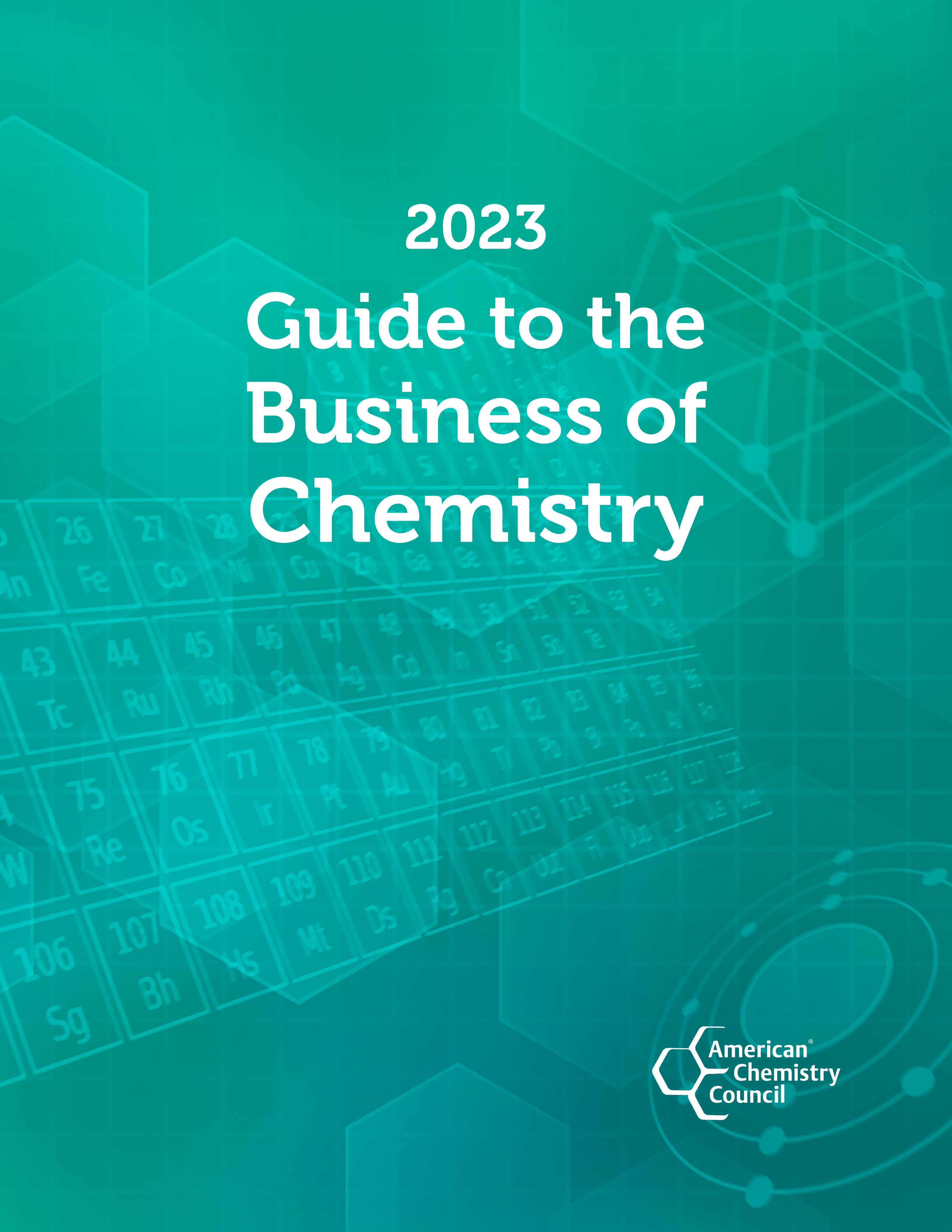

2023

Guide to the Business of Chemistry

American Chemistry Council

2023

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American®
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Dear Colleagues,

The *Guide to the Business of Chemistry* provides valuable insight into the state of our industry and how it is interwoven with the economy and our everyday lives.

Year after year, the business of chemistry holds a bright spot for the U.S. and global economy. It doesn't "just happen." ACC members put in the work—innovating at the scale needed to address global challenges, reducing emissions, protecting air and water, and improving safety.

Our industry supports a vast supply chain and creates economic activity across the country. With $639 billion worth of shipments in 2022, the United States accounts for 11% of the world's total chemical production. American chemistry comprises 1.1% of US GDP and provides more than half a million jobs, with average pay of more than $92,000 per year. For every chemistry industry job, more than six jobs are supported elsewhere in the economy.

In 2022, the U.S. chemical industry was one of the world's largest exporters at $179 billion, accounting for 10% of all U.S. goods exports. The industry has maintained a large and growing trade surplus, reaching $24 billion last year. Increasing exports and growing trade with our partners is critical to the success of the U.S. chemical producers, and results in tremendous benefits for the broader economy.

The chemical industry is also a leader in capital investment, with more than $26 billion in new spending in 2022. These investments include projects to expand capacity in order to meet growing demand and make industry operations more sustainable. Our industry is expanding technological frontiers, with $13.4 billion in R&D investment in 2022. 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.

As they did last year, U.S. chemical manufacturers continue to face tremendous challenges from persistent inflation, competition overseas, and a dramatic increase in regulations at home. Despite tremendous growth in recent years, the United States is second to China in global chemical production.

This year's *Guide to the Business of Chemistry* includes a new chapter examining the importance and impact of regulations. Our industry and many of our downstream partners are wrestling with a massive increase in regulations. Chemical manufacturing is the most heavily regulated subsector of manufacturing with more than one million restrictions in place that apply directly to our operations, a total that has doubled in the past 20 years. On top of this, there are a great number of planned rules targeting chemical manufacturing that will increase the compliance costs by 50%, bringing the annual compliance costs for our industry up to roughly $4 billion a year.

This massive rise in regulations is handicapping our industry's ability to create products that are important to national priorities, including the manufacture of semiconductors and electric vehicles in America. This regulatory overload threatens to offshore jobs, production, and supply chains by weakening the ability of the United States to compete with international rivals – such as China. Unless policymakers take a different approach to how they create and apply regulations, critical chemistries will suffer—and the important products chemistry supports will suffer as well.

I hope this year's *Guide to the Business of Chemistry* will help increase everyone's understanding of our industry and why it's important to a stronger economy and a brighter future.

Sincerely,

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

BPA - Bisphenol A

BPD - Barrels per day

BTU - British thermal unit

BTX - Benzene, toluene and xylenes.

CIF - Cost, Insurance and Freight

DME - Dimethyl ether

DMT - Dimethyl terephthalate

EBITDA - Earnings before Interest, Taxes, Depreciation and Amortization

EDC - Ethylene dichloride

EG - Ethylene glycol

EO - Ethylene oxide

EPDM - Ethylene propylene diene monomer

EPS - Expandable polystyrene

EV - Electric vehicle

EVA - Ethylene-vinyl acetate

EVOH - Ethylene-vinyl alcohol

FOB - Free On Board

GHG - Greenhouse gas

GMO - Genetically modified organisms

HDPE - High-density polyethylene

HMDA - Hexamethylene diamine

JV - Joint Venture

LDPE - Low-density polyethylene

LLDPE - Linear low-density polyethylene

LNG - Liquefied natural gas(es)

LPG - Liquefied petroleum gas(es)

MDI - Methylene diphenyl diisocyanate

MEG - Monoethylene glycol

MMA - Methyl methacrylate

MTBE - Methyl tertiary butyl ether

NAICS - North American Industry Classification System

NGLs - Natural gas liquids

OEM - Original equipment manufacturer

PC - Polycarbonate resins

PDH - Propane dehydrogenation

PE - Polyethylene

PET - Polyethylene terephthalate

PF Resins - Phenol formaldehyde resins

PMMA - Polymethyl methacrylate

PO - Propylene oxide

PP - Polypropylene

PS - Polystyrene

PTA - Purified terephthalic acid

PP&E - Property, plant, and equipment

PVC - Polyvinyl chloride

PX - Paraxylene

ROW - Rest of the world

SAN - Styrene acrylonitrile

SB Latex - Styrene-butadiene latex

SBR - Styrene-butadiene rubber

TAME - Tertiary-amyl methyl ether.

TPE - Thermoplastic elastomer

UF Resins - Urea formaldehyde resins

USGC - United States Gulf Coast (includes the states of Texas, Louisiana, Mississippi, Alabama, and Florida)

VAM - Vinyl acetate monomer

VCM - Vinyl chloride monomer

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 ACCExchange (ACC member platform) or from the ACC Store at https:\\store.americanchemistry.com.

The American Chemistry Council has made reasonable efforts to ensure the information contained in this reference book is complete and accurate. However, ACC expressly disclaims any warranty or guarantee, whether express or implied, associated with this reference book or any of the data contained herein and assumes no liability or responsibility for any use, or the results of such use, of any information or data disclosed in this material.

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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:

Cleaning and Disinfection

Chemistry contributes around 75% of the value of material inputs in cleaning compounds such as hand sanitizers, surface cleaners, dish soap, and laundry detergent, to name a few. Chlorine disinfectants are 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

In 2021, a typical automobile contained over $4,000 worth of chemistry, including 411 pounds of plastics and polymers composites, 219 pounds of synthetic rubber, 99 pounds of textiles, and 45 pounds of 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 Automobiles*, American Chemistry Council, March 2023). 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. Given their light weight, plastics and polymer composites can help to offset added weight from the introduction of autonomous and advanced propulsion mechanisms, including batteries and hydrogen fuel cells. Additionally, the desirable conductive properties of plastics and polymer composites make them sought-after materials for various components of electric vehicle batteries, including battery casings and enclosures. In addition to the chemistry used directly in electric vehicles, chemistry is a key component of the associated infrastructure needed to keep electric vehicles charged. Plastics and other products of chemistry can be used for a wide array of components within the larger structure of alternative fueling stations and electric vehicle charging ports, such as charger housings, covers over front displays or touchscreens, lenses, connectors, light guides, and other components.

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 membrane separators and electrolytes. 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 (including measles and polio) 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.

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 essential materials.

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 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.

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, generating several rounds of economic spending and re-spending.

Table 2.1 - U.S. Business of Chemistry Industry Snapshot, 2022

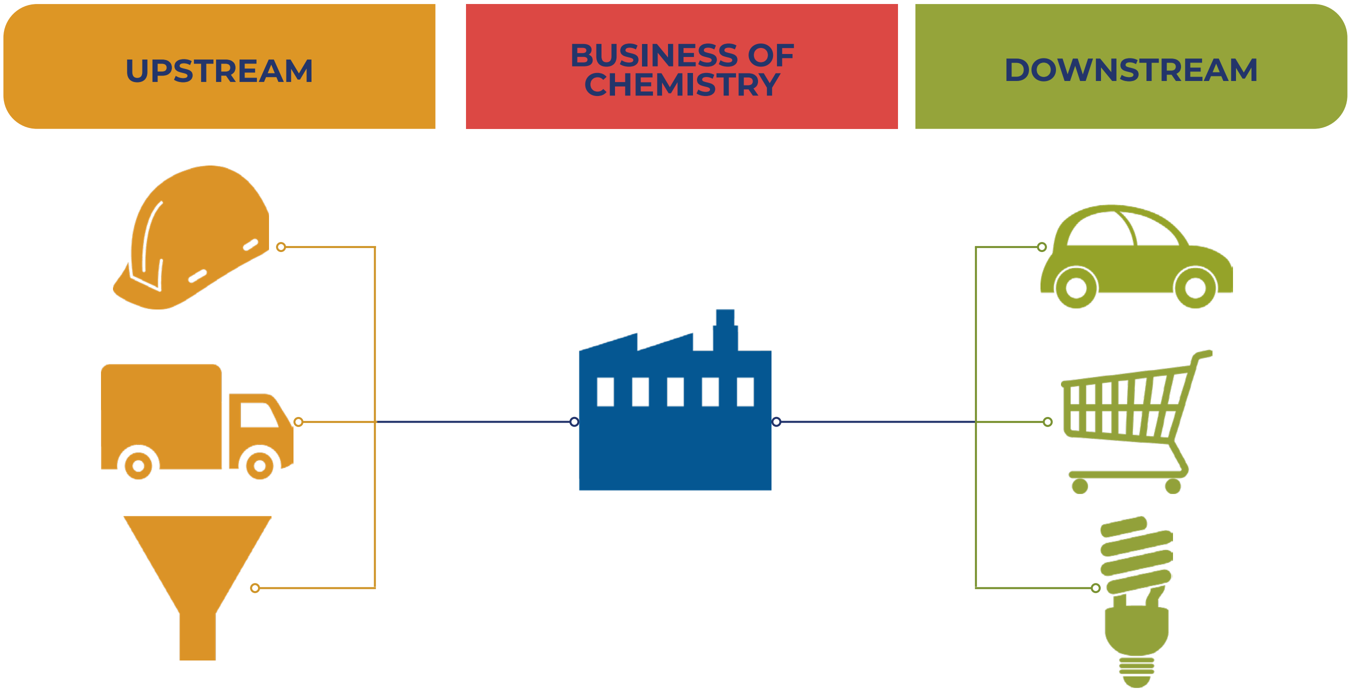
Jobs (in thousands)		**Expenditures (in billions)**	
Direct Jobs	555	Total Wages & Salaries	$53.5
Supplier Jobs	1,849	Benefits	$16.3
Expenditure-Induced Jobs	1,703	**Total Compensation**	**$69.8**
Total Jobs	**4,107**		
Multiplier*	**6.4**	**Value-Added**	**$270.0**

*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.

Figure 2.1 - Upstream and Downstream Operations



DOWNSTREAM IMPACTS

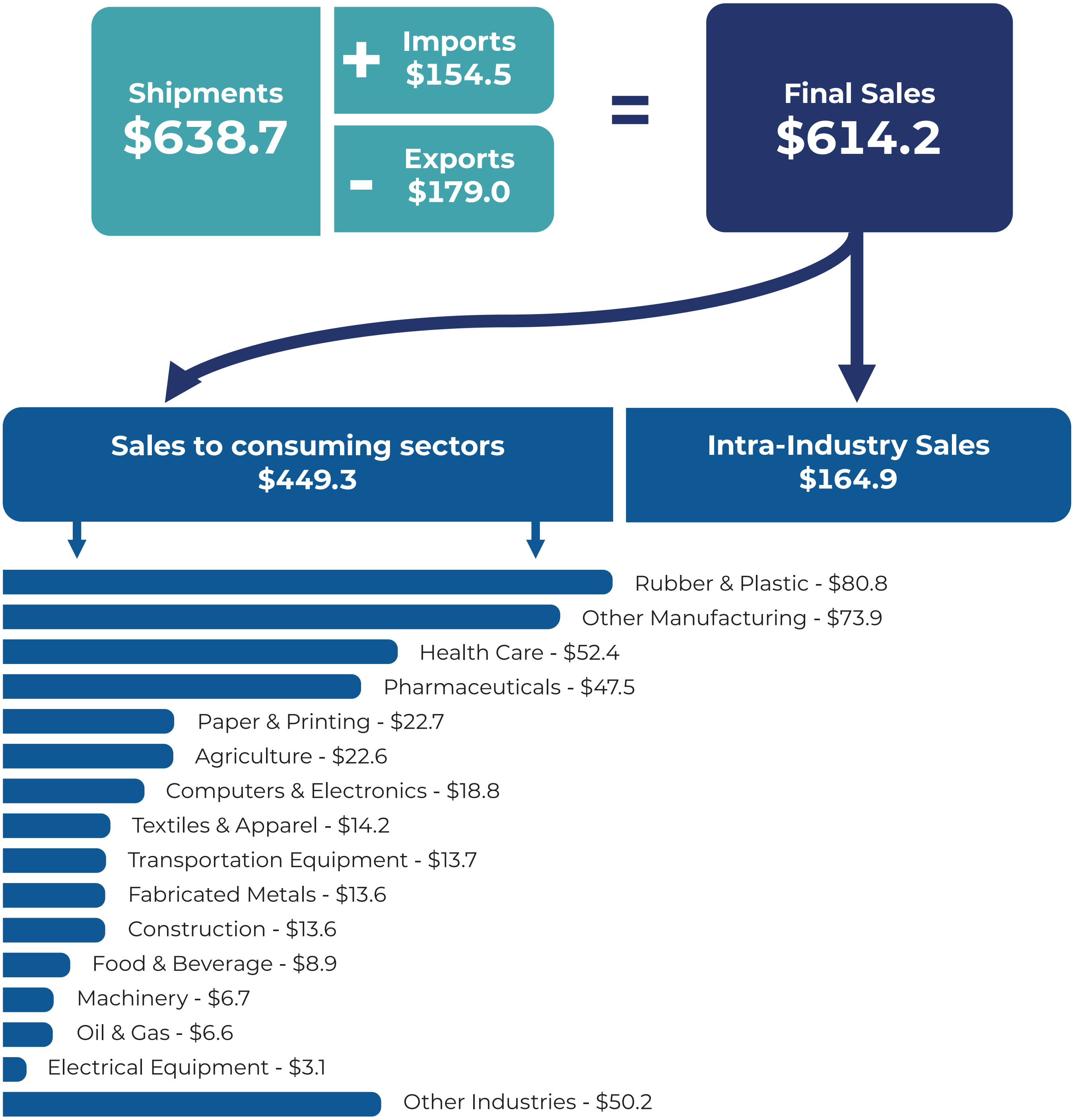
The impact of chemistry on the U.S. economy is much more extensive than standard output and job multipliers derived using input-output analysis indicate. While the former looks only at the jobs directly related to the industry, the latter primarily focuses on supplier relationships rather than downstream 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, automobiles and other 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, 2022 (in billions)



[1] IMPLAN 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, 2022

Industry	Employment (in thousands)	Payroll (in $billions)	Value-Added (in $billions)
Business of Chemistry	**555**	**$53.5**	**$270.0**
Intermediate Goods			
Agriculture	811	25.0	243.5
Oil & Gas Extraction and Mining	556	65.6	371.2
Water and Sewage Treatment	56	4.1	22.0
Textiles & Fabrics	96	5.3	11.5
Engineered Wood Products	85	5.6	19.2
Paper & Paper Products	362	27.7	65.6
Petroleum Products	104	13.8	233.7
Rubber & Plastic Products	747	47.8	95.6
Nonmetallic Mineral Products	415	28.8	75.0
Aluminum	60	4.7	15.7
Windows & Doors	71	4.3	7.5
Metal Coating	128	7.6	17.6
Industrial Machinery	130	13.2	20.4
Commercial & Service Industry Machinery	90	7.8	15.2
Ventilation & HVAC Equipment	142	9.4	26.2
Semiconductors & Electronic Components	385	52.8	55.2
Electrical Equipment & Components	335	26.7	59.2
Total – Intermediate Goods	**4,573**	**$350.2**	**$1,354.2**
Consumer and Other Final Products			
Food, Beverage & Tobacco	2,012	116.4	326.7
Textile Mill Products	105	4.9	11.9
Apparel & Leather Products	119	6.4	9.3
Printing	377	21.6	39.7
Pharmaceuticals	344	44.7	186.1
**Book & Periodical Publishing and Software	160	27	83.0
Computers & Electronics	701	106.2	282.5
Household Appliances	69	4.7	14.4
Mobile homes	32	2.0	2.7
Light Vehicles & Parts	999	72.0	172
Aerospace	499	56.8	87.3
Ship & Boatbuilding	150	10.7	22.6
Furniture & Fixtures	377	20.3	34.2
Medical Equipment & Supplies	334	28.3	62.3
Other Miscellaneous Manufacturing	292	18.7	111.5
Total – Consumer & Other Final Products	**6,570**	**$540.7**	**$1,445.8**

Table 2.2 - Industries Dependent on the Business of Chemistry, 2022

Industry	**Employment (in thousands)**	**Payroll (in $billions)**	**Value-Added (in $billions)**
Construction			
Residential Building Contractors	914	63.9	123.5
Nonresidential Building Contractors	832	76.4	178.0
Specialty Trade and Heavy Contractors	5,964	425.8	705.5
Total - Construction	**7,710**	**$566.1**	**$1,007.0**
Wholesale Distribution			
Chemical Wholesalers	147	15.5	57.0
Druggist Goods Wholesalers	254	38.3	125.7
Farm Supplies	118	9.4	12.1
Paint Wholesalers	23	1.7	1.8
Total - Wholesale Distribution	**542**	**$64.9**	**$196.6**
Services			
Testing Labs	177	15.9	40.1
Specialized Design Services	150	12.1	25.4
Scientific R&D Centers	887	143.5	198.9
Photographic Services	47	1.9	6.3
Veterinary Services	452	23.3	37.9
Facilities Support Services	156	9.1	22.0
Document Preparation Services	40	1.9	5.5
Services to Buildings and Dwellings	22	86.8	180.7
Waste Management & Remediation Services	475	33.7	72.3
Health Care Services	16,171	1,112.0	1,672.2
Auto Repair	973	48.1	102.9
Personal and Laundry Services	1,473	52.7	164.7
Total - Services	**21,022**	**$1,541.0**	**$2,528.8**
Total – Industries Dependent on Chemistry	**40,417**	**$3,063**	**$6,532**
Total U.S. – All Sectors	149,987	$10,497	$25,463
Industries Dependent on Chemistry, as a Percent of U.S. Totals	26.9%	29.2%	25.7%

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.

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 is 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.

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 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.

Table 3.1 - Business of Chemistry Summary, 2018-2022

	2018	2019	2020	2021	2022
			in billions		
Shipments	$548.8	$510.4	$463.9	$583.8	$638.7
Capital Expenditures	$24.1	$27.0	$22.7	$24.8	$26.1
Funds for Research & Development	$11.3	$10.5	$10.1	$12.8	$13.4
Exports	$140.1	$135.5	$124.7	$153.4	$179.0
Imports	$109.0	$101.9	$96.8	$128.4	$154.5
Trade Balance	$31.1	$33.7	$27.9	$25.1	$24.5
Production Index (2017=100)	99.6	94.2	89.7	93.4	95.5
Price Index (2017=100)	104.9	104.3	101.7	119.5	137.7
Employment (thousands)	538	544	531	537	555

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 ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

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.

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.*

Figure 3.1 - Business of Chemistry Shipments by Segment, 2013-2022

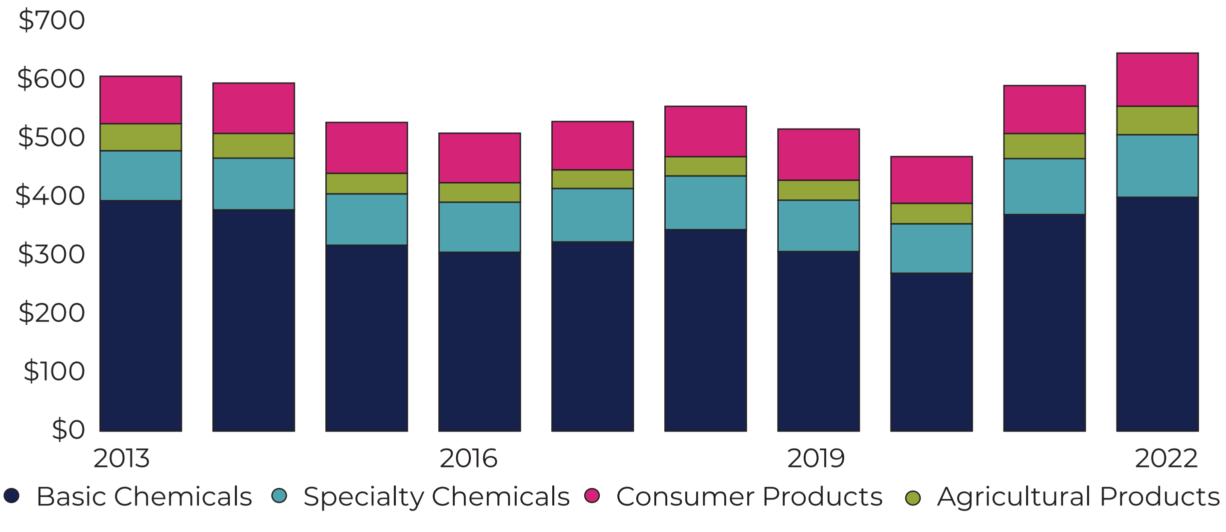


Table 3.2 - Business of Chemistry Shipments by Segment, 2018-2022

	2018	2019	2020	2021	2022
			in $millions		
Chemicals	**548,807**	**510,424**	**463,886**	**583,840**	**638,738**
Basic Chemicals	340,379	303,328	266,618	365,812	394,926
Inorganic Chemicals	49,791	47,596	44,648	50,329	55,852
Bulk Petrochemicals & Intermediates	180,896	158,703	134,104	202,427	222,670
Plastic Resins	94,853	82,768	76,545	99,971	101,971
Synthetic Rubber	8,396	7,985	6,297	7,531	8,435
Manufactured Fibers	6,444	6,275	5,024	5,554	5,998
Specialty Chemicals	90,652	86,875	83,491	94,587	105,765
Coatings	27,352	26,382	26,207	29,493	31,558
Other Specialties	63,300	60,493	57,284	65,094	74,207
Agricultural Chemicals	32,590	33,609	34,627	42,323	48,206
Consumer Products	85,186	86,612	79,149	81,118	89,841
Pharmaceuticals	209,256	221,183	228,363	248,438	271,045
Chemicals & Pharmaceuticals	758,063	731,607	692,249	832,277	909,783

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 ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

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.

The North American Industry Classification System is a classification system that was developed by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia. According to the Bureau of Labor Statistics, "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).

Table 3.3 - Industrial Production Indices, 2018-2022

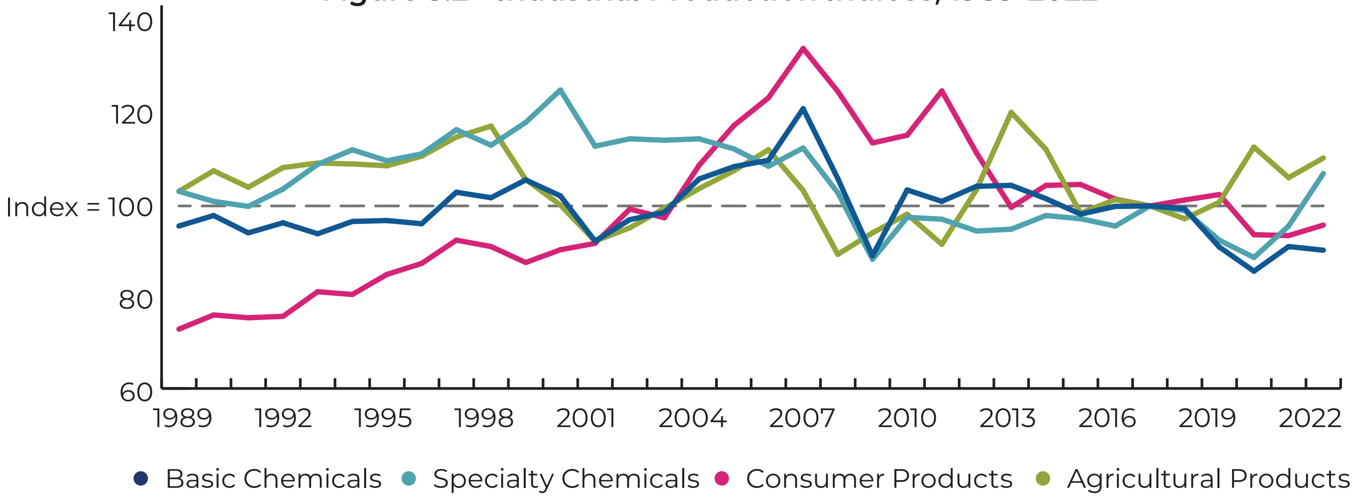
	2018	2019	2020	2021	2022
			2017=100		
Chemicals	**99.6**	**94.2**	**89.7**	**93.4**	**95.5**
Basic Chemicals	99.4	91.0	85.7	91.1	90.3
Inorganics	95.3	88.4	86.4	89.1	96.4
Bulk Petrochemicals & Intermediates	100.2	91.6	85.0	94.3	89.6
Specialty Chemicals	99.0	92.5	88.7	95.6	107.1
Agricultural Chemicals	97.2	100.8	112.9	106.2	110.5
Consumer Products	101.3	102.5	93.7	93.5	95.8
Pharmaceuticals	97.1	102.1	104.3	109.7	112.2
Chemicals & Pharmaceuticals	**98.6**	**97.3**	**95.3**	**99.7**	**101.9**

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 ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

Figure 3.2 - Industrial Production Indices, 1989-2022



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, 2018-2022

	2018	2019	2020	2021	2022
			2017=100		
Chemicals	**104.9**	**104.3**	**101.7**	**119.5**	**137.7**
Basic Chemicals	106.7	104.6	100.0	122.9	143.0
Inorganics	110.3	113.5	109.7	121.4	156.3
Bulk Petrochemicals & Intermediates	106.3	102.5	97.2	121.6	143.5
Specialty Chemicals	102.7	105.2	105.6	112.2	128.8
Agricultural Chemicals	107.3	107.5	101.5	126.6	170.7
Consumer Products	102.0	102.9	103.1	106.2	116.7
Pharmaceuticals	103.8	106.9	108.6	110.3	114.2
Chemicals & Pharmaceuticals	**104.5**	**105.2**	**104.1**	**116.3**	**129.6**
Feedstocks	**129.2**	**79.3**	**68.7**	**169.7**	**194.8**
Chemical Exports	**105.5**	**104.1**	**100.8**	**123.1**	**130.5**
Chemicals Imports	**105.6**	**102.5**	**99.0**	**116.6**	**134.6**

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 ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

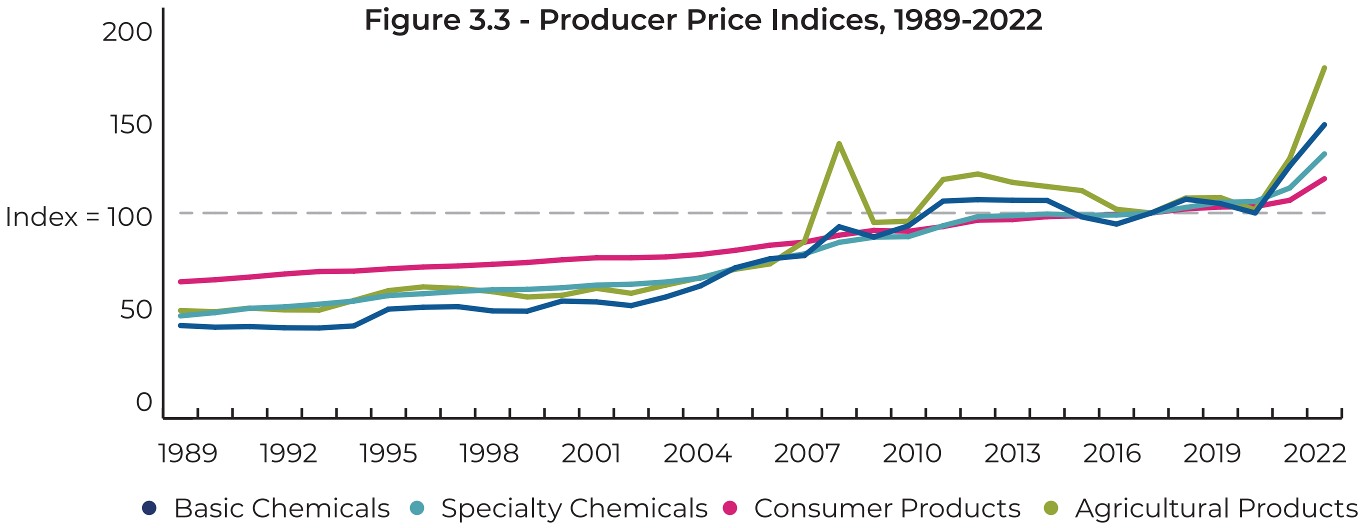


Figure 3.3 - Producer Price Indices, 1989-2022

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, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Current Ratio	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.1
Quick Ratio	0.8	0.9	0.8	0.9	0.8	0.8	0.7	0.9	0.8	0.8
Cash Ratio	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2
Debt-to-Equity Ratio	1.5	1.5	1.7	1.7	1.6	1.4	1.4	1.5	1.4	1.4
Inventory Turnover	1.8	1.8	1.6	1.7	1.6	1.6	1.5	1.6	1.8	1.6
Operating Margin (%)	9.7	10.9	11.2	10.7	10.0	10.0	9.2	9.0	12.5	11.9
Profit Margin (%)	10.6	9.8	8.9	9.7	11.2	9.0	6.0	7.9	14.5	12.7
Inventories as a % of Revenue	12.1	12.2	13.0	12.9	13.1	13.6	14.2	13.7	11.9	13.0
Inventory Days of Supply	50.7	52.1	56.0	55.3	55.9	57.8	60.3	58.1	52.1	56.4
					in thousands of dollars					
Revenues/Employee	1,011	958	879	855	872	884	845	858	1,072	1,228
Net Income/ Employee	107.2	94.3	78.4	83.4	97.3	79.6	51.0	67.9	155.5	155.7

Sources: American Chemistry Council, based on the U.S. Census Bureau Quarterly Financial Report (QFR).

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 ACCExchange. 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, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Large Firms (total assets $25 million and over)										
Current Ratio	1.2	1.3	1.3	1.3	1.1	1.0	1.0	1.1	1.1	1.1
Quick Ratio	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.8	0.8	0.8
Cash Ratio	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.3	0.3
Debt-to-Equity Ratio	2.2	2.2	2.3	2.3	1.6	1.4	1.5	1.6	1.5	1.5
Inventory Turnover	1.8	1.7	1.6	1.6	1.5	1.5	1.5	1.7	2.0	1.8
Operating Margin (%)	7.5	9.0	9.1	9.0	7.8	8.2	7.5	6.1	13.1	11.8
Profit Margin (%)	7.3	7.2	6.7	5.2	8.3	5.6	4.6	2.0	13.1	11.4
Inventories as a % of Revenue	12.6	12.6	13.8	13.4	14.3	14.4	14.2	13.1	10.5	11.9
Inventory Days of Supply	51.6	52.5	57.9	56.9	59.8	60.5	59.5	54.8	46.6	51.8
Small Firms (total assets under $25 million)										
Current Ratio	1.7	1.8	2.0	2.4	2.7	2.6	2.0	3.0	3.5	2.6
Quick Ratio	1.1	1.3	1.4	1.6	2.0	1.8	1.3	2.0	2.5	1.7
Cash Ratio	0.4	0.4	0.5	0.5	0.8	0.7	0.4	0.8	1.2	0.7
Debt-to-Equity Ratio	2.2	2.2	1.1	0.8	0.7	0.8	1.1	0.6	0.4	0.6
Inventory Turnover	2.1	2.4	2.3	1.9	2.1	1.6	1.4	1.7	1.7	1.3
Operating Margin (%)	4.1	3.4	5.8	7.9	6.9	8.1	7.1	9.6	8.9	8.4
Profit Margin (%)	3.1	1.9	3.8	6.6	5.4	6.7	5.5	7.4	9.5	8.2
Inventories as a % of Revenue	11.2	9.7	10.0	11.6	10.7	13.6	15.7	12.6	16.9	16.5
Inventory Days of Supply	43.6	37.3	39.5	46.8	42.8	55.3	63.1	52.4	70.6	67.9

Sources: American Chemistry Council, based on the U.S. Census Bureau Quarterly Financial Report (QFR).

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, 2012-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Large Firms (total assets $25 million and over)										
Current Ratio	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.1
Quick Ratio	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.7
Cash Ratio	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.2
Debt-to-Equity Ratio	1.1	1.2	1.3	1.3	1.3	1.3	1.3	1.4	1.3	1.3
Inventory Turnover	1.8	1.7	1.7	1.7	1.7	1.7	1.6	1.5	1.6	1.5
Operating Margin (%)	13.4	13.9	14.3	13.0	12.2	12.2	10.1	11.5	11.8	12.3
Profit Margin (%)	15.6	13.8	12.0	15.0	13.9	13.1	4.7	13.4	16.4	14.4
Inventories as a % of Revenue	11.6	11.9	12.4	12.5	12.7	12.7	13.5	14.1	13.3	14.0
Inventory Days of Supply	50.4	52.5	55.3	54.6	55.1	55.0	57.5	60.9	57.6	60.8
Small Firms (total assets under $25 million)										
Current Ratio	2.0	2.1	2.2	2.1	2.2	2.3	2.7	2.9	2.6	2.5
Quick Ratio	1.3	1.3	1.4	1.3	1.4	1.4	1.7	1.9	1.7	1.5
Cash Ratio	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.8	0.7	0.6
Debt-to-Equity Ratio	1.3	1.3	1.0	1.0	0.9	0.7	0.6	0.5	0.6	0.6
Inventory Turnover	1.9	1.9	1.9	1.9	1.8	1.7	1.4	1.3	1.4	1.5
Operating Margin (%)	6.3	7.8	5.7	6.4	9.3	10.6	9.3	13.0	12.7	9.4
Profit Margin (%)	4.5	6.3	4.4	5.3	7.8	8.3	8.2	11.9	13.0	9.8
Inventories as a % of Revenue	12.3	11.9	12.1	12.1	12.6	13.2	16.2	16.1	15.2	14.9
Inventory Days of Supply	48.7	47.7	47.8	48.2	51.9	54.9	66.9	69.4	65.3	61.2

Sources: American Chemistry Council, based on the U.S. Census Bureau Quarterly Financial Report (QFR).

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).

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.

There is no definitive 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).

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.

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.

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

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.

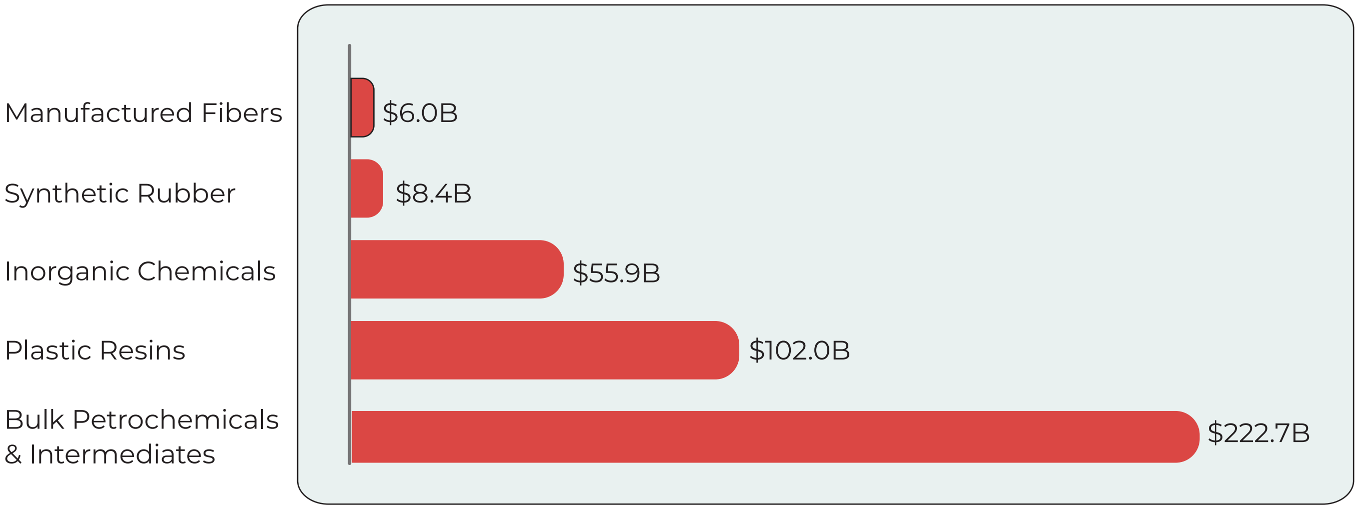
These crackers need to be located close to the feedstock, which limits the geography where facilities could be located, as well as access to distribution networks. Distribution of basic chemicals is largely by rail and water to a limited number of large-volume customers.

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 make 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.

Figure 4.1 - Basic Chemicals Shipments, 2022



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

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 be 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.

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.

Table 4.1 - Plastic Resins Summary, 2018-2022

	2018	2019	2020	2021	2022
Shipments (in $millions)	94,853	82,768	76,545	99,971	101,971
Production Index (2017=100)	102.3	91.9	88.3	88.3	87.9
Production (in million pounds)*	119,559	121,457	123,147	123,955	127,883
Production (in million metric tons)	54.2	55.1	55.9	56.2	58.0
Capital Expenditures (in $millions)	4,875	8,331	4,337	4,465	5,031
Price Index (2012=100)	104.8	100.5	96.9	129.2	132.4
Employment (in thousands)	58.9	58.9	58.9	58.9	59.5
Exports (in $millions)	32,025	31,712	28,890	37,083	42,541
Imports (in $millions)	15,586	13,696	11,939	19,517	20,959
Trade Balance (in millions)	16,440	18,016	16,951	17,566	21,582

*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

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 cyclicality. Earnings, on the other hand, tend to be less volatile.

Specialty chemicals 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 the 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 and 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 “more than 90% of 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 prospects.

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.

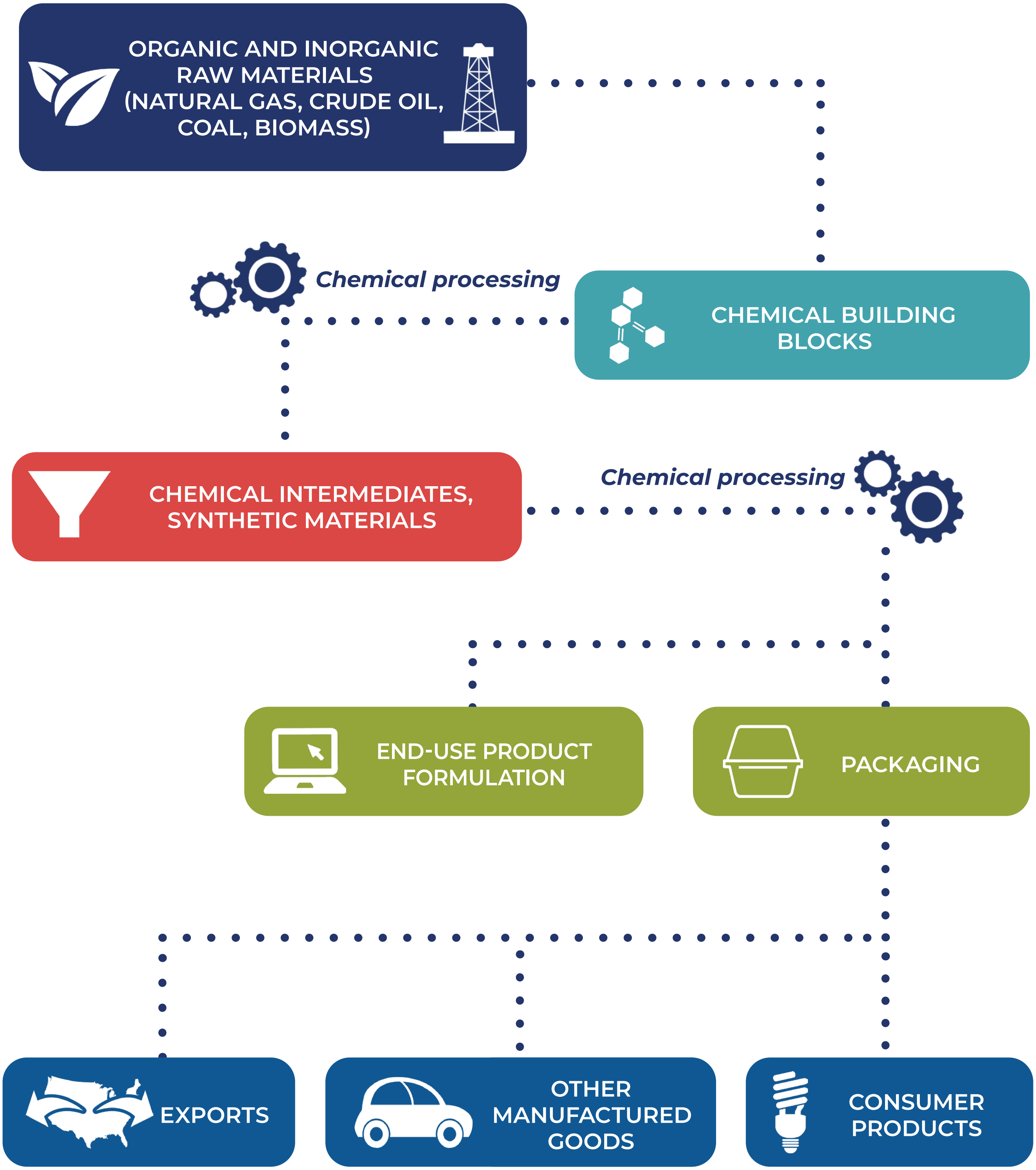
Technology advantages are extremely important in pharmaceuticals, and there is increasing convergence between biology and chemistry as biotechnology innovations further diffuse. As a result, R&D spending in pharmaceuticals as a percent of sales is the highest among all industries. Pharmaceuticals have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



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 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.

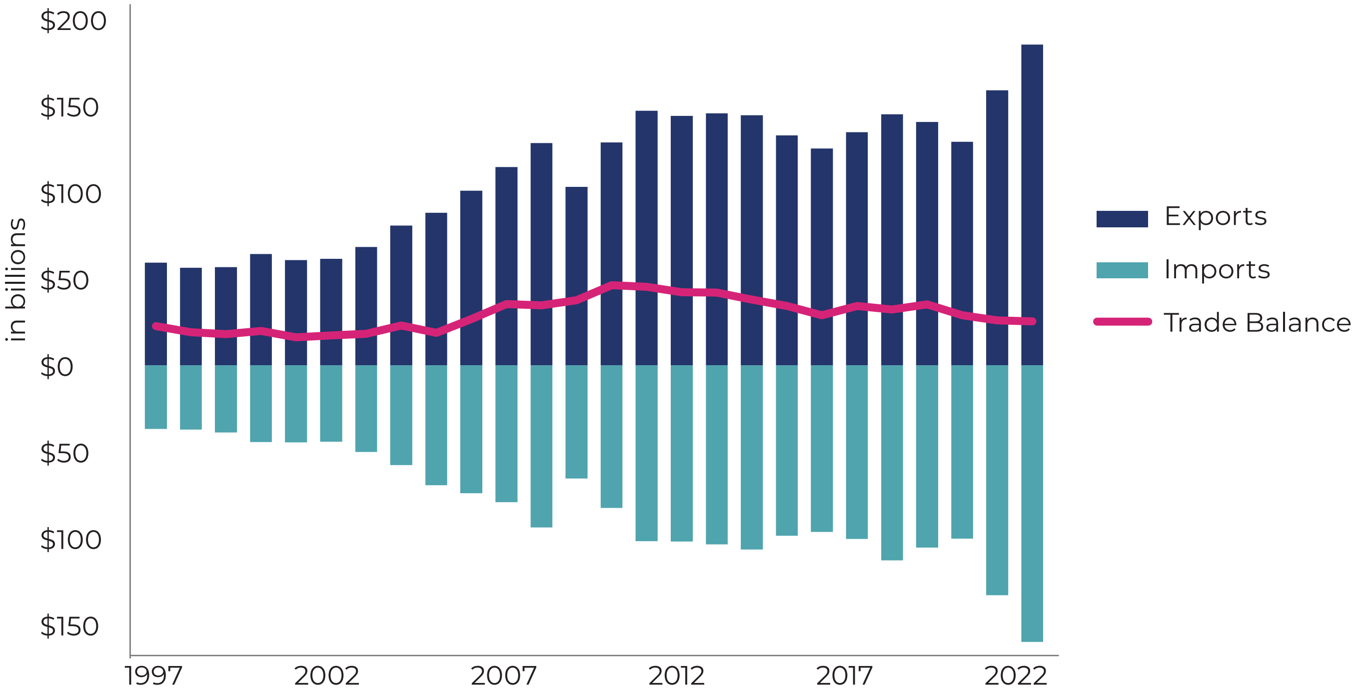
U.S. trade in chemicals (both imports and exports) has grown steadily over the years but, on balance, the U.S. chemical industry has maintained a net exporter position (a positive trade balance). Due to access to abundant and affordable shale gas, U.S. chemical manufacturers continue to face comparatively 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.

2022 TRADE AT A GLANCE

EXPORTS	IMPORTS	TRADE BALANCE
$179.0 billion	**$154.5** billion	**$24.5** billion
Top Countries: *Mexico* *Canada* *China*	**Top Countries:** *Canada* *China* *Germany*	**Top Countries:** *Mexico* *Brazil* *Canada*
Top Products: *Bulk Petrochemicals* *Plastic Resins* *Other Specialties*	**Top Products:** *Bulk Petrochemicals* *Plastic Resins* *Other Specialties*	**Top Products:** *Plastic Resins* *Bulk Petrochemicals* *Inorganics*

TOTAL TRADE

Figure 5.1 - U.S. Trade in the Business of Chemistry



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

Figure 5.2 - Chemicals Trade Balance by Segment

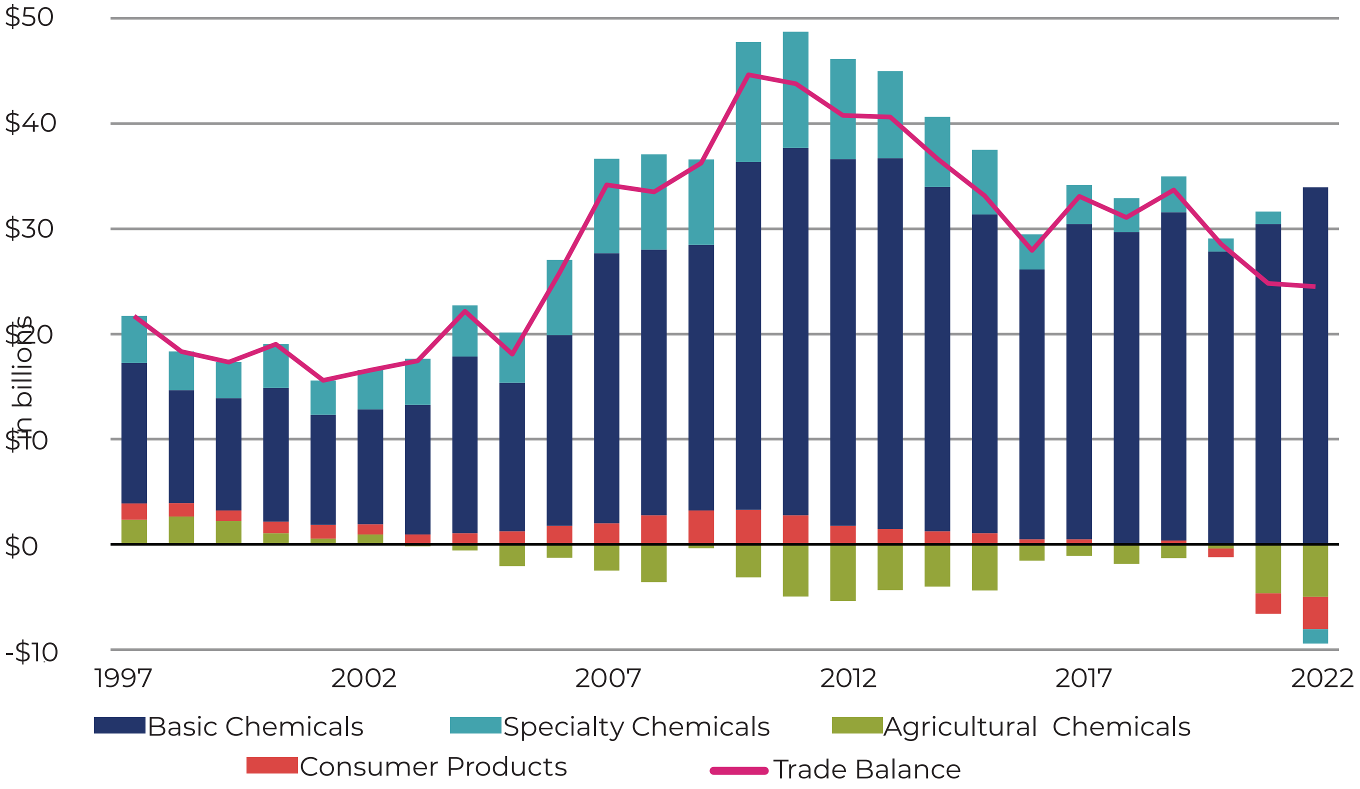
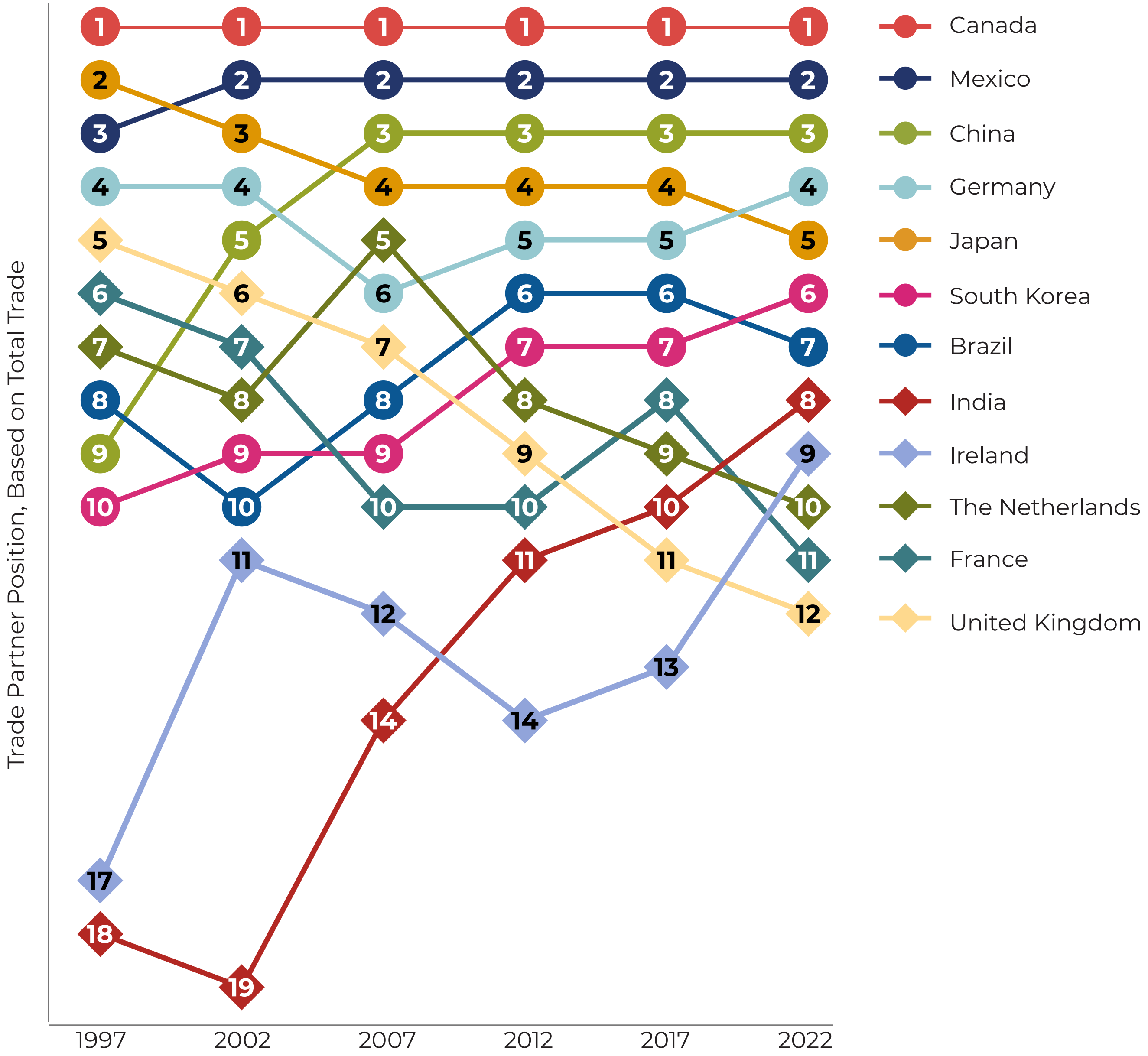


Figure 5.3 - Top Trade Partners Over the Years



Trade Partners

Over the past quarter century, Canada and Mexico have consistently been top trade partners of the United States, with Canada retaining the #1 spot. Many other U.S. trade partners have maintained positions within the top ten (based on total trade value) including China (which was #9 25 years ago, but has maintained the #3 spot since 2007), Germany, Japan, South Korea, and Brazil. India and Ireland have played increasingly larger trade roles in recent years, where trade between the U.S. and the United Kingdom and France has declined.

EXPORTS BY COUNTRY/REGION

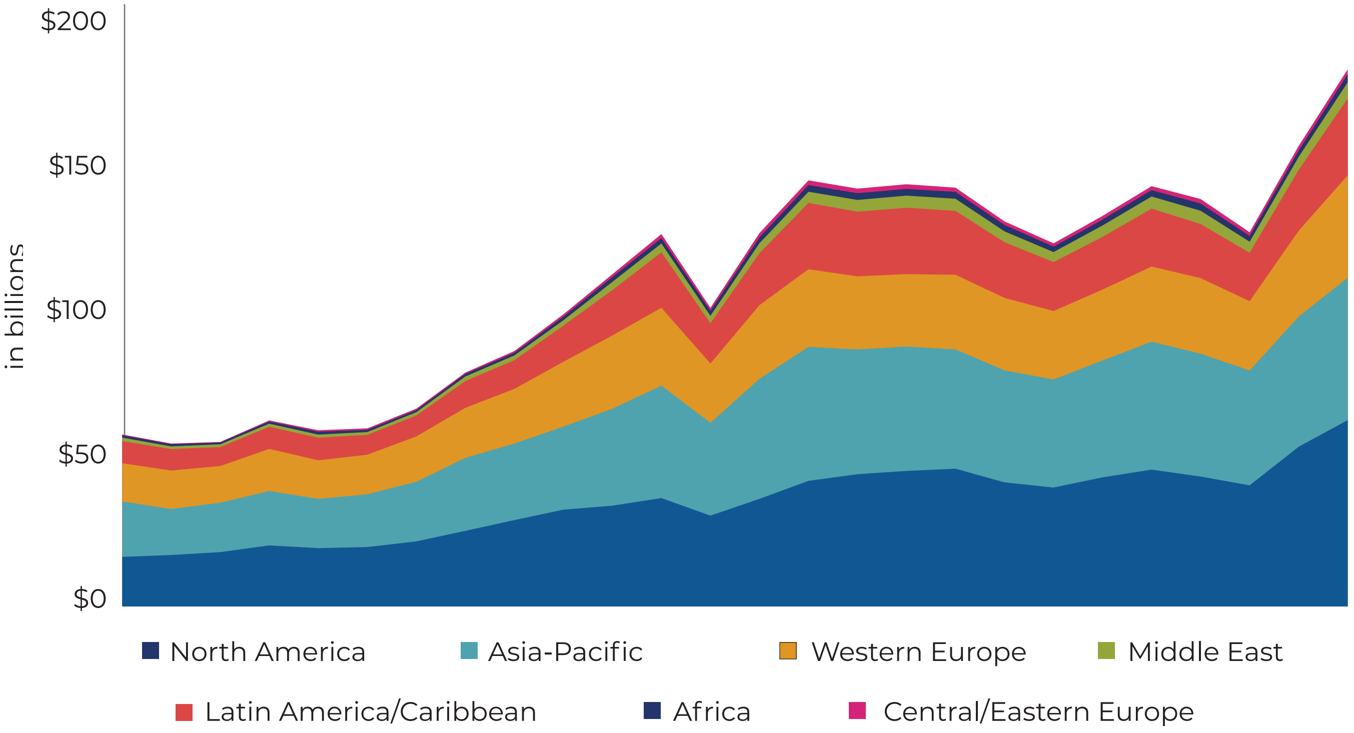
Table 5.1 - Top Chemicals Export Destinations, 2018-2022

	2018	2019	2020	2021	2022
			in $millions		
Mexico	22,985	21,548	19,369	27,278	31,344
Canada	22,618	21,754	20,995	25,934	30,759
China	11,726	10,032	10,968	12,725	14,235
Brazil	7,748	7,317	6,522	7,826	10,373
Japan	6,357	5,871	4,929	5,933	6,693
The Netherlands	4,714	4,927	4,549	5,224	6,312
South Korea	5,997	5,750	5,247	5,687	5,978
India	3,753	4,220	3,555	4,083	4,783
Germany	3,055	3,102	3,192	3,699	4,262
Singapore	3,339	3,197	2,927	3,219	3,434

Note. In descending order based on 2022 exports.

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

Figure 5.4 - Total U.S. Chemicals Exports by Region



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

IMPORTS BY COUNTRY/REGION

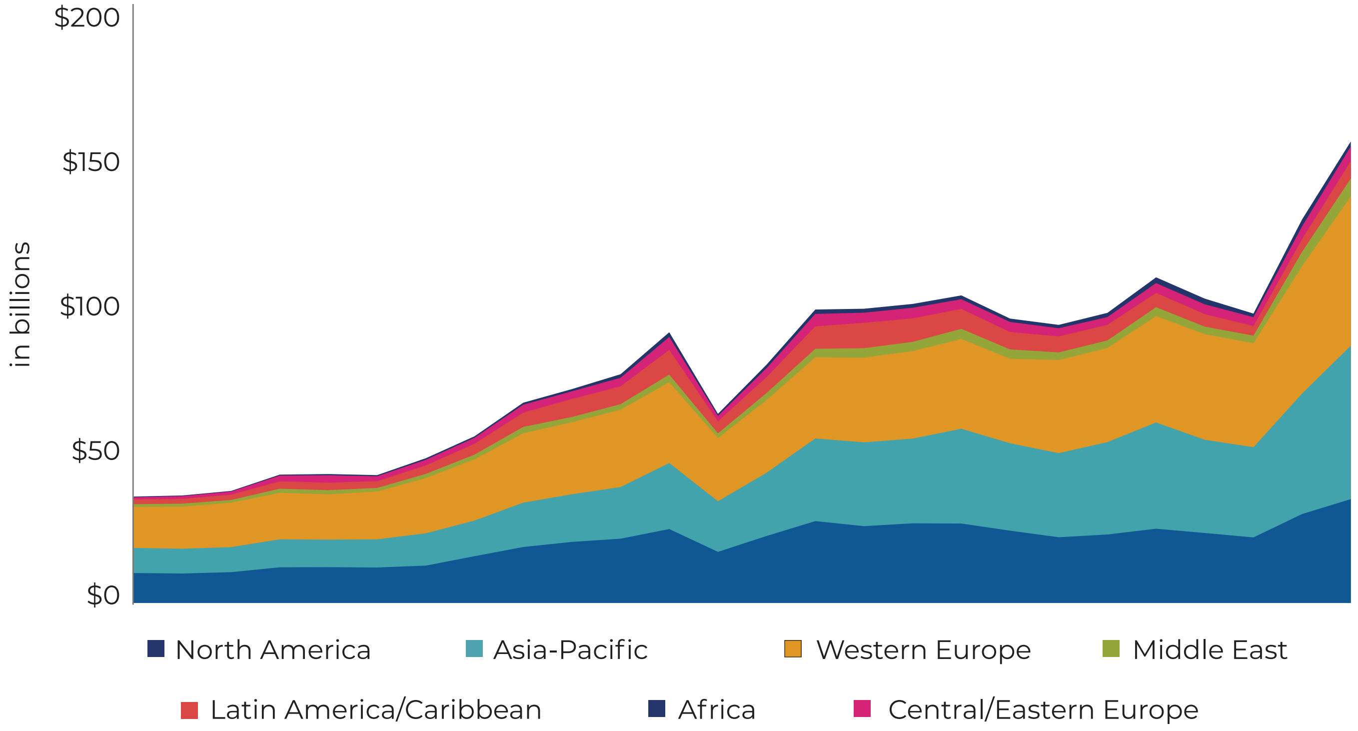
Table 5.2 - Top Chemicals Import Countries of Origin, 2018-2022

	2018	2019	2020	2021	2022
			in $millions		
Canada	19,465	18,074	16,519	23,238	26,852
China	15,801	11,488	11,515	14,616	18,904
Germany	8,253	8,086	7,733	9,373	11,302
Ireland	4,839	5,530	6,674	6,913	9,979
Japan	6,728	7,093	6,358	7,251	8,766
South Korea	3,828	3,699	3,682	5,515	7,918
Mexico	5,389	5,340	5,418	6,524	7,900
France	4,683	4,601	4,381	5,537	6,689
India	3,392	3,732	3,538	4,744	6,374
The Netherlands	3,286	3,208	2,874	3,869	3,930

Note. In descending order based on 2022 imports.

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

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



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

TRADE BY SEGMENT

Table 5.3 - Chemical Exports by Segment, 2018-2022

	2018	2019	2020	2021	2022
			in $millions		
Chemicals	**140,053**	**135,534**	**124,692**	**153,428**	**178,956**
Basic Chemicals	95,328	92,033	84,055	105,889	122,336
Inorganics	14,811	14,598	13,266	15,778	18,594
Bulk Petrochemicals & Intermediates	41,166	39,139	36,279	46,165	53,516
Plastic Resins	32,025	31,712	28,890	37,083	42,541
Synthetic Rubber	5,186	4,560	3,945	4,973	5,659
Manufactured Fibers	2,140	2,025	1,675	1,890	2,027
Specialties	25,874	24,725	23,184	28,295	32,220
Coatings	2,777	2,764	2,488	2,843	3,345
Other Specialties	23,097	21,961	20,696	25,452	28,874
Agricultural Chemicals	7,320	7,222	6,867	7,866	12,311
Consumer Products	11,532	11,553	10,586	11,378	12,090
Pharmaceuticals	54,737	59,802	58,937	80,135	81,759
Chemicals & Pharmaceuticals	194,791	195,335	183,629	233,562	260,715
Total U.S. Goods Exports	1,413,168	1,392,664	1,207,383	1,478,858	1,744,047
Chemistry % of Total U.S. Goods Exports	9.9%	9.7%	10.3%	10.4%	10.3%

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

Table 5.4 - Chemical Imports by Segment, 2018-2022

	2018	2019	2020	2021	2022
			in $millions		
Chemicals	**108,994**	**101,862**	**96,832**	**128,377**	**154,452**
Basic Chemicals	65,680	60,843	56,223	75,434	88,408
Inorganics	10,918	10,818	9,003	12,113	14,905
Bulk Petrochemicals & Intermediates	33,483	31,044	31,017	38,309	45,538
Plastic Resins	15,586	13,696	11,939	19,517	20,959
Synthetic Rubber	3,161	2,983	2,390	3,159	4,235
Manufactured Fibers	2,532	2,302	1,873	2,336	2,772
Specialties	22,660	21,314	21,944	27,119	33,592
Coatings	1,207	1,236	1,179	1,462	1,638
Other Specialties	21,453	20,078	20,765	25,657	31,954
Agricultural Chemicals	9,166	8,531	7,256	12,508	17,276
Consumer Products	11,488	11,174	11,409	13,316	15,177
Pharmaceuticals	135,583	151,868	167,507	176,416	175,617
Chemicals & Pharmaceuticals	244,578	253,730	264,339	304,793	330,070

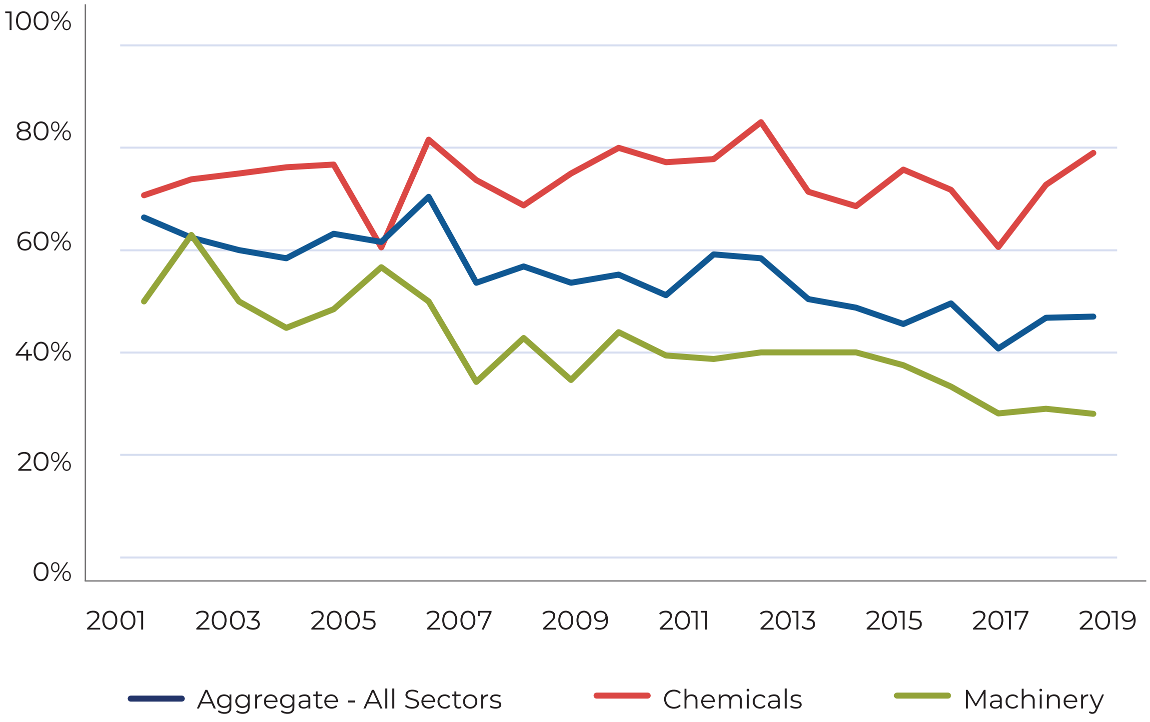
Source: U.S. Department of Commerce, American Chemistry Council analysis

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 5.6 - 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.

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, 2018-2022

	2018	2019	2020	2021	2022
			in $billions		
North America	633.0	588.2	534.2	663.7	726.6
Latin America	260.5	254.4	244.9	293.9	384.6
Europe	767.7	723.2	707.6	880.1	1,055.2
Former Soviet Union	91.0	94.6	92.5	114.8	131.4
Africa and Middle East	166.1	181.1	199.2	296.8	433.3
Asia-Pacific	2,219.7	2,158.6	2,118.6	2,816.4	2,990.2
Total Global Shipments	**$4,138.1**	**$4,000.1**	**$3,897.1**	**$5,065.5**	**$5,721.4**

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.

Sources: ABIQUIM, ANIQ, CCPA, CEFIC, JCIA, VCI, Bureau of the Census, Eurostat, IHS Markit (part of S&P Global), 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 ACCExchange. Non-members may purchase the data at store. americanchemistry.com.

Figure 6.1 - Global Chemical Apparent Consumption (Domestic Sales) by Region, 2022

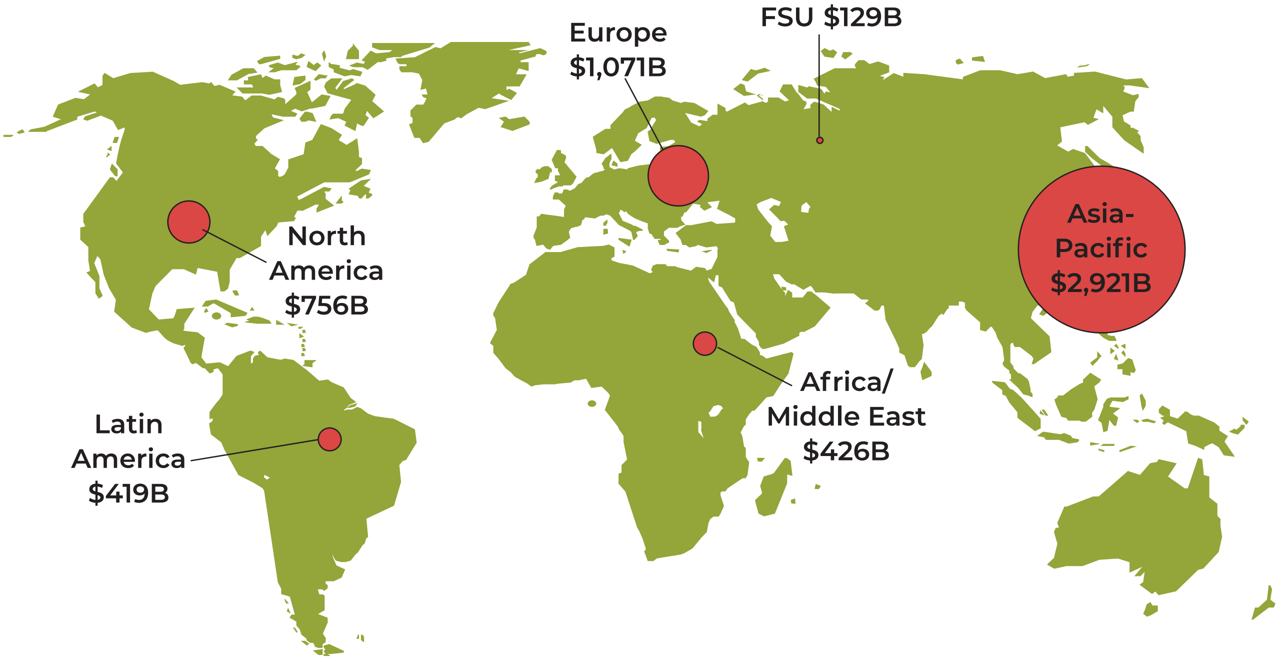


Figure 6.2 - Top Global Chemical Shipments

As a percent of total

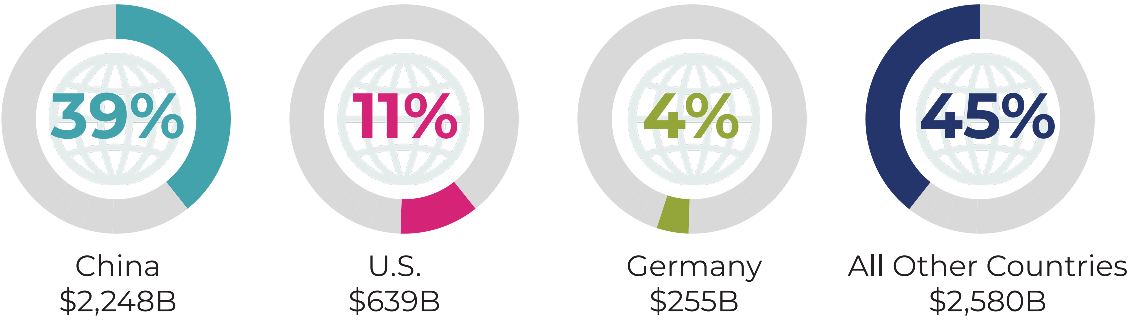


Table 6.2- Global Chemical Exports and Imports by Region, 2018-2022

	2018	2019	2020	2021	2022
			in $billions		
Exports					
North America	169.0	163.8	150.3	187.5	217.7
Latin America	27.7	26.8	24.3	25.9	29.8
Europe	612.2	580.9	551.9	661.4	758.9
Former Soviet Union	30.7	28.2	22.0	22.6	22.0
Africa and Middle East	81.4	76.5	66.5	72.5	93.4
Asia-Pacific	578.2	549.1	509.9	612.9	673.3
Total Global Exports	**$1,499.2**	**$1,425.3**	**$1,324.9**	**$1,582.8**	**$1,795.2**
Imports					
North America	175.7	167.2	154.6	204.1	247.0
Latin America	70.8	65.0	52.7	61.1	64.4
Europe	585.8	556.0	532.0	633.5	775.2
Former Soviet Union	28.3	28.9	23.7	27.1	19.4
Africa and Middle East	88.2	87.3	75.1	81.9	85.7
Asia-Pacific	550.4	520.9	486.9	575.1	603.6
Total Global Imports	**$1,499.2**	**$1,425.3**	**$1,324.9**	**$1,582.8**	**$1,795.2**

Sources: ABIQUIM, ANIQ, CCPA, CEFIC, JCIA, VCI, Bureau of the Census, Eurostat, IHS Markit (part of S&P Global), 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 ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

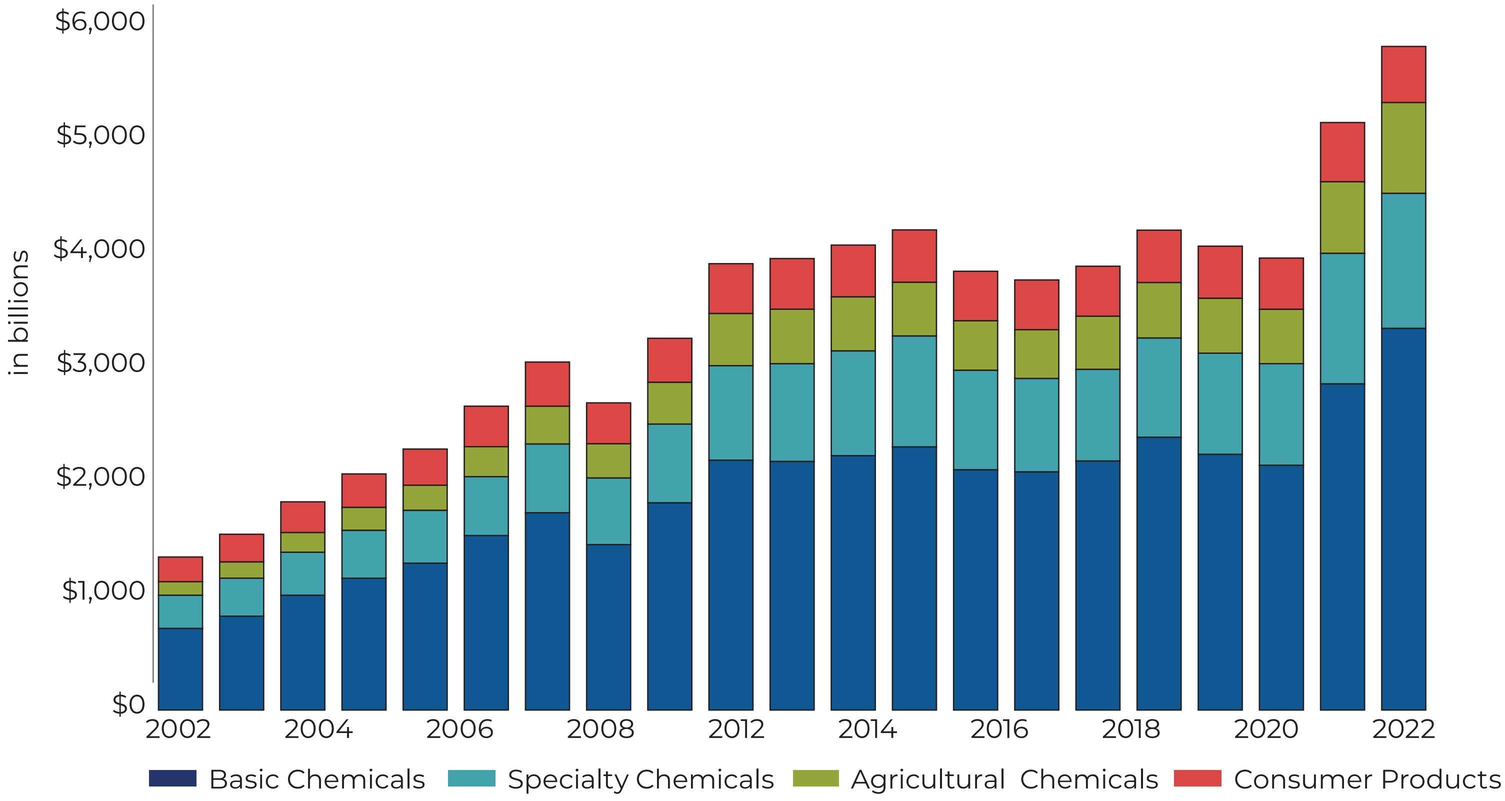
Table 6.3 - Global Consumption and Shipments by Region, 2022

	Shipments	Exports	Imports	Balance	Consumption/ Domestic Sales
			in $billions		
China	2,247.9	187.3	187.2	0.04	2,247.8
United States	638.7	179.0	154.5	24.5	614.2
Germany	255.3	140.8	148.5	-7.7	263.0
Brazil	137.3	13.2	31.8	-18.6	155.9
South Korea	159.5	92.0	64.0	28.0	131.5
India	108.5	46.8	67.8	-21.0	129.5
Japan	163.0	84.2	44.7	39.4	123.6
Italy	92.3	39.3	70.6	-31.3	123.6
Russia	118.4	21.1	16.4	4.7	113.7
France	101.3	61.9	67.8	-5.9	107.2

Top ten chemical-consuming countries, listed by 2022 consumption. Additional data available to ACC members for free on ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

Sources: ABIQUIM, ANIQ, CCPA, CEFIC, JCIA, VCI, Bureau of the Census, Eurostat, IHS Markit (part of S&P Global), Oxford Economics, Statistics Canada, United Nations, WTO, American Chemistry Council estimates

Figure 6.4 - Global Chemical Shipments by Segment



Source: American Chemistry Council estimates

Table 6.4 - Global Shipments by Segment, 2018-2022

	2018	2019	2020	2021	2022
			in $billions		
Chemicals	**4,138.1**	**4,000.1**	**3,897.0**	**5,065.5**	**5,721.4**
Basic Chemicals	2,351.2	2,204.0	2,109.7	2,811.6	3,290.0
Inorganics	411.1	378.3	376.5	489.7	753.4
Bulk Petrochemicals & Intermediates	946.1	885.7	851.5	1,129.9	1,333.4
Plastic Resins	695.7	647.1	600.0	802.4	820.4
Synthetic Rubber	60.2	59.1	60.1	81.8	35.2
Manufactured Fibers	237.7	233.6	221.6	307.7	347.6
Specialties	856.2	872.7	876.7	1,125.6	1,164.3
Coatings	225.4	226.7	234.9	291.5	329.2
Other Specialties	630.7	646.5	641.8	834.4	942.4
Agricultural Chemicals	478.1	473.1	468.5	617.6	783.4
Consumer Products	452.1	449.8	442.2	510.7	483.8
Pharmaceuticals	1,483.6	1,514.6	1,633.6	2,060.1	2,174.1
Chemicals & Pharmaceuticals	5,621.7	5,514.7	5,530.6	7,125.5	7,895.6
Maritime Trade in Chemicals (millions of metric tons)					
Global Seaborne Trade	363.0	374.0	370.0	378.0	370.0

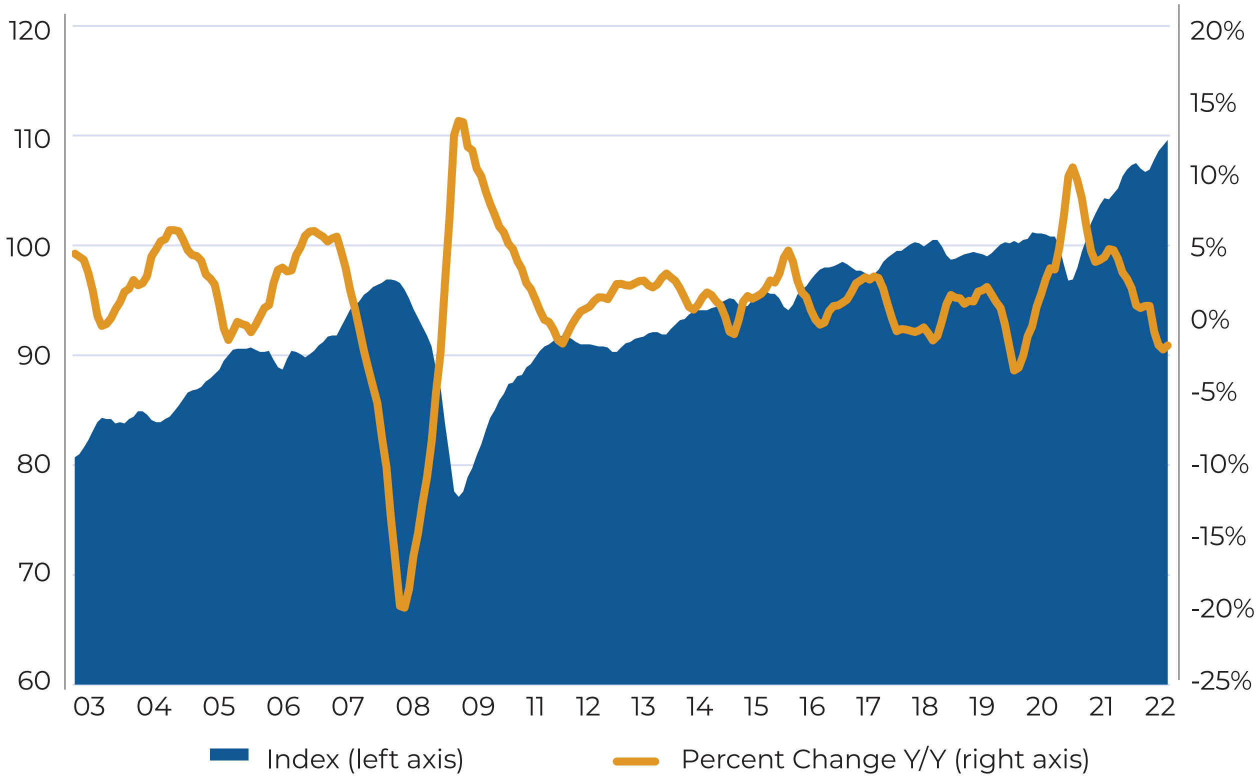
Additional data available to ACC members for free on ACCExchange. Non-members may purchase the data at store.americanchemistry.com.

Source: American Chemistry Council analysis, Shipbuilders' Association of Japan

GLOBAL CPRI

The Global CPRI measures the production volume of the chemical industry for 55 key nations, sub-regions, and regions, all aggregated to the world total. While most data are seasonally adjusted at source, some are adjusted using the U.S. Census Bureau's X-12 model to present data comparable to the United States. In a few cases, ACC creates indices of production based on actual production data weighted according to industry structure. The index uses the total value added as a proxy for individual country weights to arrive at the total. This method accounts for the changes in each country's share relative to global production, which is more reflective of the ever-changing global production dynamics. The Global CPRI measures production activity generally consistent with the overall industry nomenclature of NAICS 325 (less pharmaceuticals) and the EU NACE 20 industries. The index measures the production of soaps and detergents, personal care products, fertilizers, and other downstream products in addition to measuring inorganic chemicals, organic chemicals, plastic resins, synthetic fibers, synthetic rubber, adhesives and sealants, coatings, and other specialty chemicals. Production of pharmaceuticals is excluded.

Figure 6.5 - Global Chemical Production Regional Index



The Global CPRI is released on a monthly basis. Total world and regional, monthly, quarterly and annual time series, as well as detailed sub-regional data *are available for ACC members on ACCExchange*.

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 in Context

Among the nations of the world, the United States spends the most on research and development (R&D), followed closely by China (across sectors). However, the United States ranking in R&D intensity—measured as a percentage of GDP—is falling, as other countries, notably middle income countries like China and India—have ramped up R&D spending since the turn of the century.

Table 7.1 - Human and Financial Resources for R&D, 2019

Nation	Total (billions of PPP $)	% of GDP
USA	668.4	3.13%
China	525.7	2.23%
Japan	173.3	3.20%
Germany	148.1	3.19%
Korea	102.5	4.64%
India	58.7	0.65%
Great Britain	56.9	1.76%
World	**2,419.1**	**2.48%**

Source: OECD

The National Science Foundation estimates U.S. R&D spending, of which business accounts for 72%, with the government share at 22% (the remaining 6% is universities). The portion of R&D spending by government has fallen since its heyday in the mid-1960s, when spending by NASA and DoD was much higher than it is today. In contrast, business spending on R&D has continued to increase in the 21st century. Businesses account for the vast majority of spending on applied R&D and a relatively smaller portion of basic R&D.

In terms of U.S. business spending on R&D, five sectors: chemical manufacturing (including pharmaceuticals), computer and electronics, transportation equipment (including automotive and aerospace), professional services (including computer systems design), and information services (including software publishing) account for the majority.

Academic studies suggest that, over the past few decades, the productivity of R&D has been declining. This observation has been found across a number of fields (Bloom, p.1104-1144.) In other words, it takes more R&D resources to achieve a unit increase in productivity today than it did decades ago. The implication is that innovation-driven R&D is becoming more expensive over time, and yet such investment is necessary to ensure economic growth. For example, Moore's law, which states that computer chip speed doubles every 18 months, is increasingly costly, as the most recent doubling was 17x more expensive than it was in 1970.

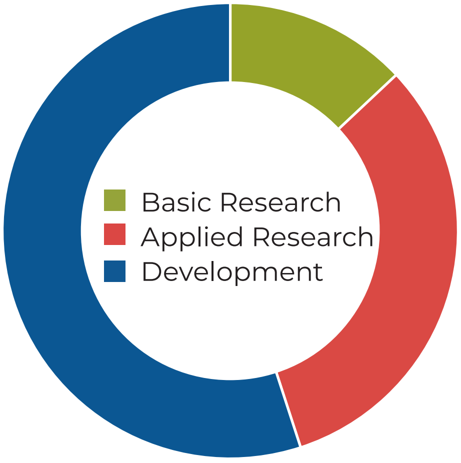
RESEARCH AND DEVELOPMENT ACTIVITIES

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.

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



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.

Table 7.2 - Research & Development Spending, 2013-2022

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Business of Chemistry ($billions)	10.9	11.8	12.2	10.8	10.9	11.3	10.5	10.1	12.8	13.4
As a % of Shipments	1.8	2.0	2.3	2.1	2.1	2.1	2.1	2.2	2.2	2.1

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

Source: 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.

For companies, of interest are metrics that convey the performance of R&D innovation and compare it with other similar companies. In 2018, McKinsey & Company (Aase, G., Swaminathan, S. and Roth, E., 2018. Taking the measure of innovation. The McKinsey Quarterly) recommended two metrics linking inputs with outputs: (1) R&D spending/new product sales and (2) gross margin/new product sales. These metrics, which can be obtained from publicly available data, allow a company to determine if investment in its R&D portfolio convert to meaningful profit over time.

ACC 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.

Table 7.3 - Business of Chemistry Innovation Metrics, 2013-2022

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Share of Revenues from New Products (%)	14.0	16.0	14.2	15.4	12.7	17.8	14.2	14.1	14.7	11.4
R&D-to-Product Conversion Ratio	7.7	7.9	6.1	7.2	6.1	8.7	6.9	6.5	6.7	5.4
New Products-to-Margin Conversion Ratio	1.4	1.5	1.3	1.4	1.3	1.8	1.5	1.6	1.2	1.0

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

Source: American Chemistry Council.

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. The chemical industry 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.

CHAPTER 8

Investment in the Future

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.

25%

OF CHEMICAL COMPANY CAPITAL EXPENDITURE BUDGETS ALLOCATED TO SUSTAINABLE MANUFACTURING

Source: ACC Economic Survey

The business of chemistry has consistently been one of the largest U.S. private-sector investors in new plant 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 less than 4% to nearly 20%.

In recent years, companies in the business of chemistry have increasingly allocated more capital spending toward sustainable manufacturing practices, such as lower carbon emissions technologies. A study by ACC showed that 25% of chemical company capital expenditures were allocated to sustainable manufacturing.

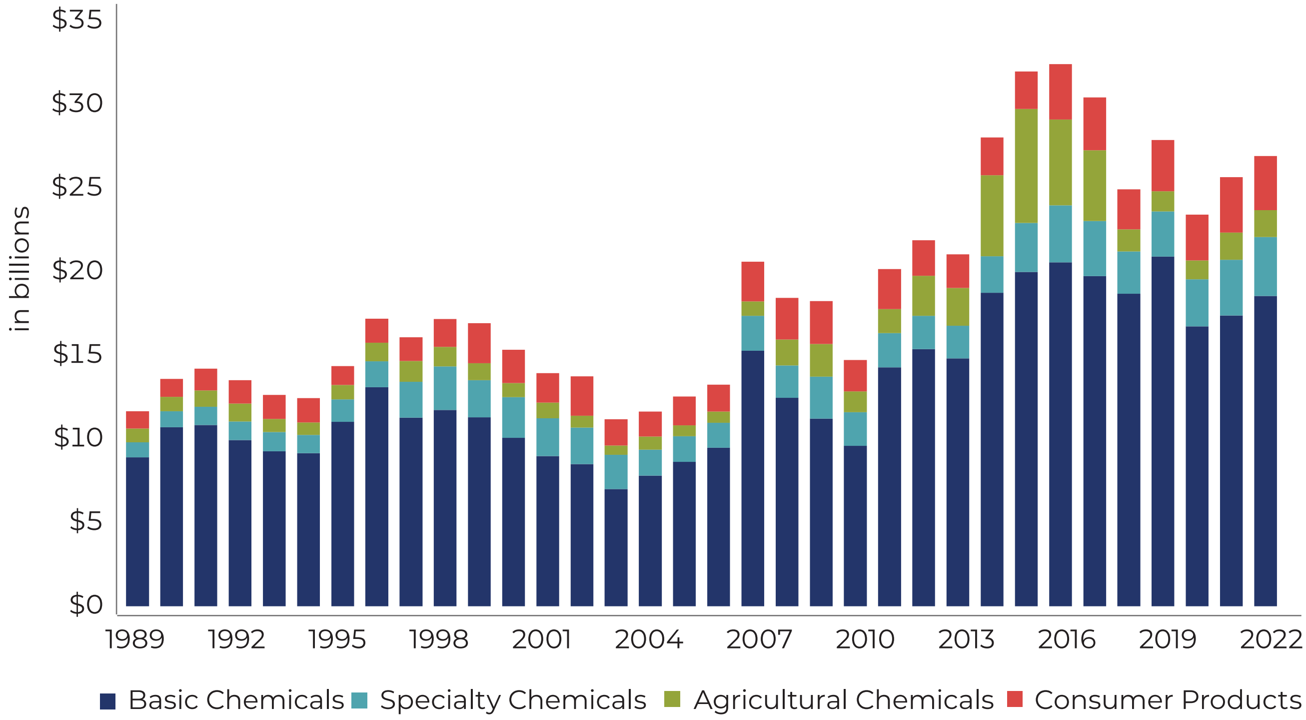
Table 8.1 - Capital Investment by Asset Class, 2018-2022

	2018	2019	2020	2021	2022
			in $millions		
General Industrial Equipment	9,567	10,548	8,793	9,484	9,936
Special Industrial Machinery	4,080	5,069	3,952	4,123	4,519
Instrumentation	3,321	3,646	3,270	3,402	3,565
Pressure Vessels & Other Fabricated Equipment	1,458	1,601	1,285	1,426	1,485
Other Machinery & Equipment	1,046	1,153	1,017	1,077	1,121
Computers & Related	676	720	665	690	718
Communications Equipment	531	563	471	541	543
Other Transportation Equipment	406	390	225	368	336
Motor Vehicles	312	366	155	332	289
Furniture	258	253	204	248	243
Electric Transmission & Distribution	54	59	48	52	55
Total Equipment	**21,710**	**24,369**	**20,086**	**21,744**	**22,809**
Manufacturing	2,312	2,503	2,454	2,963	3,098
Office Buildings	71	70	75	81	88
Other	54	57	63	62	71
Total Structures	**2,437**	**2,629**	**2,591**	**3,105**	**3,258**
Total Capital Investment	**24,147**	**26,998**	**22,677**	**24,849**	**26,067**
As a % of Shipments	4.4%	5.3%	4.9%	4.3%	4.1%

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

Sorted highest to lowest based on 2022 results.

Figure 8.1 - Capital Investment - Chemicals



Source: Bureau of Economic Analysis and ACC 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 needed 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 to 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.

Table 8.2 - Motivation for Capital Investment

	2018	2019	2020	2021	2022
	as % of total capital investment				
Replace Existing Plant & Equipment	23.0%	28.4%	31.2%	28.1%	30.8%
Expand Capacity for Existing Products	35.0%	21.6%	26.3%	22.9%	24.0%
Capacity for New Products	12.7%	11.5%	16.2%	21.1%	14.2%
Improving Operating Efficiencies	6.7%	15.2%	6.7%	7.1%	9.0%
Health & Safety	5.9%	8.4%	6.7%	7.1%	8.1%
Environmental Protection	3.7%	3.3%	3.8%	3.5%	5.7%
Energy Savings	1.2%	0.6%	0.6%	0.8%	0.9%
Other	11.8%	11.0%	8.5%	9.4%	7.3%

Source: American Chemistry Council

Sorted highest to lowest based on 2022 results.

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.

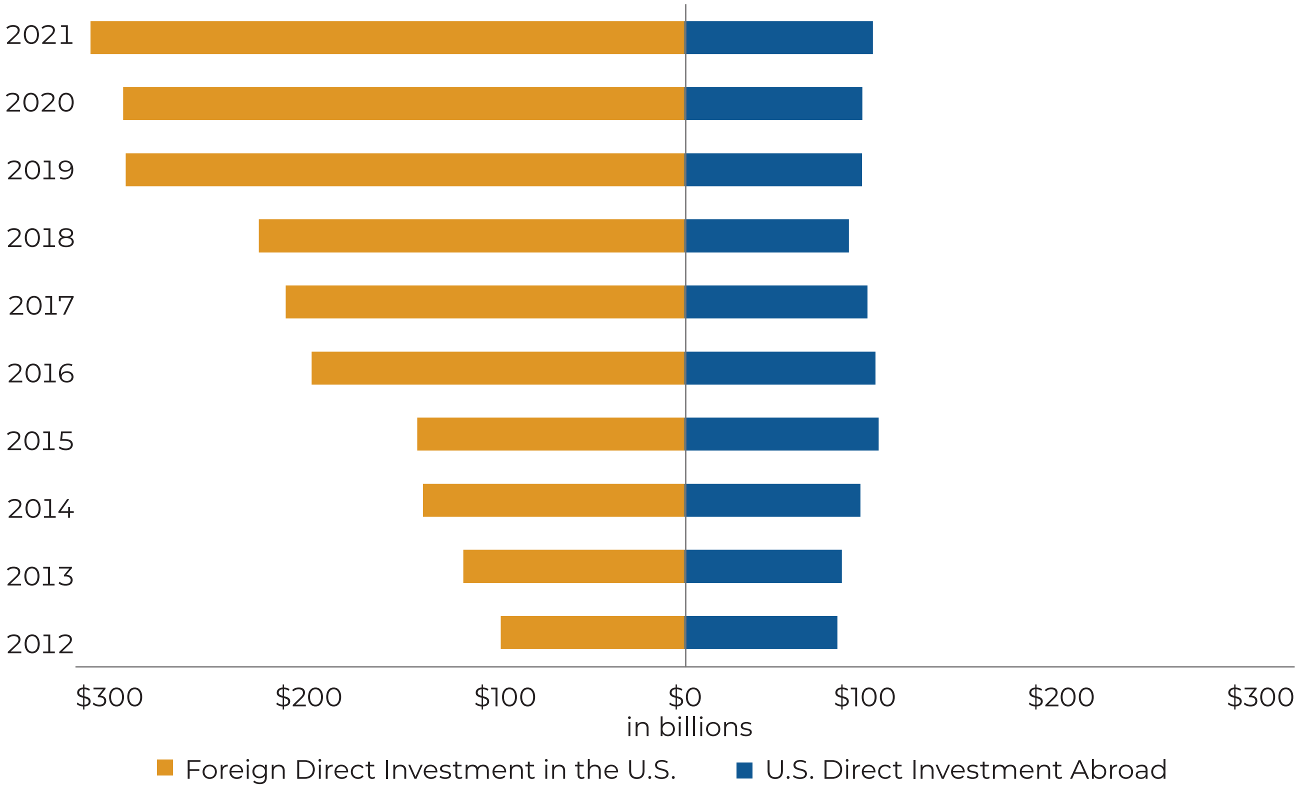
Historically, the chemical industry has not been at the forefront of digital technologies. However, the benefits of investing in new technologies, such as artificial intelligence (AI), advanced analytics and the use of Big Data, are immense. According to Forbes magazine, "Big data analytics helps organizations 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.

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.

Figure 8.4 - Foreign Direct Investment



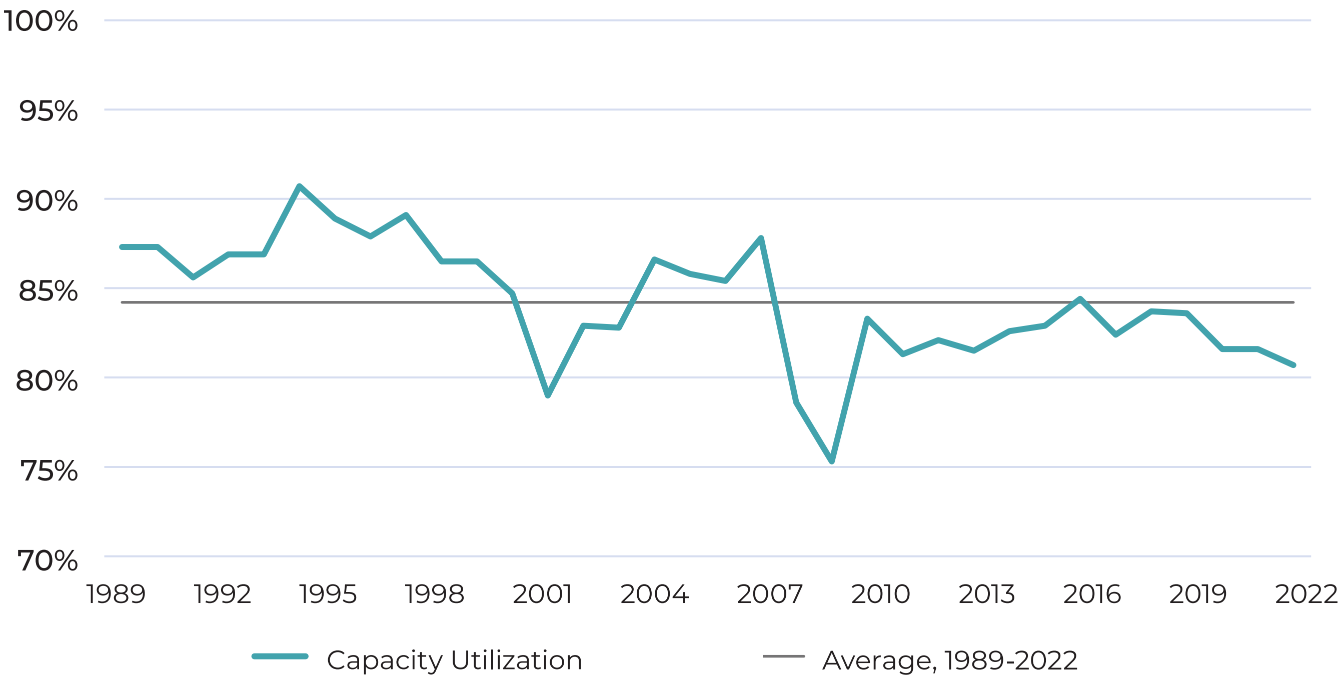
Source: Bureau of Economic Analysis (2021 is latest available data)

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

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.

Figure 8.5 - Capacity Utilization



Source: American Chemistry Council, based on Federal Reserve Board data.

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, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
					in thousands					
Employees	517	524	526	526	531	538	544	531	537	555
By Occupation										
Production Worker	329	333	339	342	342	350	359	337	344	374
Other	188	191	186	184	190	189	185	194	193	181
By Sex										
Female	120	125	129	128	131	137	144	145	143	147
Male	397	399	397	398	400	401	400	385	394	409
Median Worker Age (years)	45.9	45.1	45.0	46.1	46.0	43.9	44.6	45.9	44.0	44.3

Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, National Science Foundation, ACC analysis.

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

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.
- *Supply Chain (or 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.
- *Payroll-Induced (or Expenditure-Induced) Employment* — 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		
Business of Chemistry Jobs	**555**			
Transportation and Warehousing		246	93	339
Health Care and Social Assistance		0.02	321	321
Manufacturing, excluding Chemicals		243	72	315
Retail Trade		66	218	285
Other Services (except Public Administration)		124	154	278
Wholesale Trade		226	49	275
Administrative and Support and Waste Management and Remediation Services		173	91	263
Accommodation and Food Services		43	210	253
Professional, Scientific, and Technical Services		164	87	251
Finance and Insurance		65	125	190
Agriculture		150	29	178
Real Estate and Rental and Leasing		82	76	158
Management of Companies and Enterprises		114	23	136
Arts, Entertainment, and Recreation		17	44	60
Information		25	31	56
Educational Services		3	50	52
Mining		47	3	50
Utilities		27	6	33
Construction		21	11	33
Public Administration		15	10	24
Total Jobs - All Industries	**555**	**1,849**	**1,703**	**4,107**

Source: Bureau of Labor Statistics and American Chemistry Council analysis. Sorted by highest number of total jobs. Industry definitions based on 2022 NAICS (North American Industry Classification System).

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.

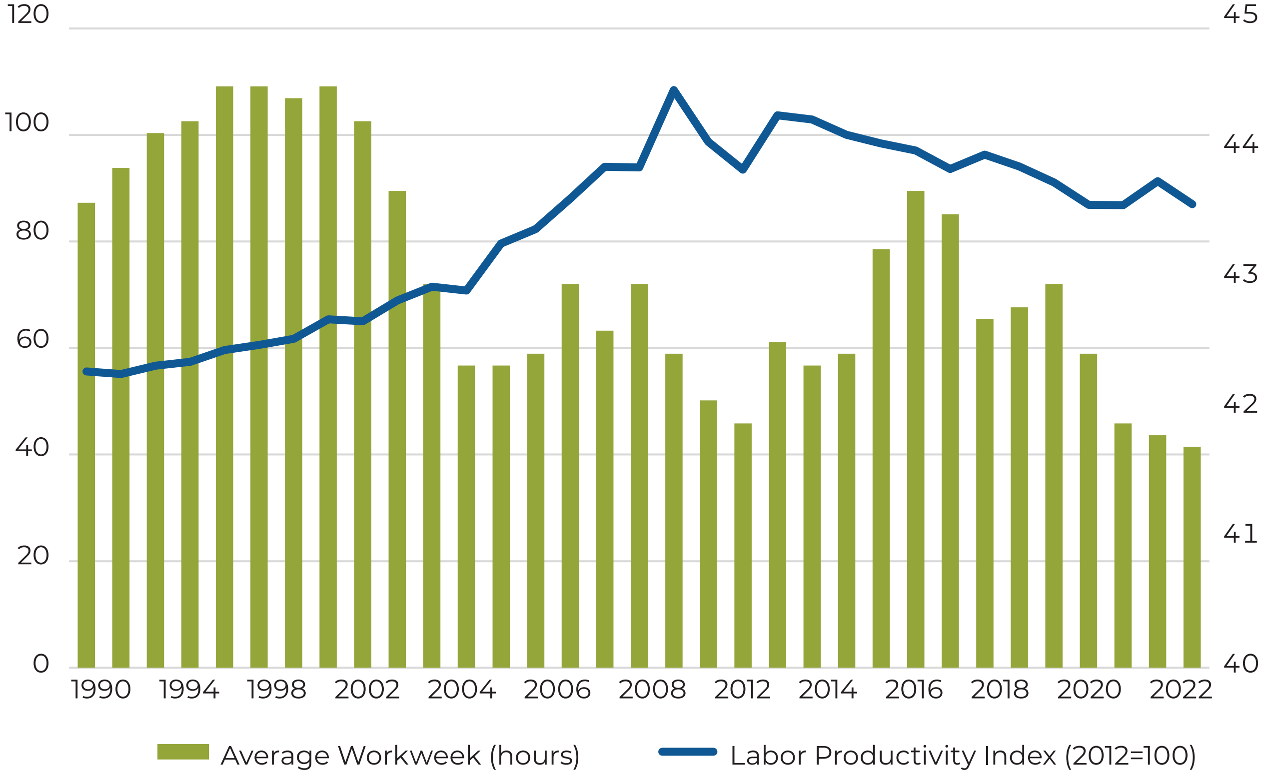
Table 9.3 - Chemical Industry Total Employee Compensation

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
					in $billions					
Wages & Salaries	39.0	40.8	42.7	42.9	44.4	45.9	47.5	47.8	49.4	53.5
Value of Benefits	12.3	12.9	12.8	13.2	14.4	14.2	14.6	14.5	15.1	16.3
Total Compensation	51.3	53.7	55.4	56.1	58.8	61.0	62.7	62.1	65.0	69.8
Benefits as a % of Wages and Salaries	32%	32%	30%	31%	32%	31%	31%	30%	31%	31%

Sources: Bureau of Labor Statistics, Census Bureau, ACC analysis.

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

Figure 9.1 - 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 provides employment data for only 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.

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

Regulation

Issued by government agencies under the authority delegated to them, *regulations* are specific standards or instructions concerning what individuals, businesses, and other organizations can and cannot do. Free enterprise depends on a legal framework that allows property rights and authorizes regulation, or rules.

From the perspective of economists, regulation of commerce may be justified when markets, under certain circumstances, allocate societal resources sub-optimally. These so-called "market failures" include *externalities* (e.g., pollution) when prices do not reflect the full social cost of a good; *market power* (e.g., monopoly) when production or consumption are very concentrated; and *information asymmetry* (e.g., moral hazard) when buyers or sellers have insufficient information to make optimal decisions. But there are also other reasons to regulate: for example, to improve an inherently governmental process, address unfairness in the distribution of resources, ensure privacy, or promote personal freedom.

Rules are issued by governmental agencies at all levels: local, state, federal, and international. And once issued, a regulation is seldom rescinded. Over time, as the number of regulations increases, so does the regulatory burden on those who must comply, such as businesses.

The most prolific regulator, by far, is the federal government. An average of 3,200 new regulations are issued each year, according to data from the U.S. Government Accountability Office (GAO). Although the vast majority are relatively minor and impose little burden, about 10% are "significant"; these represent the most controversial and consequently undergo a more rigorous review process before being issued. About 3% are "major", meaning each has an estimated impact of at least $100 million or more in a single year or otherwise significantly affect the economy.[1] And a handful have an estimated annual impact of more than $1 billion. Together, old and new regulations impose annual compliance costs on business estimated to be in the hundreds of billions of dollars, similar in magnitude to corporate income taxes.

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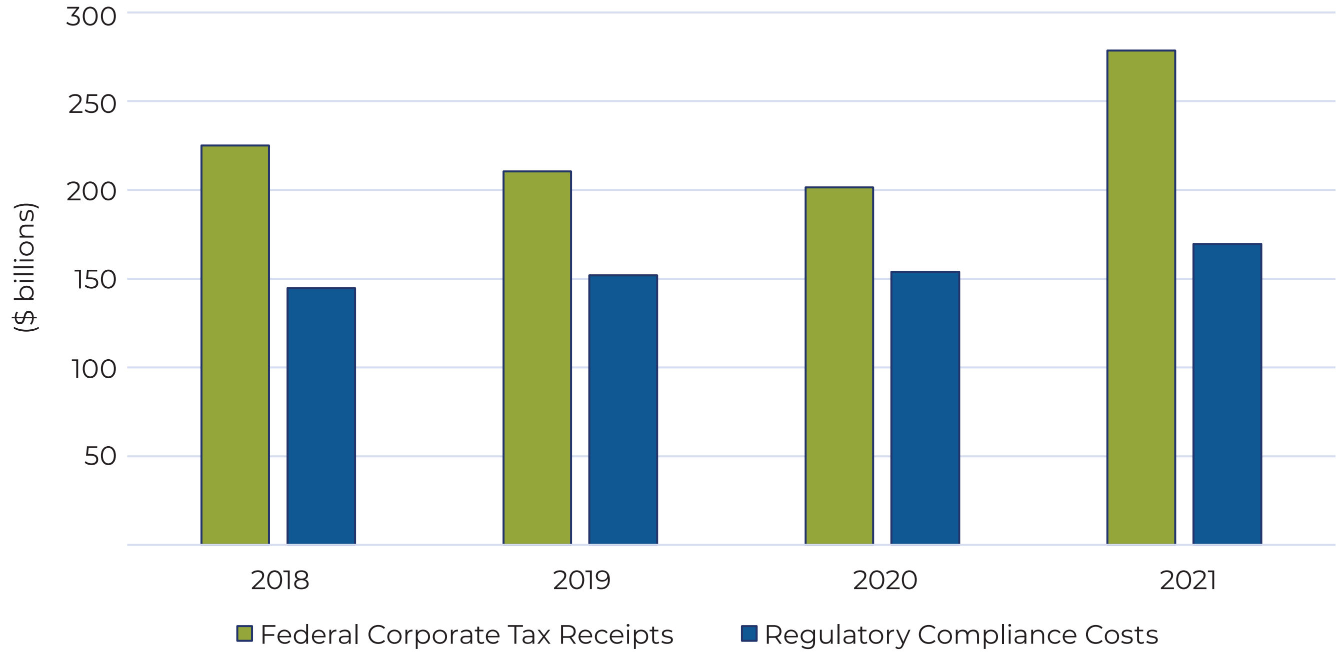
[1] According to the U.S. GAO Federal Rules Database, the annual number of major regulations issued from 2000-2014 ranges between 2%-3% of the total number of regulations.

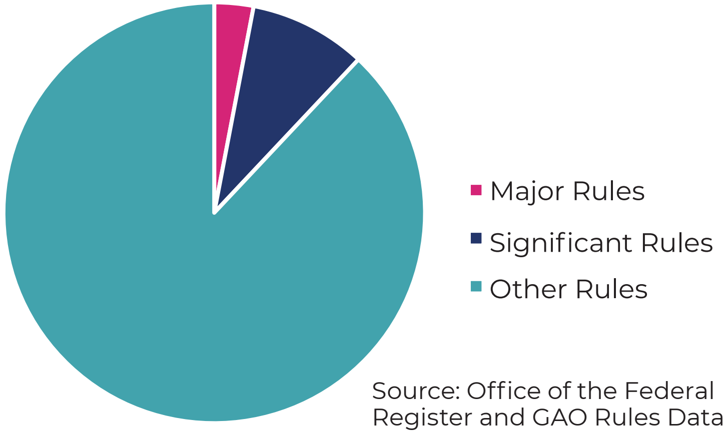
Figure 10.1 - Regulatory Compliance Costs and Corporate Income Tax Receipts Are of Similar Magnitude



Source: Federal Reserve and ACC analysis

Note. Data for costs and tax receipts economy-wide.

Figure 10.2 - A Small Subset of Regulations Has the Largest Economic Impact



Source: Office of the Federal Register and GAO Rules Database.

Note. Economy-wide

CUMULATIVE BURDEN

Chemical manufacturing is the most heavily regulated subsector of manufacturing, in terms of regulatory compliance cost as a share of total labor cost and the number of regulatory restrictions (Trebbi and Zhang, 2022). On this latter point, the 2021 version of the *Code of Federal Regulations* (CFR), a 200-volume compendium of all federal rules, imposes more than 1 million restrictions on domestic chemical manufacturing.[1] This represents 10% of the total number of restrictions in the CFR. The growth of the CFR over time is an indication of how fast regulatory burden is growing. For example, just twenty years ago, the number of restrictions impacting the business of chemistry was less than half of the current total. The largest portion of these restrictions pertain to environment, health, & safety (EH&S), followed by tax and then labor.

Because regulations, once imposed, seldom are eliminated, the accumulation of regulatory

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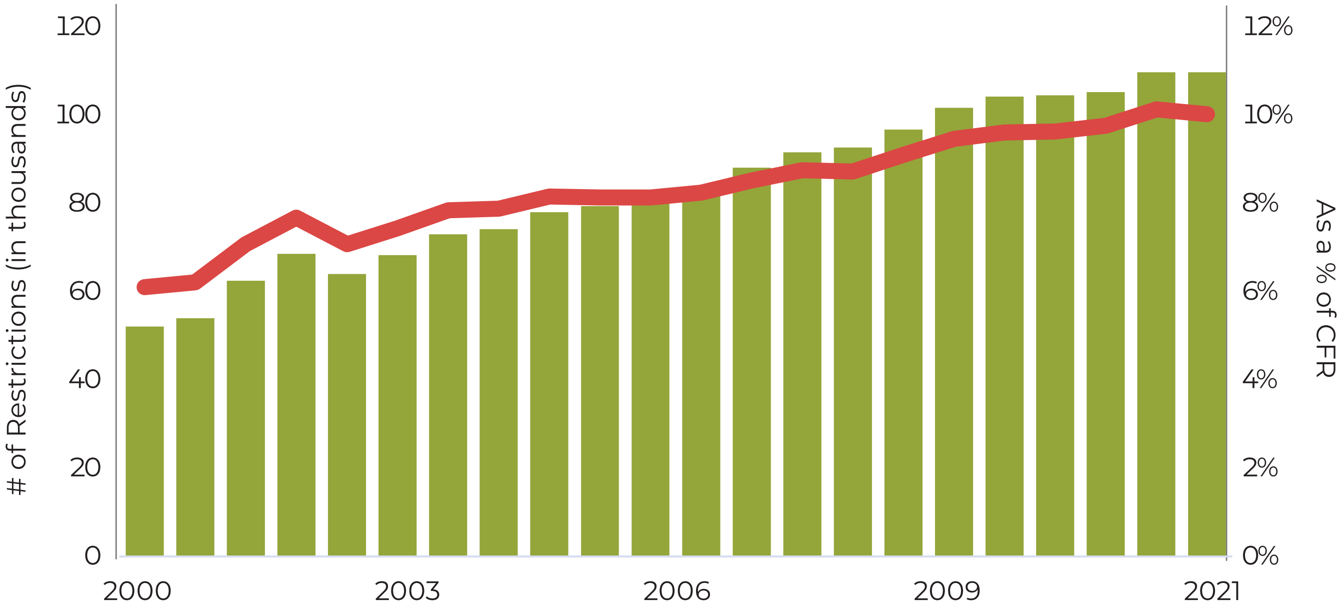
[1] Restrictions are a count of the number of occurrences of certain words – “shall”, “must”, “may not”, “required”, and “prohibited”.

requirements over time has become significant, particularly for sectors that are heavily regulated. This presents a significant barrier to entry for new firms and for smaller firms that lack personnel dedicated entirely to regulatory compliance. Although regulatory agencies are supposed to consider the cumulative impact of their handiwork and that of other regulators, they seldom do because (1) their priority is to develop and enforce new regulations and (2) there are no well-established methods for estimating cumulative impact.

Figure 10.3 - Regulatory Restrictions Have Doubled in the Last 20 Years



Source: RegHub

Note. Economy-wide restrictions

Figure 10.4 - Most Regulatory Restrictions Relate to EH&S and Tax

Source: GMU Mercatus Center, ACC analysis

Note. Economy-wide data.

OPPORTUNITY COST

Public debate over the value of a single regulation tends to focus on whether its benefits justify the cost. When benefits and/or costs are highly uncertain, the debate can become intractable. However, when it comes to the regulation of business, one fact is undisputed: resources spent complying with a mandatory requirement cannot be spent on other valuable, yet discretionary, activities. Economists refer to this as the “opportunity cost” of regulation because it represents forgone opportunities—the true measure of societal cost.

The concept of opportunity cost can be used to categorize regulation of chemical manufacturers into three types: (1) license to operate, (2) gatekeeper, and (3) functional.

License to operate regulations are those that impact the continuing operation of a chemical production facility.

These regulations include, for example, those relating to siting and permitting of a facility, air quality designations for a locality that impact industrial development, and those intended to prevent a major chemical accident. The consequences of prohibiting a new facility or shutting down an existing facility are significant for the many stakeholders impacted by the decision: workers, the community, the local economy, the value chain, and the owners of the facility. In other words, the opportunity cost of this kind of regulation is extremely high.

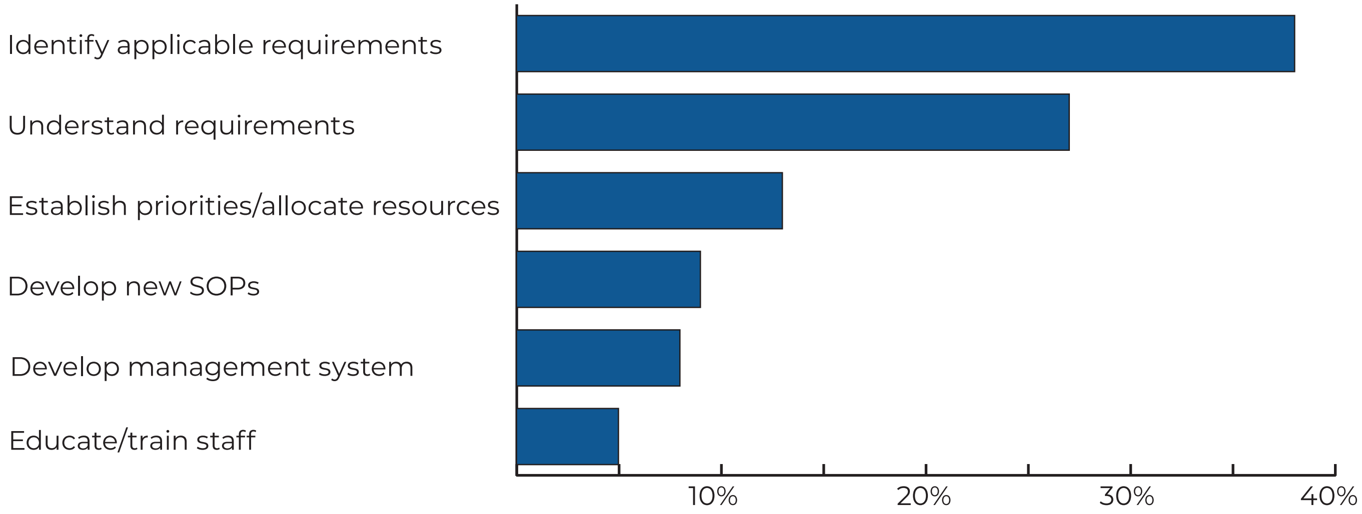
Gatekeeper regulations are those that require governmental approval before a commercial product can enter commerce. Many kinds of manufactured products—and most of the highest value-added products—require some type of government review, approval, registration, certification, or licensing before entering commerce. For example, EPA reviews new chemicals before these can be introduced into commerce. This review process can take 90 days, though the Agency often takes longer if it requests more information from the manufacturer. For food additives, FDA approval takes an average of 24 months. EPA approval of a new chemical pesticide often takes years. For some types of new products—including some medicines—regulatory approval can take decades. The opportunity cost of a lengthy regulatory review can be substantial, especially when the product represents a new technology with significant advantages over existing products. For small manufacturers, speed to market may be crucial to their economic survival.

Functional regulations are those that pertain to a single step of the production process or administration/governance of the company, such as air pollution control, product labeling, transportation of hazardous materials, and labor standards. These regulations may impose one-time capital costs and/or ongoing operational costs. Consider tax regulation: the CFR includes at least two dozen parts that impose tens of thousands of restrictions on U.S. chemical manufacturers, including income taxes, taxes on corporations, employment taxes, excise taxes, etc. Roughly 75% of the total paperwork burden imposed by the federal government is attributable to the Internal Revenue Service. Although functional regulation individually doesn't pose the same opportunity cost as license to operate or gatekeeper regulation, its cumulative impact on may well be greater due to the higher volume of such rules.

COMPLIANCE

Given the sheer number and complexity of regulations at the local, state, federal, and international levels, ensuring compliance is a challenging exercise. Chemical manufacturers tend to follow a six-step process: (1) identify applicable requirements, (2) understand these requirements and determine if and how they impact the company, (3) develop new or modify existing standard operating procedures (SOPs), (4) educate and train employees, (5) develop or modify a management system, and (6) allocate resources and revisit priorities. The entire compliance process is not simple, nor is it easy. Surveys indicate that the most challenging steps—especially for smaller firms—are typically 1 and 2—identifying and understanding new applicable requirements. Therefore, the first year of a new requirement is particularly important if the regulatory objective is to be achieved in a timely manner.

Figure 10.5 - Biggest Compliance Challenges: At the Front End



Source: National Association of Manufacturers (NAM).
Note. Data reflect NAM members.

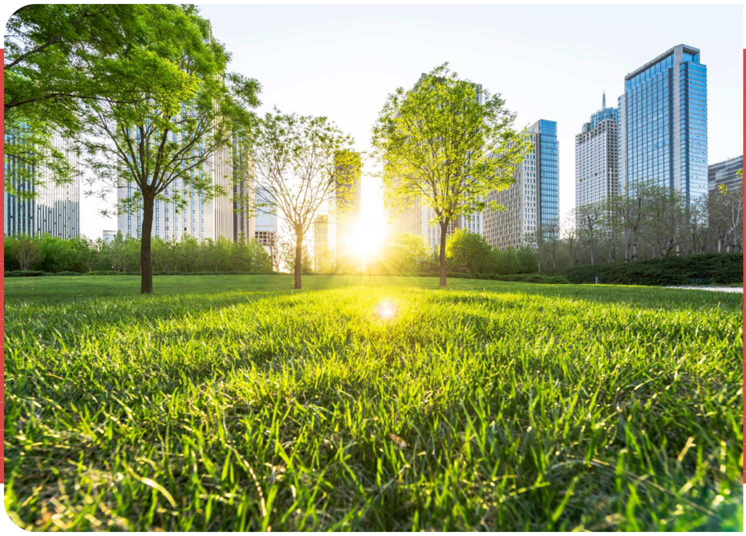
SMART REGULATION

Regulations vary enormously in cost-effectiveness. For example, for regulations designed to save lives (e.g., pollution control, workplace safety, food safety, transportation safety), cost effectiveness varies by 6 orders of magnitude—from $100,000 per life saved to $1 trillion per life saved. This large variation suggests that regulations could save more lives at the same cost and/or the same number of lives at a much lower cost. To achieve this goal, regulatory agencies should employ smart regulation—a set of principles and analytical techniques that represent best practice. For federal regulatory agencies, these principles and techniques are described in two Executive Orders (12866 and 13563) and in Office of Management and Budget (OMB) Circular A-4 (on regulatory analysis). Certain steps are particularly important when it comes to regulating business. For example, for major rules, regulators should always:

- Identify the market failure (to avoid unnecessary regulation);
- Construct regulatory alternatives sufficient to address the market failure and that vary in terms of scope (who must comply?) and stringency (to that extent must they comply?);
- Conduct benefit-cost analysis (to ensure that scarce resources are spent wisely) of each regulatory alternative, including the alternative of not regulating; and
- Conduct periodic retrospective review (to ensure existing regulations are working as intended over time).

CHAPTER 11

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

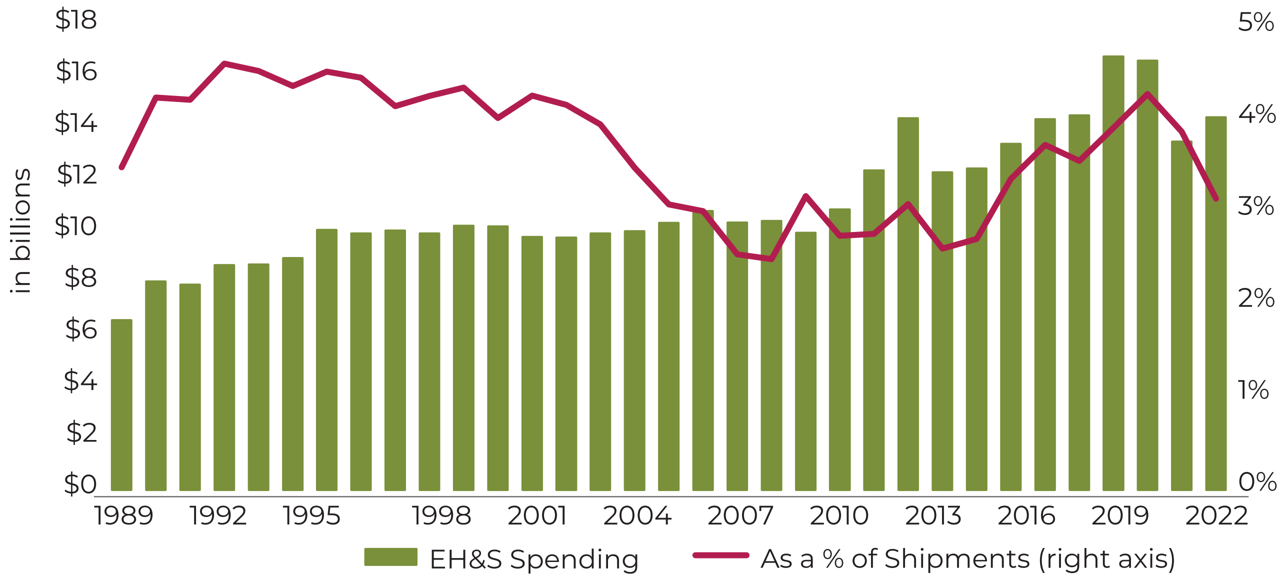
Today we're living healthier and longer lives—more than 30 years longer over the past century—thanks in large part to innovations made possible by the business of chemistry. The products of chemistry play a key role in the quality of life for a growing global population, through improved health and nutrition, 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.

Since the 1990s, 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 11.1 - EH&S Spending by Basic and Specialty Chemical Producers



Source: American Chemistry Council

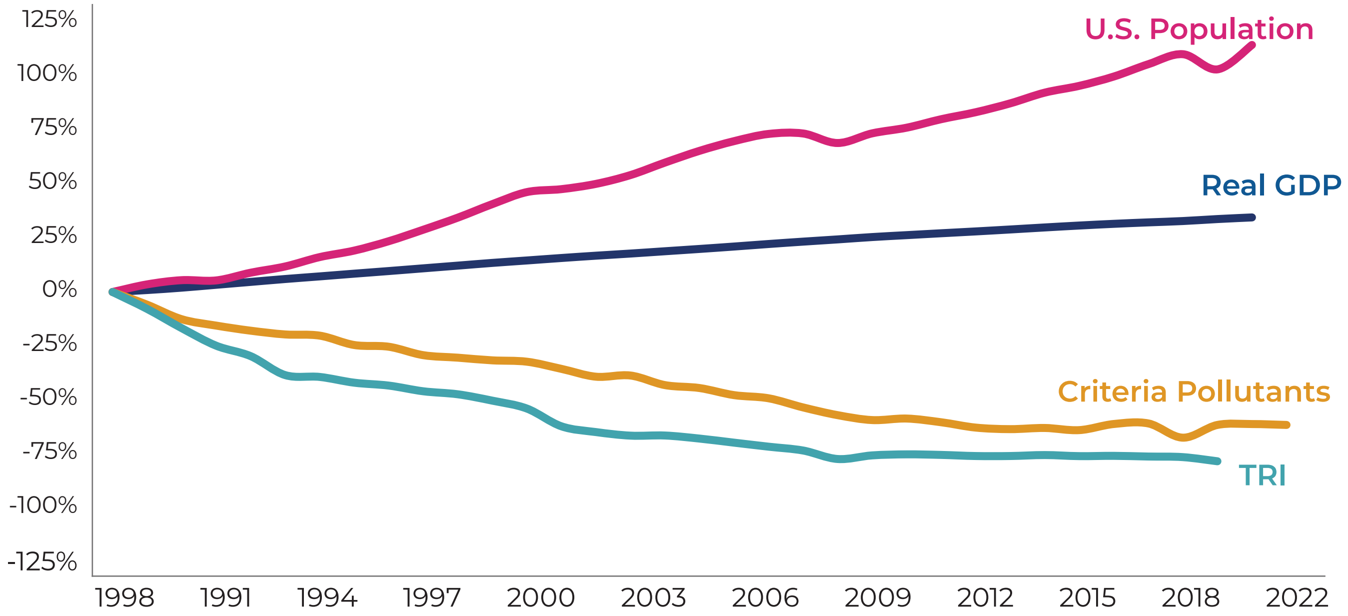
ENVIRONMENTAL PERFORMANCE

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.

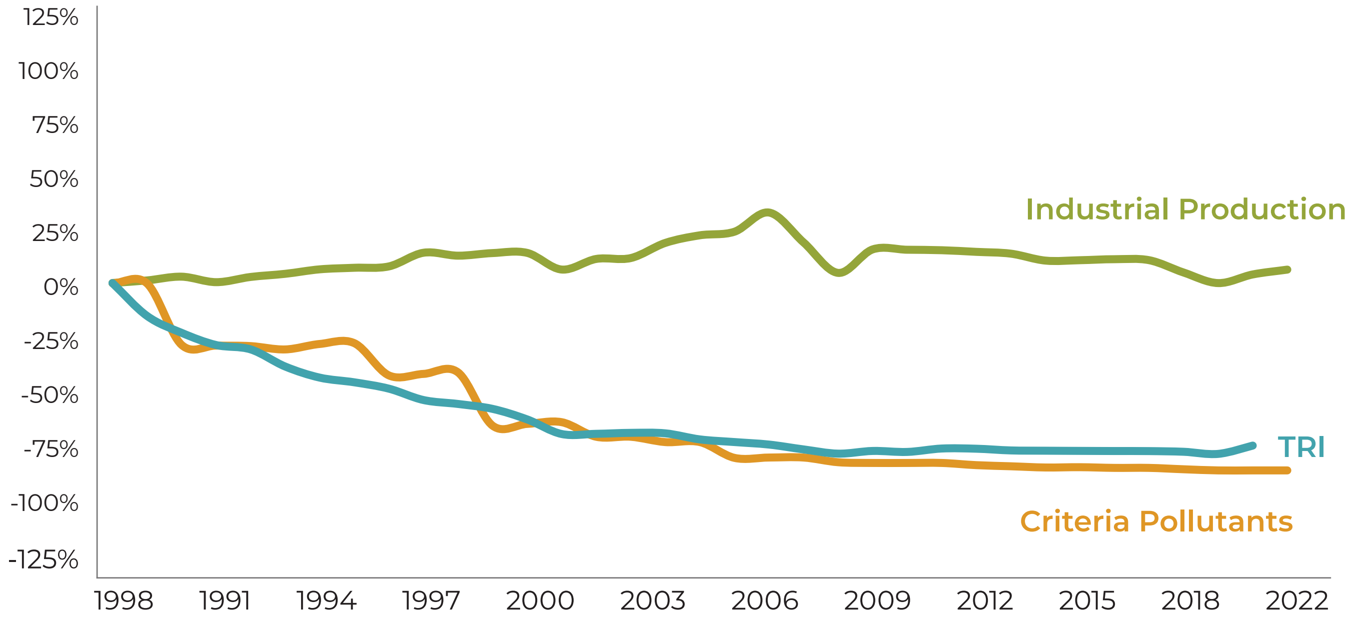
Because transforming raw materials into products used by other industries can generate pollution, basic industries such as chemicals are among those most heavily regulated, particularly as it relates to the environment. The chemical industry is one of the industry sectors required to report TRI data. 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 11.2 - Environmental Progress and Economic and Population Growth in the U.S.



1988 is base year. Criteria pollutants and TRI data for all sectors. 2021 is latest available TRI data
Source: U.S. Bureau of Economic Analysis (BEA), U.S. Census Bureau, U.S. EPA

Figure 11.3 - Environmental Progress and Production in the Business of Chemistry



1988 base year. Criteria pollutants and TRI data for chemical industry. 2021 is latest available TRI 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 11.1 - Key Pollution Indicators: A Summary of Progress

	1990	1994	1998	2002	2006	2010	2014	2018	2022
					in thousands of short tons				
Sulfur Dioxide									
Total, All Sectors	23,077	21,346	18,944	14,845	12,441	6,938	4,598	2,411	1,934
Business of Chemistry	297	275	261	259	185	126	123	106	82
As a % of Total	1.3%	1.3%	1.4%	1.7%	1.5%	1.8%	2.7%	4.4%	4.2%
Nitrogen Oxides									
Total, All Sectors	25,527	25,350	24,348	25,254	20,273	15,340	12,160	9,109	7,618
Business of Chemistry	168	160	129	70	55	51	47	40	34
As a % of Total	0.7%	0.6%	0.5%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%
Volatile Organic Compounds									
Total, All Sectors	24,108	22,570	18,781	17,333	16,470	13,596	13,365	16,156	16,557
Business of Chemistry	634	691	394	250	88	83	77	77	70
As a % of Total	2.6%	3.1%	2.1%	1.4%	0.5%	0.6%	0.6%	0.5%	0.4%
Carbon Monoxide									
Total, All Sectors	154,188	133,558	115,380	99,416	81,572	60,247	53,733	62,783	62,584
Business of Chemistry	1,183	1,171	1,081	284	186	167	129	122	115
As a % of Total	0.8%	0.9%	0.9%	0.3%	0.2%	0.3%	0.2%	0.2%	0.2%
Coarse Particulates (PM_{10})									
Total, All Sectors	27,753	28,608	22,893	16,670	16,783	16,239	15,718	17,130	16,803
Business of Chemistry	77	76	65	40	27	22	19	20	17
As a % of Total	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%
Fine Particulates ($PM_{2.5}$)									
Total, All Sectors	7,560	7,542	6,261	5,000	5,231	4,616	4,386	5,606	5,823
Business of Chemistry	47	49	40	30	21	17	14	15	13
As a % of Total	0.6%	0.6%	0.6%	0.6%	0.4%	0.4%	0.3%	0.3%	0.2%
Ammonia									
Total, All Sectors	4,320	4,589	4,940	4,354	4,522	4,439	4,336	5,218	5,495
Business of Chemistry	183	183	130	23	19	23	22	23	26
As a % of Total	4.2%	4.0%	2.6%	0.5%	0.4%	0.5%	0.5%	0.4%	0.5%

Notes. Data shown for select years only. Business of chemistry emissions do not include emissions from fuel combustion. Particulates include condensibles.

Source: Environmental Protection Agency, National Tier 1 CAPS Trends.

Table 11.2 - Toxics Release Inventory: Business of Chemistry

	1998	1991	1994	1997	2000	2003	2006	2009	2012	2015	2018	2021
	in million of pounds											
Total Releases*	690	484	376	301	237	192	162	123	140	133	132	150
Air	620	430	323	233	185	152	113	84	84	77	75	75
Surface Water	19	11	6	5	4	3	2	2	2	3	2	2
Land	51	43	47	64	49	37	47	38	54	53	55	74
Underground Injection	160	137	112	129	110	97	96	75	97	97	106	96
Off-site releases**	70	44	31	43	54	40	49	43	52	65	58	66

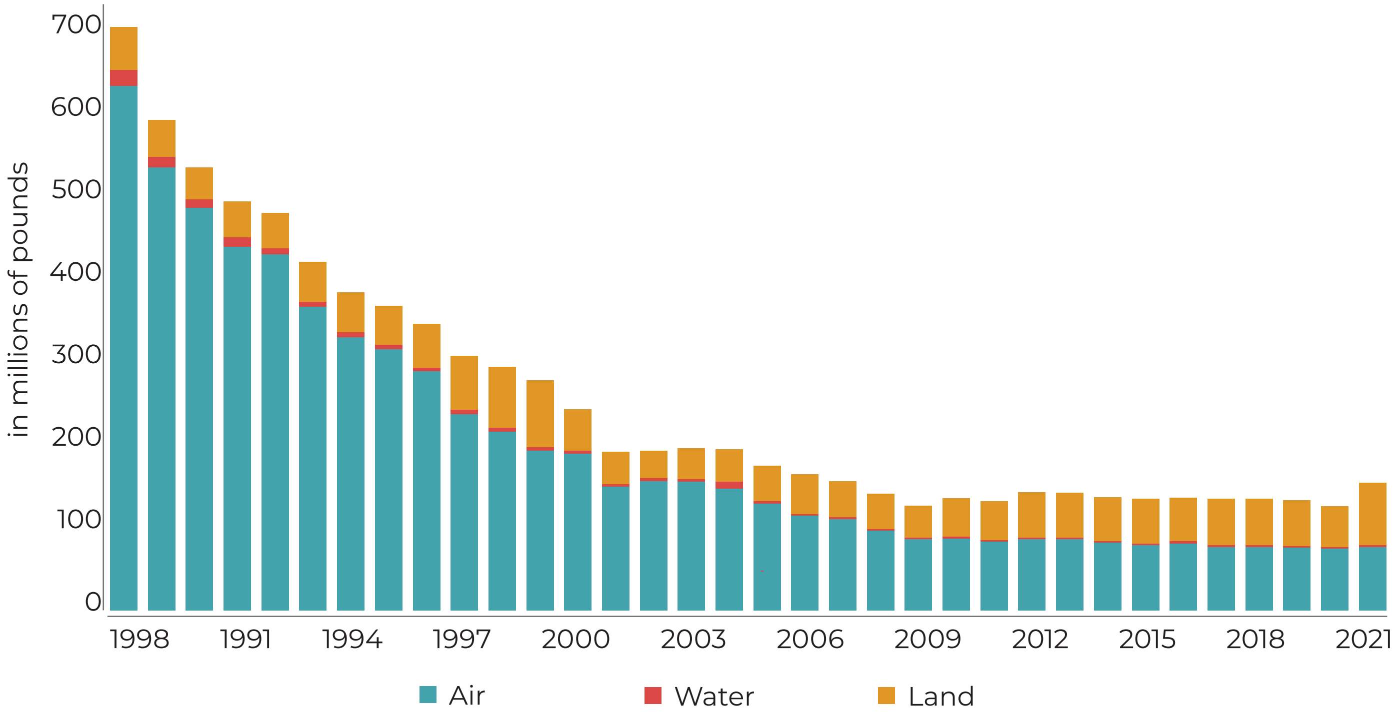
*The American Chemistry Council defines total releases to be the sum of total air, surface water, and land. Underground injections are not included in releases to the environment. Includes 1988 core chemicals only (does not include delisted chemicals; chemicals added in 1990, 1991, 1994, 1995; or aluminum 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: 2021 is latest available data. Data shown for select years only.

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

Figure 11.4 - 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 11.3 - Occupational Injury and Illness Rates

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Lost workday cases rate per 100 employees									
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

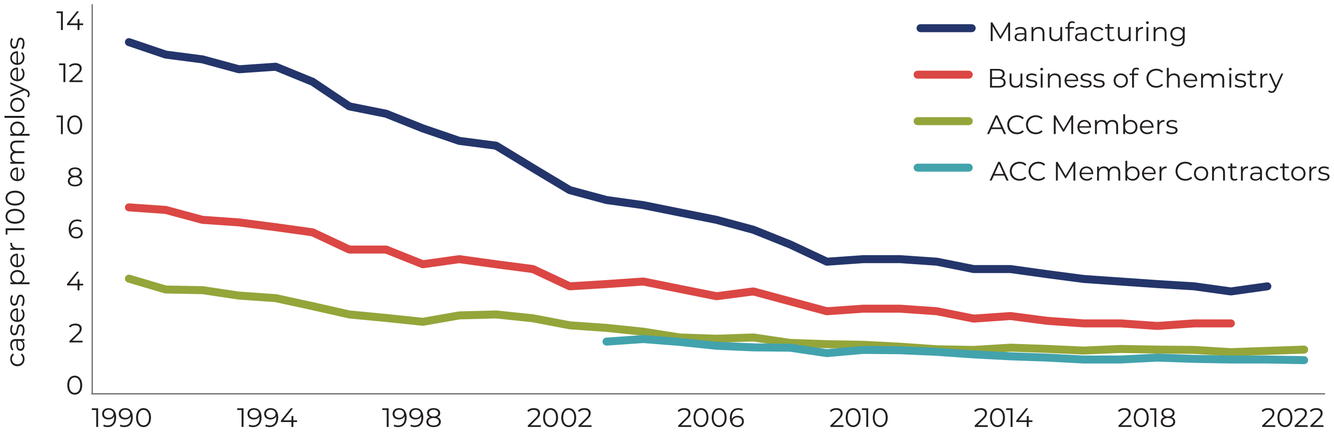


Figure 11.5 - Trends in Occupational Injury and Illness Incidence Rates

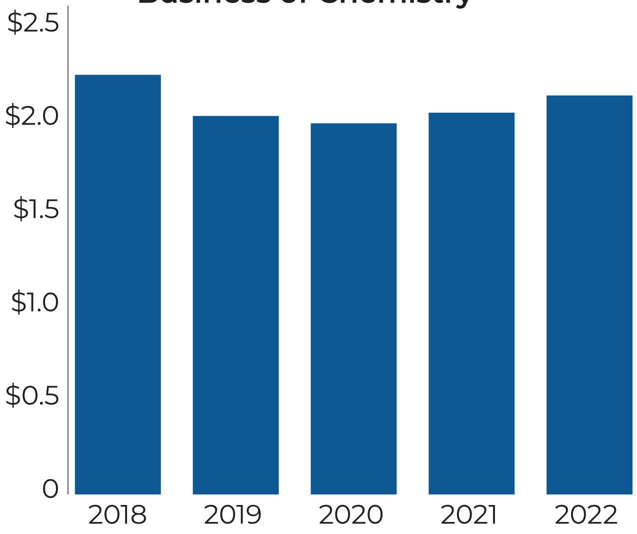
SPENDING ON SECURITY

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.

Figure 11.6 - Security Spending by the Business of Chemistry



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: cash-based spending for vulnerability assessments, development of security plans and procedures, and investment in physical improvements and cyber security improvements (including process control equipment) for facility, corporate sites and value chain, including spending to meet customer security requirements.

ACC'S COMMITMENT TO EHS&S

Responsible Care®

The safety of chemical operations and products is a core priority for ACC members. Responsible Care is our industry's commitment to the health and safety of our employees, the communities in which we 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.

Learn more at: 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.

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

TRANSCAER®

The American Chemistry Council is a sponsor of TRANSCAER® (Transportation Community Awareness Emergency Response), an outreach program covering North America. Since 1986, the organization has focused on assisting communities and training emergency responders to prepare for and respond to hazardous material transportation incidents. The TRANSCAER program is led by industry professionals and supported by partner agencies who are critical to the success of our mission.

TRANSCAER volunteer members come from a variety of sectors in the industry, including chemical manufacturing, transportation, distribution, industry & industry associations, emergency response, and government.

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

CHEMTREC®

Established in 1971 as a public service of the American Chemistry Council, 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. CHEMTREC's highly trained personnel receive hundreds of calls every day and provide assistance for incidents that range from minor to critical.

But, CHEMTREC is more than just a call center; they are an experienced partner who can help reduce risk and internal burdens so your organization can succeed and grow. As an emergency response information provider, they will support you throughout the process of chemical transportation.

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

Chemistry & Sustainability

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.

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.

This commitment to create a cleaner, safer and more sustainable future is both the right thing to do – and it's also good for the bottom line. The U.S. chemical industry can be more economically competitive on a global scale and more efficient as it cuts waste and reduces environmental impact. Our companies can build deeper relationships with employees, consumers and residents in the communities where we do business. And it won't stop here – our members are committed to continually building on these efforts.

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: www.americanchemistry.com/chemistry-in-america/chemistry-sustainability

CHAPTER 12

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, minerals, and plants, 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.

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

Figure 12.1 - Derivation of Petrochemical Feedstocks

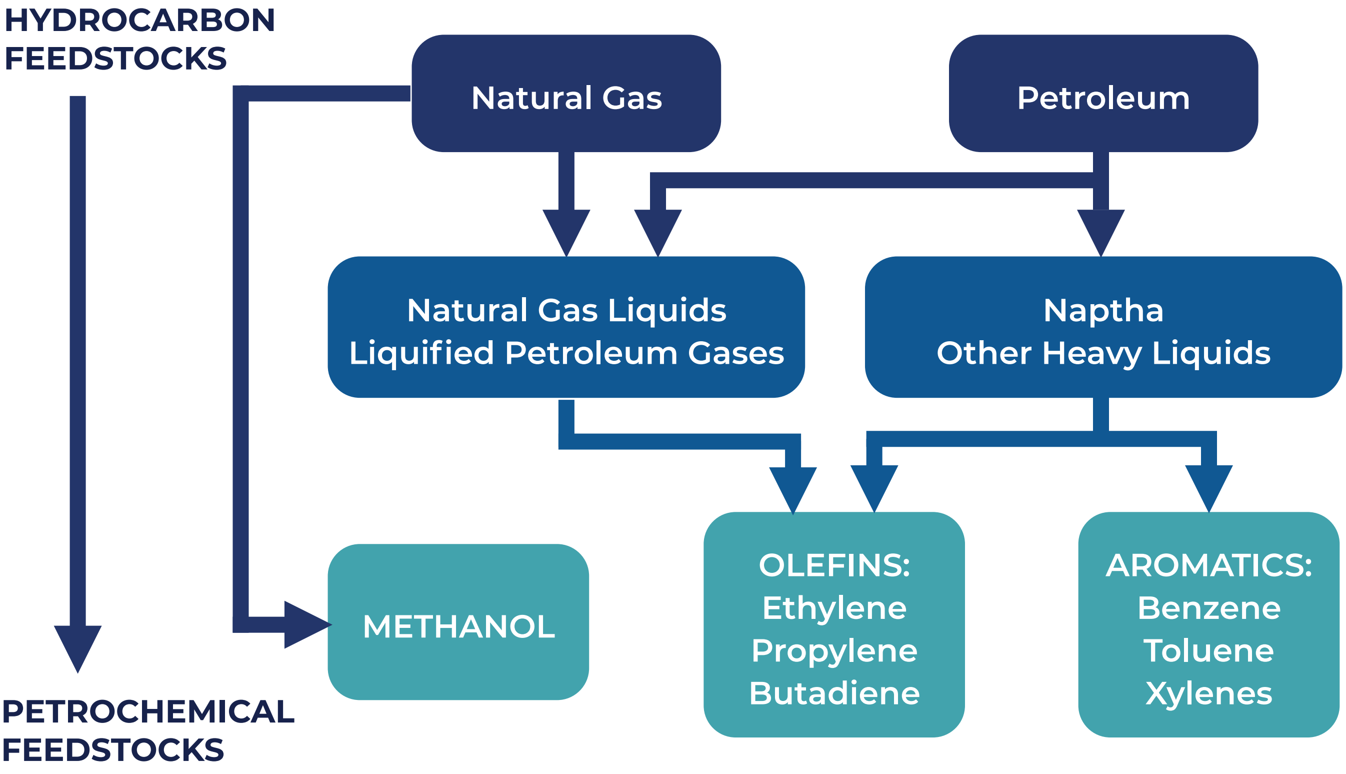
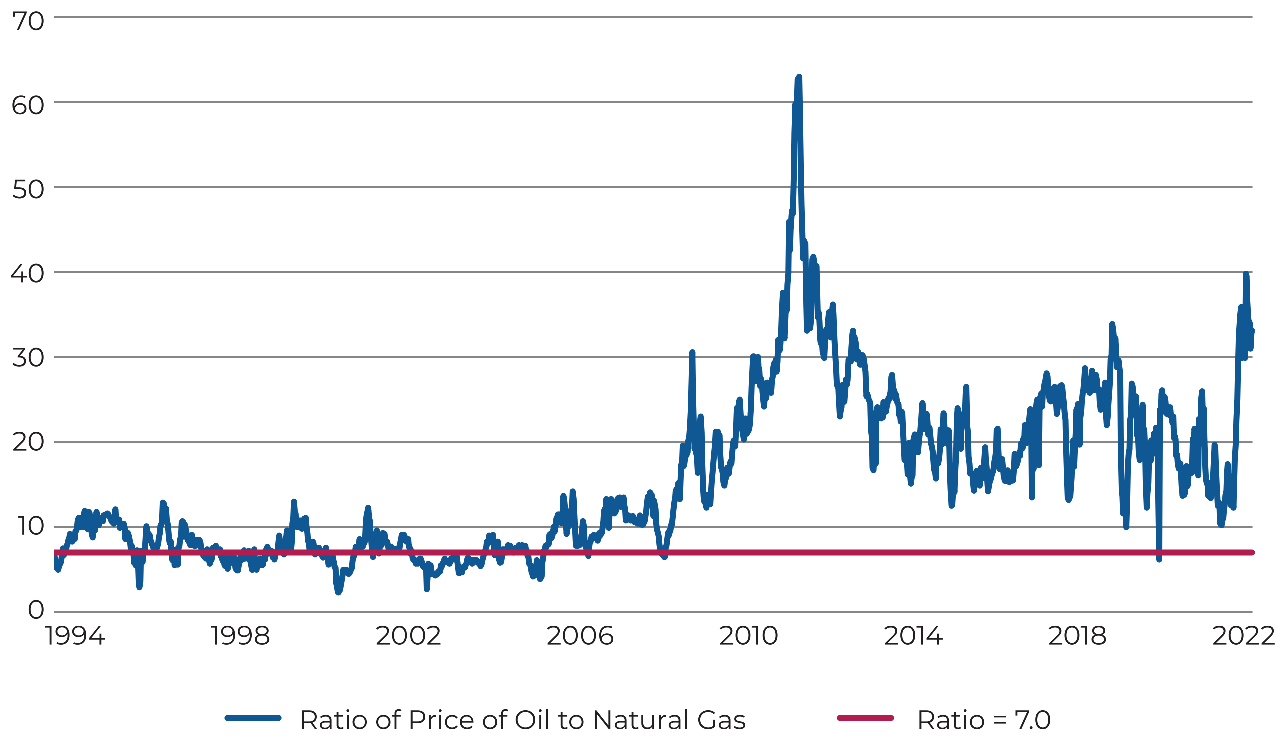


Figure 12.2 - U.S. Based Petrochemical Competitiveness: Ratio of the Price of Oil (Brent) to Natural Gas (Henry Hub)



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 largely been above 7.0 since late 2009.

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.

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%.

ENERGY CONSUMPTION & COSTS

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.

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

Table 12.1 - Energy Consumption by the Business of Chemistry

Past five years vs. historical snapshot

	1974	1990	2000	2010	2018	2019	2020	2021	2022
					in trillions of BTUs				
Natural Gas	1,612	1,641	1,804	1,729	2,282	2,268	2,102	2,150	2,197
Coal and Coke	311	272	303	188	105	99	96	95	93
Fuel Oil	285	77	59	17	15	14	11	11	11
Purchased Electricity	437	461	522	471	461	441	398	445	458
Other	377	650	973	767	826	830	784	808	825
Total Fuel & Power	3,022	3,101	3,661	3,172	3,689	3,652	3,391	3,509	3,584
NGLs/LPGs*	1,483	924	1,291	1,334	2,283	2,334	2,415	2,480	2,677
Heavy Liquids	942	1,029	1,167	943	647	597	534	537	444
Natural Gas	430	744	709	430	891	930	945	960	1,065
Coal	19	21	33	19	17	17	16	16	16
Total Feedstock	2,165	2,718	3,200	2,726	3,837	3,877	3,910	3,993	4,202

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

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

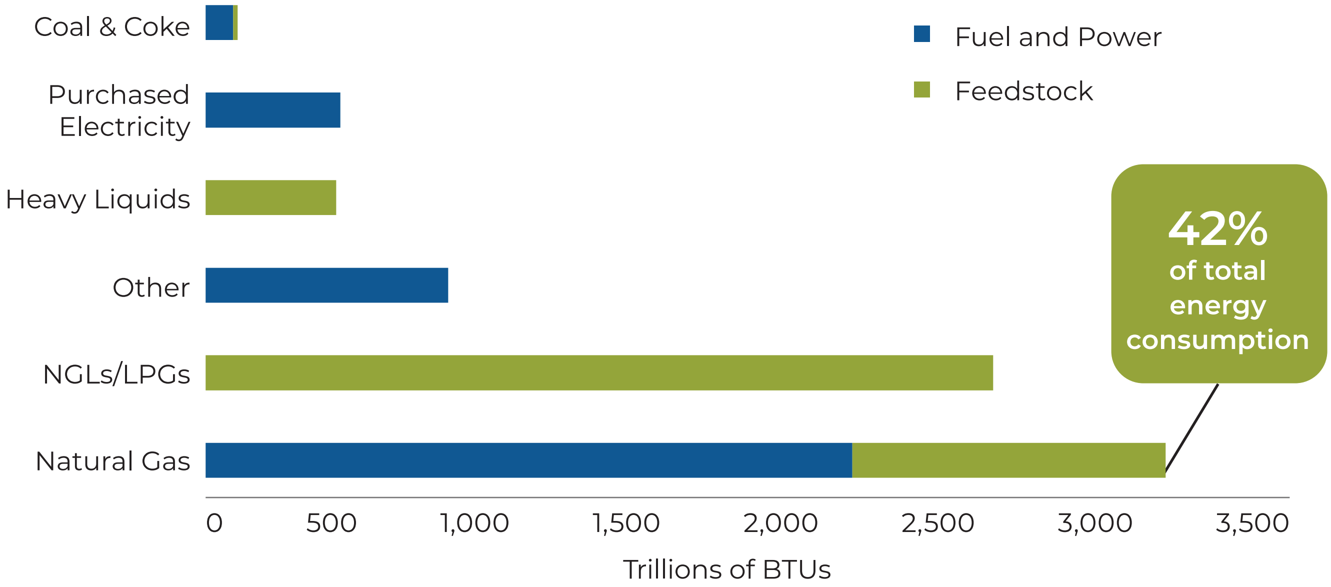
*Natural gas liquids (NGLs) and liquefied petroleum gases (LPGs) include ethane, propane, and butanes.

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.

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, there is a clear incentive for energy efficiency efforts.

Figure 12.3 - Composition of Energy Requirements, 2022



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

Table 12.2 - Value of Energy Consumed by the Business of Chemistry

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
					in $billions					
Total Value	43.1	57.2	39.3	38.5	48.1	58.6	47.5	37.6	61.1	81.5
Fuel & Power	18.0	19.1	16.9	16.5	17.0	17.0	16.0	13.5	17.8	22.2
Feedstocks	25.1	38.1	22.4	22.1	31.1	41.7	31.5	24.1	43.3	59.4

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

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

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

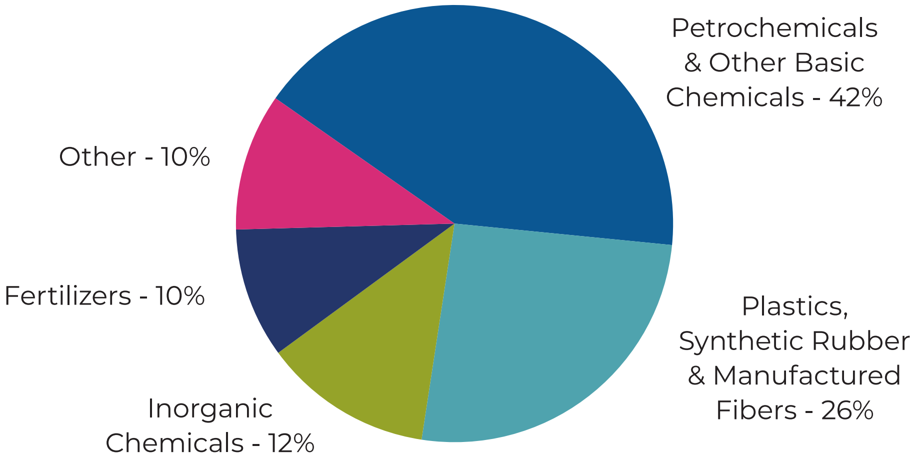
Energy Efficiency from the Products of Chemistry

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

GREENHOUSE GAS EMISSIONS

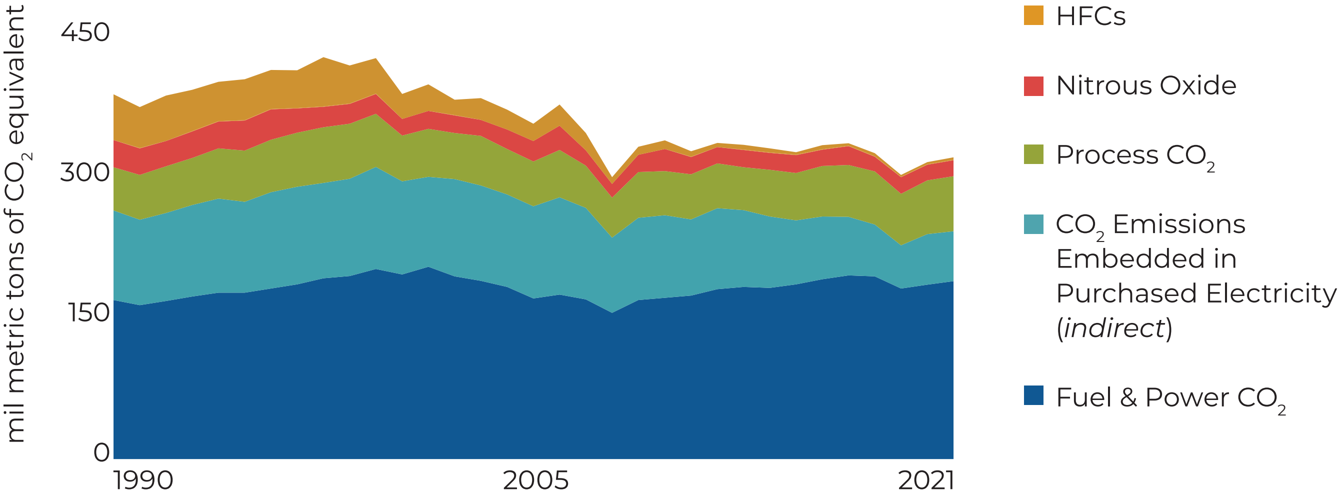
Radiation from the sun penetrates through the earth's atmosphere and warms its surface. Certain gases in the atmosphere, however, will trap (absorb) some of the outgoing infrared (long-wave) radiation; this radiation is then reradiated back toward Earth. This is similar to the way a greenhouse prevents heat from escaping through its glass panels. As a result, this phenomenon is called the

Figure 12.4 - Share of Total Energy Consumption by Segment



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

Figure 12.5 - Business of Chemistry Greenhouse Gas Emissions



"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, and nitrous oxide; other greenhouse gases are generated in some industrial processes, including hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6). There are certain human activities that add to the levels of most of these naturally-occurring gases:

- *Carbon dioxide* (CO_2) released into the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood or wood products are burned.
- *Nitrous oxide* (NO_2) emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.
- *Methane* (CH_4) 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 12.3 - Business of Chemistry Greenhouse Gas Emissions

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	in million metric tons of carbon dioxide equivalent									
Scope 1 (Direct Emissions)*										
Fuel and Power CO_2	173.0	175.2	174.2	177.7	182.9	186.9	185.8	173.4	177.5	180.9
Process CO_2	45.4	43.3	47.2	48.0	51.1	52.2	53.5	52.2	54.5	55.6
Subtotal CO_2	218.4	218.5	221.4	225.7	234.0	239.1	239.3	225.6	232.0	236.5
Nitrous Oxide	16.3	17.7	17.3	18.1	16.4	19.2	15.0	16.9	15.7	16.2
Methane	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.3	0.4	0.4
HFCs	4.1	5.0	4.3	2.8	4.3	2.7	3.1	1.8	2.2	2.5
Scope 2 (Indirect Emissions)**										
CO_2 Emissions Embedded in Purchased Electricity	82.0	77.8	72.2	64.8	63.7	59.3	52.6	43.9	51.1	50.6
Total Emissions (Scope 1 & 2)	**320.8**	**319.1**	**315.4**	**311.6**	**318.6**	**320.6**	**310.5**	**288.5**	**301.4**	**306.2**
Performance Trend Indices (1990 = 100)										
Chemical Industry Output Index	122.1	120.8	120.3	119.6	117.9	116.3	114.7	112.4	117.6	120.2
Energy Efficiency Index	90.2	91.8	92.5	94.5	98.8	102.3	102.6	97.3	96.2	96.2
GHG Emissions Index - Scope 1 & 2	86.7	86.2	85.2	84.2	86.1	86.6	83.9	78.0	81.4	82.7
GHG Intensity Index - Scope 1 & 2	71.0	71.4	70.9	70.4	73.0	74.5	73.1	69.4	69.3	68.9
GHG Emissions Index - Scope 1 only	85.5	86.4	87.1	88.4	91.3	93.6	92.3	87.6	89.7	91.5
GHG Intensity Index - Scope 1 only	70.1	71.6	72.4	73.9	77.4	80.5	80.5	78.0	76.3	76.2

Notes. Process CO_2 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 N_2O emissions. In 2013, EPA made revisions to its methodology to calculate process CO_2 emissions that resulted in significant upward revisions. The industrial production index (the denominator) was revised as well.

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

Sources: EPA, American Chemistry Council (Note: fuel and power CO_2 include revised data on embedded CO_2 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 13

Supply Chain & Distribution

Although ten states account for around two-thirds of U.S. chemical production, 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 8-12% of the business of chemistry's value of shipments.

TRANSPORTATION BY MODE

Truck

Over-the-road transportation is the most common method of domestic chemicals transportation, accounting for around three-fifths of volume shipped. Truck transportation is typically lower cost than other modes, and offers more flexibility (e.g., less reliant on set schedules, like trains or airplanes). Some companies in the business of chemistry have their own fleet of trucks while others 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 the most common mode of transport for many types of chemicals, particularly basic chemicals and resins.

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.” Around one-fifth (by volume) of chemicals are transported via rail. 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), Freight railroads moved 2.3 million carloads of plastics, fertilizers and other chemicals in 2022. 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.

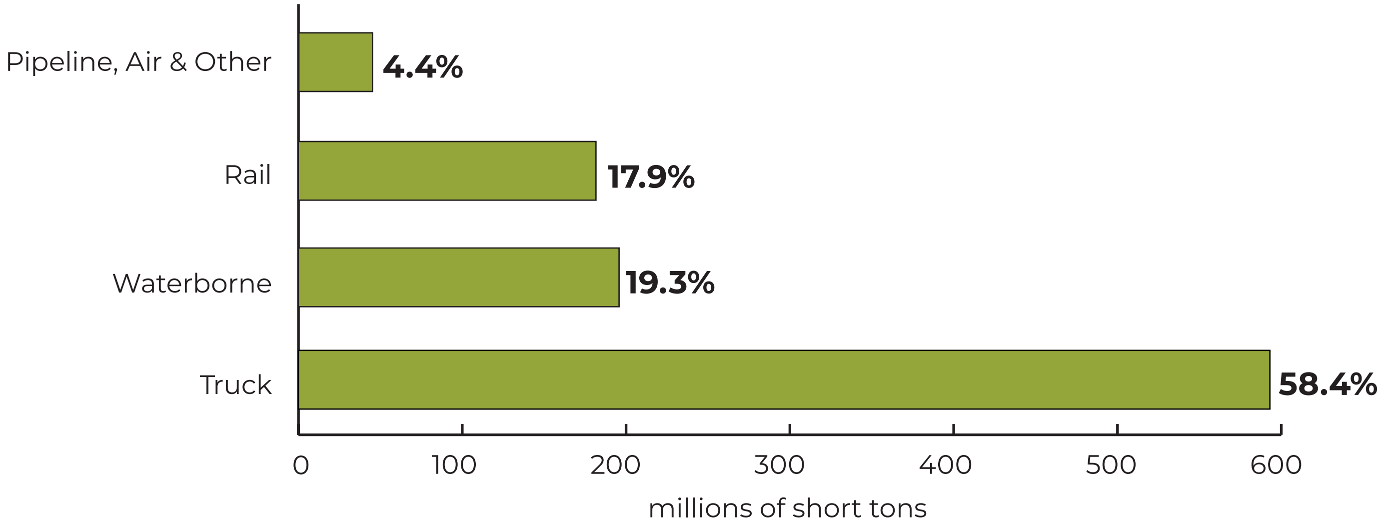
Waterborne

Waterborne transport is often the least expensive method of transporting chemicals. Depending on the product and the distance, the cost savings can be significant, but can only be realized by shipping large volumes and/or long distances. As a result, waterborne transport tends to be 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-costal system along the Gulf Coast are also major domestic water routes used to transport chemicals.

Other

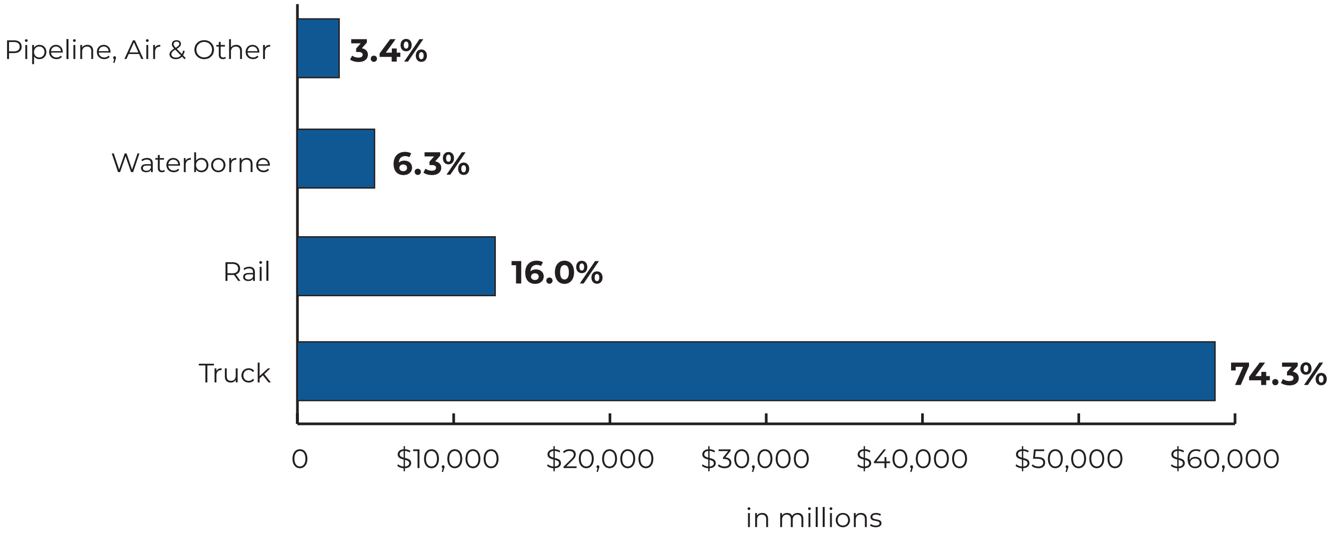
Other modes of transportation include pipeline, air, and intermodal transportation (the use of multiple modes of transportation). More than three-quarters of this category includes pipeline transportation of ethylene and oxygen, usually for short distances. Small volumes of consumer products are shipped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

Figure 13.1 - Transportation by Mode (Volume of Chemical Shipments), 2022



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

Figure 13.2 - Transportation by Mode (Value of Chemical Shipments), 2022



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

CHAPTER 14

Chemistry in the States & Regions

With nearly all manufactured goods being touched by the business of chemistry, the chemical industry is important in some facet to every state in our country. Across industries, individual state economies depend on the continued availability of goods and services from other states, as well as the ability to sell its goods and services throughout the nation. This is especially true for the business of chemistry, in that all states depend on the products of chemistry to support manufacturing, agricultural, service and other industries.

Nearly every state hosts some form of chemical production; however, the majority of chemicals production occurs in relatively few states. Much of basic chemical and resin 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, more than 90% of primary petrochemicals capacity is located in Texas and Louisiana (combined), according to data from ICIS.

Compared to basic chemicals and resins, the manufacture of other categories of chemical products is not as heavily concentrated on the Gulf Coast. For example, the Midwest leads the country in agricultural chemicals, with around one-third of total shipments, and consumer products manufacturing has a strong presence in the Southeast. The Midwest and the Southeast lead the country in the production of specialty chemicals.

Figure 14.1 - Chemistry Shipments by State

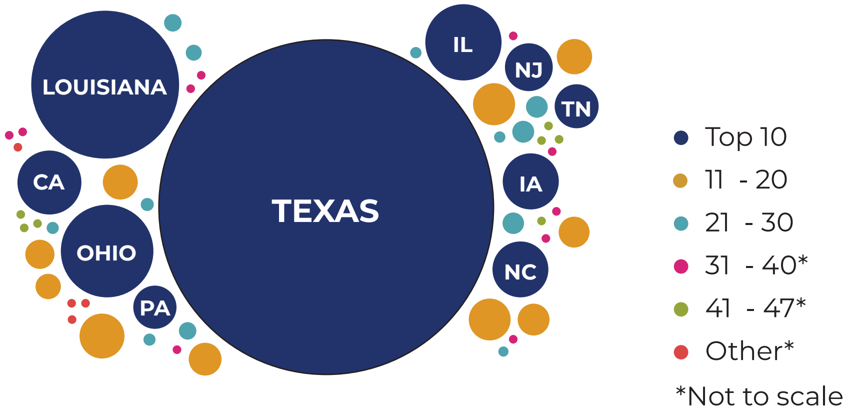


Table 14.1 - State Chemistry Statistics, 2022

State	Value of Shipments* (in $millions)	Employment	Average Wages and Salaries ($)	Chemical Exports (in $millions)
Texas	142,899	70,314	131,100	60,565
Louisiana	65,207	26,504	131,500	13,172
Ohio	31,860	42,404	105,100	7,224
Illinois	29,668	24,785	95,200	7,533
Iowa	24,256	8,065	86,400	2,422
California	20,955	36,535	83,500	8,854
North Carolina	19,193	20,825	88,300	4,468
New Jersey	15,477	19,627	106,800	9,243
Tennessee	15,023	24,198	92,700	4,279
New York	14,748	16,434	88,700	4,102
Pennsylvania	14,417	23,558	83,200	6,863
South Carolina	13,779	17,545	82,700	4,020
Georgia	13,127	20,194	77,700	4,308
Indiana	12,648	14,096	78,100	2,665
Missouri	11,636	15,442	76,700	2,990
Michigan	11,430	19,463	101,600	4,018
Kentucky	11,295	10,795	85,900	3,138
Alabama	11,047	10,404	96,300	2,647
Florida	11,021	16,337	92,800	7,033
Nebraska	9,377	4,139	76,100	337
Wisconsin	8,849	14,455	87,300	2,082
Virginia	7,006	12,362	84,300	2,341
Minnesota	6,761	7,956	99,700	1,529
West Virginia	6,746	6,567	97,100	1,711
Kansas	5,909	4,936	89,800	865
Massachusetts	4,662	6,154	99,300	2,090
Mississippi	4,444	4,916	80,100	1,329
Oklahoma	4,410	3,342	81,400	1,040
Arkansas	3,951	5,021	76,500	726
Maryland	3,547	4,111	92,600	1,319
South Dakota	3,318	1,096	77,700	465
Colorado	2,839	3,452	72,900	571
Oregon	2,754	3,968	76,700	2,292
Washington	2,716	3,923	85,600	1,026
Connecticut	2,439	4,889	136,200	1,086
Utah	2,297	2,791	69,100	895

*Shipment data for 2021 (latest available). Listed in descending order based on value of shipments.

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

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. Data include estimates and rounding and, as a result, the sum of states may not equal U.S. totals.

Table 14.1 - State Chemistry Statistics, 2022

State	Value of Shipments* (in $millions)	Employment	Average Wages and Salaries ($)	Chemical Exports (in $millions)
Wyoming	2,181	1,643	111,900	1,423
North Dakota	1,848	301	97,500	605
Arizona	1,527	4,752	69,700	1,025
Nevada	1,178	1,600	70,800	317
Delaware	1,158	2,100	115,200	891
Idaho	1,063	2,911	75,800	443
Rhode Island	848	1,388	70,600	311
New Mexico	839	655	94,600	235
Maine	432	584	66,500	49
New Hampshire	358	808	73,500	123
Vermont	252	980	62,400	76
Montana	220	385	87,800	275
Hawaii	D	392	57,400	260
Alaska	D	60	36,100	15
District of Columbia	D	<10	71,900	14
US Total	**$583,840**	**550,170**	**97,200**	**189,263**

*Shipment data for 2021 (latest available). Listed in descending order based on value of shipments.

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

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. Data include estimates and rounding and, as a result, the sum of states may not equal U.S. totals.

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 is a major employer in a number of states where the industry employs a significant percentage of the state's manufacturing workers. The business of chemistry directly employs workers in occupations such as equipment operators, engineers, sales managers, scientists, safety specialists, and environmental protection professionals. 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 made by 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.

STATE SNAPSHOTS

Texas is the largest chemistry producing state in the U.S.

In 2022, the Texas chemical industry:

- Provided 70,314 direct jobs and another 345,564 related jobs.
- Was the 2nd largest manufacturing industry in the state.
- Paid $9.2B in annual wages, with an average wage 50% higher than the average manufacturing wage in the state.
- Manufactured 36% of the nation's basic chemicals and 35% of the nation's resins.
- Invested $5.54B across the state to build & update equipment and facilities.

Louisiana is the 2nd largest chemistry producing state

In 2022, the Louisiana chemical industry:

- Provided 26,504 direct jobs and another 79,125 related jobs.
- Was the 2nd largest manufacturing industry in the state.
- Paid $3.5B in annual wages, with an average wage 55% higher than the average manufacturing wage in the state.
- Manufactured 17% of the nation's agricultural chemicals, 15% of the nation's resins, and 14% of the nation's basic chemicals.
- Invested $3.57B across the state to build & update equipment and facilities.

Ohio is the 3rd largest chemistry producing state

In 2022, the Ohio chemical industry:

- Provided 42,404 direct jobs and another 130,007 related jobs.
- Was the 4th largest manufacturing industry in the state.
- Paid $4.5B in annual wages, with an average wage 50% higher than the average manufacturing wage in state.
- Manufactured 13% of the nation's consumer products.
- Invested $847M across the state to build & update equipment and facilities

Illinois is the 4th largest chemistry producing state in the U.S.

In 2022, the Illinois chemical industry:

- Provided 24,785 direct jobs and another 64,652 related jobs.
- Was the 3rd largest manufacturing industry in the state.
- Paid $2.4B in annual wages, with an average wage 13% higher than the average manufacturing wage in the state.
- Manufactured 7% of the nation's specialty chemicals and 7% of the nation's consumer products.
- Invested $656M across the state to build & update equipment and facilities.

Iowa is the 5th largest chemistry producing state in the U.S.

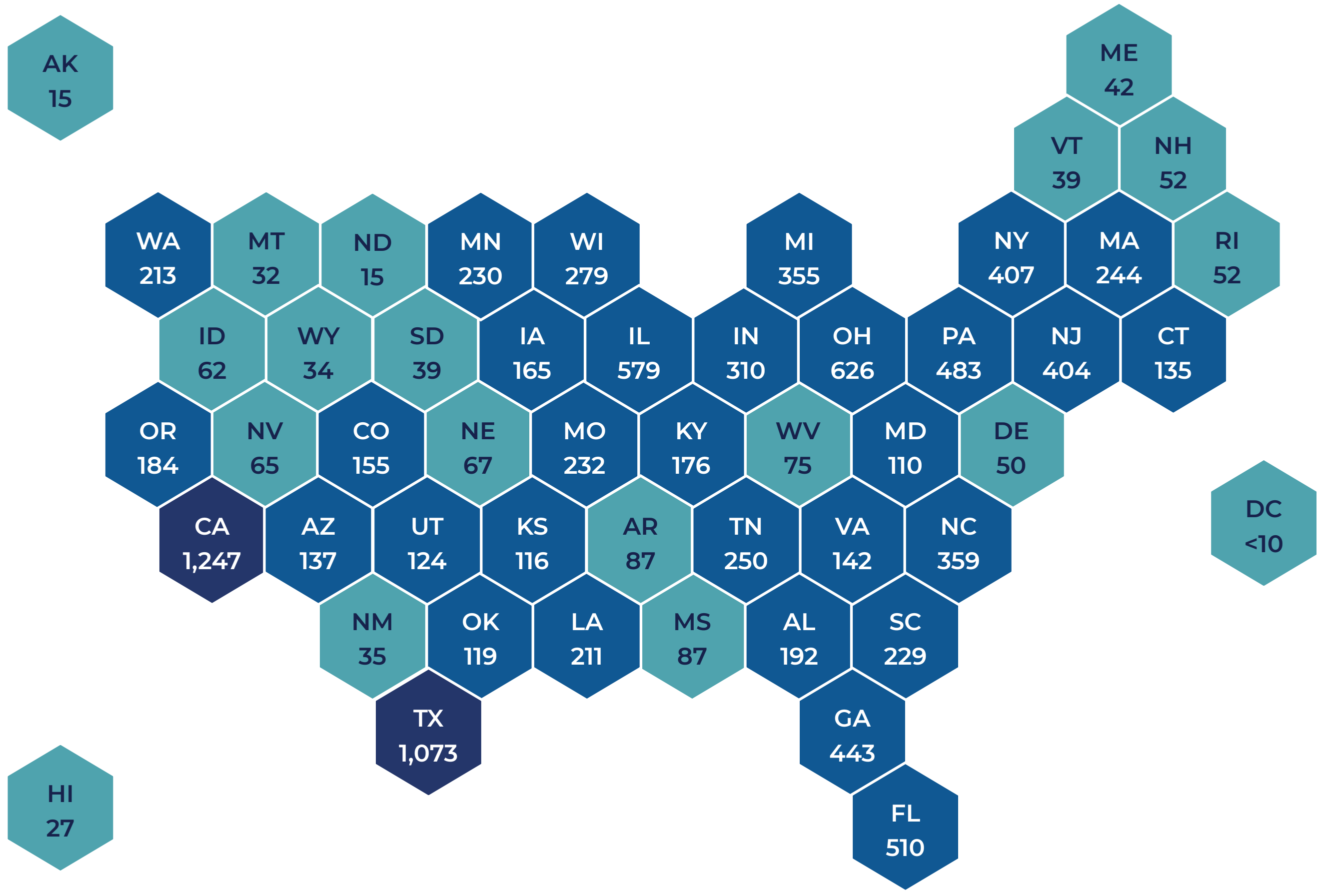
In 2022, the Iowa chemical industry:

- Provided 8,065 direct jobs and another 22,043 related jobs.
- Was the 2nd largest manufacturing industry in the state.
- Paid $697M in annual wages, with an average wage 25% higher than the average manufacturing wage in the state.
- Manufactured 7% of the nation's agricultural chemicals.
- Invested $1.39B across the state to build & update equipment and facilities.

CHEMISTRY IN THE STATES & CONGRESSIONAL DISTRICTS

The American Chemistry Council maintains detailed data on the business of chemistry in the states and congressional districts. In addition to the data presented here for the top five chemistry-producing states, the fact sheets include additional data on state, local and federal taxes, as well as jobs in the plastics and rubber products manufacturing industry. To learn more about chemistry in the states and congressional districts, visit www.chemistryinthestates.com.

Figure 14.2 - 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 2017=100. The US CPRI is based on information from the Federal Reserve and is weighted by chemical shipments by region.

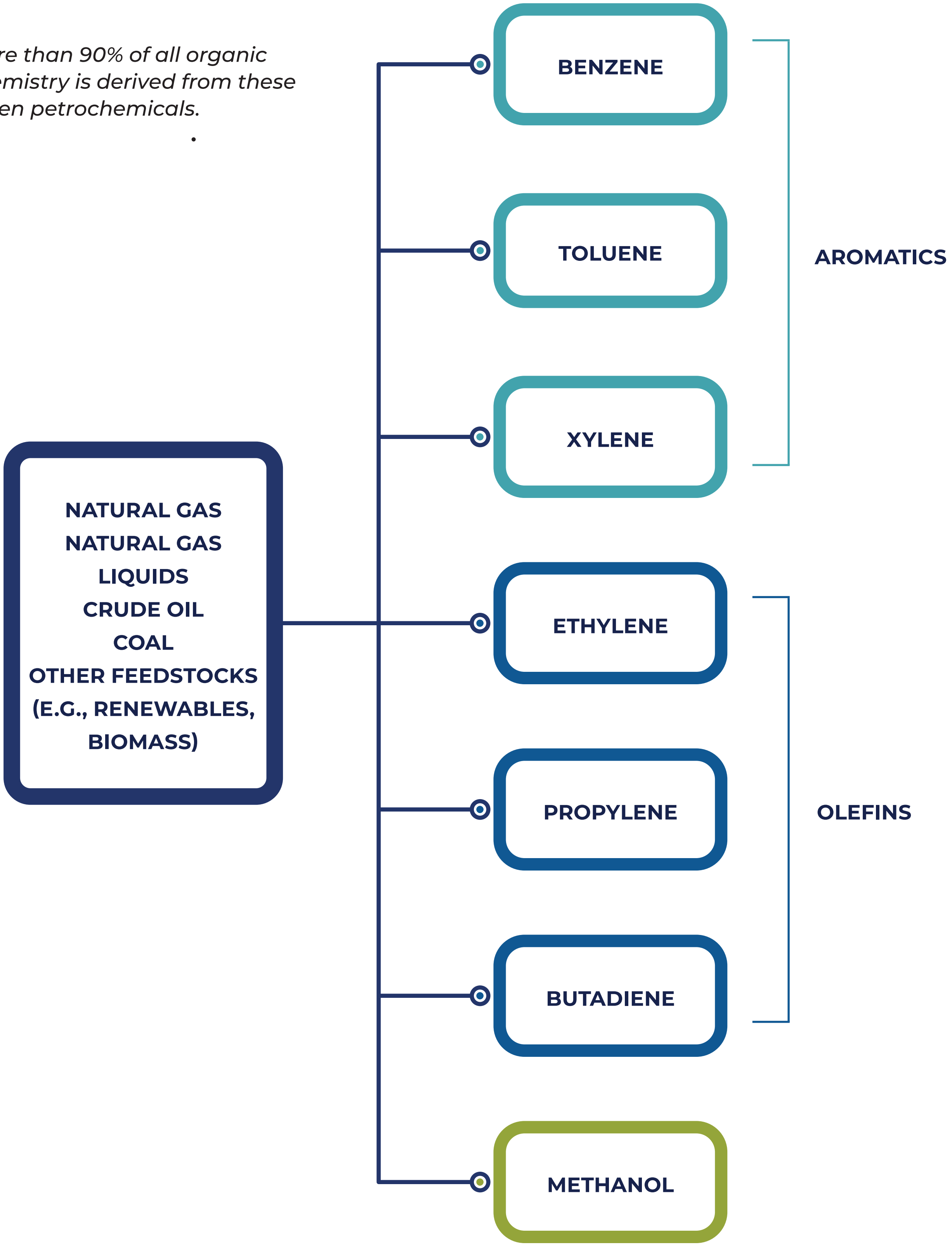
Table 14.2 - U.S. Chemical Production Regional Index, 2013-2022

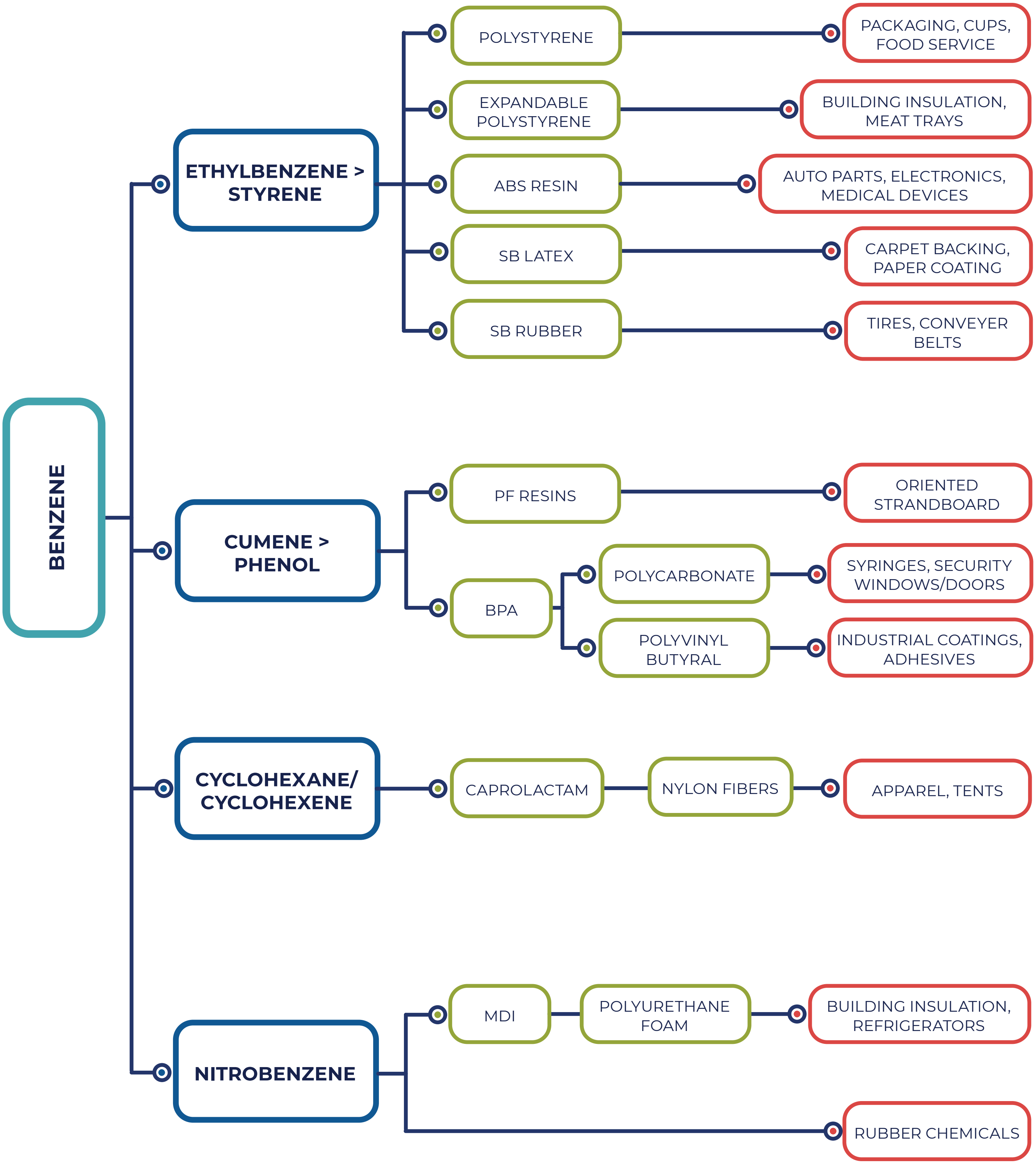
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
					2017=100					
Gulf Coast	104.4	101.9	98.2	99.5	100.0	99.5	92.1	87.5	92.0	92.3
Midwest	103.2	102.3	99.1	99.7	100.0	99.5	94.4	90.4	94.4	94.8
Ohio Valley	101.0	101.4	99.1	99.0	100.0	100.0	94.8	89.3	92.9	93.3
Mid-Atlantic	100.4	101.4	99.7	99.2	100.0	100.0	95.4	89.6	93.7	94.2
Southeast	102.2	101.9	98.8	98.8	100.0	99.9	95.0	90.6	93.8	94.2
Northeast	99.9	101.3	99.4	98.4	100.0	100.2	96.0	90.4	94.5	95.0
West Coast	102.6	102.7	99.7	99.4	100.0	99.7	96.1	92.1	95.3	95.8

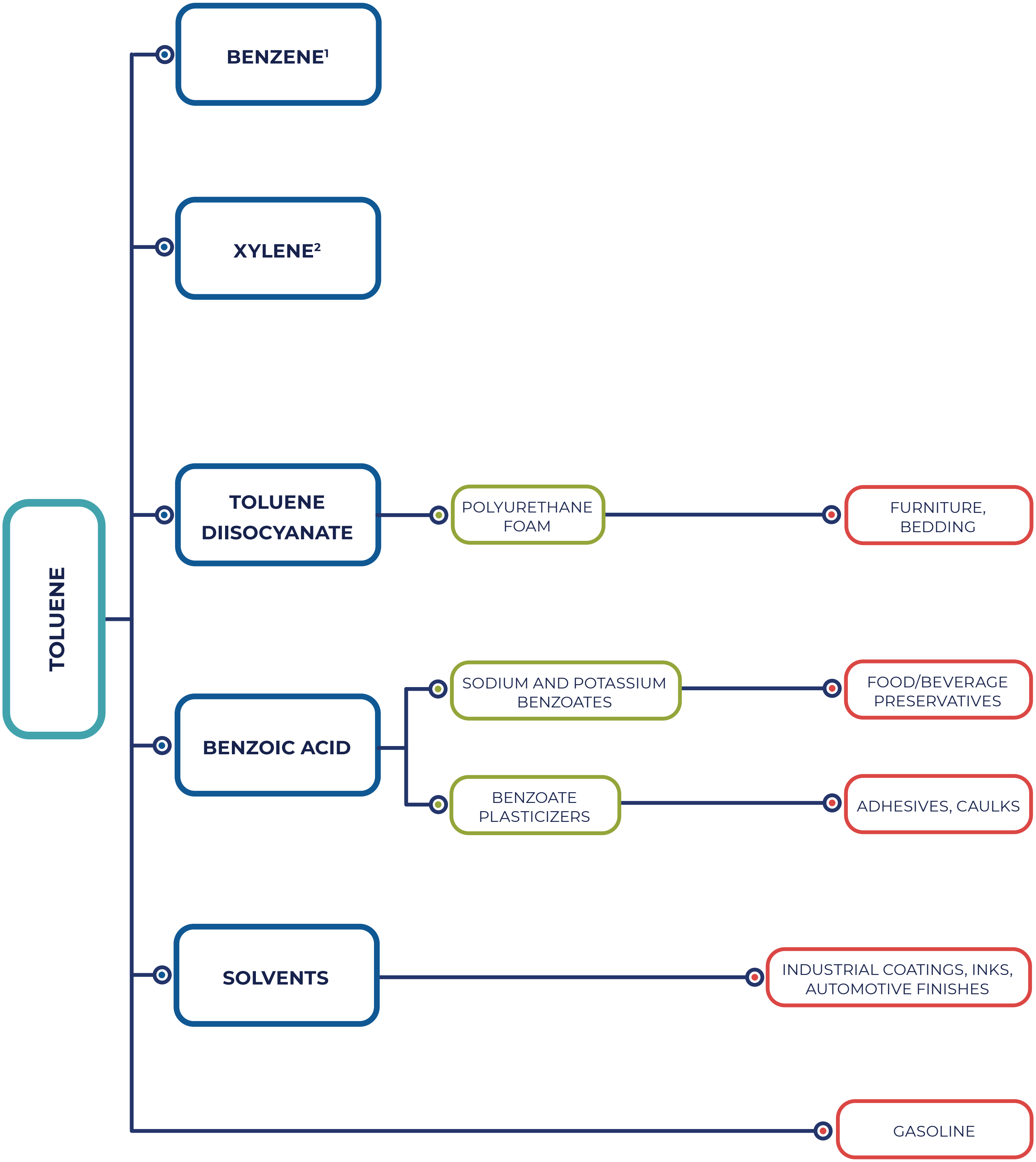
Source: American Chemistry Council

Appendix A - Chemical Chains

More than 90% of all organic chemistry is derived from these seven petrochemicals.

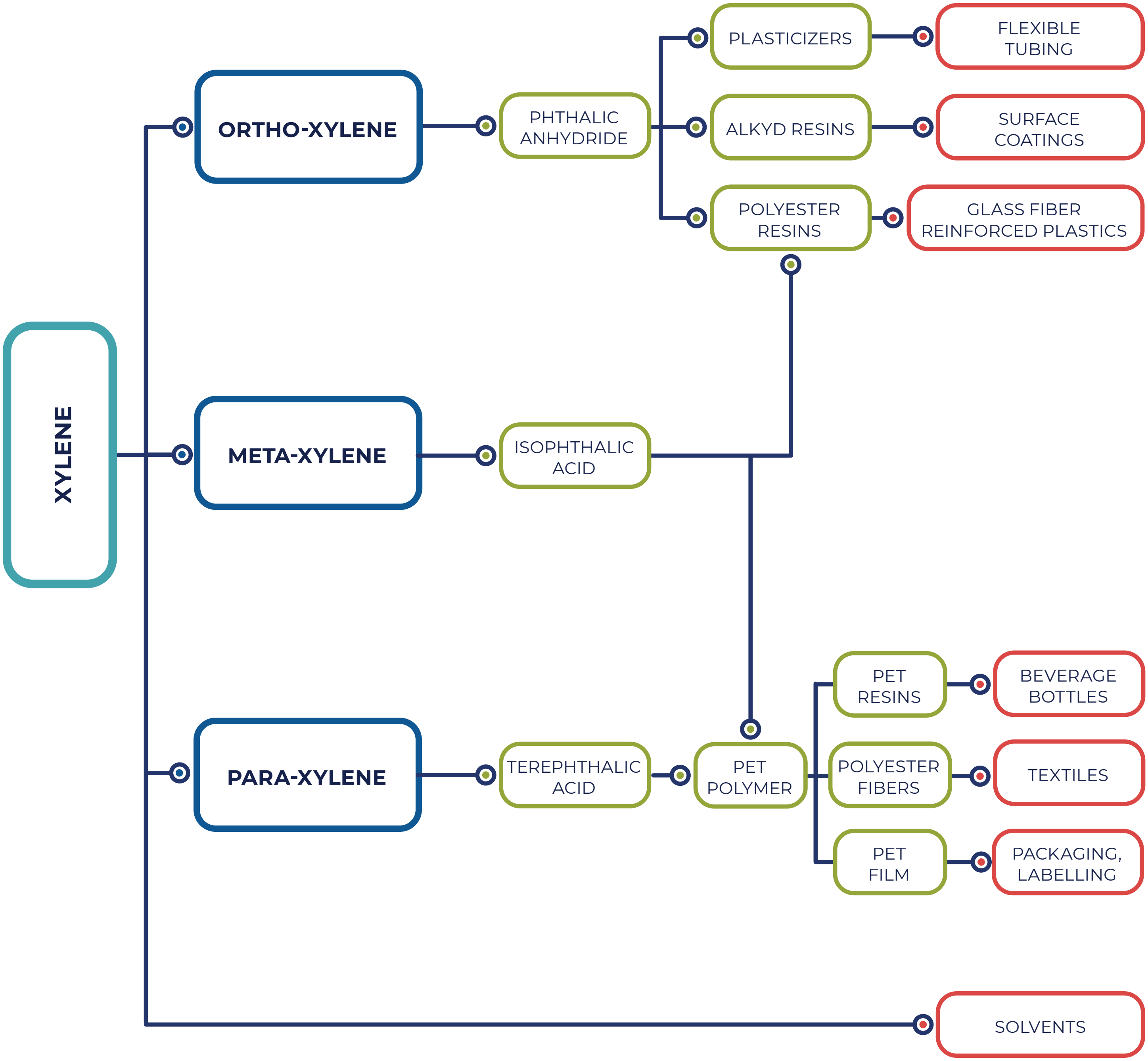


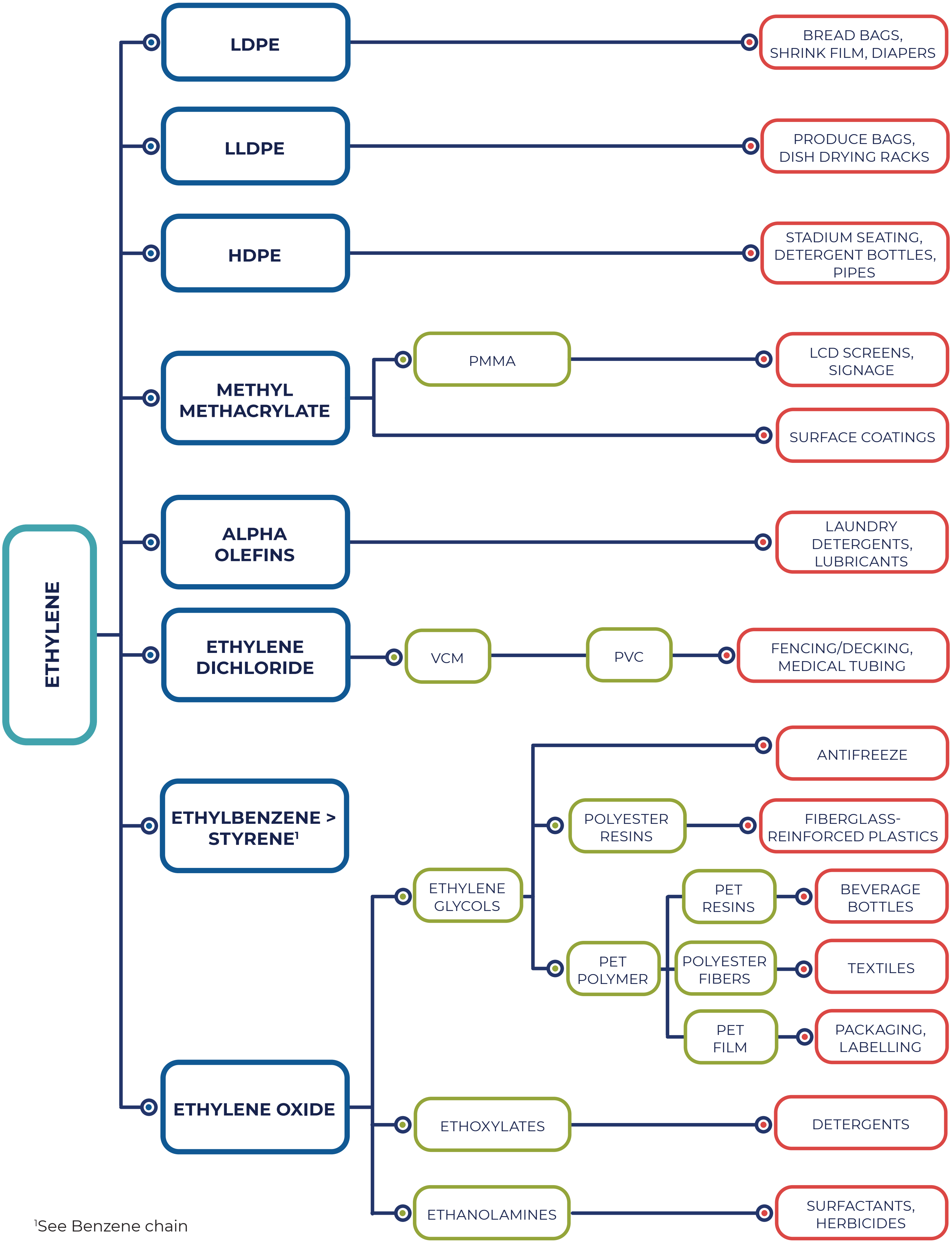

BENZENE
ETHYLBENZENE > STYRENE
POLYSTYRENE
PACKAGING, CUPS, FOOD SERVICE
EXPANDABLE POLYSTYRENE
BUILDING INSULATION, MEAT TRAYS
ABS RESIN
AUTO PARTS, ELECTRONICS, MEDICAL DEVICES
SB LATEX
CARPET BACKING, PAPER COATING
SB RUBBER
TIRES, CONVEYER BELTS
CUMENE > PHENOL
PF RESINS
ORIENTED STRANDBOARD
BPA
POLYCARBONATE
SYRINGES, SECURITY WINDOWS/DOORS
POLYVINYL BUTYRAL
INDUSTRIAL COATINGS, ADHESIVES
CYCLOHEXANE/ CYCLOHEXENE
CAPROLACTAM
NYLON FIBERS
APPAREL, TENTS
NITROBENZENE
MDI
POLYURETHANE FOAM
BUILDING INSULATION, REFRIGERATORS
RUBBER CHEMICALS



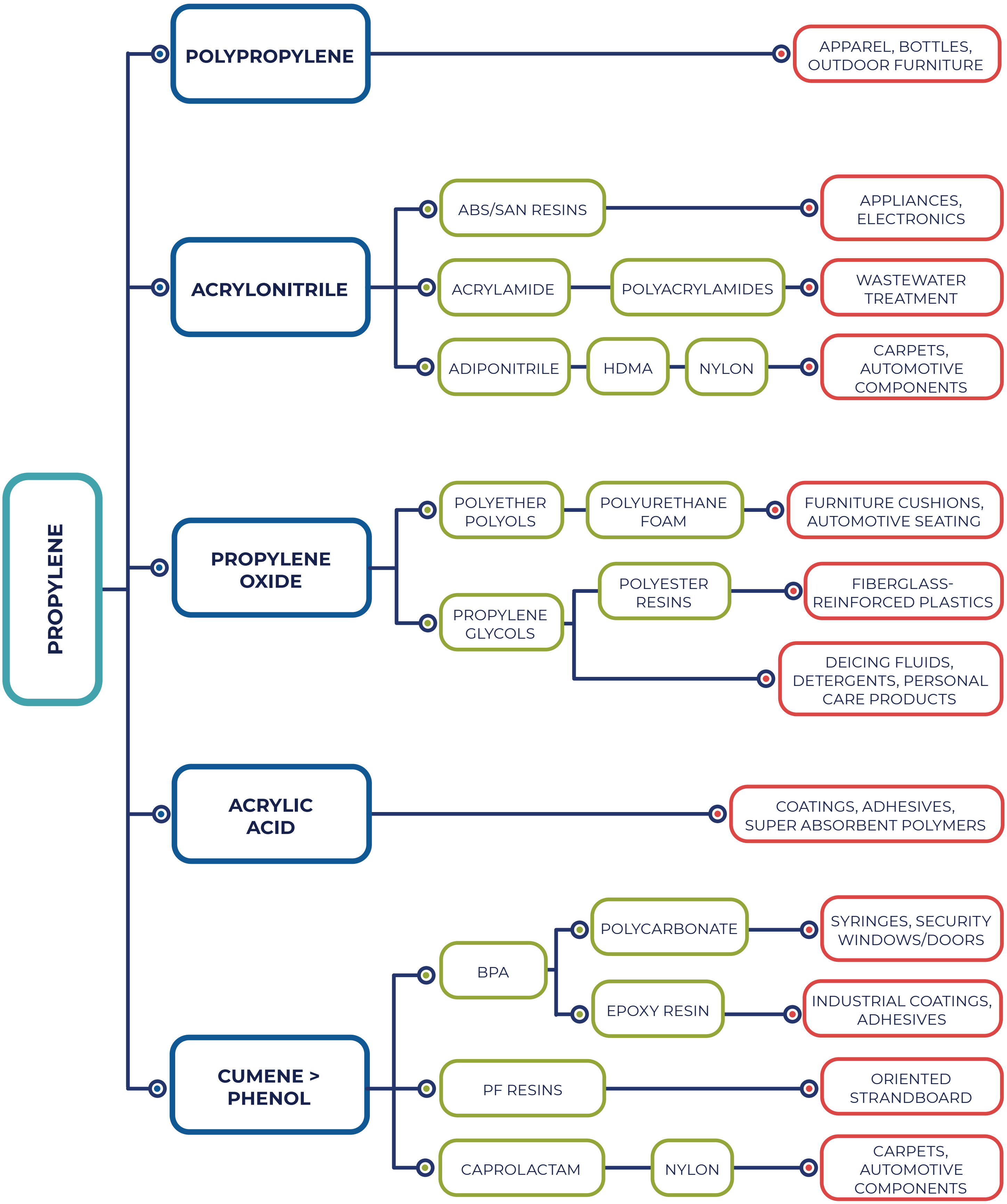
[1] See Benzene chain

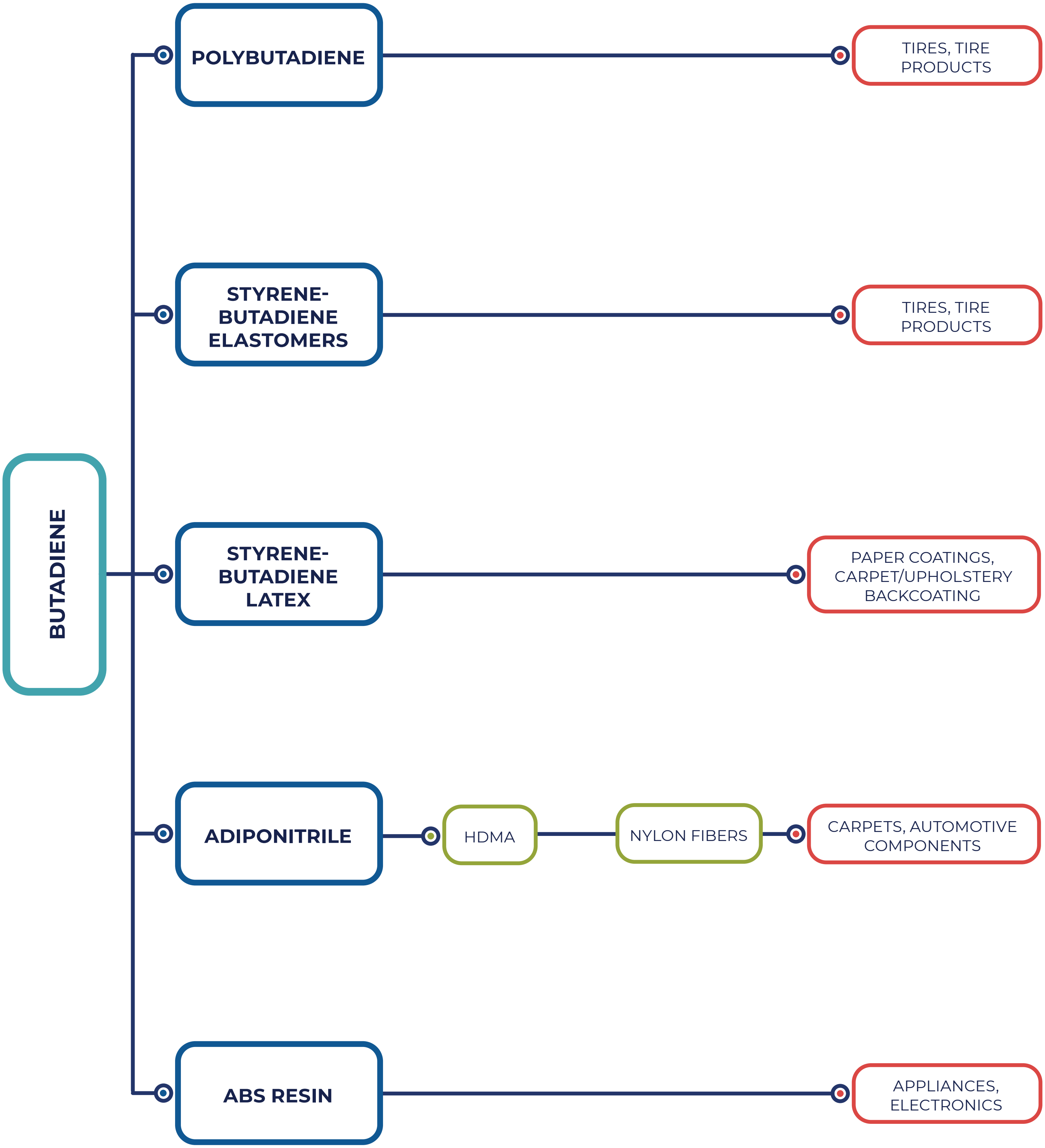
[2] See Xylene chain

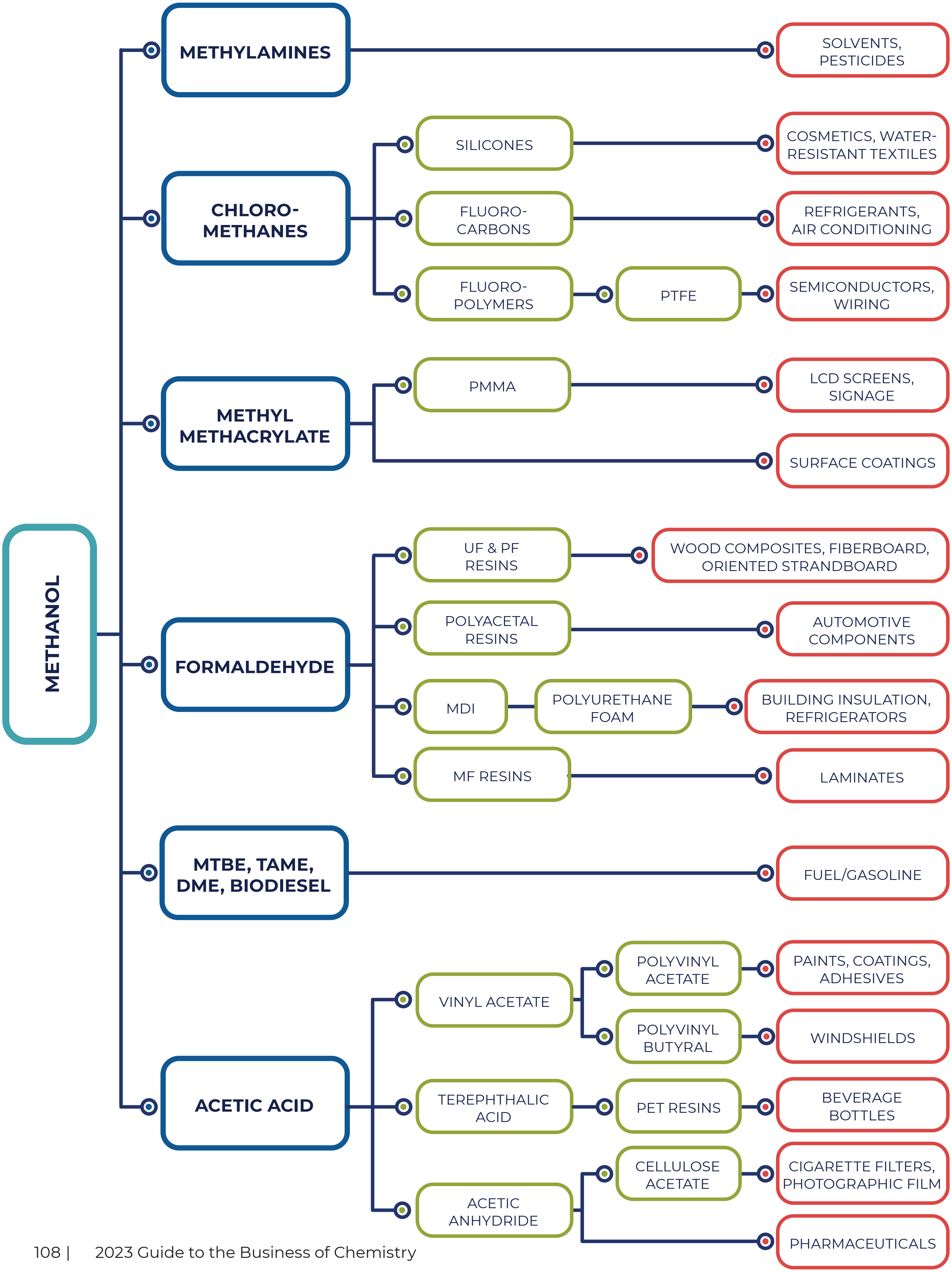

XYLENE
ORTHO-XYLENE
PHTHALIC ANHYDRIDE
PLASTICIZERS
FLEXIBLE TUBING
ALKYD RESINS
SURFACE COATINGS
POLYESTER RESINS
GLASS FIBER REINFORCED PLASTICS
META-XYLENE
ISOPHTHALIC ACID
PARA-XYLENE
TEREPHTHALIC ACID
PET POLYMER
PET RESINS
BEVERAGE BOTTLES
POLYESTER FIBERS
TEXTILES
PET FILM
PACKAGING, LABELLING
SOLVENTS

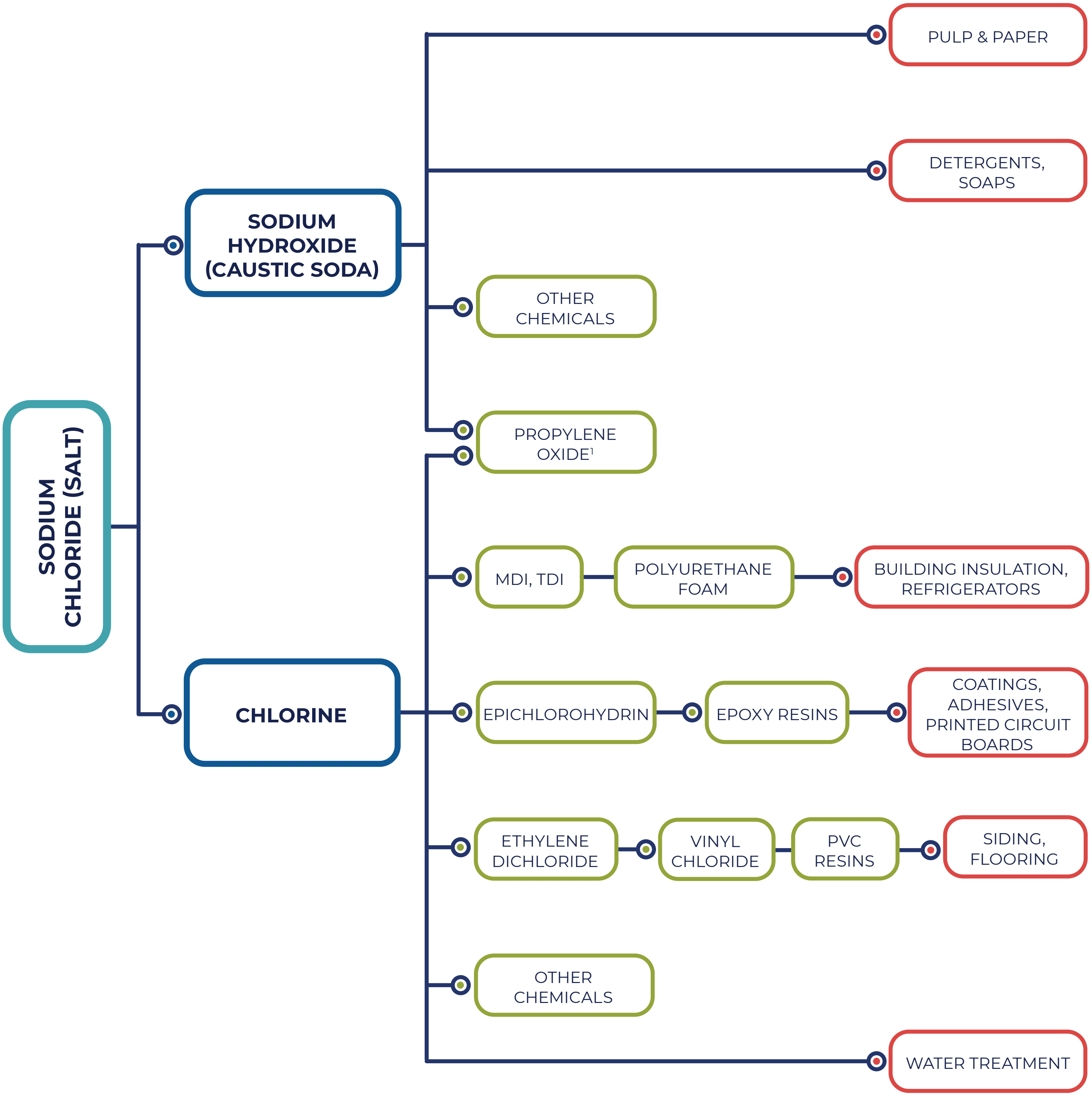


[1] See Benzene chain


PROPYLENE
POLYPROPYLENE
APPAREL, BOTTLES, OUTDOOR FURNITURE
ACRYLONITRILE
ABS/SAN RESINS
APPLIANCES, ELECTRONICS
ACRYLAMIDE
POLYACRYLAMIDES
WASTEWATER TREATMENT
ADIPONITRILE
HDMA
NYLON
CARPETS, AUTOMOTIVE COMPONENTS
PROPYLENE OXIDE
POLYETHER POLYOLS
POLYURETHANE FOAM
FURNITURE CUSHIONS, AUTOMOTIVE SEATING
PROPYLENE GLYCOLS
POLYESTER RESINS
FIBERGLASS-REINFORCED PLASTICS
DEICING FLUIDS, DETERGENTS, PERSONAL CARE PRODUCTS
ACRYLIC ACID
COATINGS, ADHESIVES, SUPER ABSORBENT POLYMERS
CUMENE > PHENOL
BPA
POLYCARBONATE
SYRINGES, SECURITY WINDOWS/DOORS
EPOXY RESIN
INDUSTRIAL COATINGS, ADHESIVES
PF RESINS
ORIENTED STRANDBOARD
CAPROLACTAM
NYLON
CARPETS, AUTOMOTIVE COMPONENTS


BUTADIENE
POLYBUTADIENE
TIRES, TIRE PRODUCTS
STYRENE-BUTADIENE ELASTOMERS
TIRES, TIRE PRODUCTS
STYRENE-BUTADIENE LATEX
PAPER COATINGS, CARPET/UPHOLSTERY BACKCOATING
ADIPONITRILE
HDMA
NYLON FIBERS
CARPETS, AUTOMOTIVE COMPONENTS
ABS RESIN
APPLIANCES, ELECTRONICS


METHANOL
METHYLAMINES
SOLVENTS, PESTICIDES
CHLORO-METHANES
SILICONES
COSMETICS, WATER-RESISTANT TEXTILES
FLUORO-CARBONS
REFRIGERANTS, AIR CONDITIONING
FLUORO-POLYMERS
PTFE
SEMICONDUCTORS, WIRING
METHYL METHACRYLATE
PMMA
LCD SCREENS, SIGNAGE
SURFACE COATINGS
FORMALDEHYDE
UF & PF RESINS
WOOD COMPOSITES, FIBERBOARD, ORIENTED STRANDBOARD
POLYACETAL RESINS
AUTOMOTIVE COMPONENTS
MDI
POLYURETHANE FOAM
BUILDING INSULATION, REFRIGERATORS
MF RESINS
LAMINATES
MTBE, TAME, DME, BIODIESEL
FUEL/GASOLINE
ACETIC ACID
VINYL ACETATE
POLYVINYL ACETATE
PAINTS, COATINGS, ADHESIVES
POLYVINYL BUTYRAL
WINDSHIELDS
TEREPHTHALIC ACID
PET RESINS
BEVERAGE BOTTLES
ACETIC ANHYDRIDE
CELLULOSE ACETATE
CIGARETTE FILTERS, PHOTOGRAPHIC FILM
PHARMACEUTICALS



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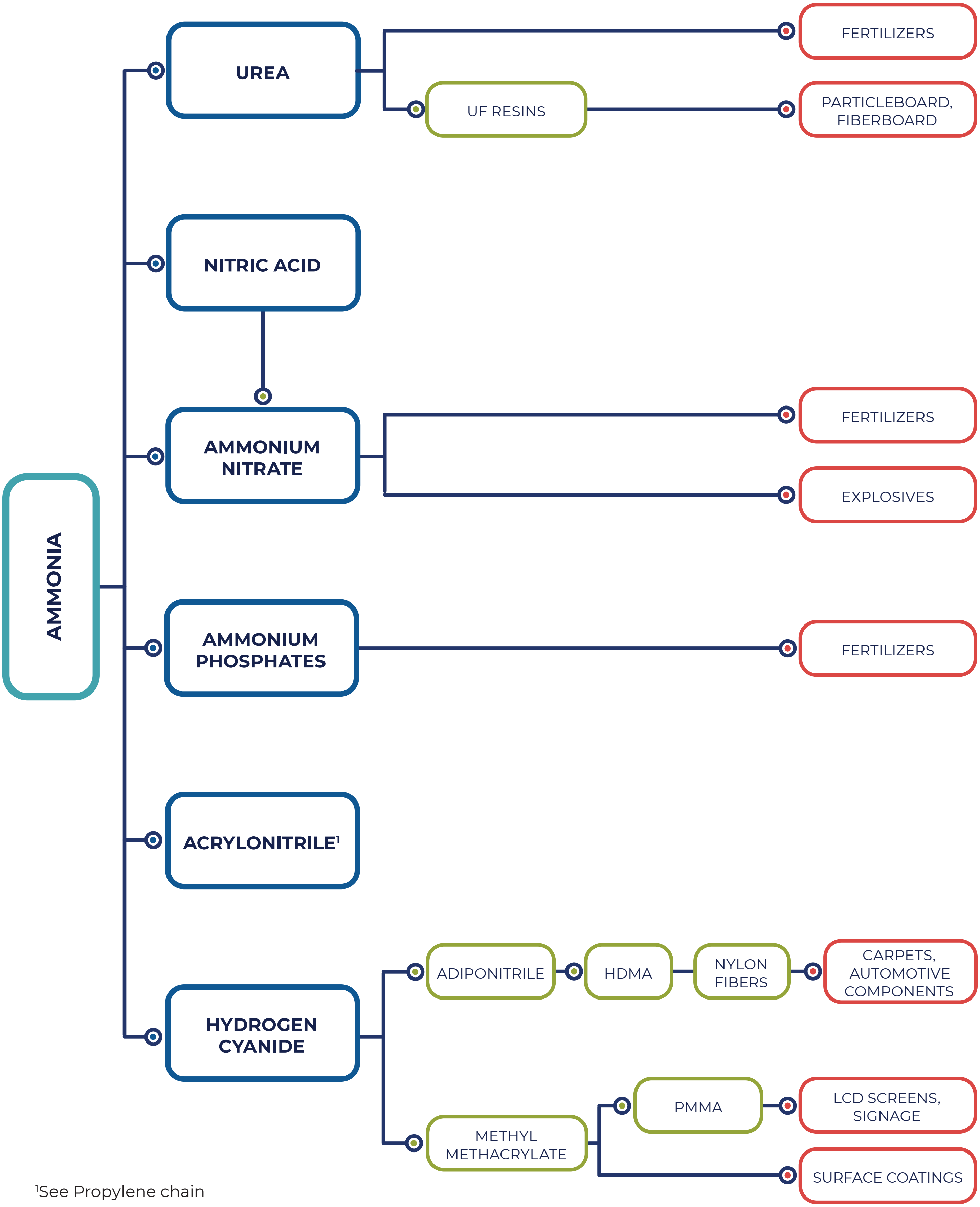
[1] See Propylene chain



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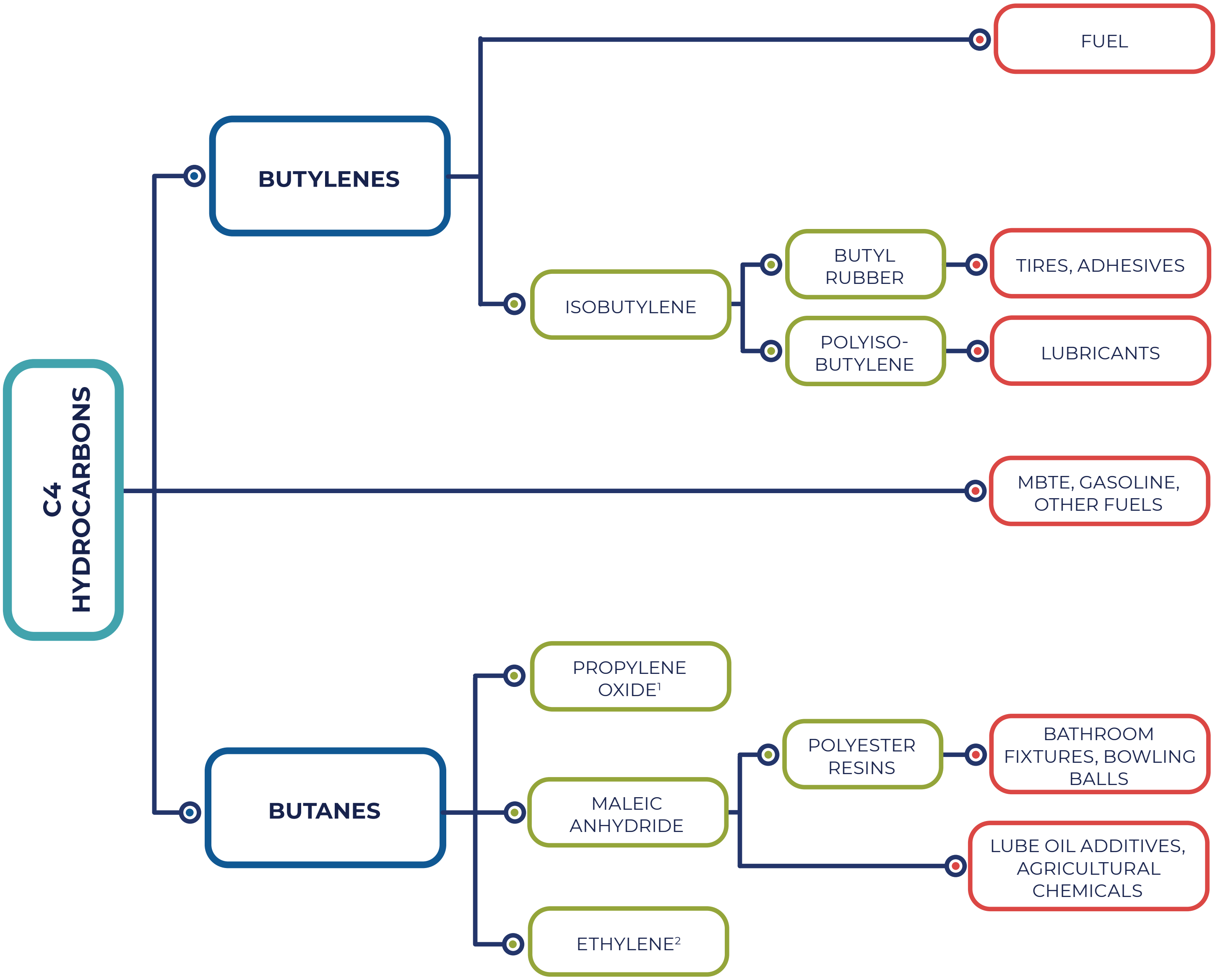
[1] See Propylene chain



[1] See Propylene chain

[2] See Ethylene chain

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 (H_2O) 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 faction containing hydrocarbons. It is used as feedstock for steam cracking and as fuel.

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

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 synthetic 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 mixtures 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.

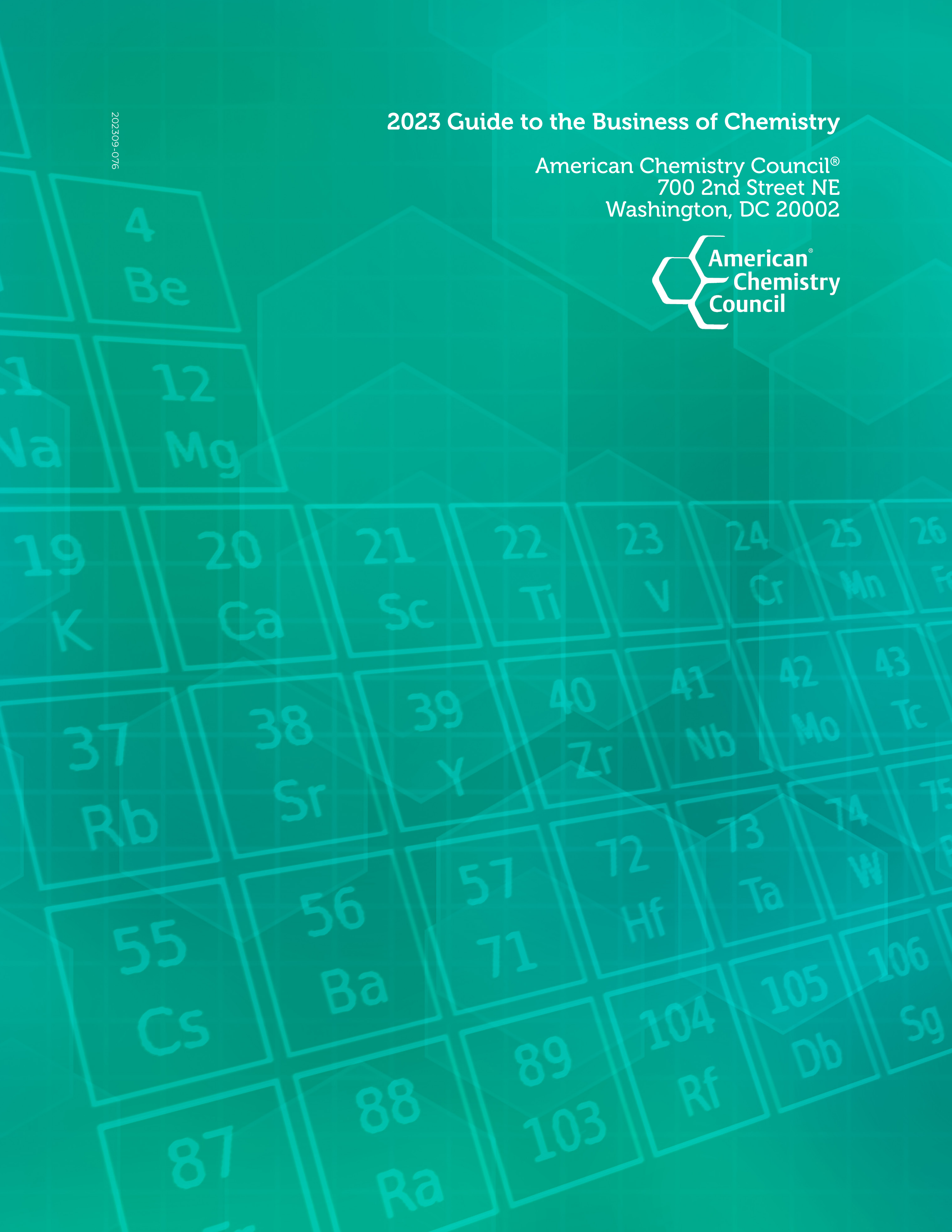
wholesaler. A marketing and distribution intermediary that sells to other organizations.

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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