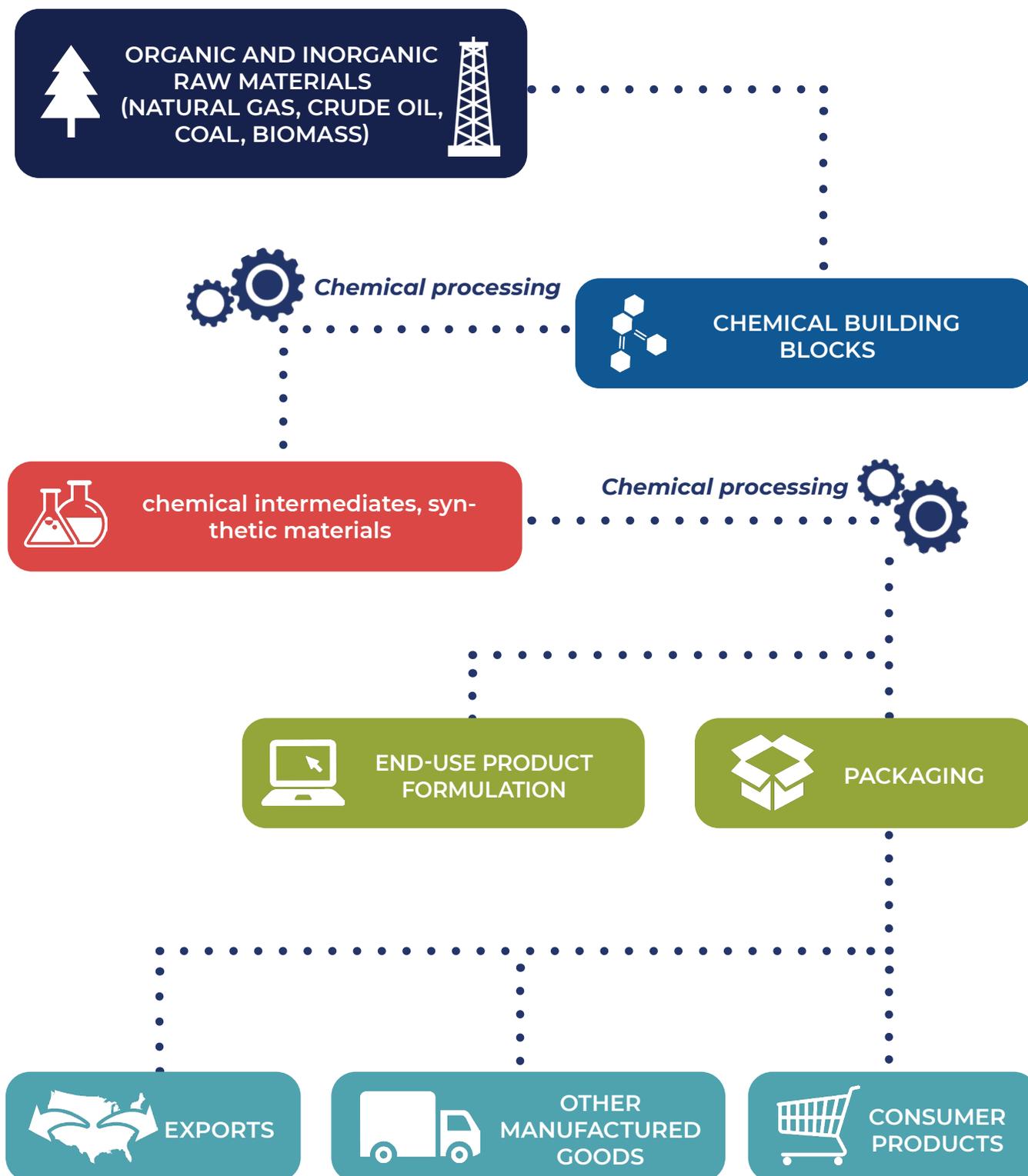
Technology advantages are extremely important in pharmaceuticals, and there is increasing convergence between biology and chemistry as biotechnology innovations further diffuse. As a result, R&D spending in pharmaceuticals as a percent of sales is the highest among all industries. Pharmaceuticals have 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. Product approval can be a 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).

Figure 4.2 - 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.



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CHAPTER 5

U.S. TRADE IN THE BUSINESS OF CHEMISTRY



Chemicals trade in the U.S. began with limited exports of potash and naval stores (pitch and tar) to Great Britain in the 18th century. However, with abundant natural resources and a highly skilled workforce, the U.S. chemical industry quickly became a major exporter of a multitude of chemical products to markets throughout the world. Today, the chemical manufacturing sector is one of America's top exporting industries, accounting for around 10 percent of all U.S. exports.

American manufacturers and chemical producers also import chemicals that are essential inputs to their production process. These 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.

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. 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.

2021 TRADE AT A GLANCE

EXPORTS

\$153.1

billion

IMPORTS

\$128.3

billion

NET EXPORTS

\$24.8

billion

Figure 5.1 - Top 10 U.S. Export Countries

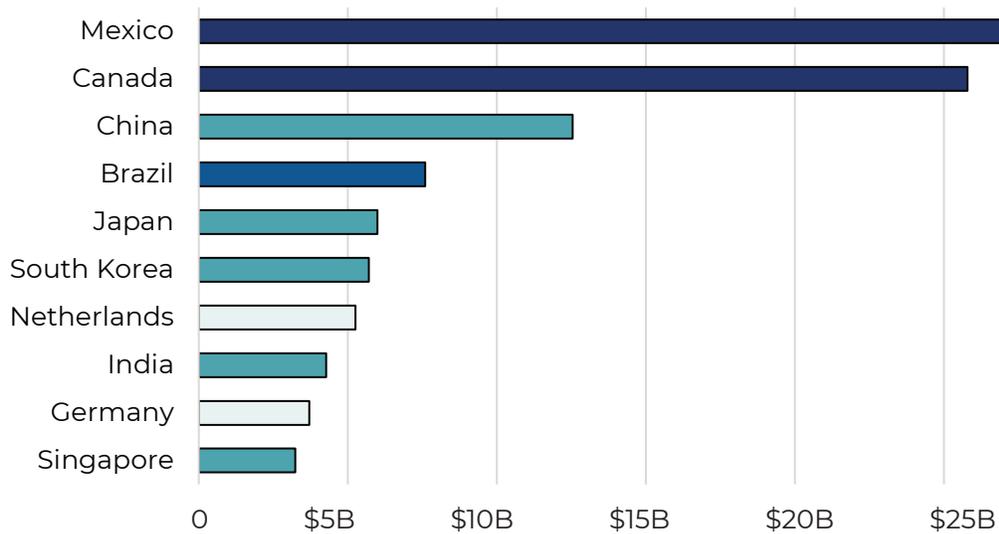
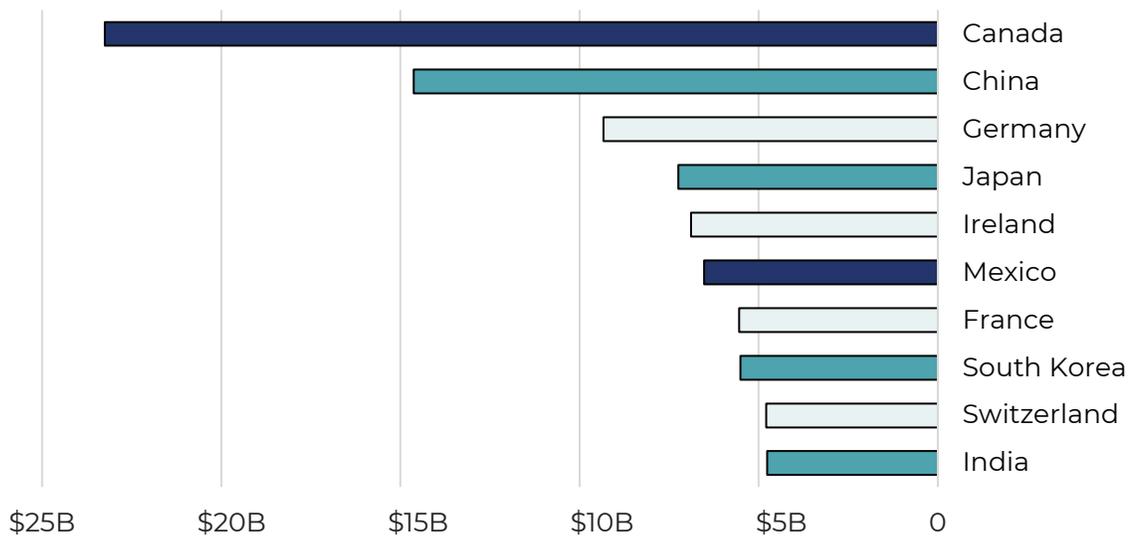
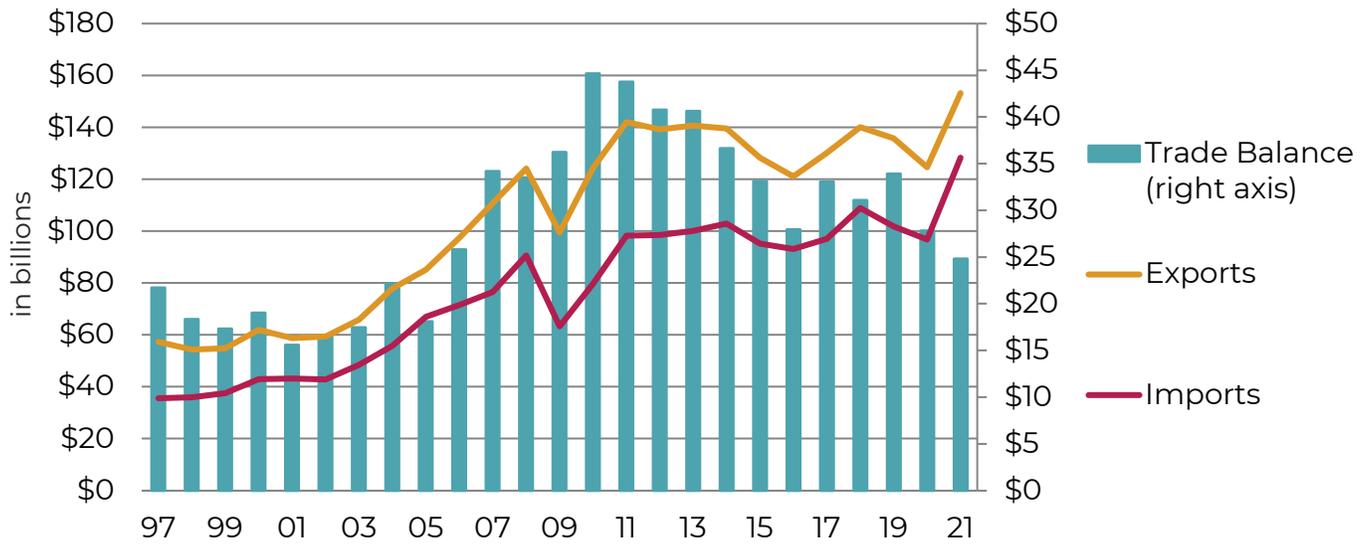


Figure 5.2 - Top 10 U.S. Import Countries



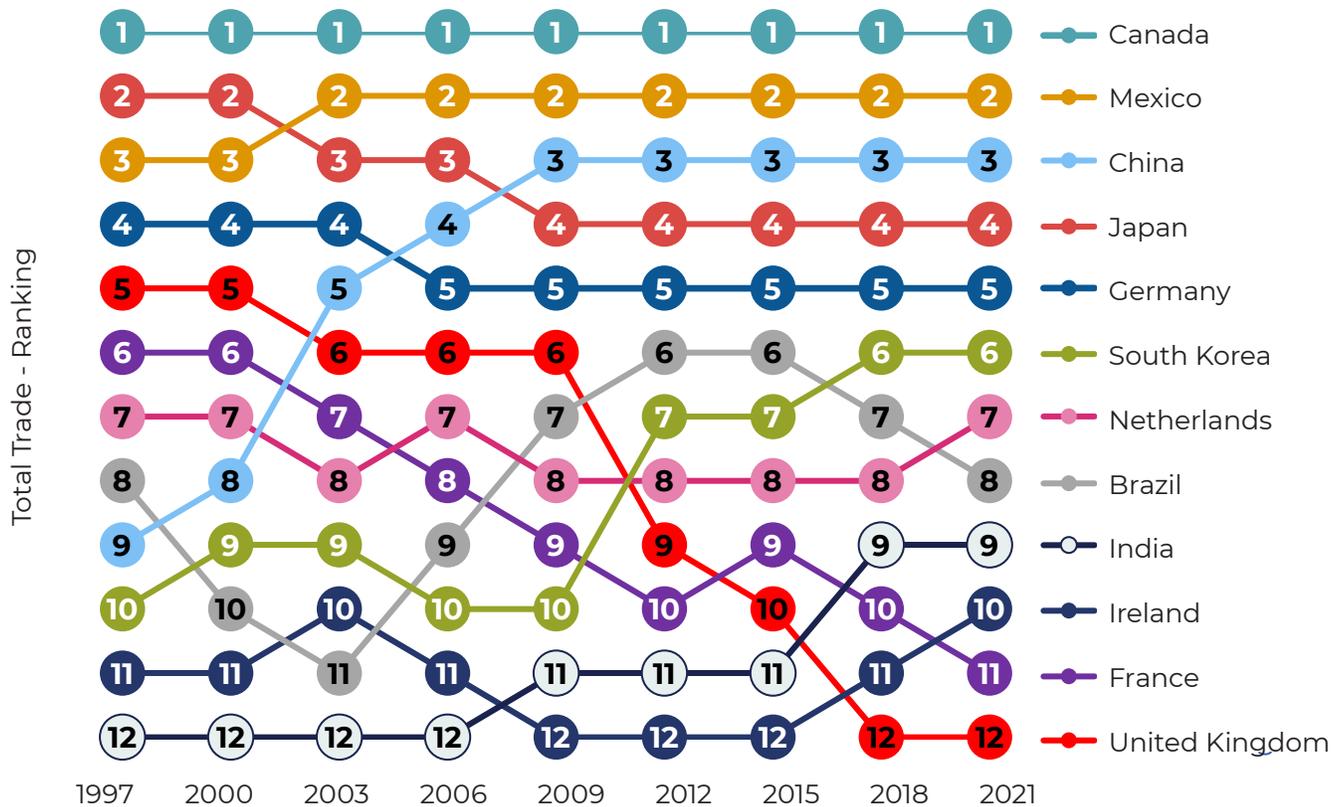
Sources: U.S. Department of Commerce, American Chemistry Council analysis.

Figure 5.3 - U.S. Trade in the Business of Chemistry



Source: U.S. Department of Commerce, American Chemistry Council analysis.

Figure 5.4 - Top Trade Partners Over the Years



Source: U.S. Department of Commerce, American Chemistry Council analysis.

TRADE BY COUNTRY/REGION

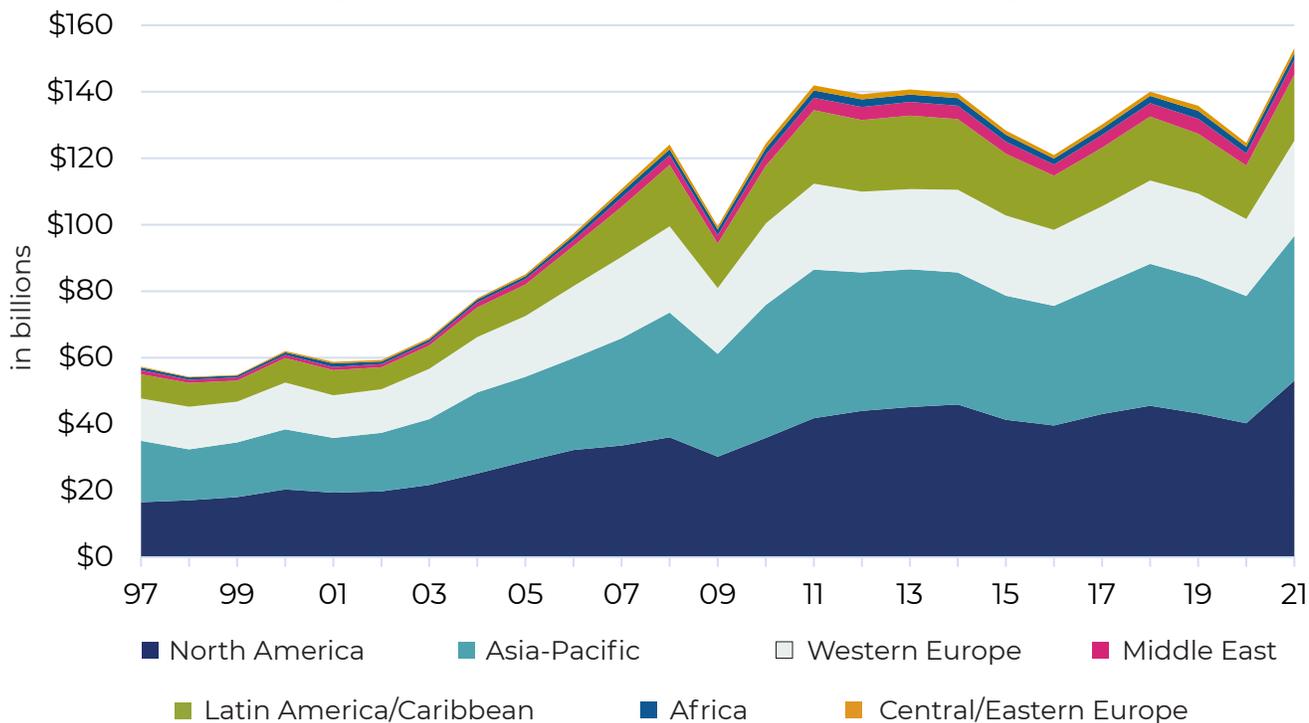
Table 5.1 - Top Chemicals Export Destinations, 2017-2021

	2017	2018	2019	2020	2021
	in \$millions				
Mexico	21,007	22,985	21,548	19,344	27,299
Canada	22,024	22,618	21,754	20,981	25,785
China	11,525	11,726	10,032	10,986	12,536
Brazil	6,695	7,748	7,317	6,520	7,595
Japan	5,792	6,357	5,871	4,914	5,987
South Korea	5,242	5,997	5,750	5,248	5,698
Netherlands	4,376	4,714	4,927	4,549	5,254
India	3,022	3,753	4,220	3,552	4,274
Germany	3,225	3,055	3,102	3,193	3,704
Singapore	3,078	3,339	3,197	2,929	3,240

Note. In descending order based on 2021 exports.

Electronic data tables, including historic data are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

Figure 5.5 - Total U.S. Chemicals Exports by Region



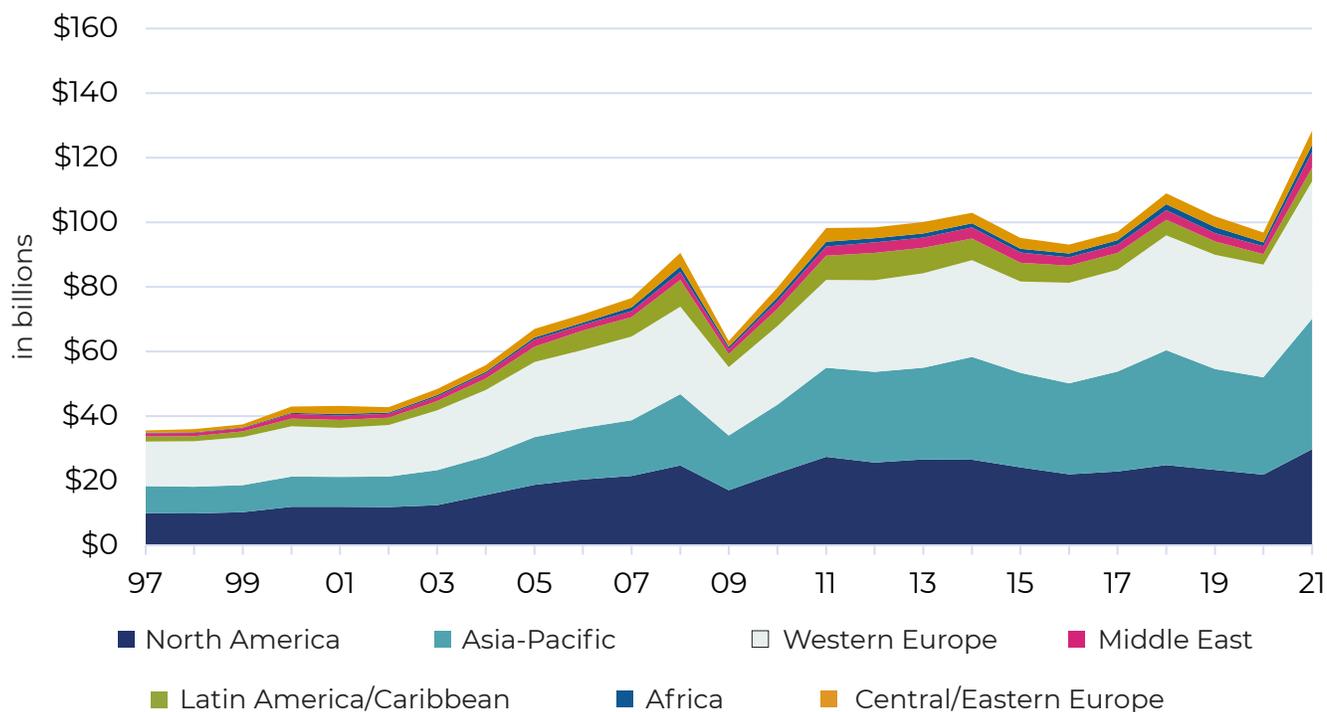
Source: U.S. Department of Commerce, American Chemistry Council analysis.

Table 5.2 - Top Chemicals Import Countries of Origin, 2017-2021

	2017	2018	2019	2020	2021
	in \$millions				
Canada	17,992	19,465	18,074	16,520	23,245
China	12,910	15,801	11,488	11,535	14,626
Germany	7,698	8,253	8,086	7,730	9,333
Japan	6,002	6,728	7,093	6,320	7,242
Ireland	3,902	4,839	5,530	6,692	6,884
Mexico	4,917	5,389	5,340	5,421	6,527
France	4,492	4,683	4,601	4,377	5,548
South Korea	3,312	3,828	3,699	3,679	5,514
Switzerland	3,820	4,357	4,077	4,008	4,790
India	3,026	3,392	3,732	3,525	4,761

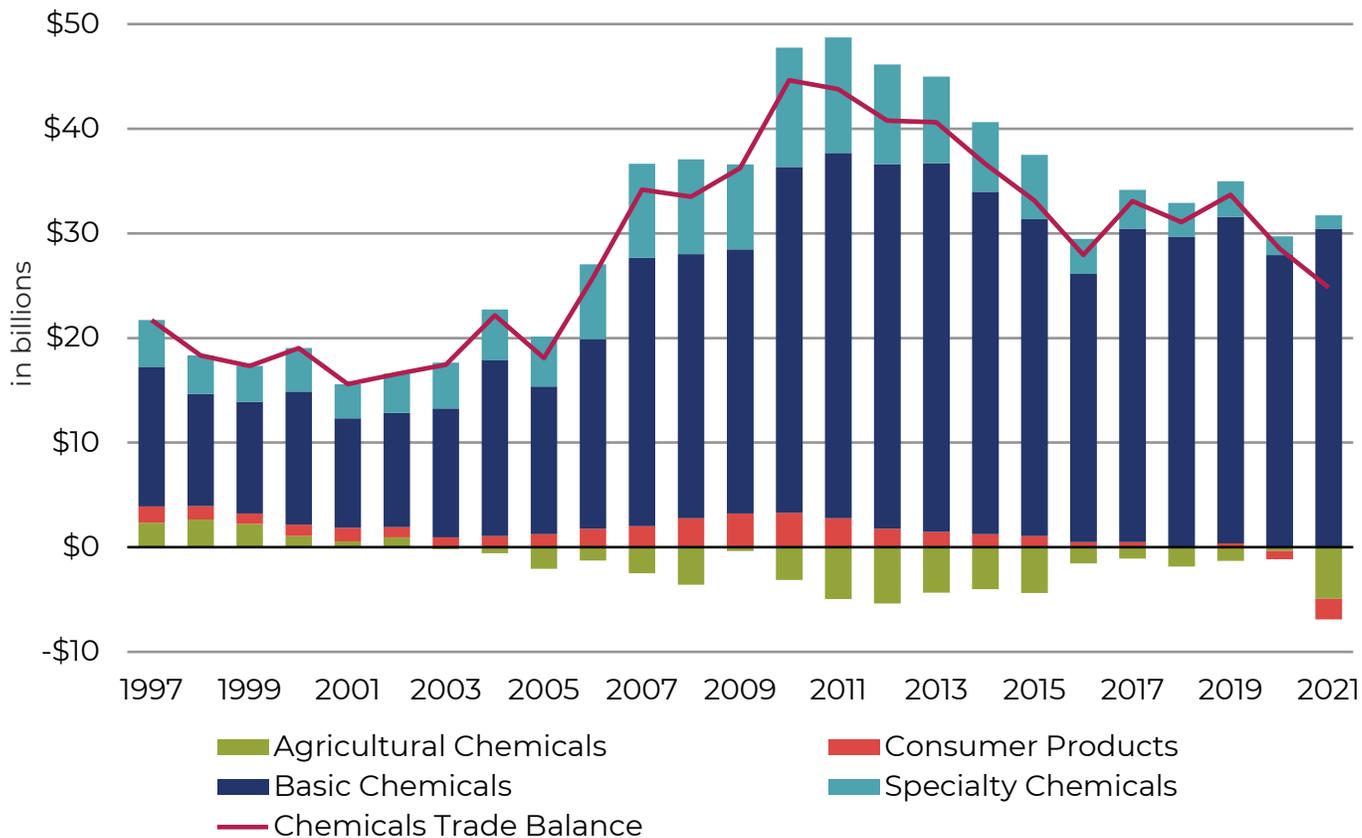
Note. In descending order based on 2021 imports.

Electronic data tables, including historic data are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

Figure 5.6 - Total U.S. Chemicals Imports by Region

Source: U.S. Department of Commerce, American Chemistry Council analysis.

Figure 5.7 - Chemicals Trade Balance by Segment

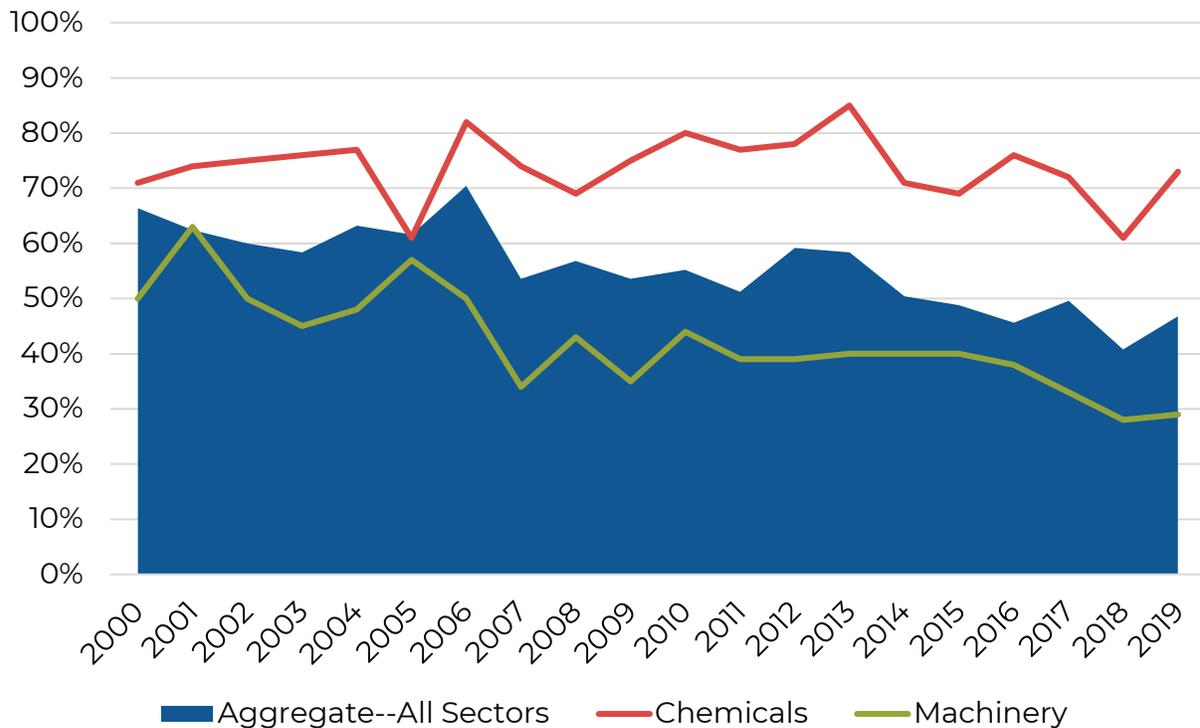


Note. The U.S. trade data in this section are from by the U.S. Department of Commerce and are presented by chemical segments. The entire business of chemistry is represented by NAICS 325 (Chemical Manufacturing). Exports shown in this section are domestic exports valued free alongside ship (FAS). Imports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

COMPLEXITY

A nation is said to have a revealed comparative advantage in producing a good if it exports more than its fair share to satisfy world demand.* Particularly important is a good’s “complexity,” or the level of productive knowledge that is required for the manufacturing of the good (Atlas of Economic Complexity). Complexity is ascertained from trade flows where few nations possess a comparative advantage and those that do tend to be advanced economies. Complexity of a nation’s export basket largely explains differences in economic growth and per-capita wealth across nations. In the 21st century, the United States has seen its comparative advantage in the most complex traded goods gradually decline. Looking more closely—at the two sectors with the most complex traded goods—we see the United States lagging in machinery, whereas chemicals remains a persistent bright spot.

Figure 5.8 - U.S. Comparative Advantage in Traded Goods of Greatest Complexity



*The concept of “revealed comparative advantage” was popularized by economist Bela Balassa in his 1965 article *Trade Liberalisation and “Revealed” Comparative Advantage*. The revealed comparative advantage (RCA) looks at trade performance of individual countries for a given manufactured good.

TRADE BY SEGMENT**Table 5.3 - Chemical Exports by Segment, 2017-2021**

	2017	2018	2019	2020	2021
	in \$millions				
Chemicals	\$130,128	\$140,053	\$135,534	\$125,249	\$153,139
Basic Chemicals	87,909	95,328	92,033	84,470	105,821
Inorganics	13,573	14,811	14,598	13,351	15,805
Bulk Petrochemicals & Intermediates	38,326	41,166	39,139	36,621	46,031
Plastic Resins	28,574	32,025	31,712	28,875	37,092
Synthetic Rubber	5,275	5,186	4,560	3,948	4,997
Manufactured Fibers	2,161	2,140	2,025	1,674	1,896
Specialties	24,177	25,874	24,725	23,297	28,371
Coatings	2,654	2,777	2,764	2,486	2,843
Other Specialties	21,522	23,097	21,961	20,811	25,529
Agricultural Chemicals	7,008	7,320	7,222	6,920	7,580
Consumer Products	11,034	11,532	11,553	10,562	11,367
Pharmaceuticals	51,147	54,737	59,802	59,188	80,289
Chemicals & Pharmaceuticals	181,274	194,791	195,335	184,437	233,428
Total U.S. Goods Exports	1,308,395	1,413,168	1,392,664	1,207,383	1,478,858
Chemistry % of Total U.S. Goods Exports	9.9%	9.9%	9.7%	10.4%	10.4%

Source: U.S. Department of Commerce, American Chemistry Council analysis

Table 5.4 - Chemical Imports by Segment, 2017-2021

	2017	2018	2019	2020	2021
	in \$millions				
Chemicals	\$97,063	\$108,994	\$101,862	\$96,697	\$128,328
Basic Chemicals	57,977	65,680	60,843	56,556	75,407
Inorganics	9,172	10,918	10,818	9,371	12,110
Bulk Petrochemicals & Intermediates	30,000	33,483	31,044	30,967	38,238
Plastic Resins	13,670	15,586	13,696	11,950	19,533
Synthetic Rubber	2,879	3,161	2,983	2,395	3,189
Manufactured Fibers	2,255	2,532	2,302	1,874	2,337
Specialties	20,459	22,660	21,314	21,500	27,075
Coatings	1,100	1,207	1,236	1,180	1,463
Other Specialties	19,359	21,453	20,078	20,320	25,612
Agricultural Chemicals	8,095	9,166	8,531	7,276	12,509
Consumer Products	10,532	11,488	11,174	11,365	13,338
Pharmaceuticals	112,651	135,583	151,868	167,431	176,424
Chemicals & Pharmaceuticals	209,713	244,578	253,730	264,128	304,752

Source: U.S. Department of Commerce, American Chemistry Council analysis

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CHAPTER 6

GLOBAL BUSINESS OF CHEMISTRY



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 in some regions, the industry 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 toward 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 around the world 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, policies that support industrial growth and competitiveness, as well as advances in technology, logistics and distribution, have fostered 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.

International investment by American and Western European companies grew at a particularly rapid pace during the 1980s and 1990s. Prior to that time, many developing nations had only moderate domestic chemical production and imported most of their chemicals from more developed nations. By the 1990s, however, many developing nations embarked on programs to develop globally competitive chemical industries, including several of the newly industrialized countries of Asia (Singapore, South Korea, Taiwan, and Thailand) and many of the larger economies of Latin America (Argentina, Brazil, Mexico, and Venezuela).

During the 2000s, the Middle East was emerging as a major player in global petrochemical markets, and U.S. chemical production 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, attracting record levels of investment in new facilities and expanded production capacity over the past decade.

WORLD TRADE

Chemical manufacturers have developed global supply chains to create and deliver the products of chemistry efficiently. International trade, including related-party trade, is essential to the global business of chemistry. Market access and minimizing tariff and nontariff barriers has been key to the globalization of the chemical industry and the fluidity of world trade.

Table 6.1 - Global Chemical Shipments by Region, 2017-2021

	2017	2018	2019	2020	2021
	<i>in \$billions</i>				
North America	603.0	633.0	588.2	534.2	603.6
Latin America	244.6	261.9	246.7	208.2	257.8
Europe	705.1	767.7	723.2	707.6	904.1
Former Soviet Union	82.4	90.4	92.6	90.3	134.3
Africa and Middle East	142.0	154.2	160.4	171.3	211.6
Asia-Pacific	2,049.4	2,239.4	2,147.5	2,082.9	2,620.6
Total Global Shipments	\$3,826.5	\$4,146.7	\$3,958.6	\$3,794.5	\$4,732.1

Notes. The term “shipments” is equivalent to the term “turnover,” or value of output. The data are expressed in U.S. dollars, with average annual market exchange rates used to convert other currencies into U.S. dollars. Source: Bureau of the Census (from the ASM-1 report).

Sources: ABIQUIM, ANIQ, CCPA, CEFIC, JCIA, VCI, Bureau of the Census, Eurostat, IHSMARKIT, Oxford Economics, Statistics Canada, United Nations, American Chemistry Council estimates

Electronic data tables, including historic data (back to 1989) and country break-outs for select countries are available to ACC members for free on MemberExchange. Non-members may purchase the data at store. americanchemistry.com.

Figure 6.1 - Global Chemical Apparent Consumption (Domestic Sales) by Region, 2021

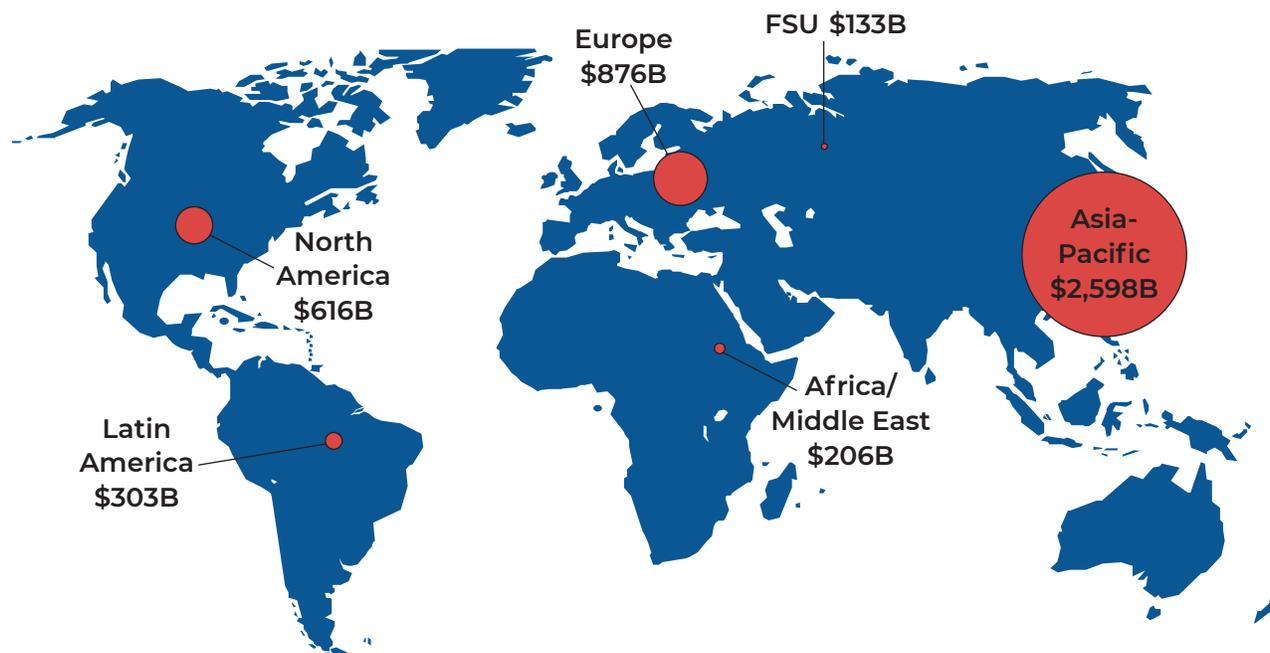


Figure 6.2 - Global Chemical Shipments by Country

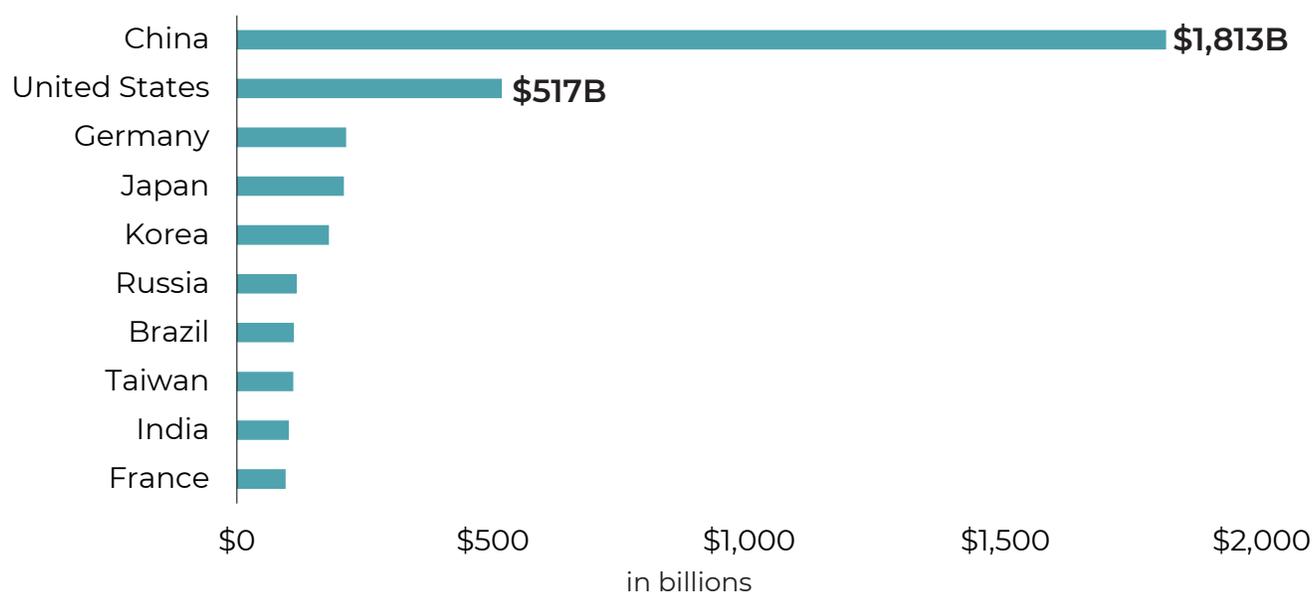


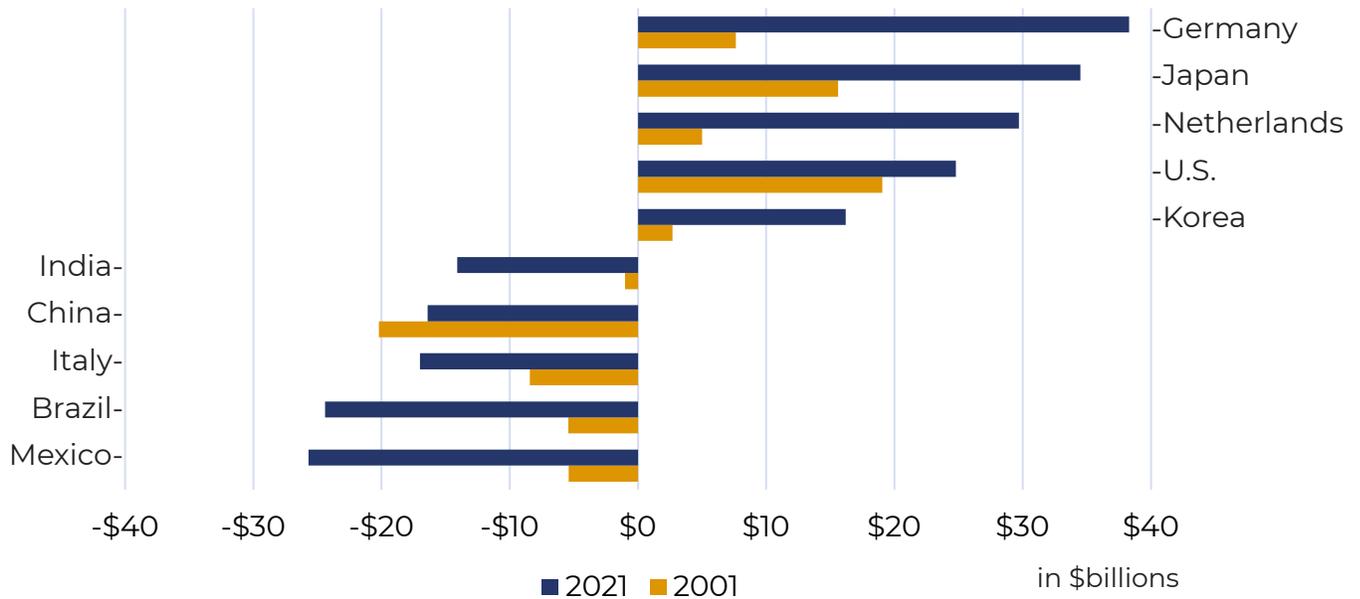
Table 6.2- Global Chemical Exports and Imports by Region, 2017-2021

	2017	2018	2019	2020	2021
	in \$billions				
Exports					
North America	159.0	169.0	163.8	150.3	186.0
Latin America	26.3	27.5	25.8	24.7	32.6
Europe	546.5	612.2	580.9	551.9	708.7
Former Soviet Union	22.7	31.0	28.5	22.3	32.0
Africa and Middle East	77.5	95.3	89.0	90.7	128.1
Asia-Pacific	513.8	576.8	544.7	508.8	653.5
Total Global Exports	\$1,345.7	\$1,511.8	\$1,432.7	\$1,348.7	\$1,741.0
Imports					
North America	159.9	175.7	167.2	154.6	199.1
Latin America	63.8	71.5	68.6	56.8	78.0
Europe	525.8	585.8	556.0	532.0	706.2
Former Soviet Union	25.1	27.4	26.9	24.2	30.2
Africa and Middle East	90.0	100.8	98.0	93.6	122.4
Asia-Pacific	481.1	550.7	516.0	487.5	631.1
Total Global Imports	\$1,345.7	\$1,511.9	\$1,432.7	\$1,348.7	\$1,767.1

Sources: ABIQUIM, ANIQ, CCPA, CEFIC, JCIA, VCI, Bureau of the Census, Eurostat, IHSMarkit, Oxford Economics, Statistics Canada, United Nations, WTO, American Chemistry Council estimates.

Electronic data tables, including historic data (back to 1989) and country break-outs for select countries are available to ACC members for free on MemberExchange. Non-members may purchase the data at store. americanchemistry.com.

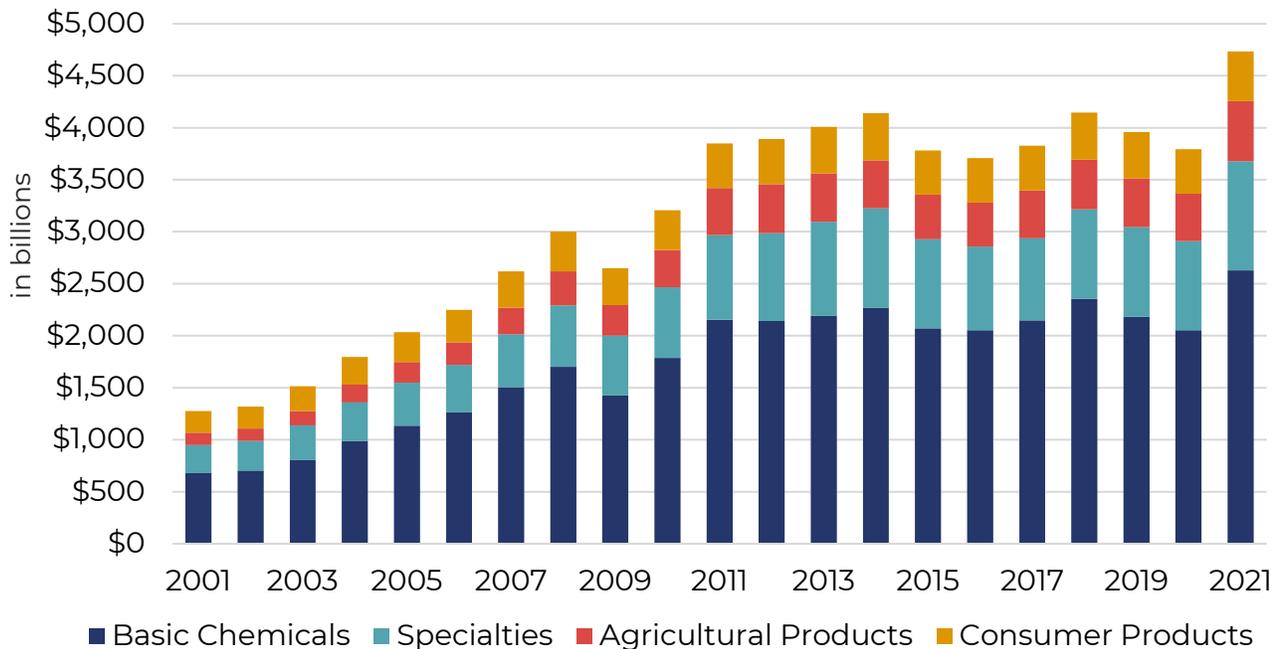
Figure 6.3 - Global Chemicals Trade Balance, 2021 vs. 2001



Note. Chart shows the countries with the five highest trade balances (positive and negative) for 2021. Electronic data tables, including historic data (back to 1989) and country break-outs for select countries are available to ACC members for free on MemberExchange. Non-members may purchase the data at store. americanchemistry.com.

Sources: ABIQUIM, ANIQ, CCPA, CEFIC, JCIA, VCI, Bureau of the Census, Eurostat, IHSMarkit, Oxford Economics, Statistics Canada, United Nations, WTO, American Chemistry Council estimates

Figure 6.4 - Global Chemical Shipments by Segment



Source: American Chemistry Council estimates

CHAPTER 7

INNOVATION



Innovation can be found in all aspects of the chemical industry, from research and development to manufacturing to customer relationships. Many innovative products and technologies made possible by the business of chemistry help to improve functionalities, reduce costs, and increase productivity across a wide range of industries.

Increasingly, innovation in the chemical industry is focused on products and technologies that support circularity and sustainability. Innovation is essential in the pursuit of a more circular economy, one that prioritizes resource conservation and efficiency, design innovations that enable longer product lifespans, and reuse, recycling and recovery technologies.

At its core, the business of chemistry is all about science—science aimed at driving innovations in products and technologies that help make our lives healthier, safer, more sustainable and more productive.

RESEARCH AND DEVELOPMENT ACTIVITIES

Once centered mainly in laboratories, modern research and development (R&D) in the chemical industry extends beyond the development of new chemical compounds and products. R&D encompasses a wide range of activities, such as research on manufacturing improvements, novel uses of existing products, use of artificial intelligence, and digitalization of processes.

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 and, increasingly, digital technologies as opposed to simply increasing manufacturing output.

Companies are adopting a more open innovation model, using more ideas from outside, including collaboration with customers and the use of Big Data. 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.

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.

The Organisation for Economic Co-operation and Development (OECD) includes three types of activity in research and development: basic research, applied research, and experimental development. Basic research involves work done in search of new knowledge based on principles of general validity, without regard to commercial objectives. Applied research, on the other hand, is when the investigation is planned with the intent of accomplishing a particular objective. Experimental development uses the findings from the research to generate new products or services.

Chemical companies allocate, on average, 2-3% of their annual sales toward R&D, although some companies may allocate as much as 8-9%. And, unlike some other manufacturing industries that receive government funding for research, the business of chemistry in the U.S. typically funds its own R&D. For example, in 2019, chemical companies funded 91% of their own R&D, whereas 46% of R&D in aerospace products and parts manufacturing was federally funded. (National Science Board. 2022).

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. In recent years, there has been a growing interest in data-driven R&D, which has become increasingly accessible in the age of digitalization. Beyond traditional researchers, companies are integrating technology, such as artificial intelligence and digital simulations, into their R&D processes.

Figure 7.1 - Basic & Specialty Chemical Company R&D Spending by Type (% of Total)

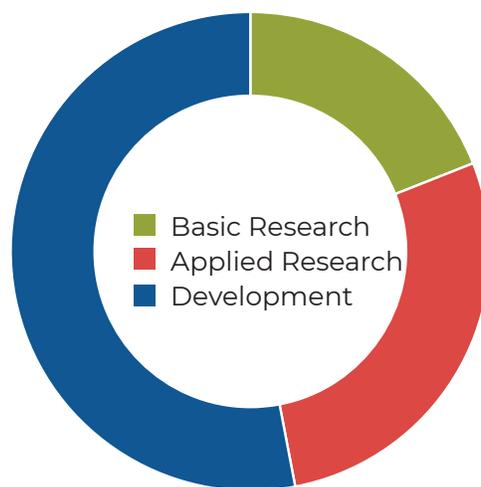


Table 7.1 - Share of Revenues from New Products, 2012-2021

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Share of Revenues from New Products	14.0%	14.0%	16.0%	14.2%	15.4%	12.7%	17.8%	14.2%	14.1%	14.7%
R&D-to-Product Conversion Ratio	7.9	7.7	7.9	6.1	7.2	6.1	8.7	6.9	6.5	6.7
New Products-to-Margin Conversion Ratio	1.4	1.4	1.5	1.3	1.4	1.3	1.8	1.5	1.6	1.2

Sources: American Chemistry Council.

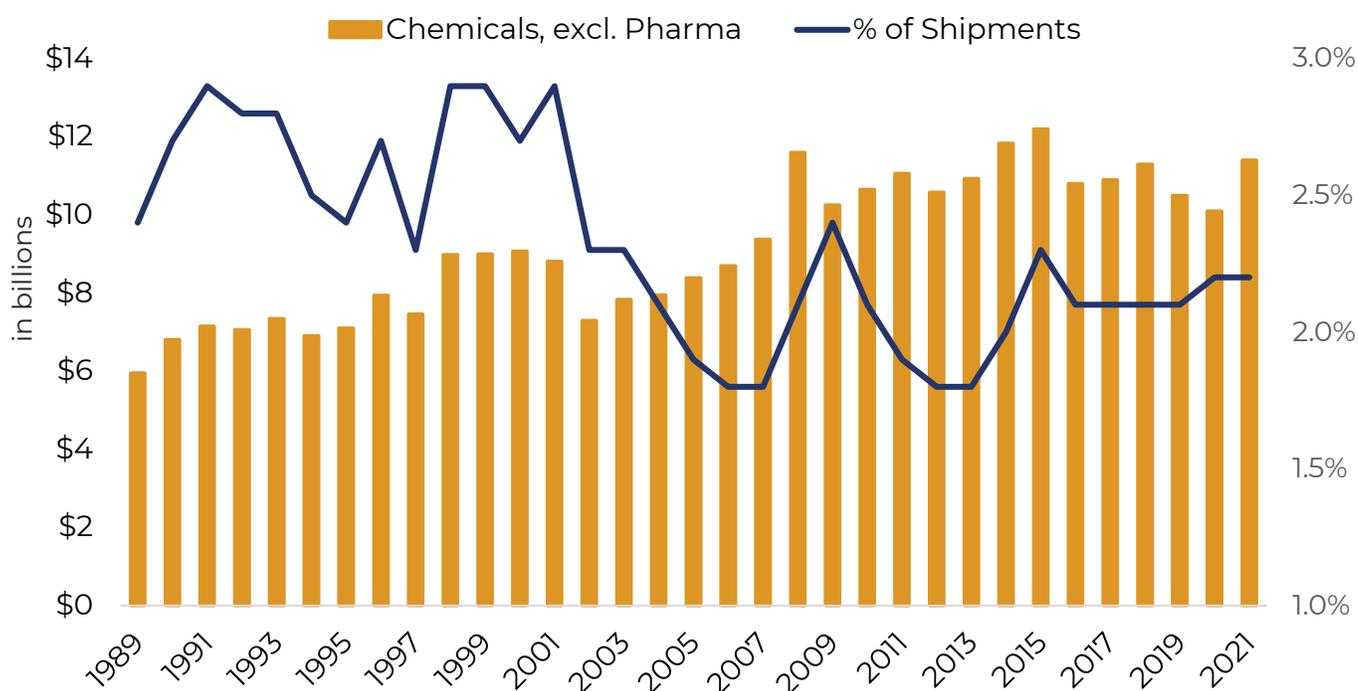
Measuring Innovation

The role of innovation is often viewed as critical to success. However, measuring innovation can be difficult. For industries and companies, many different measures of the innovation can be used such as annual R&D spending as a percent of total sales or number of patents filed. Measuring the percent share of revenues from new products and services is another metric that has found acceptance among stock analysts, academics, and others. 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, through the ability to launch new products and services, create additional value for customers, and improve operating efficiencies, a company can penetrate new markets and increase revenues and margins.

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 devote a slightly higher share of revenues on new products and services compared to basic chemical companies. 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 7.2 - R&D Spending in the Business of Chemistry



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.

Sustainability and Innovation

Chemistry is fundamental to understanding the world’s most pressing sustainability challenges, and essential to overcoming them. The chemical manufacturing industry plays an integral role in reimagining the products, technologies, resources, and systems that will power a circular, sustainable economy and is working 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.

Today, one of the greatest challenges society faces is addressing climate change and its impacts. As an industry, it is rising to the challenge and taking meaningful actions on climate and bringing innovative solutions to reduce emissions. Companies are publicly reporting progress on efforts to reduce emissions, and ACC members are innovating to create products that help protect the climate and save energy.

The chemical industry plays a vital role in developing the products and technologies that enable clean water. Advances in technologies made possible by chemistry will support water conservation, sanitation, reuse, and the transformation of contaminated water into clean, safe drinking water for people around the world.

The chemical industry is taking steps to make products safer, make manufacturing processes more

stringent, and to be more transparent about what it is doing well and where it can improve. In developing new products and technologies, ACC members consider product safety and sustainable chemistry throughout the product innovation process. This means incorporating product safety assessments to identify hazards and potential risks early in the product development process, as well as reviewing existing product portfolios to identify opportunities to innovate products with improved safety profiles.

The chemical industry also plays a key role in promoting the systemic transition to a circular economy, in which resources and materials are continuously cycled to eliminate waste, while creating value for all. This includes:

- Innovations that help improve the reuse, repurposing and recycling rates of products like plastics;
- Technologies that recapture and repurpose chemicals used in manufacturing and break down discarded materials into their basic chemical building blocks, to extend the lifespan and create additional value for these molecules as raw materials that can be made into new products; and
- Sustainable product design and materials selection that improves product durability, extends product lifespans, and enables repurposing of product components, preserving their value and usefulness in a regenerative system.

Innovations in chemistry also contribute to the sustainability efforts of other industries. For example, in the electronics sector, chemistry is enabling the design of more durable products and the reuse and recycling of component parts. In the building and construction sector, insulation products made possible by chemistry help conserve energy and mitigate climate impacts. In the automotive sector, chemistry has enabled significant fuel efficiency gains through the development of lightweight, yet strong and safe materials. And thanks to chemistry, a wide range of vehicle parts can now be made from recycled plastics or can be recycled themselves.

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CHAPTER 8

INVESTMENT IN THE FUTURE: CAPITAL



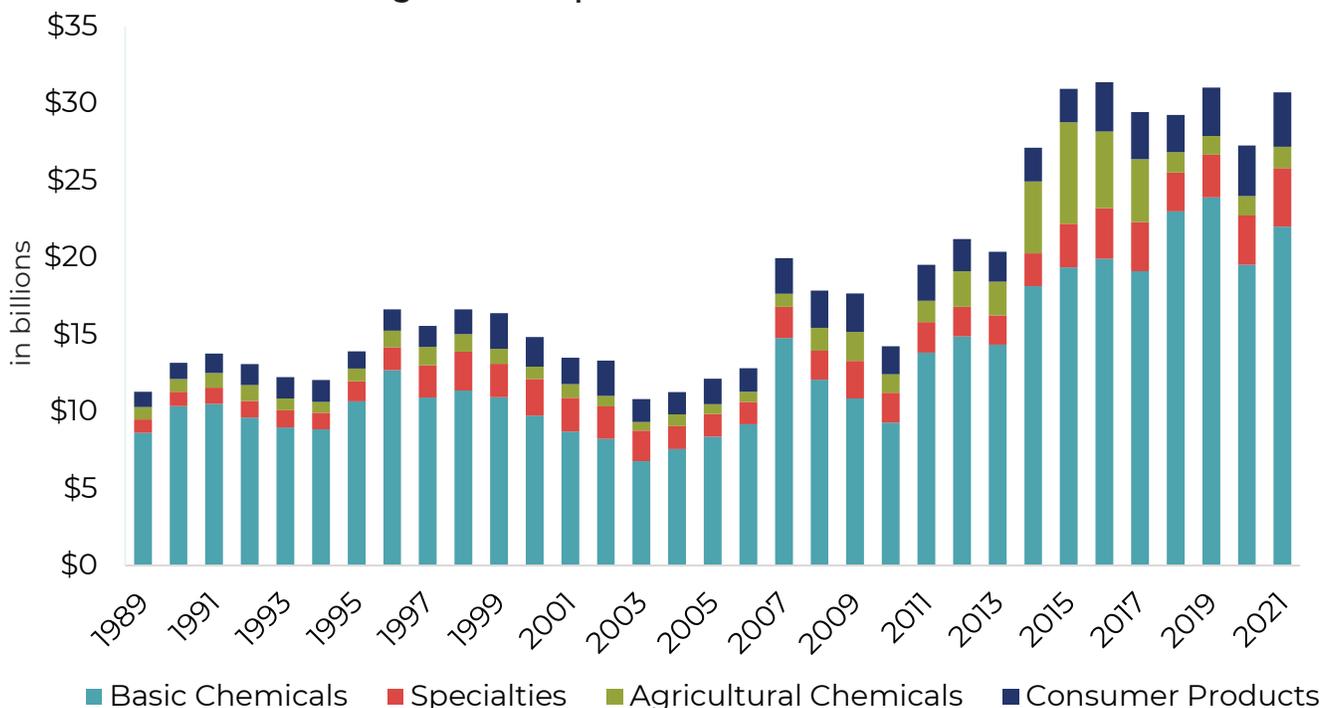
The business of chemistry is a capital-intensive industry. According to the U.S. Bureau of Labor Statistics, “Capital intensity is the ratio of capital services [e.g., property and equipment] to hours worked in the production process. The higher the capital to hours ratio, the more capital intensive the production process is.” There are numerous factors that contribute to the high capital costs of the chemical industry: 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; technology requirements (and the rapid technological obsolescence); and transportation and infrastructure costs.

Increasing levels of capital employed per worker may contribute to improved productivity, indicating that workers are equipped with the advanced resources 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 disadvantage 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 EXPENDITURES

Capital expenditures (“CapEx”) are funds used to purchase and/or maintain physical assets, such as structures and equipment. To a large degree, structures in the chemical industry 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 may include spending for administrative buildings. 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 and digital technologies. Of the two, equipment is notably more important to long-term growth potential for the manufacturing sector and the business of chemistry because it is essential to the production process.

Figure 8.1 - 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. In general, real (that is, adjusted for the effects of inflation) investment in structures (or plants) and equipment by the business of chemistry parallels overall U.S. economic activity, rising during periods of expansion and falling during periods of economic downturns.

Capital spending trends among companies differ based on their main business focus. Basic chemical companies, particularly manufacturers of plastic resins and synthetic rubber, generally allocate the largest share of their sales for capital investment, followed by agricultural chemicals, specialty chemicals, and consumer products. Capital spending by agricultural chemicals companies tends to fluctuate significantly based on economic conditions. Over the past ten years, spending by agricultural chemicals companies has ranged from 3.7% to 18.9%.

Figure 8.2 - Capital Investment as a Percent of Shipments (10-Year Average)



Table 8.1 - Capital Investment by Asset Class, 2017-2021

	2017	2018	2019	2020	2021
	in \$millions				
Computers & Related	804	701	761	790	853
Communications Equipment	662	551	595	559	668
Instrumentation	3,946	3,444	3,853	3,885	4,207
Pressure Vessels & Other Fabricated Equipment	1,689	1,512	1,692	1,527	1,763
Special Industrial Machinery	4,775	4,232	5,357	4,695	5,098
General Industrial Equipment	11,663	9,922	11,148	10,446	11,727
Electric Transmission & Distribution	58	57	62	58	64
Motor Vehicles	457	324	387	184	411
Other Transportation Equipment	551	422	413	268	455
Furniture	303	267	268	243	306
Other Machinery & Equipment	1,239	1,084	1,218	1,208	1,332
Total Equipment	\$26,146	\$22,517	\$25,753	\$23,863	\$26,885
Manufacturing	3,165	2,397	2,645	2,915	3,664
Office Buildings	87	74	74	89	100
Other	62	56	60	75	76
Total Structures	3,315	2,528	2,779	3,079	3,840
Total Capital Investment	\$29,461	\$25,045	\$28,531	\$26,941	\$30,725
As a % of Shipments	5.6%	4.6%	5.6%	5.8%	5.9%

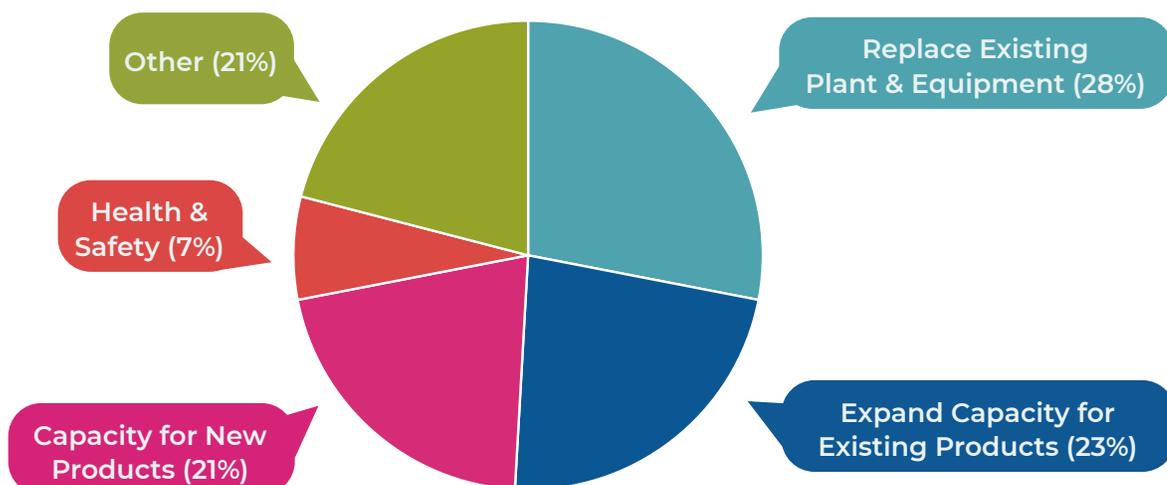
Source: Bureau of Economic Analysis and American Chemistry Council analysis (based on Bureau of the Census data).

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 capital investment include energy savings, addressing changing environmental considerations, and other initiatives need to remain competitive.

Maintenance and repairs also require significant capital to keep plant operations efficient and safe. Of these expenses, about half are for labor and the other half for materials. As a share of shipments, maintenance 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.

A long lead-time can be 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.

Figure 8.3 - Motivation for Capital Investment

PROFITS AND OTHER DETERMINANTS OF INVESTMENT

Profit margins (and operating profits) and capacity utilization rates are key drivers for capital investment. A number of factors drive the magnitude and composition of investment in new plants and equipment, such as after-tax profits, the business cycle, long-term business expectations, taxation policies, regulatory burdens, the cost of capital, the burden of debt, the supply of credit, and mandated expenditures.

In terms of profit margins, the chemical industry can be quite volatile. 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 largely by developments in shale gas, which made the U.S. increasingly more attractive as a place to manufacture chemicals. However, the impacts of plant shutdowns due to COVID-19 and weather-related outages in the Gulf Coast over the past two years have negatively impacted spending.

INFORMATION TECHNOLOGY

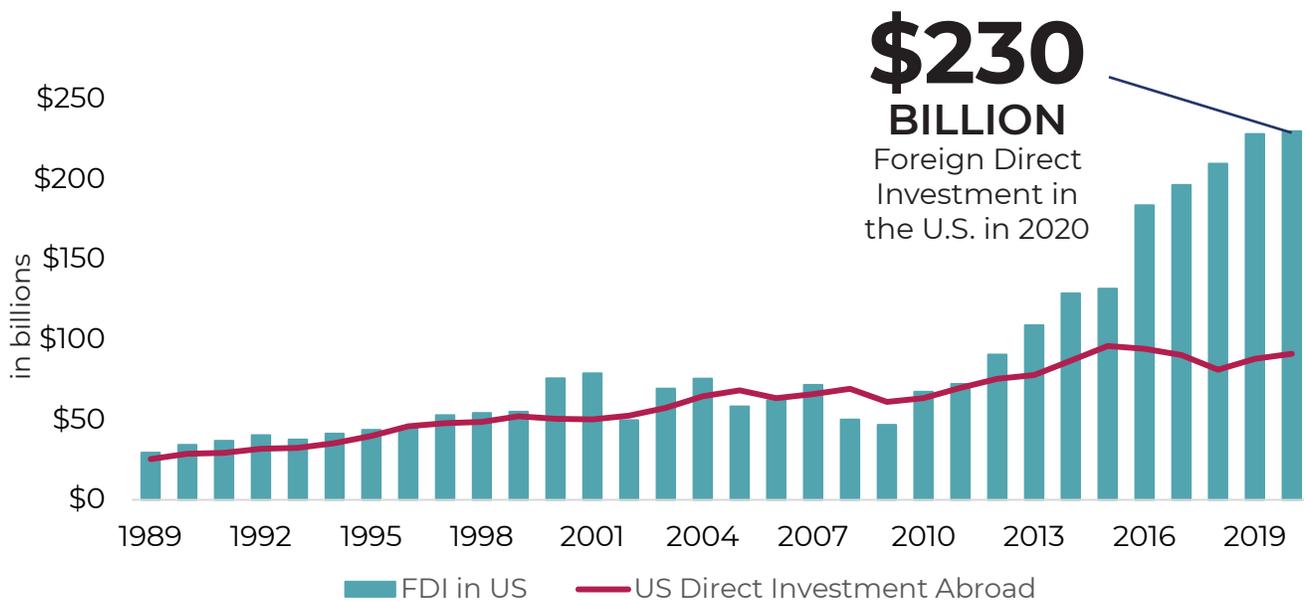
The chemical sector uses information technology to streamline the delivery of products and services. Reliable information technology is key to engineering new scientific and chemical developments, managing the supply chain, executing processes in plants, maintaining productivity in offices, storing employee benefit and payroll information, and securing business and manufacturing control systems. As technology continues to advance, so will the chemical industry's use of IT to improve the way it conducts business.

Advances in information technology are improving product and process development. 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.

Historically, the chemical industry has not been at the forefront of digital technologies. However, the benefits of investing in new technologies, such as artificial intelligence (AI), advanced analytics and the use of Big Data, are immense. According to Forbes magazine, “Big data analytics helps organizations reduce costs, make faster, better decisions, and create new products or services to meet customers’ changing needs” (2019). Operational disruptions due to COVID-19 also accelerated the use of digital technologies across many industries, including the business of chemistry. As many aspects of the industry worked remotely, there was an increased need in technology to conduct business, from video calls with colleagues to remote operations of plants.

Figure 8.4 - Foreign Direct Investment



Source: Bureau of Economic Analysis (2020 is latest available data)

Note: Country details are available at www.bea.gov

FOREIGN DIRECT INVESTMENT

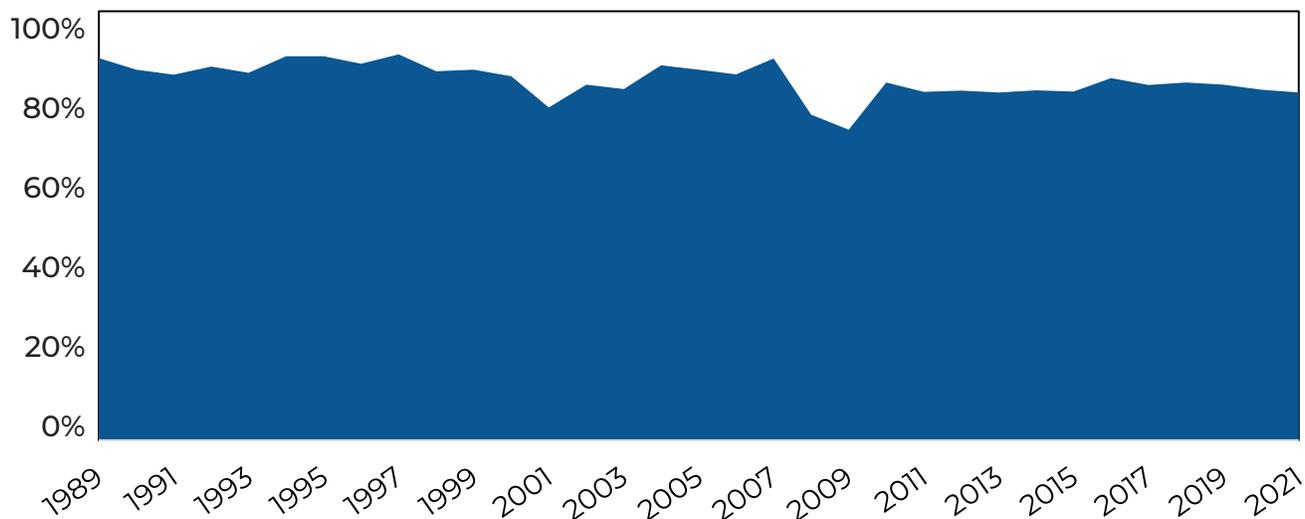
Foreign direct investment (FDI) is the funnel through which exports flow. In conjunction with growing exports, since the early 1980s, the business of chemistry has become increasingly global in scope, with growing U.S. investment abroad and increasing foreign investments in the United States.

American companies have a long-established presence in overseas markets. Europe accounts for the majority of the overseas chemical industry investment by American companies. Canada, China, Japan, India, Brazil, Singapore, and Thailand are other key destinations. 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.

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.

Figure 8.5 - Capacity Utilization



Source: Federal Reserve Board.

CHAPTER 9

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.

Table 9.1 - Employment in the Business of Chemistry, 2012-2021

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	<i>in thousands</i>									
Employees	513.0	517.0	524.1	525.5	525.8	531.3	538.4	544.2	530.5	536.9
By Occupation										
Production Worker	332.7	329.0	333.2	339.3	341.9	341.8	349.9	359.3	336.9	343.9
Other	180.3	188.0	190.9	186.2	183.9	189.5	188.5	184.5	193.0	193.0
By Sex										
Female	124.9	120.4	125.4	128.5	128.0	131.2	137.4	144.3	145.4	143.0
Male	388.1	396.6	398.7	397.0	397.8	400.1	401.0	399.9	385.1	393.9
Median Worker Age (years)										
	46.1	45.9	45.1	45.0	46.1	46.0	43.9	44.6	45.9	44.0

Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, National Science Foundation, ACC 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., manufacturers of trucks needed to transport materials to/from the plant), and in those industries supported by the wages paid to employees in the communities where they live (e.g., medical facilities, coffee shops).

Table 9.2 - Total Jobs Supported by the Business of Chemistry

	Direct	Supply Chain	Payroll-Induced	Total
	in thousands			
Chemicals Jobs	537			
Agriculture		137	31	169
Mining		57	4	60
Utilities		35	6	40
Construction		23	13	36
Manufacturing, excluding Chemicals		239	71	310
Wholesale Trade		238	46	285
Retail Trade		72	220	292
Transportation		229	84	313
Information		26	31	57
Finance and Insurance		83	148	230
Professional, Scientific, Technical Services		239	145	384
Management of Companies and Enterprises		110	22	132
Administrative and Waste Management Services		165	64	229
Health Care and Education		67	401	468
Arts, Entertainment, and Recreation		15	55	70
Accommodation and Food Services		48	211	259
Other Services		75	168	242
Government		33	19	53
Total Jobs - All Industries	537	1,892	1,737	4,166

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

KNOWLEDGE WORKERS

The business of chemistry is a powerful engine of innovation and creativity, stemming from the knowledge base of its employees. “Knowledge worker” is a term that was originally coined by management guru Peter Drucker in his book *The Landmarks of Tomorrow* more than a half century ago. It refers to highly productive and creative workers who apply knowledge gained from formal training and/or education.

The highly technical nature of chemical manufacturing demands that production workers, technicians, and other employees have specialized skills. 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). As a result, workers in the chemical industry earn a substantial wage premium compared to the manufacturing average. In other areas, the need for chemists, engineers, financial analysts, researchers, and programmers, continues to grow.

WAGES, BENEFITS AND OTHER LABOR INDICATORS

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. Many 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.

Figure 9.1 - Total Chemical Industry Employee Compensation

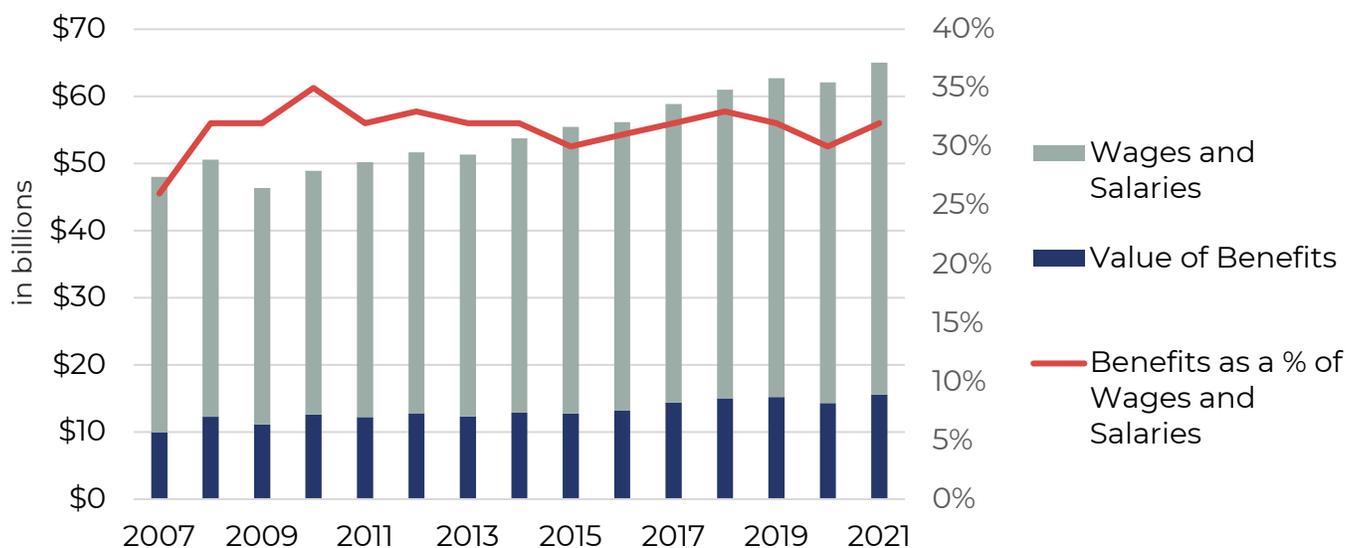
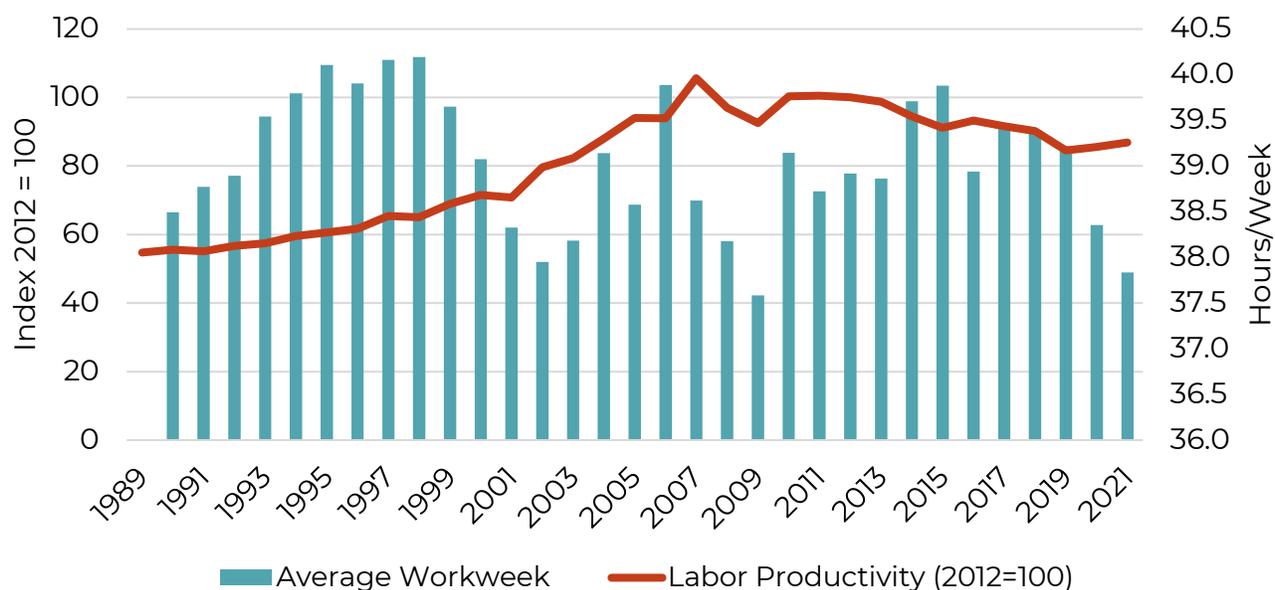


Figure 9.2 - Labor Productivity



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.

Note: 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.

CHAPTER 10

ENVIRONMENT, HEALTH, SAFETY & SECURITY



Chemistry plays an essential role in the products and technologies we use every day, from vital ingredients in consumer products to raw materials in manufacturing processes. These chemicals must be produced and used in ways that protect human health and the environment. The chemical industry continues to improve performance, as well as advocate for cost-effective laws and regulations that improve the nation's overall environmental performance and promote the shared national goal of a healthy environment while encouraging innovation and high-skilled, high-paying jobs in the business of chemistry.

ENVIRONMENTAL, HEALTH AND SAFETY SPENDING

Environment

Efforts to preserve the environment are made possible in large part thanks to the innovative products of chemistry. America's chemical makers create products that help protect the environment and are committed to continuous environmental improvement in their own operations. Many environmental improvements are achieved due to the energy efficiency enabled by 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, air filters for automobiles, homes and commercial buildings use absorbents, catalysts and plastic fibers to clean the air we breathe; 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.

Health

Today we're living healthier and longer lives—more than 30 years longer over the past century—thanks in large part to innovations made possible by the business of chemistry. 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

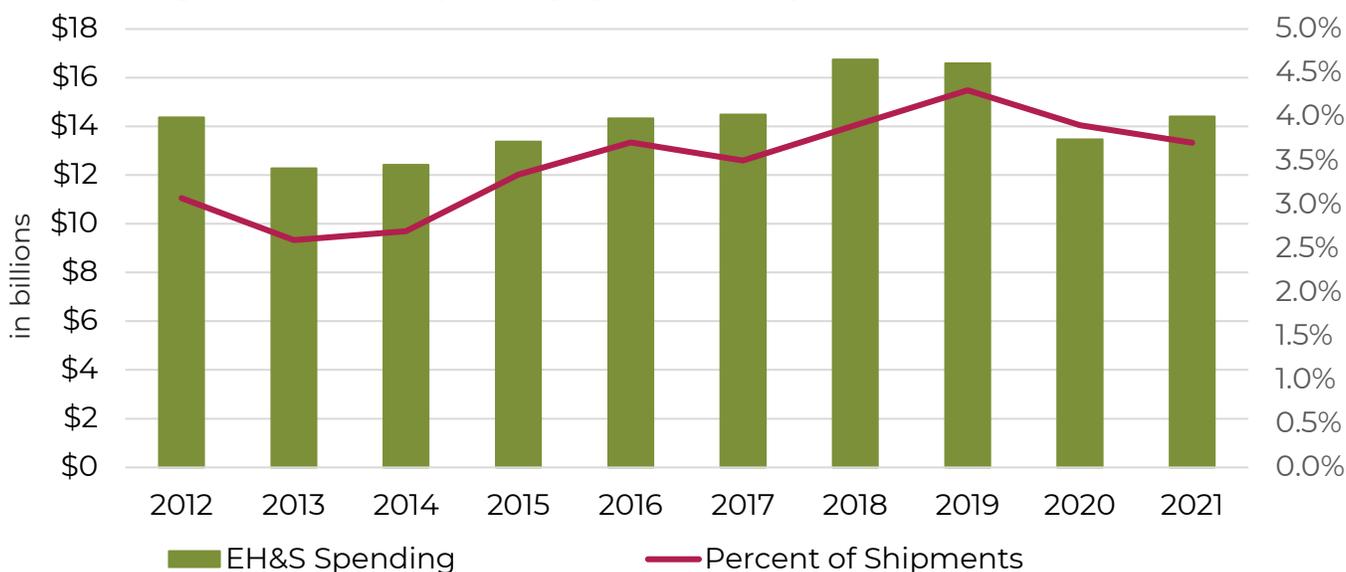
soil, and chlorine chemistry used to clean and disinfect drinking water around the world. Lifesaving medicines derived from chemistry help us combat disease and live longer; the use of antimicrobial products can reduce the spread of dangerous microorganisms.

Safety

From bike helmets to battlefield technologies, the products of chemistry continue to help make the world a safer place. At the same time, it is imperative that chemicals are used both safely and responsibly. 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 further 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.

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. Additionally, the costs to maintain and improve EH&S programs can be significantly lower than the costs to establish them.

Figure 10.1 - EH&S Spending by Basic and Specialty Chemical Producers



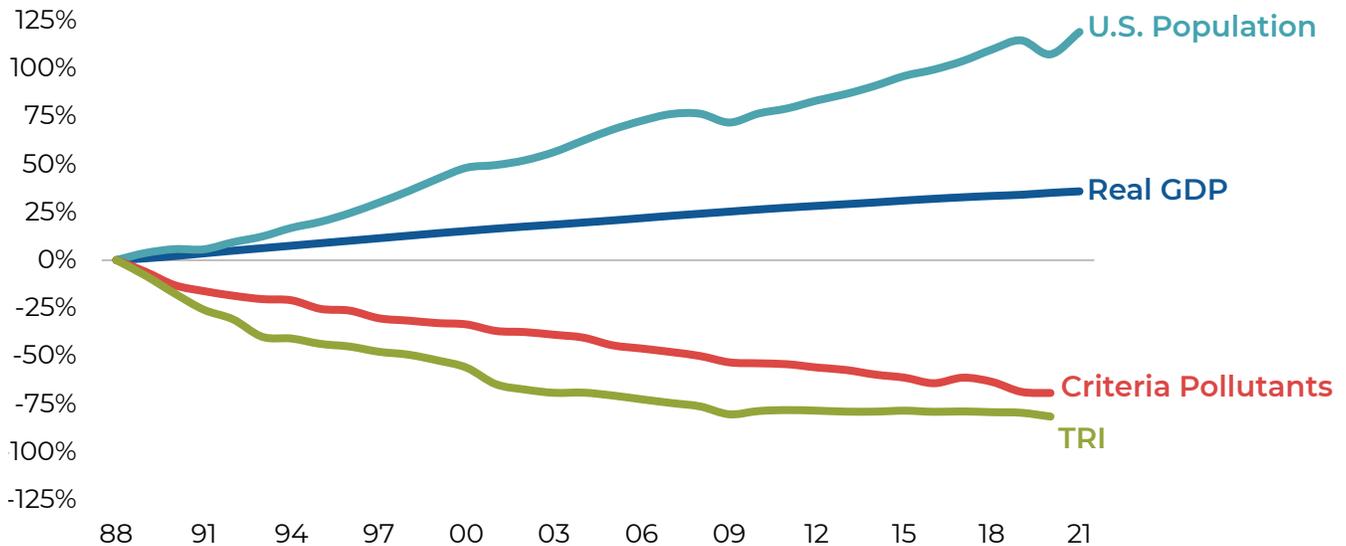
ENVIRONMENTAL PERFORMANCE

Environmental protection has been a national priority for decades. There are numerous government and industry programs that focus on environmental protection and health. One such program is the Toxics Release Inventory (TRI). Established in 1986 by the U.S. EPA, the 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.

Since the 1980s, total toxic releases and air emissions of principal (or 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. The chemical industry is one of the industry sectors required to report TRI data. The long-term downward trend in the releases by the chemical industry is evidence of the industry's dramatic improvement in environmental performance. Additionally, the toxic releases and air emissions of criteria pollutants have declined, even as chemical production has increased.

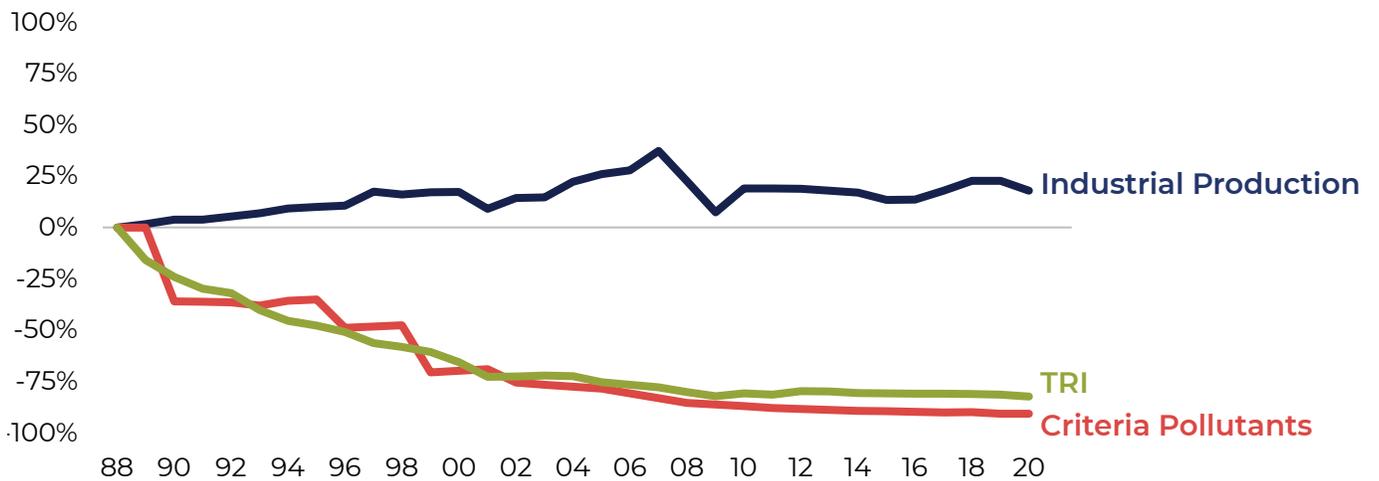
Figure 10.2 - Environmental Progress and Economic and Population Growth in the U.S.



1988 is base year. Criteria pollutants and TRI data for all sectors.

Source: U.S. Bureau of Economic Analysis (BEA), U.S. Census Bureau, U.S. EPA

Figure 10.3 - Environmental Progress and Production in the Business of Chemistry



1988 base year. Criteria pollutants and TRI data for chemical industry. 2020 is latest available data.

Source: U.S. EPA, ACC

The following table shows the total emissions, as well as emissions from the chemical industry, to the air of several key pollutants for a select number of years. For all indicators, the business of chemistry makes up a very small percentage of total emissions.

Table 10.1 - Key Pollution Indicators: A Summary of Progress

	1988	1990	2000	2010	2017	2018	2019	2020	2021
in thousands of short tons									
Sulfur Dioxide									
Total, All Sectors	22,693	23,077	16,347	7,732	2,539	2,438	1,984	1,782	1,882
Business of Chemistry	449	297	338	146	111	107	96	96	96
As a % of Total	2.0%	1.3%	2.1%	1.9%	4.4%	4.4%	4.9%	5.4%	5.1%
Nitrogen Oxides									
Total, All Sectors	26,074	25,527	22,598	14,846	9,838	9,211	8,569	8,050	7,710
Business of Chemistry	274	168	105	53	40	42	38	38	38
As a % of Total	1.1%	0.7%	0.5%	0.4%	0.4%	0.5%	0.4%	0.5%	0.5%
Volatile Organic Compounds									
Total, All Sectors	26,974	24,108	17,512	17,835	17,185	16,435	13,678	13,567	13,456
Business of Chemistry	982	634	254	85	75	78	75	75	75
As a % of Total	3.6%	2.6%	1.4%	0.5%	0.4%	0.5%	0.5%	0.6%	0.6%
Carbon Monoxide									
Total, All Sectors	174,418	154,188	114,467	73,771	66,605	62,283	52,118	51,256	50,393
Business of Chemistry	1,917	1,183	361	173	118	123	115	115	115
As a % of Total	1.1%	0.8%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Coarse Particulates (PM₁₀)									
Total, All Sectors	42,834	27,753	23,747	20,823	17,035	16,395	15,082	15,071	15,060
Business of Chemistry	62	77	55	23	19	20	18	18	18
As a % of Total	0.1%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Fine Particulates (PM_{2.5})									
Total, All Sectors	N/A	7,560	7,288	5,964	5,681	5,419	4,533	4,520	4,507
Business of Chemistry	N/A	47	46	18	15	15	14	14	14
As a % of Total	N/A	0.6%	0.6%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Ammonia									
Total, All Sectors	N/A	4,320	4,907	4,271	4,297	4,933	4,864	4,864	4,864
Business of Chemistry	N/A	183	26	22	23	23	23	23	23
As a % of Total	N/A	4.2%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%

Notes. Data shown for select years only. Electronic data tables, including historic data for all years since 1998, are available to ACC members for free on MemberExchange. Non-members may purchase the data at store. americanchemistry.com.

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

Source: Environmental Protection Agency.

Table 10.2 - Toxics Release Inventory: Business of Chemistry

	1988	1990	2000	2010	2016	2017	2018	2019	2020
	in million of pounds								
Total Releases*	690	525	237	132	132	132	131	129	122
Air	620	476	185	85	79	75	75	74	73
Surface Water	19	11	4	2	3	2	2	2	2
Land	51	38	49	46	51	54	54	53	48
Underground Injection	160	156	110	97	99	100	106	91	89
Off-site releases**	70	56	54	50	55	53	59	56	50

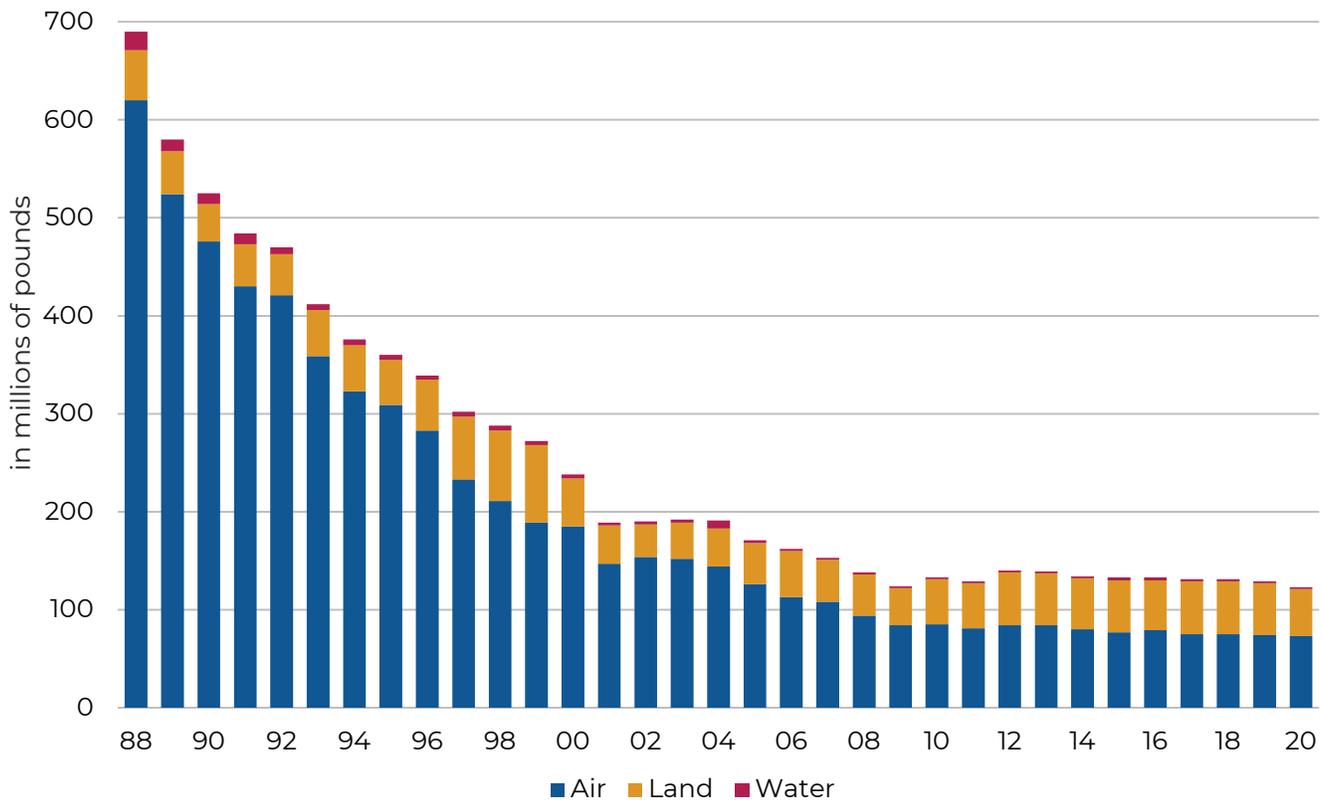
*The American Chemistry Council defines total releases to be the sum of total air, surface water, and land. Underground injections are not included in releases to the environment. Includes 1988 core chemicals only (does not include delisted chemicals; chemicals added in 1990, 1991, 1994, 1995; or aluminum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

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

Note: 2020 is latest available data. Data shown for select years only. Electronic data tables, including historic data for all years since 1998, are available to ACC members for free on MemberExchange. Non-members may purchase the data at store.americanchemistry.com.

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

Figure 10.4 - TRI Releases by Media: Business of Chemistry



Source: U.S. EPA

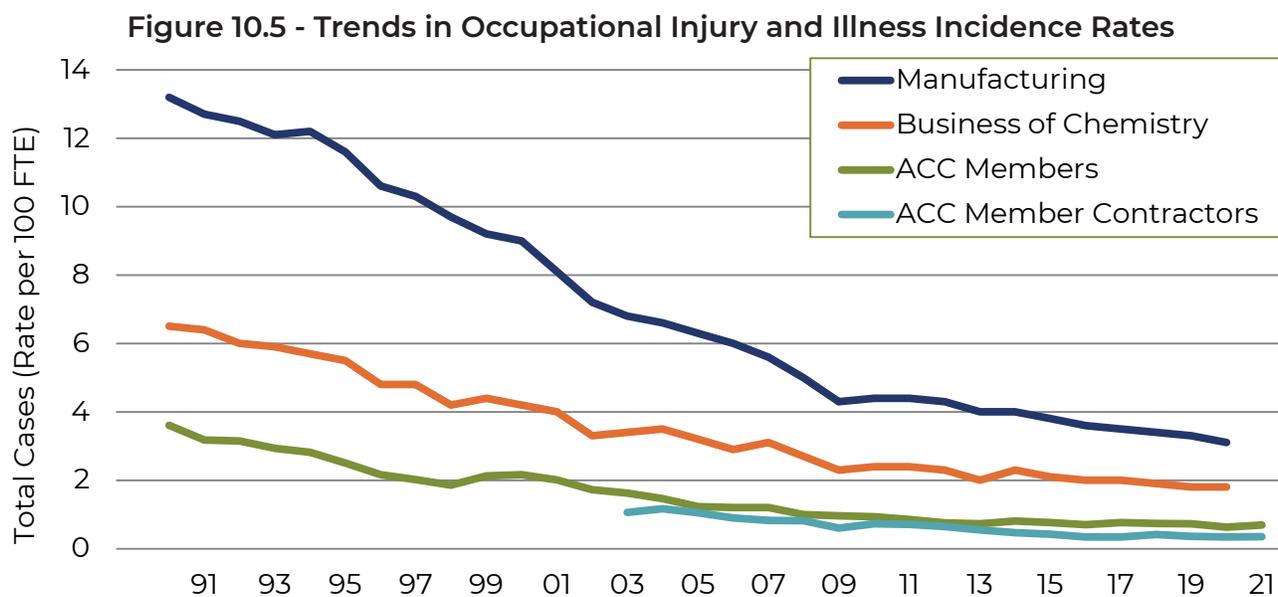
WORKER HEALTH AND SAFETY

In addition to its environmental protection activities, the business of chemistry has also achieved a remarkable record of worker safety, 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 value of these investments is supported by data from the Bureau of Labor Statistics that indicates the business of chemistry has illness and injury rates of 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 10.3 - Occupational Injury and Illness Rates

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
<i>Lost workday cases rate per 100 employees</i>										
Manufacturing										
Total OIIR Cases	4.3	4.0	4.0	3.8	3.6	3.5	3.4	3.3	3.1	n/a
Lost Workday Cases	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.9	1.1	n/a
Business of Chemistry										
Total OIIR Cases	2.3	2.0	2.1	1.9	1.8	1.8	1.7	1.8	1.8	n/a
Lost Workday Cases	0.7	0.5	0.7	0.6	0.6	0.6	0.6	0.6	0.7	n/a
American Chemistry Council Companies										
Total OIIR Cases	0.75	0.73	0.82	0.76	0.70	0.76	0.74	0.72	0.63	0.69
Lost Workday Cases	0.17	0.17	0.20	0.20	0.17	0.20	0.21	0.22	0.26	0.24
American Chemistry Council Company Contractors										
Total OIIR Cases	0.65	0.55	0.47	0.42	0.34	0.34	0.41	0.36	0.34	0.35
Lost Workday Cases	0.13	0.09	0.09	0.08	0.06	0.07	0.10	0.07	0.08	0.02

Sources: Bureau of Labor Statistics and American Chemistry Council



SPENDING ON SECURITY

The chemical industry manufactures products that are vital to the everyday health and well-being of our nation, which is why the Department of Homeland Security designated the chemical industry 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”).

Within months of the terrorist attacks of 9/11, ACC created a mandatory security program called the Responsible Care® Security Code. Since 9/11/2001, ACC members have invested heavily under the Security Code to further enhance site, transportation, and cyber security at their facilities. The Security Code has served as a model for regulatory programs.

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 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 ACC 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. Security spending includes guard services, electronic surveillance, remote electronic monitoring of security, other security services, and miscellaneous protective services. Security costs also include those traditionally associated with information, computer, network, and related IT security. 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 a fraction of it; actual total spending for security could be several times this amount.

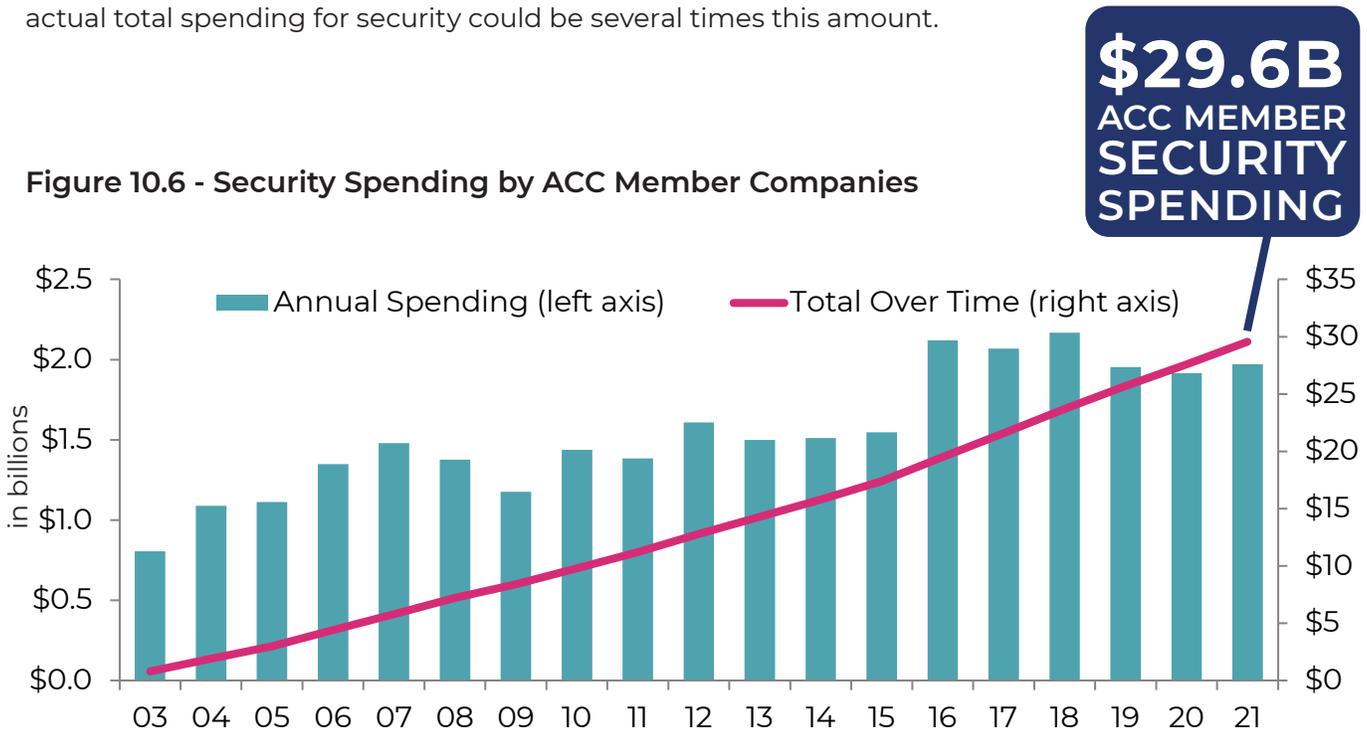


Figure 10.6 - Security Spending by ACC Member Companies

*For more information, visit americanchemistry.com/security

ACC'S COMMITMENT TO EHS&S

Responsible Care®: Driving Safety & Industry Performance

The members of the American Chemistry Council (ACC) are committed to safety and sustainability in the communities where we operate and in the products we manufacture. Through implementation of Responsible Care®, our members demonstrate their commitment to the health and safety of their employees, the communities in which they operate and the environment as a whole.

For nearly 35 years, companies practicing Responsible Care have worked to significantly enhance their environmental, health, safety and security (EHS&S) performance. Participation in Responsible Care is a mandatory for all ACC members and Responsible Care Partner companies, all of which have made CEO-level commitments to the program, including:

- Signing the Responsible Care Guiding Principles
- Tracking and transparently reporting company performance on environmental, health, safety and security metrics
- Undergoing third-party audit and certification to Responsible Care Management System (RCMS®)/RC14001®
- Implementing the Product Safety, Process Safety and Security Codes



RESPONSIBLE CARE®
OUR COMMITMENT TO SUSTAINABILITY

Learn more at: <https://www.americanchemistry.com/chemistry-in-america/responsible-care-driving-safety-industry-performance>

Long-Range Research Initiative

The Long-Range Research Initiative (LRI) was established by the American Chemistry Council in 1999 to demonstrate its commitment to advance scientific understanding of the potential impacts of chemicals on human health and the environment. By design, the LRI research program does not focus on specific chemicals but rather identifies broad areas of scientific investigation that are relevant to the chemical industry and society. The LRI is an extension of the ACC Responsible Care® initiative, the chemical industry's global voluntary commitment to continuous improvement in environmental, health, safety, and security performance.

The ACC LRI is part of a global LRI program under the auspices of the International Council of Chemical Associations (ICCA) and includes LRI programs supported by the European Chemical Industry Council (Cefic) and the Japan Chemical Industry Association (JCIA). Through the ICCA, these independently managed LRI research programs support complementary areas of scientific investigation with the overall goal to promote improvements in the way that industry, academia, and governments evaluate chemicals.



Learn more at: <https://www.americanchemistry.com/better-policy-regulation/research/long-range-research-initiative-lri/lri-research-program>

TRANSCAER®

Effective emergency response begins with planning and preparation. This is what the TRANSCAER mission and purpose is all about. TRANSCAER (Transportation Community Awareness and Emergency Response) is a voluntary national outreach program that focuses on assisting communities to prepare for and respond to a possible hazardous materials transportation incident.

TRANSCAER volunteer members come from a variety of sectors in the industry, including: chemical manufacturing, transportation, distribution, industry & industry associations, emergency response, and government. The TRANSCAER purpose is to promote safe transportation and handling of hazardous materials; educate and assist communities near major transportation routes about hazardous materials; and aid community emergency response planning for hazardous material transportation incidents.

To fulfill its mission and purpose, TRANSCAER offers a variety of services to communities and to emergency responders, including planning assistance, hazmat training, drills & exercises, reference and training materials, networking opportunities, local resources, and awards programs.

TRANSCAER is sponsored by the American Chemistry Council (ACC), American Petroleum Institute (API), Association of American Railroads (AAR), CHEMTREC®, Center for Liquefied National Gas (CLNG), Industrial Steel Drum Institute (ISDI), PRBA - The Rechargeable Battery Association, The Chlorine Institute (CI), The Fertilizer Institute (TFI), and Renewable Fuels Association (RFA).



Learn more at: <https://www.americanchemistry.com/about-acc/transcaer>

CHEMTREC®

Established in 1971 as a public service of the American Chemistry Council (ACC), CHEMTREC is a 24/7 public service hotline for firefighters, law enforcement officials, and other emergency responders who need immediate critical response information for emergency incidents involving chemicals, hazardous materials, and dangerous goods.

With over 50 years of experience, CHEMTREC's world-leading call center operates on a 24-hour basis, seven days a week, providing emergency response information wherever hazardous materials are manufactured, stored, transported, or used. With the right procedures and protocols in place, and by doing what's right quickly and effectively, CHEMTREC helps minimize environmental impacts, protect people, and preserve the assets and reputations of its customers.

Operating globally, CHEMTREC has major offices and strategic partners in major regions, on-the-ground knowledge of local regulations, understanding of local nuances, and appreciation of cultural sensitivities. CHEMTREC offers a suite of services along with L1 emergency response, including safety data sheet solutions, hazardous materials training, consulting services, battery compliance, and incident reporting. CHEMTREC is proud to contribute to the practice of safe handling and transportation of hazardous materials throughout the supply chain.



Learn more at: <https://www.americanchemistry.com/about-acc/chemtrec>

Chemistry & Sustainability

The chemical industry is committed to advancing sustainability worldwide, through innovation, collaboration and technologies that enhance the safety and environmental impacts of our products and our operations.

For more than a century, chemistry has enabled solutions to some of the world's most daunting sustainability challenges. Products, processes and technologies that many of us take for granted today, like clean drinking water, pasteurization and vaccines, began as breakthroughs in chemistry.

Over time, our challenges have grown more complex as we seek to sustain the health and well-being of Earth's growing population and its natural environment.

Today, one of the greatest challenges our global society faces is addressing climate change and its impacts. To combat negative impacts on climate, we must reduce greenhouse gas (GHG) emissions, in our own operations and in society as a whole, and chemistry is a key power behind lower carbon, renewable energy and energy-efficient technologies.

Other areas of critical importance include air and water quality, the safety of the products we manufacture, and the need to conserve Earth's resources while developing products and technologies that will benefit and advance society.

A sustainable future will need commitments from individuals, communities, governments, business and industry. The chemical industry is committed to being part of the solution.

Learn more at: <https://www.americanchemistry.com/chemistry-in-america/chemistry-sustainability>

CHAPTER 11

ENERGY



The business of chemistry transforms natural raw materials from earth, water, and air into valuable products that enable safer and healthier lifestyles. Chemistry is the science behind innovative solutions that empower cleaner energy options, create green jobs, and propel U.S. economic growth. Chemistry enables energy-saving and renewable applications including solar panels and wind turbines, electric and fuel-efficient vehicles, high-performance building materials, advanced batteries, energy-efficient lighting, and more.

Chemical manufacturers use energy in two ways: for fuel and power and as raw materials, or “feedstocks,” in the manufacture of many of its products. 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 manufacturing is the largest user of energy). 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.

Note. 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. The industry consumes energy to generate heat, steam, pressure, and electricity used in manufacturing processes.

The chemical industry purchases electricity and some steam from electric utilities or other suppliers. The chemical industry is a leader in the use of combined heat and power (CHP), a highly efficient process for generating heat and electricity on-site, and helped pioneer catalytic technologies that let facilities produce more with less energy.

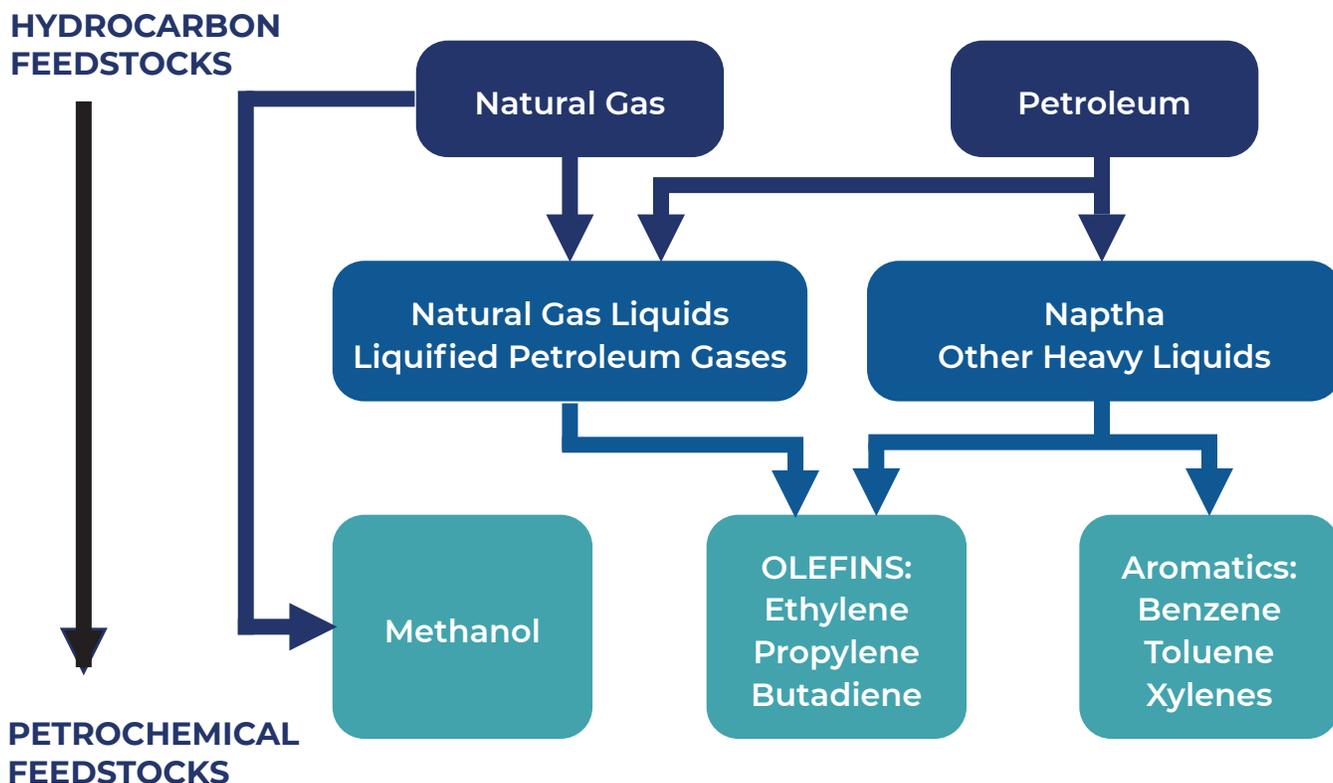
FEEDSTOCKS

In addition to air, water, and minerals, the business of chemistry uses large quantities of energy such as natural gas, natural gas liquids, and naphtha as raw materials and/or feedstocks. (A small amount of coal is also used.) Natural gas contains 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 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.

Figure 11.1 - Derivation of Petrochemical Feedstocks

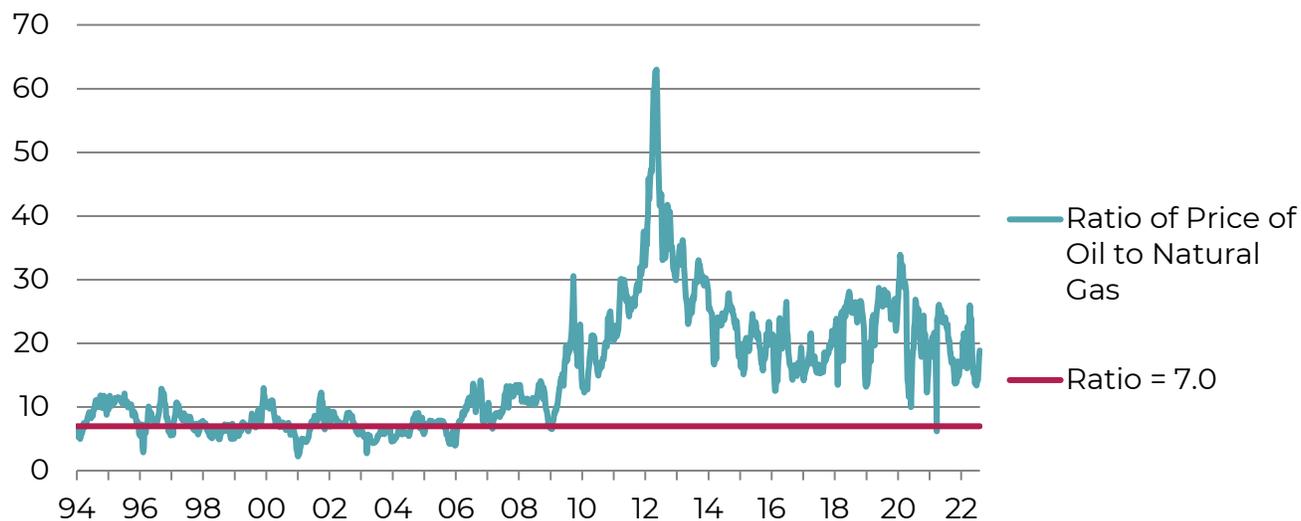


These petrochemical feedstocks are the foundation of chemistry of plastics, pharmaceuticals, electronic materials, fertilizers, and thousands of other products that improve the lives of a growing and prospering population. The product chains for these petrochemical feedstocks can be found in the appendices.

NATURAL GAS & PETROLEUM PRODUCTS

The business of chemistry is a large user of natural gas and petroleum products, accounting 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.

**Figure 11.2 - 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 since late 2009.

Due to the relative abundant production 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. ethylene production is based on natural gas liquids, while two-thirds of European and Asian ethylene 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 significant U.S. methanol capacity, ammonia capacity, and ethylene capacity, all which depend on natural gas or natural gas derivatives as feedstocks. From 2002 to 2010, total U.S. ethylene capacity had dropped more than 5%. In the 2010s, with the advent of abundant supplies of shale gas, the situation started to reverse; since 2010, U.S. ethylene capacity has increased by more than 50%. Closed plants have been restarted, new plants are under construction, and substantial new investments have been announced.

ENERGY CONSUMPTION

Petroleum and natural gas are important for both fuel and power in feedstock uses of energy. The following table provides a snapshot 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.

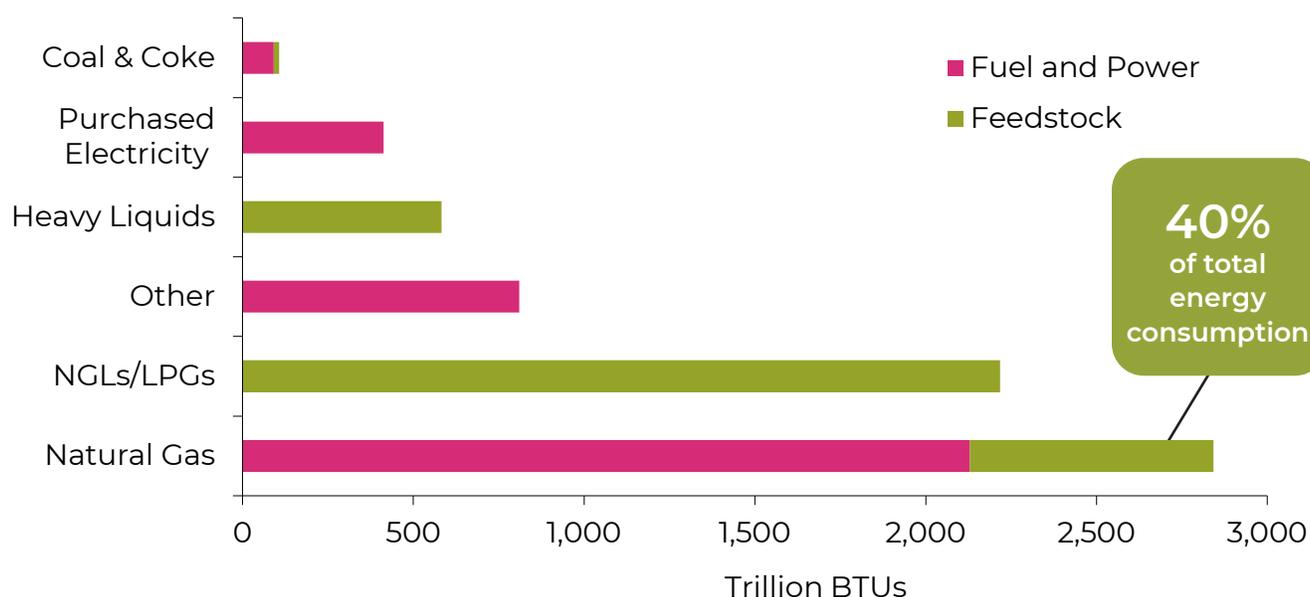
Table 11.1 - Energy Consumption by the Business of Chemistry

	1974	1990	2000	2010	2017	2018	2019	2020	2021
	in trillions of BTUs								
Natural Gas	1,612	1,641	1,804	1,729	2,197	2,277	2,267	2,104	2,129
Coal and Coke	311	272	303	188	106	105	98	98	91
Fuel Oil	285	77	59	17	16	15	14	11	12
Purchased Electricity	437	461	522	471	464	449	441	407	413
Other	377	650	973	767	824	830	832	793	798
Total Fuel & Power	3,022	3,101	3,661	3,172	3,607	3,676	3,652	3,413	3,443
NGLs/LPGs*	1,483	924	1,291	1,334	1,724	2,025	2,089	2,214	2,218
Heavy Liquids	942	1,029	1,167	943	699	671	630	583	583
Natural Gas	430	744	709	430	651	675	708	712	713
Coal	19	21	33	19	17	17	17	16	16
Total Feedstock	2,165	2,718	3,200	2,726	3,091	3,388	3,444	3,525	3,530

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 11.3 - Composition of Energy Requirements, 2021



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.

Table 11.2 - Value of Energy Consumed by the Business of Chemistry

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	in \$billions									
Total Value	\$82.3	\$84.6	\$88.5	\$49.0	\$49.3	\$65.7	\$86.6	\$67.0	\$58.7	\$101.5
Fuel & Power	16.2	18.0	19.1	16.9	16.5	17.0	17.0	16.0	13.8	23.5
Feedstocks	66.1	66.6	69.5	32.1	32.8	48.8	69.6	51.0	44.9	78.0

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

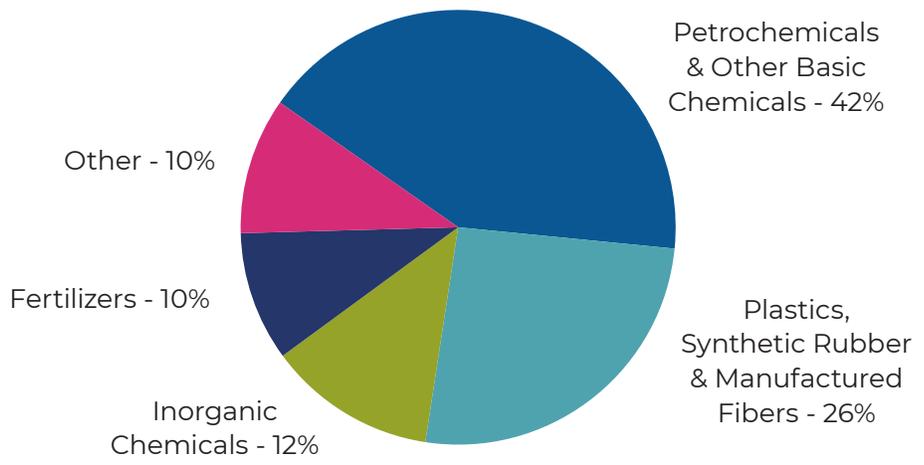
CHEMICAL INDUSTRY ENERGY EFFICIENCY

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.

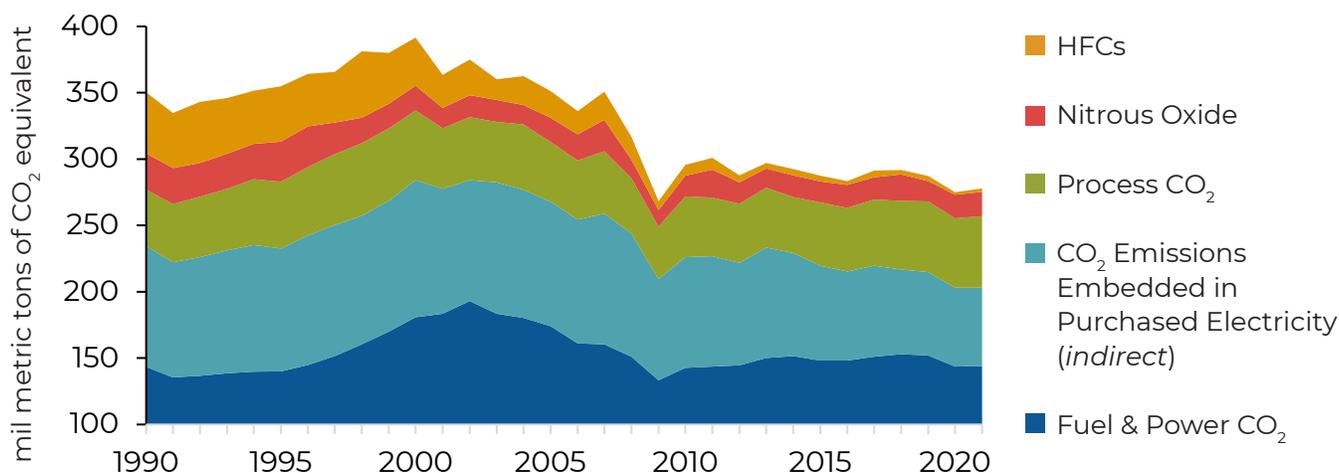
Figure 11.4 - Share of Total Energy Consumption by Segment



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

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.

Figure 11.5 - Business of Chemistry Greenhouse Gas Emissions

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.

According to EPA, there are three categories of GHG emissions: Scope 1 (emissions that occur from sources that are controlled or owned by an organization), Scope 2 (indirect emissions, i.e., purchased

electricity, steam, etc.), and Scope 3 (emissions that are the result of activities from assets not owned or controlled by the reporting organization (i.e., supply chain). ACC compiles data for Scope 1 and Scope 2 emissions.

Table 11.3 - Business of Chemistry Greenhouse Gas Emissions

	1990	1995	2000	2005	2010	2018	2019	2020	2021
	in million metric tons of carbon dioxide equivalent								
Scope 1 (Direct Emissions)*									
Fuel and Power CO ₂	143.3	140.1	180.7	174.0	142.7	152.9	152.0	143.5	144.1
Process CO ₂	42.5	50.3	52.7	45.1	45.6	51.6	53.2	52.4	54.0
Subtotal CO ₂	185.8	190.4	233.4	219.1	188.3	204.5	205.2	195.9	198.1
Nitrous Oxide	27.3	30.4	18.6	18.4	15.7	20.1	15.3	17.6	18.3
Methane	0.2	0.3	0.3	0.1	0.0	0.3	0.3	0.3	0.3
HFCs	46.1	41.7	36.2	20	8	3.3	3.7	2.1	2.5
Scope 2 (Indirect Emissions)**									
CO ₂ Emissions Embedded in Purchased Electricity	91.1	92.4	103.3	93.7	83.5	63.9	62.9	59.5	58.9
Total Emissions (Scope 1 & 2)	350.5	355.2	391.8	351.3	295.5	292.1	287.4	275.4	278.1
Performance Trend Indices (1990 = 100)									
Chemical Industry Output Index	100.0	106.7	121.3	137.8	127.9	116.1	112.5	109.5	115.2
Energy Efficiency Index	100.0	99.4	97.3	77.3	80.0	102.1	104.7	100.5	96.4
GHG Emissions Index - Scope 1 & 2	100.0	101.3	111.8	100.2	84.3	83.3	82.0	78.6	79.3
GHG Intensity Index - Scope 1 & 2	100.0	95.0	92.1	72.7	65.9	71.8	72.9	71.7	68.9
GHG Emissions Index - Scope 1 only	100.0	101.3	111.2	99.3	81.7	88.0	86.5	83.2	84.5
GHG Intensity Index - Scope 1 only	100.0	94.9	91.7	72.1	63.9	75.7	76.9	76.0	73.4

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).

Reportable GHG Scope 1 and Scope 2 Emissions

*Scope 1 Emissions: GHG emissions from sources owned or operated by the reporting company (e.g., stationary combustion, process emissions, and fugitive emissions). Scope 1 emissions includes transportation emissions from vehicles owned or operated by the reporting company.

**Scope 2 Emissions: GHG emissions from the source(s) of energy purchased by the reporting company (e.g., electricity, steam, heat). The source(s) of energy under this category are not owned or operated by the reporting company.

CHAPTER 12

SUPPLY CHAIN & DISTRIBUTION



Although much of the U.S. chemical production is concentrated in about a dozen states, 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 may be 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 7-11% of the business of chemistry's value of shipments.

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 are generally shipped in tank cars (liquids and liquefied gases), hopper cars (dry commodities), and some boxcars (dry bulk or packaged chemical products). According to data from the American Associations of Railroads (AAR), 184 million tons of chemicals were transported via rail (19% of total tonnage) in 2021. The business of chemistry is also one of the top sources of revenue for the railroad industry, accounting for \$10.8 billion (17%) in 2020. Ethanol is the highest-volume chemical transported by rail, followed by industrial chemicals, plastic resins, and agricultural chemicals.

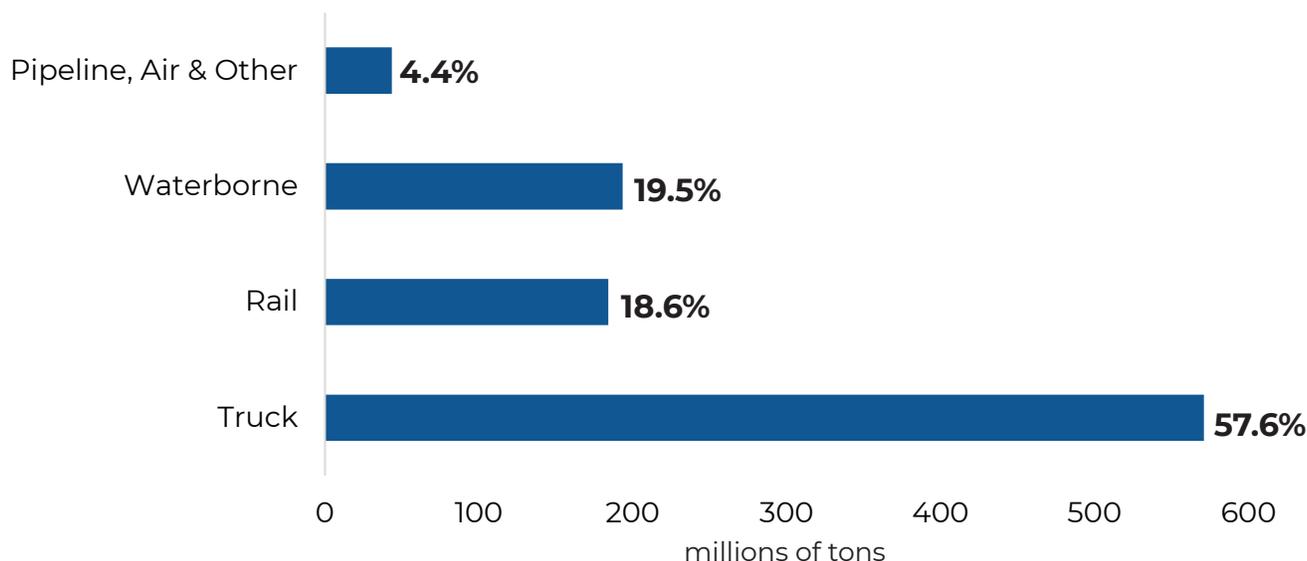
Waterborne

Waterborne transport is often the least expensive method of transporting chemicals. Depending on 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. 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-coastal system along the Gulf Coast are also major domestic water routes used to transport chemicals.

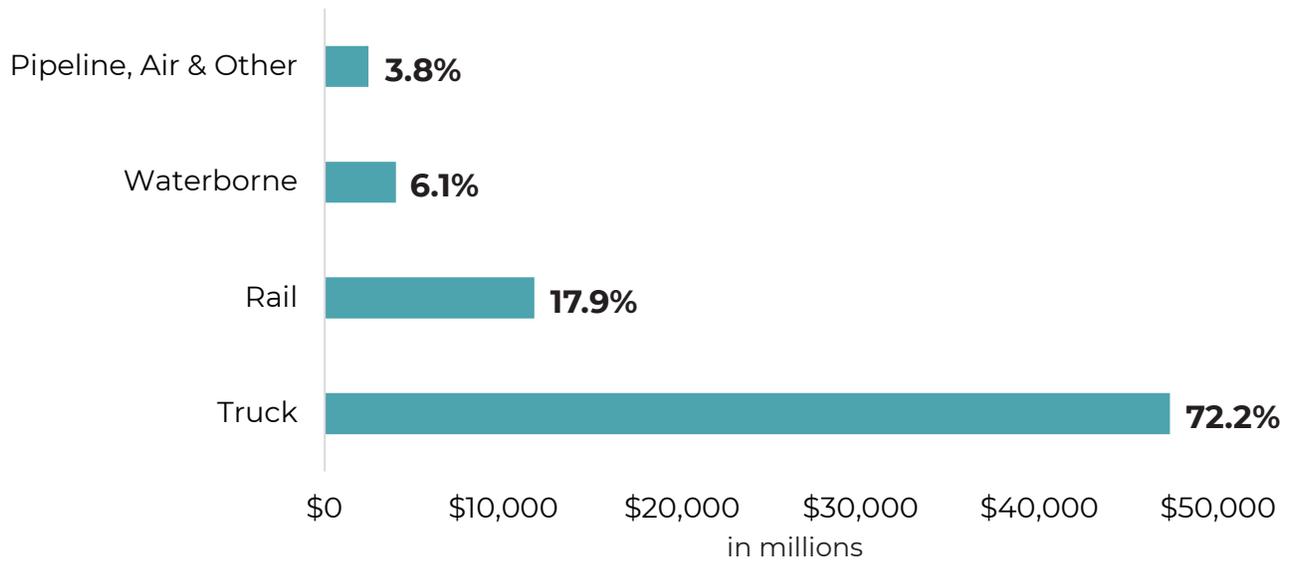
Other

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.

Figure 12.1 - Transportation by Mode (Volume of Chemical Shipments), 2021



Sources: Association of American Railroads, Bureau of the Census, US Army Corps of Engineers, American Chemistry Council analysis.

Figure 12.2 - Transportation by Mode (Value of Chemical Shipments), 2021

Sources: Association of American Railroads, Bureau of the Census, US Army Corps of Engineers, American Chemistry Council analysis.

SUPPLY CHAIN & FREIGHT TRANSPORTATION CONSTRAINTS FOR CHEMICAL MANUFACTURERS

55%

of chemical manufacturers report port related delays and congestion have gotten worse since 3Q 2021.

21%

of chemical manufacturers report inland waterways transportation delays and congestion challenges have gotten worse since 3Q 2021.

39%

of chemical manufacturers report rail transportation related delays/service challenges have gotten worse since 3Q 2021.

55%

of chemical manufacturers report truck transportation related delays and capacity constraints have gotten worse since 3Q 2021.

Results of ACC Survey

The pandemic has contributed to supply chain and freight transportation disruptions in industries around the globe. U.S. chemical producers and their customers have experienced considerable challenges. The American Chemistry Council (ACC) conducted a survey of chemical manufacturers doing business in the U.S. in the third quarter of 2021, and a follow-up in March 2022, to better understand the issues chemical manufacturers were facing. The survey identified significant challenges for the efficient movement of freight across transportation modes and showed how these problems negatively impacted the operations of the chemical industry.

Key Findings

-  Among respondents, 99% of companies reported impacts to their U.S. manufacturing business.
-  Two thirds reported lost production and nearly all reported shipping delays and increased transportation costs.
-  Among respondents, 85% of companies reported being impacted by shortages of raw materials/inputs.
-  More than one third of companies experienced or declared force majeure as a result of supply chain/freight transportation issues.

Challenges by Transportation Mode

-  Most rail users reported longer transit times, typically about 8 days longer with some companies reporting an increase of more than three weeks.
-  Nearly all companies reported either moderate or severe delays and capacity constraints in the trucking industry.
-  Companies using inland waterways reported longer shipment times, with shipments taking an average of 6 days longer.
-  Most companies shipping via ocean reported longer transit times, cancelled bookings, and shortages of available shipping containers.

Statistics as of March 2022

CHAPTER 13

CHEMISTRY IN THE STATES AND REGIONS



The states (and regions) in the United States are economically interdependent. Each state's economy depends on the continued 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.

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 80% 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 13.1 - Chemistry Shipments by State

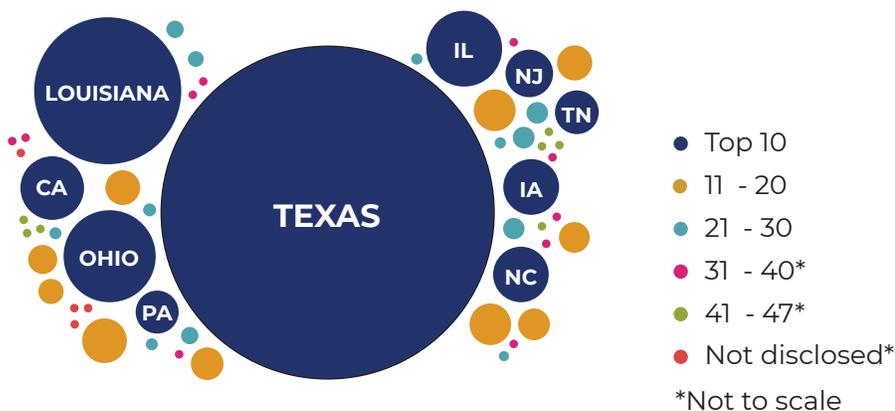


Table 13.1 - State Chemistry Statistics, 2021

State	Value of Shipments* (in \$millions)	Employment (in thousands)	Average Wages and Salaries (\$)	Chemical Exports (in \$millions)
Texas	100,021	68,062	121,281	49,361
Louisiana	44,429	25,981	123,368	10,312
Ohio	27,948	40,984	104,545	6,410
Illinois	23,109	25,009	87,754	6,552
California	19,444	35,991	81,143	8,052
Iowa	17,083	7,605	79,760	1,735
North Carolina	17,020	19,121	84,278	3,571
New Jersey	14,605	19,381	104,143	8,394
Pennsylvania	13,674	23,088	79,800	6,166
Tennessee	13,487	23,902	87,742	4,215
New York	13,369	16,162	86,803	4,034
Georgia	12,537	19,138	74,895	3,529
South Carolina	12,488	17,151	76,956	3,376
Missouri	10,495	15,428	72,111	2,631
Michigan	10,390	19,381	94,851	3,881
Alabama	9,766	9,851	92,240	2,215
Indiana	9,502	13,614	75,055	2,428
Kentucky	9,205	10,396	81,776	2,785
Florida	8,696	15,758	80,620	5,345
West Virginia	7,839	8,965	94,004	1,584
Wisconsin	7,546	14,592	83,955	1,917
Nebraska	6,506	3,937	71,197	441
Virginia	6,471	11,952	81,488	1,924
Minnesota	5,207	7,844	92,240	1,162
Kansas	4,747	4,701	74,816	803
Mississippi	3,890	4,760	76,527	1,289
Arkansas	3,584	4,966	71,063	692
Maryland	3,378	4,126	87,997	1,245
Massachusetts	3,363	5,935	100,228	1,984
Oklahoma	3,021	2,870	82,626	660
Oregon	2,572	4,269	70,814	1,441
Colorado	2,335	3,435	67,837	567
Connecticut	2,207	4,774	139,098	1,035
Wyoming	2,184	1,504	107,434	1,048
Washington	2,116	3,854	84,138	809
South Dakota	2,105	1,062	72,427	227

*Shipment data for 2020 (latest available). Listed in descending order based on value of shipments.

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

Notes. 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.

Table 13.1 - State Chemistry Statistics, 2021

State	Value of Shipments* (in \$millions)	Employment (in thousands)	Average Wages and Salaries (\$)	Chemical Exports (in \$millions)
Utah	2,094	2,804	67,708	1,155
Arizona	1,651	4,211	67,324	987
Delaware	1,509	2,030	108,928	763
Nevada	1,306	1,455	69,089	176
Idaho	1,178	2,856	63,287	369
New Mexico	884	626	84,868	165
North Dakota	847	726	82,433	412
Rhode Island	736	1,475	69,030	336
Maine	421	592	61,846	42
New Hampshire	300	774	70,064	117
Montana	243	384	79,919	270
Vermont	N/D	952	58,683	61
Hawaii	N/D	385	55,348	40
Alaska	N/D	58	35,586	6
District of Columbia	N/D	4	66,692	10
U.S. Total	\$467,939	536,217	\$92,140	\$160,804

*Shipment data for 2020 (latest available). Listed in descending order based on value of shipments.

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

Notes. 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.

EMPLOYMENT IMPACT OF THE BUSINESS OF CHEMISTRY

The true employment impact of an industry goes well beyond those employees it directly employs. It 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, healthcare, 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.

Table 13.2 - Jobs and Payroll Generated by the Business of Chemistry by State, 2021

State	in thousands				in \$millions			
	Direct	Supply Chain	Payroll Induced	Total Jobs	Direct	Supply Chain	Payroll Induced	Total Payroll
Alabama	9.9	13.8	8.9	32.5	909	664	284	1,856
Alaska	0.1	0.0	0.0	0.1	2.1	2.3	0.9	5.3
Arizona	4.2	6.3	4.6	15.1	284	273	139	696
Arkansas	5.0	7.8	4.1	16.9	353	394	137	883
California	36.0	45.8	32.0	113.8	2,920	3,396	1,602	7,918
Colorado	3.4	4.7	3.9	12.1	233	267	122	621
Connecticut	4.8	6.7	13.2	24.7	664	254	226	1,144
Delaware	2.0	2.0	2.2	6.2	221	107	69	397
Dist of Columbia	0.004	N/A	N/A	0.004	0.27	N/A	N/A	0.27
Florida	15.8	21.9	17.3	55.0	1,270	1,158	628	3,056
Georgia	19.1	25.5	18.3	62.9	1,433	1,447	664	3,544
Hawaii	0.4	N/A	N/A	0.4	21	N/A	N/A	21
Idaho	2.9	4.5	2.7	10.0	181	203	80	464
Illinois	25.0	38.4	32.2	95.6	2,195	2,488	1,369	6,051
Indiana	13.6	18.1	13.1	44.9	1,022	1,009	519	2,550
Iowa	7.6	13.1	11.7	32.5	607	410	207	1,224
Kansas	4.7	8.8	5.2	18.8	352	472	173	997
Kentucky	10.4	13.0	9.6	33.1	850	596	317	1,763
Louisiana	26.0	80.4	47.0	153.3	3,205	4,473	1,556	9,235
Maine	0.6	1.1	0.6	2.2	37	50	21	108
Maryland	4.1	4.2	3.6	11.9	363	299	164	826
Massachusetts	5.9	6.5	5.9	18.3	595	484	293	1,371
Michigan	19.4	27.1	24.4	70.8	1,838	1,426	856	4,120
Minnesota	7.8	13.3	12.8	34.0	724	748	439	1,911
Mississippi	4.8	10.9	4.6	20.3	364	499	145	1,009
Missouri	15.4	25.3	18.4	59.1	1,113	1,571	753	3,436

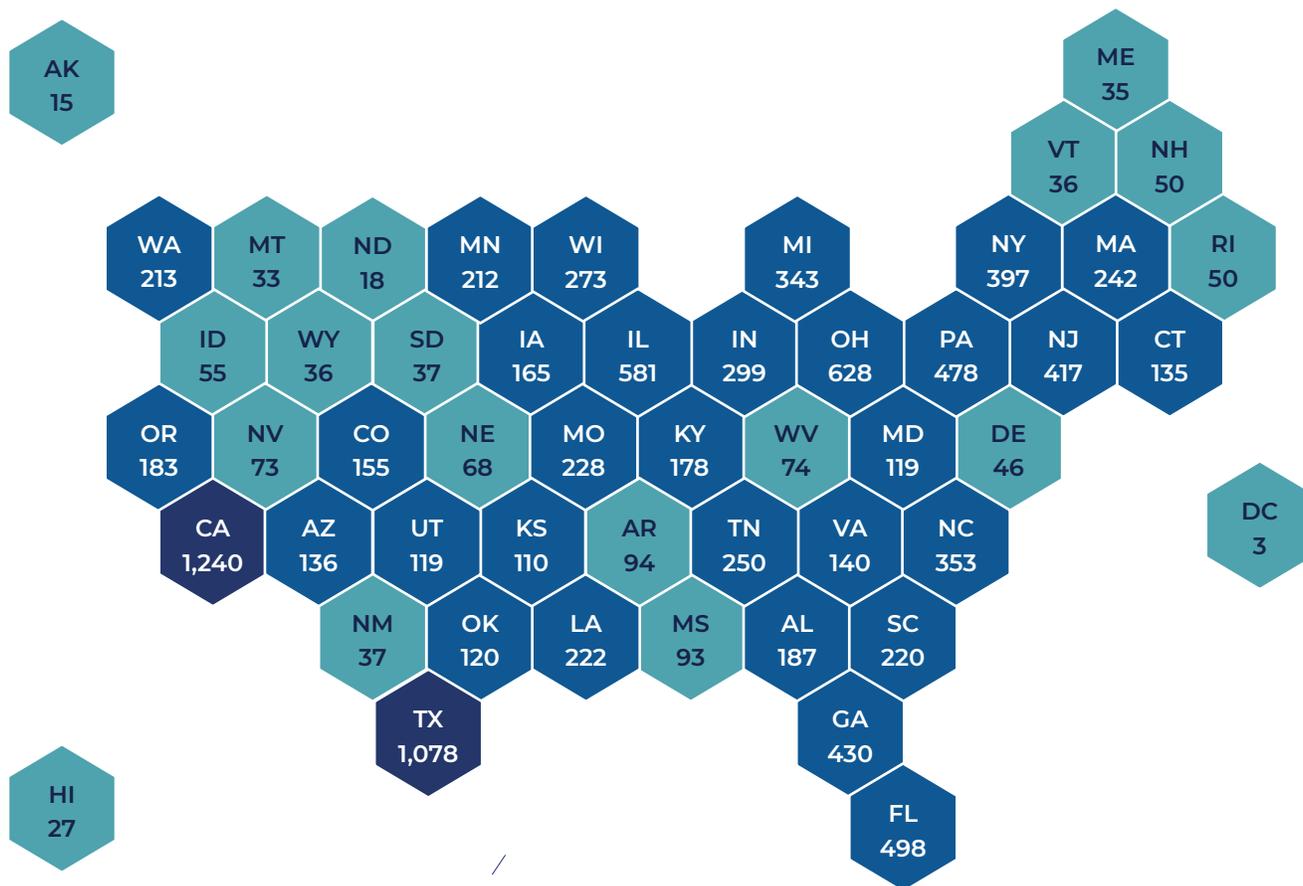
Sources: Bureau of Labor Statistics and American Chemistry Council analysis.

Table 13.2 - Jobs and Payroll Generated by the Business of Chemistry by State, 2021

State	in thousands				in \$millions			
	Direct	Supply Chain	Payroll Induced	Total Jobs	Direct	Supply Chain	Payroll Induced	Total Payroll
Montana	0.4	0.5	0.4	1.3	31	30	13	74
Nebraska	3.9	8.1	5.2	17.3	280	376	147	804
Nevada	1.5	1.3	0.9	3.7	101	62	31	193
New Hampshire	0.8	0.8	0.6	2.1	54	47	27	128
New Jersey	19.4	29.9	32.4	81.7	2,018	1,632	978	4,628
New Mexico	0.6	0.7	0.5	1.8	53	34	18	105
New York	16.2	18.5	14.8	49.5	1,403	1,423	704	3,529
North Carolina	19.1	25.7	17.7	62.5	1,611	1,339	607	3,558
North Dakota	0.7	1.4	0.7	2.8	60	82	28	170
Ohio	41.0	54.4	52.6	148.0	4,285	3,287	1,901	9,473
Oklahoma	2.9	3.9	2.6	9.4	237	216	95	548
Oregon	4.3	6.6	4.4	15.3	302	409	189	900
Pennsylvania	23.1	32.5	33.4	89.1	1,842	1,732	1,131	4,705
Rhode Island	1.5	1.1	0.8	3.4	102	61	34	197
South Carolina	17.2	17.7	13.1	47.9	1,320	764	378	2,462
South Dakota	1.1	2.5	2.8	6.3	77	51	29	157
Tennessee	23.9	29.3	23.0	76.2	2,097	1,540	949	4,587
Texas	68.1	302.5	184.2	554.8	8,255	20,571	7,139	35,964
Utah	2.8	4.3	2.8	10.0	190	217	93	500
Vermont	1.0	0.9	0.7	2.5	56	42	24	122
Virginia	12.0	11.0	9.6	32.5	974	599	348	1,921
Washington	3.9	5.1	3.2	12.2	324	358	155	837
West Virginia	6.3	10.7	7.4	24.4	326	218	117	662
Wisconsin	14.6	20.5	17.9	53.0	1,225	1,081	609	2,915
Wyoming	1.5	1.8	1.1	4.4	162	103	32	296

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

Figure 13.2 - Number of Business of Chemistry Establishments by State



U.S. CHEMICAL PRODUCTION REGIONAL INDEX

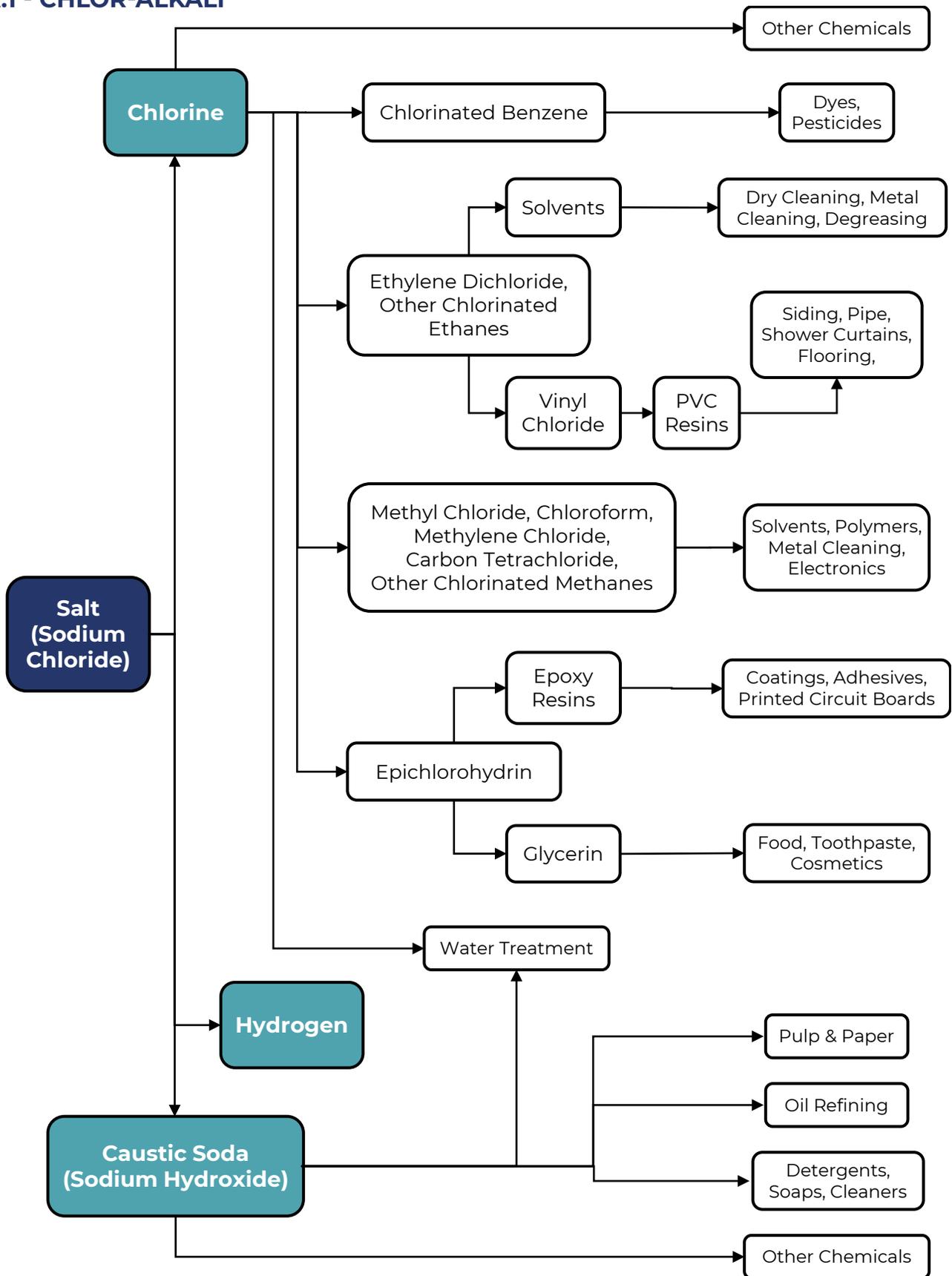
The U.S. Chemical Production Regional Index (US CPRI), which tracks chemical production activity in seven regions of the United States, was developed by Moore Economics for the American Chemistry Council. The US CPRI is comparable to the U.S. industrial production index for chemicals published by the 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 13.3 - U.S. Chemical Production Regional Index, 2011-2020

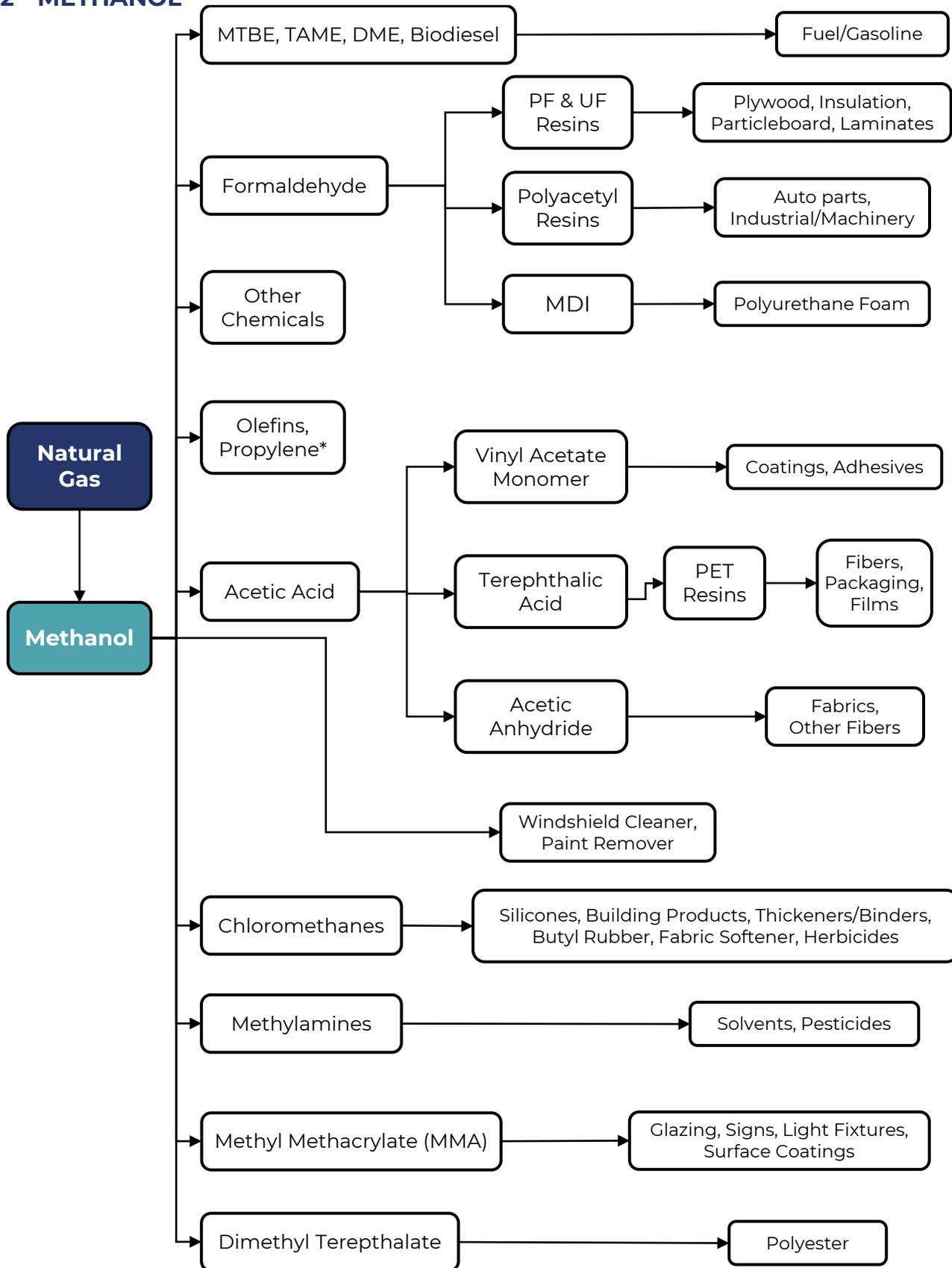
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	2012=100									
Gulf Coast	97.3	100.0	100.6	98.3	94.8	96.0	98.6	102.3	102.1	99.6
Midwest	99.7	100.0	100.0	99.2	96.1	96.6	101.4	105.5	105.4	100.8
Ohio Valley	101.2	100.0	98.3	98.8	96.7	96.7	100.7	105.0	104.9	99.7
Mid-Atlantic	102.5	100.0	97.5	98.6	97.0	96.7	100.7	105.0	105.0	99.3
Southeast	100.4	100.0	99.4	99.2	96.2	96.2	100.7	105.1	105.2	100.2
Northeast	103.6	100.0	97.0	98.3	96.4	95.4	99.1	103.5	104.1	98.3
West Coast	101.5	100.0	98.9	99.3	96.8	96.7	101.9	106.2	106.3	100.6

Source: American Chemistry Council

A.1 - CHLOR-ALKALI

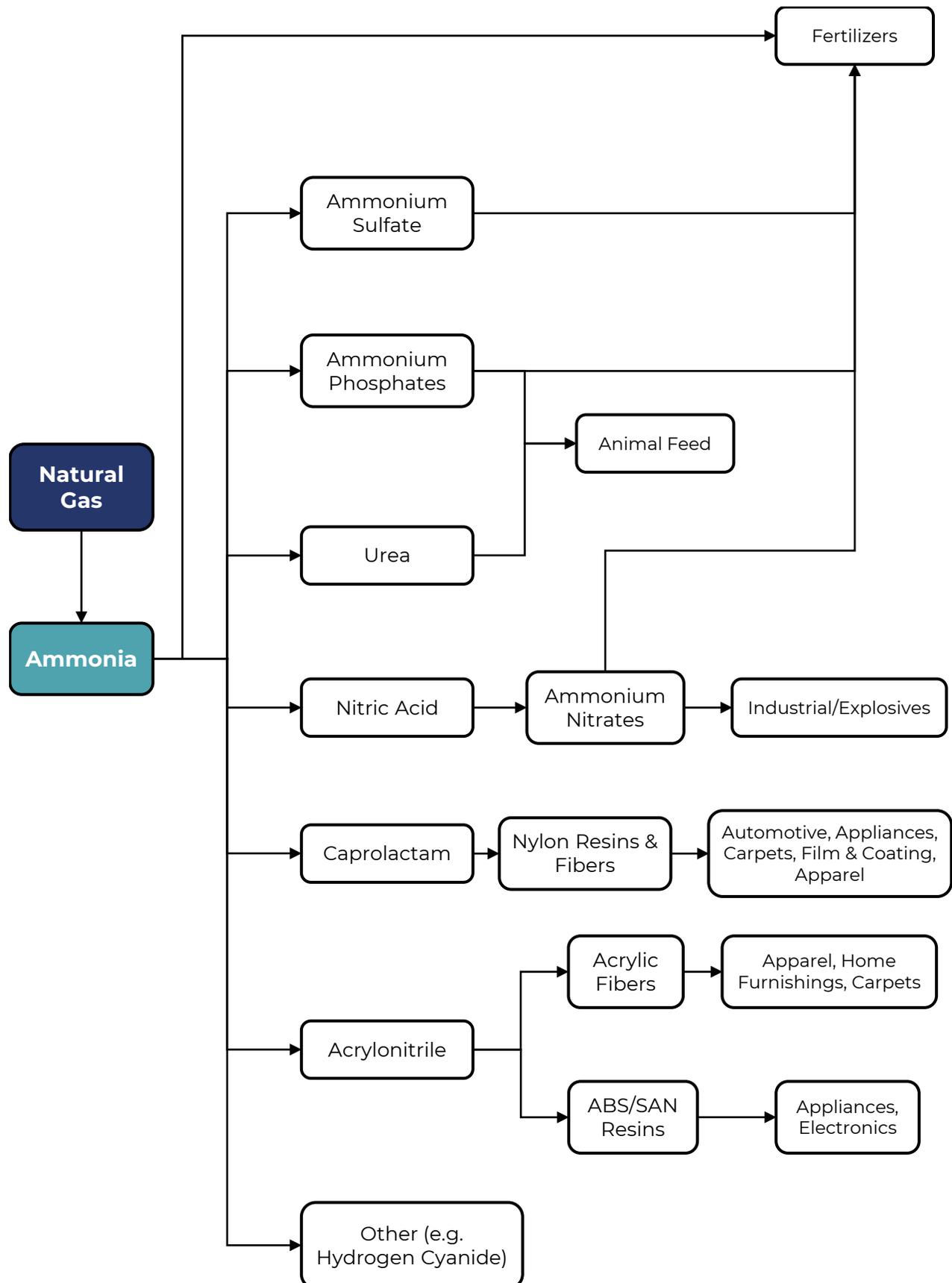


A.2 - METHANOL

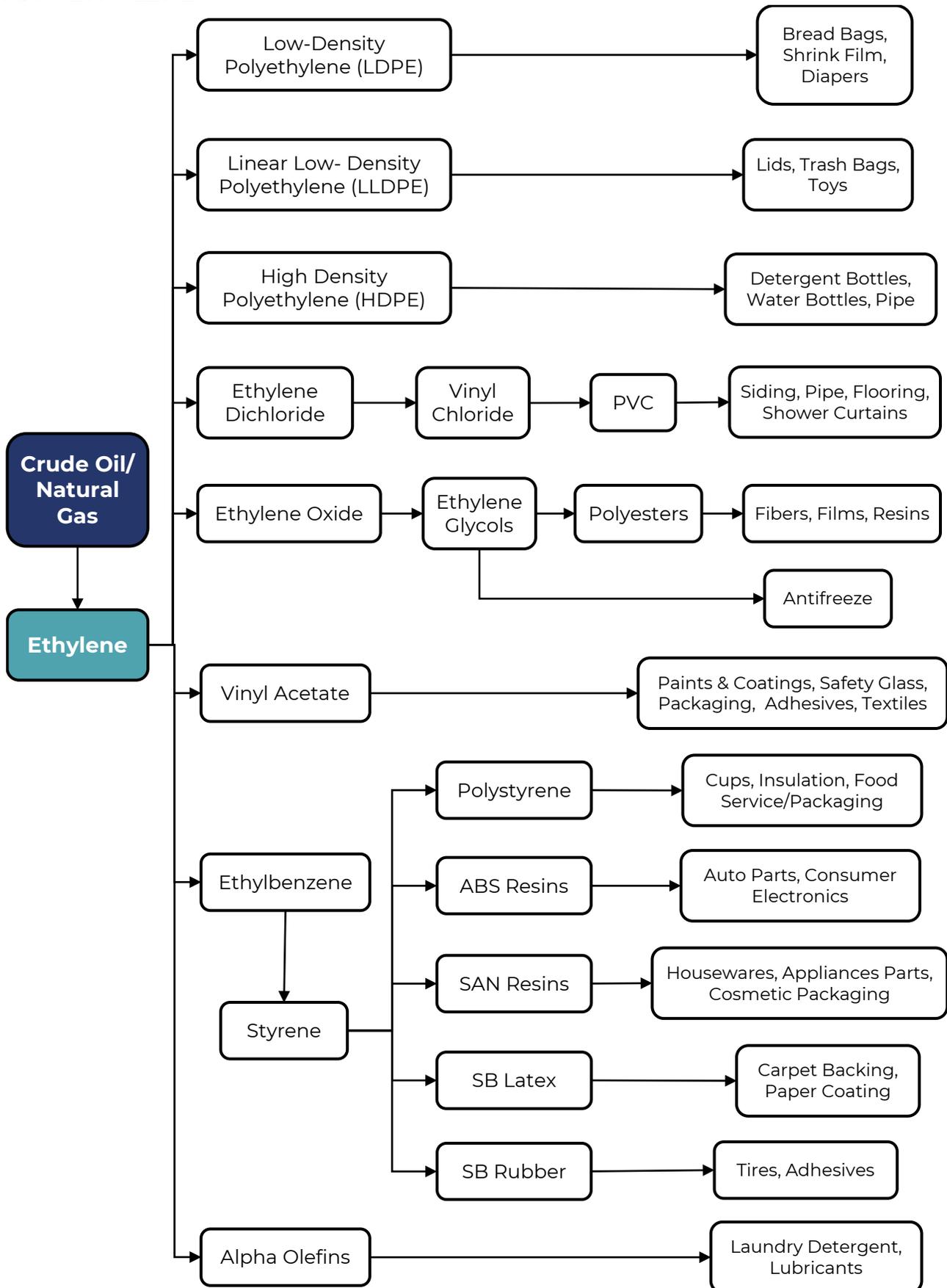


*See Propylene Chain for end uses

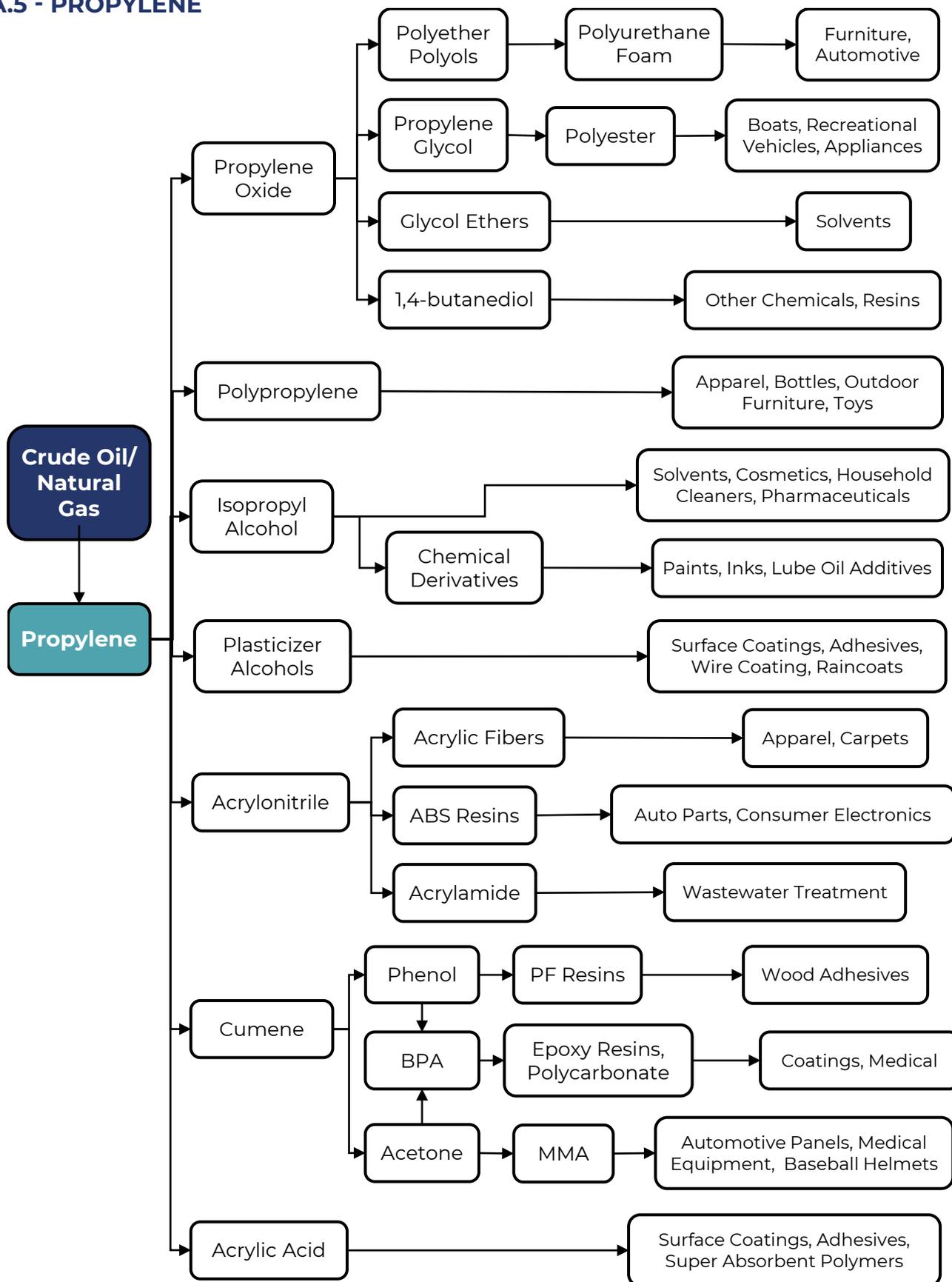
A.3 - AMMONIA



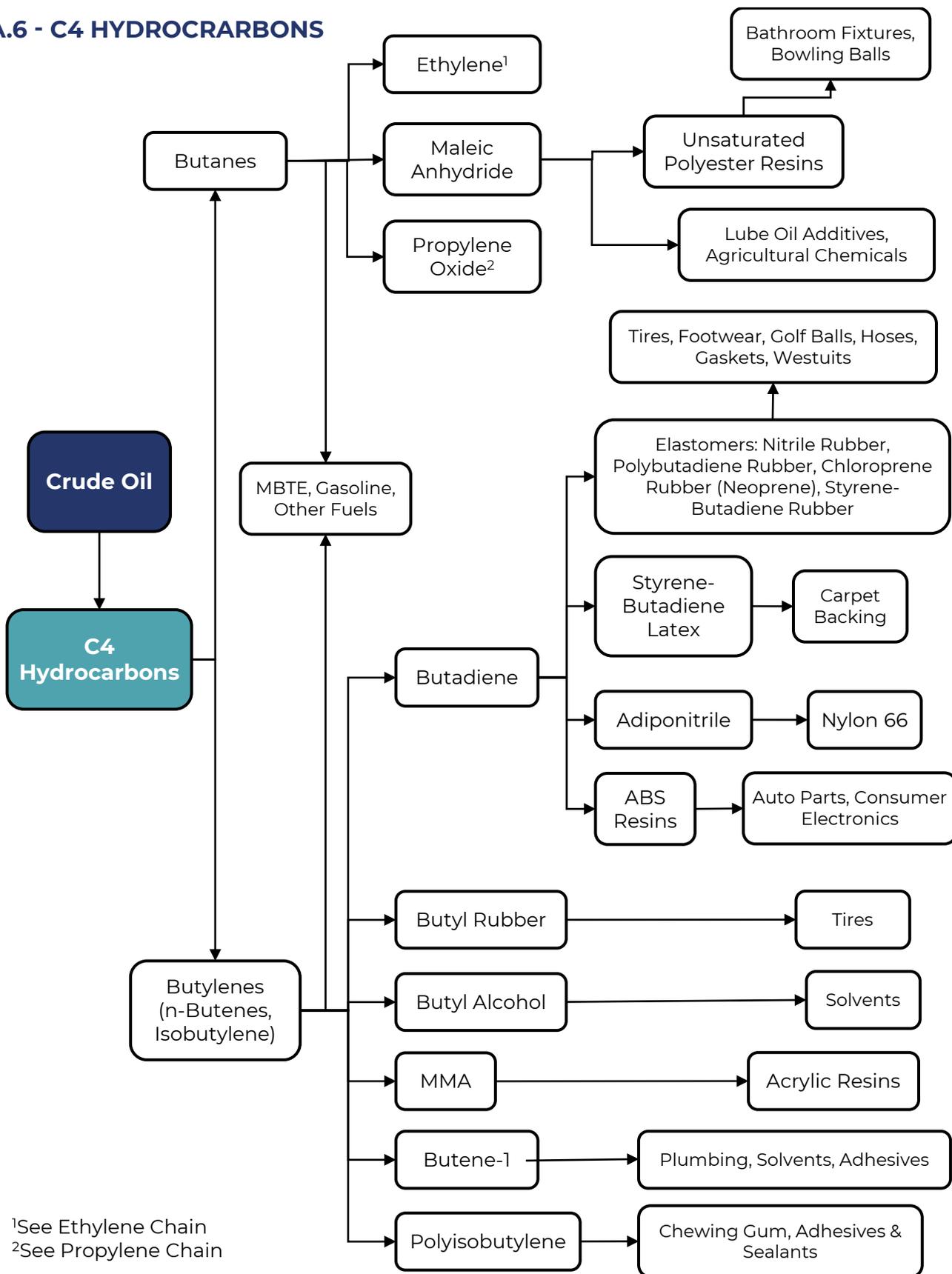
A.4 - ETHYLENE



A.5 - PROPYLENE

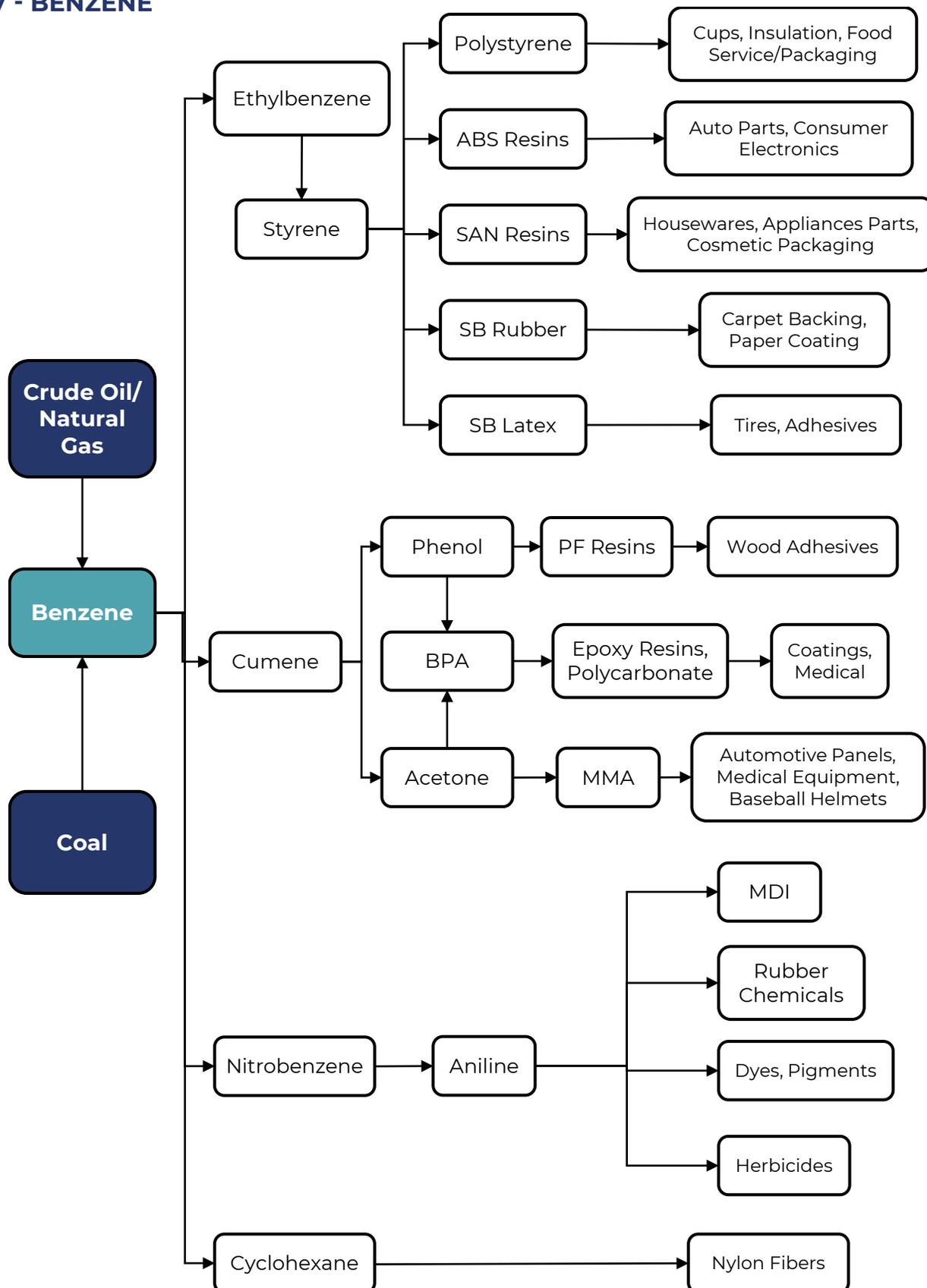


A.6 - C4 HYDROCARBONS

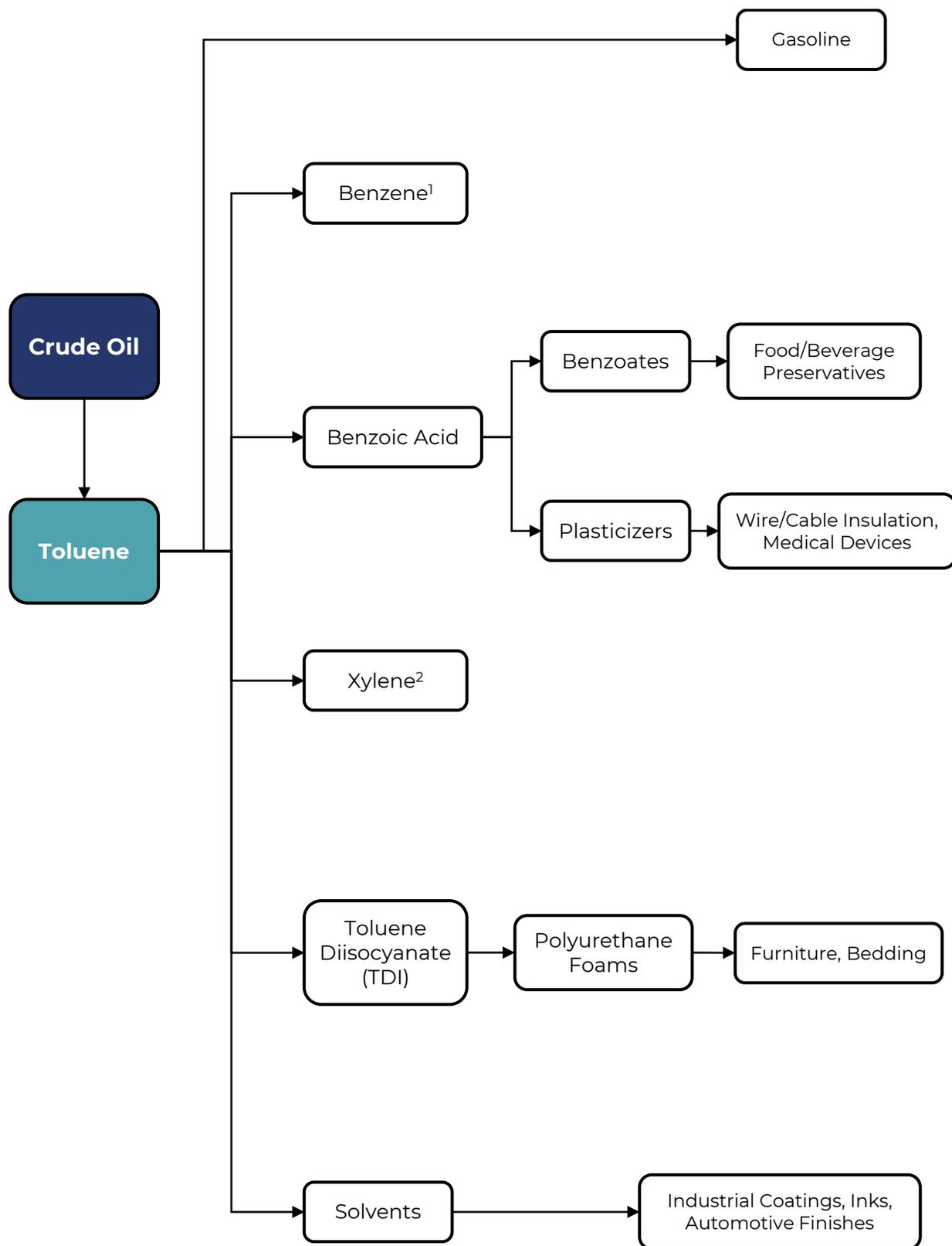


¹See Ethylene Chain
²See Propylene Chain

A.7 - BENZENE



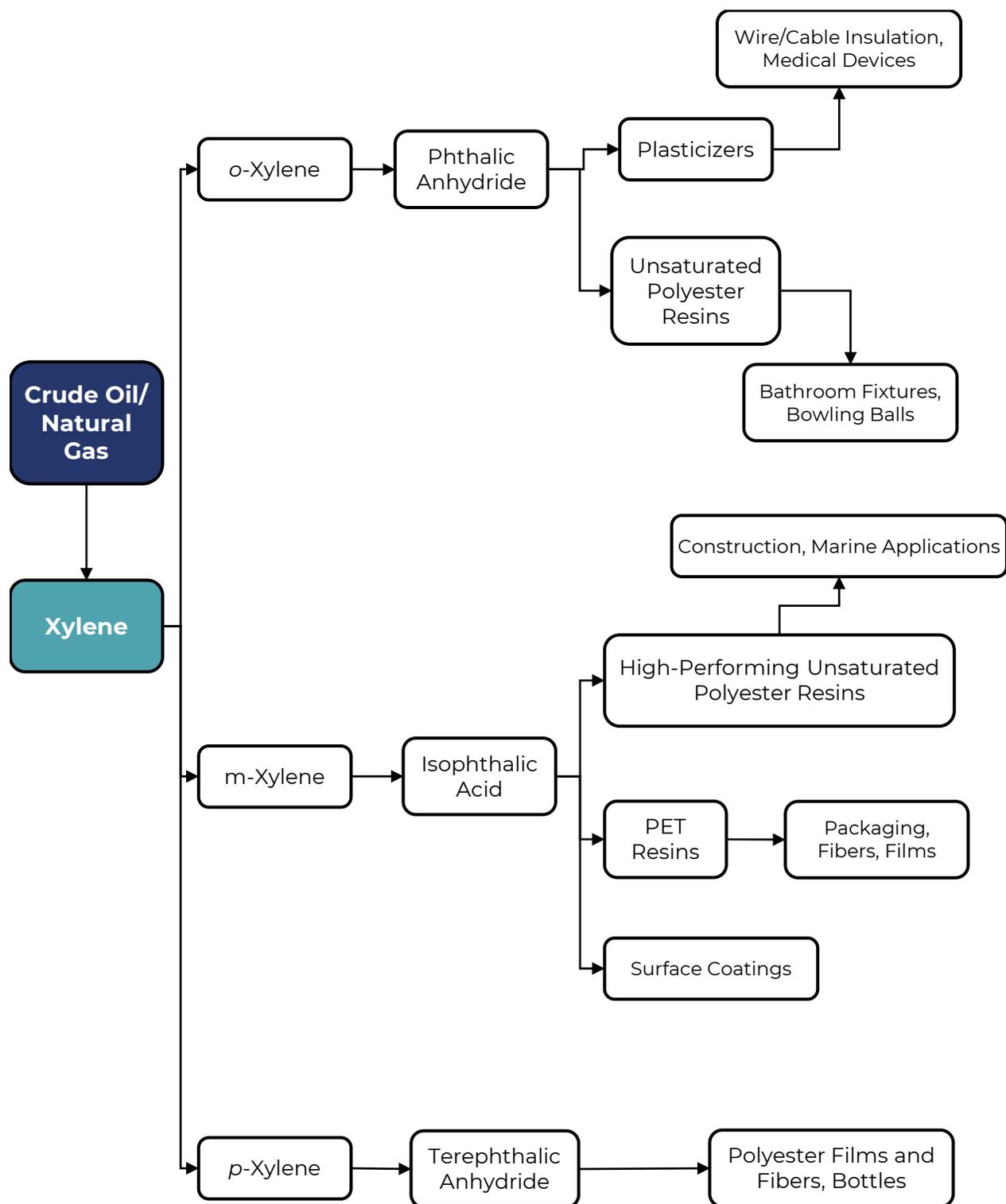
A.8 - TOLUENE



¹See Benzene Chain

²See Xylene Chain

A.9 - XYLENE



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APPENDIX B: GLOSSARY

of business and technical terms in the business of chemistry

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 ratio. See *quick ratio*.

acquisition. The purchase (or acquisition) of the assets and obligations of one company by another company.

acrylonitrile butadiene styrene (ABS). A category of thermoplastic polymer comprised of styrene, acrylonitrile and butadiene. Used in applications including appliances and automotive parts.

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.

air separation gas(es). See *industrial gas(es)*.

alcohol. An organic compound (usually liquid) containing a hydroxyl group (-OH) attached to a carbon atom. Examples include ethanol and methanol.

aldehyde. An organic compound consisting of carbon atom double-bonded to an oxygen atom, single-bonded to a hydrogen atom, and single-bonded to another atom or group. Examples include formaldehyde and butyraldehyde.

aliphatic. One of two types of hydrocarbons, an aliphatic compound is characterized by having an open-chain structure of carbon atoms. See also *aromatics*.

alkane. An aliphatic hydrocarbon with single bonds (known as saturated hydrocarbons). The simplest alkane is methane. Also referred to as paraffin.

alkene. See *olefin*.

alkyne. An aliphatic hydrocarbon that contains a carbon-carbon triple bond.

alkyl group. A hydrocarbon containing single-bonded carbon and hydrogen atoms.

alkylation. This process involves the transferring of an alkyl group from one compound to another.

aromatic. One of two types of hydrocarbons, an aromatic compound contains a cyclic (or ring) structure. Examples include benzene, toluene, and xylene. See also *aliphatic*.

asset. 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.

barrels per day (BPD). A measurement of production or consumption used for petroleum and petroleum products.

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

basic chemical. A class of chemical that tends to be produced in large volumes to chemical composition specifications that are homogeneous in nature; also called commodity chemicals.

batch process. 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). See also *continuous process*.

benzene. An aromatic compound in which 6 carbon atoms are structured in a ring. Benzene is used to manufacture other chemicals, 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. Blow molded products tend to be hollow, such as bottles.

brand equity. The value associated with a brand name. Includes a combination of factors such as awareness, loyalty, perceived quality, images, and emotions that customers associate with a given brand name.

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. Examples include butanes, butenes, butadienes, and butylenes.

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

capacity utilization. The percentage of actual output compared to total potential output.

capital employed. Also referred to as operating assets, the dollar value of fixed capital plus the dollar value of working capital less payables.

capital expenditures (CapEx). Major investments in long-term assets such as process equipment, other equipment, buildings, land, etc.

capital intensity. The volume of capital (cash) spent on physical assets, such as property and equipment, particularly in comparison to capital spent on labor.

captive use. When a product manufactured by a company is consumed internally by the company in the manufacture of other products.

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 in which a catalyst is used to increase the rate of a chemical reaction.

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 chemical. See *basic chemical*.

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.

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 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.

cost of goods sold (COGS). 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 needed to cover the cost of investment.

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 asset. An asset which can be converted into cash within a short period of time (often one year). Current assets include cash, time and demand deposits, U.S. government and other short-term securities, trade accounts and trade notes receivable, inventories, etc.

current liability. A liability (or debt) which must be paid within a short period of time (generally one year). Current liabilities include short-term loans, other short-term debt, trade accounts and trade notes payable, etc. See also *liability*.

current ratio. Current assets divided by current liabilities.

custom manufacturing. An arrangement in which a company produces a product exclusively for, and to the specifications of, 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 that removes a methyl or ethyl group from an organic compound.

debottlenecking. The process improving efficiency in the manufacturing process; may include identifying and adjusting processes or equipment that are not operating at an optimal level.

dehydrogenation. The chemical process of removing one or more hydrogen atoms from a compound. See also *hydrogenation*.

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.

distillation. A 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.

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). A 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.

economies of scale. In manufacturing, the point at which adding capacity reduces the per unit cost of output.

elastomer. A synthetic polymer with rubber-like properties that can be stretched and will retract to their original form. Examples include nitrile rubbers and polybutadiene.

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 resin. Polymers that can be used in industrial applications, often replacing metals or glass. Examples include fluoropolymers and polycarbonate.

equity capital. Funds raised from within a company or through the sale of ownership of the company.

ester. A simple organic compound usually formed by the chemical reaction between an acid and an alcohol. Examples include isobutyl acetate and *n*-butyl acetate.

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

ethane. A 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 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.

EVA copolymer. The copolymer of ethylene and vinyl acetate that approaches elastomeric materials in softness and flexibility yet can be processed like other thermoplastics.

expandable polystyrene (EPS). Small beads of polystyrene, generally in a foam. End-use applications include foam insulation and drinking cups.

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.

fatty alcohols. Long-chain alcohols with 6 to 40 carbon atoms. Typically used in detergents and surfactants.

feedstock. In chemistry, the term is mainly used to refer to a gaseous or liquid hydrocarbon raw material (e.g., ethane, propane) used to manufacture petrochemicals.

finished good. The final product of a manufacturing operation produced for commerce.

fine chemical. An undifferentiated intermediate, medicinal or aroma chemical typically produced in low volumes.

fixed cost. An expense that does not vary with output. Examples include rent and salaries.

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*.

free cash flow. A measure of financial performance 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 fraction 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.

group. Elements that make up a column in the periodic table.

Henry Hub. 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 car. A rail car designed for loading and unloading of plastic resins or other powder or pellet material.

hydrocarbons. A compound 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 called “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 gas(es). 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. Also called air separation gases.

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 into a mold. The plastic is then cooled and solidifies. Common uses include yogurt containers and bottle caps.

intangible asset. An item of value that have no physical form, such as patents, copyrights, intellectual property, knowledge, and brand.

intermediate. 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.

intellectual property (IP). 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 has either a positive or negative electrical charge.

joint venture (JV). A partnership between two or more companies to undertake a major project or business.

ketone. An organic compounds derived from secondary alcohols. These compounds contain carbonyl groups that are bonded to alkyl groups. Acetone is an example of a ketone.

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

liability. A company's debt and/or financial obligation.

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 gas (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. Liabilities such as loans from banks, leases, other long-term debt, etc. that must be paid after one year.

loss. When costs and expenses exceed revenues.

manufactured fiber. A fiber made from sythetic materials. Also called synthetic fiber.

market research. The analysis of markets to determine opportunities and challenges.

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.

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. Examples include ethylene and propylene.

monopoly. A market in which there is no competition.

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 Examples include methane, ethane, and propane.

natural gas liquids (NGLs). 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 received from investments, either from earnings on the investment or from capital gains on the investment.

nonwoven. Textiles which are neither woven nor knit; 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.

olefin. An aliphatic hydrocarbon that contains double bonds. Double bonds are more reactive than the than the single bonds found in most fractions of crude oil and natural gas. Also called alkenes, examples of olefins include ethylene and propylene.

oligomer. A short chain polymer 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 chemical. A chemical compound that contains carbon.

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.

patent. Government authority (or license) allowing an individual or company exclusive rights to a product or process for a set period of time.

performance chemical. See *specialty chemical*.

petrochemical. Substance derived from petroleum or natural gas.

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

plastic resin. An organic polymer that, when soft or liquid, can be shaped or molded into a form that hardens as it cools. The final form may be rigid or flexible depending on the type of polymer.

plasticizer. A substance that is added to plastic resin to impart certain functionality.

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. Polymers 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.

polyolefin. A polymer made from light olefins (linear unsaturated hydrocarbons). The most common polyolefins are polyethylene and polypropylene.

polypropylene (PP). A polymer made from many propylene molecules linked together.

polystyrene (PS). A polymer 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 such as egg cartons.

polyvinyl chloride (PVC). A polymer made from the polymerization of vinyl chloride. PVC is used in vinyl siding, pipe and fittings, conduit, window profiles, and vinyl shower curtains.

product differentiation. The characteristics - either real or perceived - that set a product apart from other similar products.

product life cycle. A theoretical model of what happens to sales and profits for a product or class of products over time.

profit. The difference between what a company spends and what it earns.

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 less inventories divided by current liabilities. Also called acid-test ratio.

retained earnings. Income after taxes, less the dividends paid.

revenue. 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.

salt. A compound formed by the reaction of acids and bases.

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).

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.

solvent. A substance that dissolves another substance.

specialty chemical. A low-volume, high-value compound sold on the basis of what it does (i.e., its performance), not what it is. Also known as performance chemicals.

supply chain management. The comprehensive process of minimizing inventory and moving goods through the channels of distribution most effectively and efficiently.

surfactant. A compound that reduces the surface tension between two substances. Surfactants include detergents, emulsifiers, wetting agents, etc.

synthetic fiber. See *manufactured fiber*.

synthesis gas. A mixture of carbon monoxide and hydrogen used for manufacturing certain petrochemicals. It is generally produced by steam reforming of hydrocarbons such as methane.

thermoplastic. A type of plastic resin that can be repeatedly softened by heat and re-cooled.

thermosets. A type of plastic resin that, once cooled into its final form, cannot be resoftened or reshaped.

toll manufacturing. An arrangement in which a company produces a product for a customer using the customer's process.

toluene. A liquid compound containing seven carbon atoms, is an aromatic and is a basic building block for industrial chemicals.

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.

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 cost. A cost that varies 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.

worldscale 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.

xylene. 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.

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