ACS CHANGE DRIVERS

A Planning Tool for Staff and Volunteers

December 2020

Contact strategicplan@acs.org for more information.

OVERVIEW

The Change Drivers framework is a result of in-depth research into current and projected changes that are important to the chemical enterprise and the Society into the future.

This slide deck reviews seven Change Drivers that are most relevant to the chemical enterprise and includes a discussion guide that will help you use them to focus your work with the Society.

What is a Change Driver?

Change Drivers are indicators of fundamental driving forces showing where important change is, or could be, happening that will impact strategic planning over the next 3 to 5 years. They are developed from research and environmental scanning.

Quote from Barbara Sawrey, 2020 Chair, ACS Committee on Strategic Planning

"The ACS Change Drivers and discussion guide is a useful tool for leadership throughout the Society. As we have all experienced in the past year, the environment in which our members and the Society operate is rapidly evolving. These trends show us where those changes are highly relevant to the chemical enterprise. I offer my encouragement and thanks to our leaders and staff to make full use of these insights in their work with ACS."

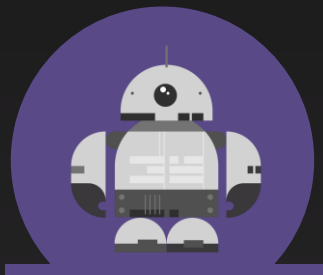
2020 ACS Change Drivers

- MARKET DISRUPTION AND ECONOMIC DOWNTURN
- ACCELERATING AUTOMATION OF CHEMISTRY
- STRAINED PIPELINE AND CHANGING WORKPLACE
- CONTINUED GLOBALIZATION OF CHEMISTRY
- CHEMISTRY AND SOCIAL RESPONSIBILITY
- EMBRACING OPEN SCIENCE
- SCIENTIFIC DOUBT AND POLARIZATION IN THE U.S.

Contact strategicplan@acs.org for more information.

MARKET DISRUPTION AND ECONOMIC DOWNTURN

- The world is facing an economic downturn as a result of the COVID-19 pandemic.
- Petrochemical production and investment has been increasing leading up to 2020, revealing opportunities in emerging economies.
- Market disruptions and issues of supply pose a threat to the industry.



ACCELERATING AUTOMATION OF CHEMISTRY

- Artificial intelligence (AI) and machine learning are increasingly being used in data mining and chemical manufacturing.
- Lab-based research is more commonly being outsourced.
- Clean energy is a motivator for technological advancements.
- Automation has security and workforce implications.

STRAINED PIPELINE AND CHANGING WORKPLACE

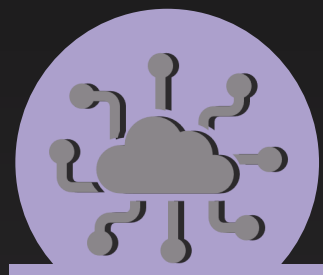
- Economic, institutional, and immigration issues disrupt the chemistry workforce pipeline.
- Millennials and Gen Z will soon make up the majority of the global workforce.
- Advancements in technology may address workforce shortages but will require new skills of employees.
- Workplaces and meetings have shifted to being increasingly virtual.

CONTINUED GLOBALIZATION OF CHEMISTRY

- Asia is rapidly prospering and becoming the focus of the scientific enterprise.
- Foreign investment into Asia continues to grow.
- Concerns around research quality in developing markets persist.
- Recent years have seen particularly acute and intensifying geopolitical tensions.

CHEMISTRY AND SOCIAL RESPONSIBILITY

- Chemistry has room to be more diverse and representative.
- Investment in diversity, equity, inclusion, and respect (DEIR) is growing.
- Consumers have higher expectations for safe, ethical, and transparent practices in the chemical industry.
- The industry continues to move towards a “greener” future.



EMBRACING OPEN SCIENCE

- Many influential funders and policy makers support open science and require open access to articles and data.
- Revenue from open-access publishing comes at the expense of traditional subscriptions.
- Preprint publishing is a growing means by which chemistry research is disseminated.
- The COVID-19 pandemic has spurred calls for open science.

SCIENTIFIC DOUBT AND POLARIZATION IN THE U.S.

- Americans are divided on key scientific issues and have differing levels of trust in scientists.
- Common online sources of scientific information are unsubstantiated.
- U.S. policy has reflected a shift away from scientific research and towards deregulation, particularly with regards to environmental protections.

MARKET DISRUPTION AND ECONOMIC DOWNTURN

The world is facing an economic downturn as a result of the COVID-19 pandemic, with economic recovery projected to occur as late as 2024 in some cases.

Petrochemical production and investment has been increasing leading up to 2020, revealing opportunities in emerging economies.

Market disruptions and issues of supply pose a threat to the industry.

MARKET DISRUPTION AND ECONOMIC DOWNTURN

The world is facing an economic downturn as a result of the COVID-19 pandemic, with economic recovery projected to occur as late as 2024 in some cases.

- Global and U.S. GDP have declined.
- Global and U.S. trade has declined.
- Employment within the chemical industry has decreased significantly but is expected to recover within the next four years.

Petrochemical production and investment has been increasing leading up to 2020, revealing opportunities in emerging economies.

- Capital and foreign direct investment into the industry has increased since 2014.
- Demand for plastics in emerging economies continues to grow with urbanization.

Market disruptions and issues of supply pose a threat to the industry.

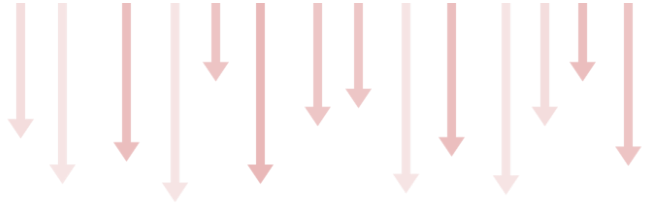
- Trade conflicts have disrupted supply chains.
- The oversupply of natural gas is partially attributable to global bans on single-use plastics.

Contact strategicplan@acs.org for more information.

MARKET DISRUPTION AND ECONOMIC DOWNTURN

The world is facing an economic downturn as a result of the COVID-19 pandemic, with economic recovery projected to occur by 2024 in some cases.

Global and U.S. GDP and chemicals production has declined significantly in 2020. However, it is projected that 2021 will see some recovery, with **full recovery for trade and production to occur by 2023.**



EMPLOYMENT

- After seven consecutive years of gains, U.S. chemical industry employment is set to **fall by nearly 20,000** in 2020.
- As demand for chemistry strengthens in 2021 and 2022, employment will start to recover, but **won't reach pre-COVID levels until 2024**.

Global and U.S. Economic Projections

		2020	2021
$	Global GDP	↓ 4.3%	↑ 5.3%
	World trade	↓ 15.7%	↑ 14.4%
	Global industrial production	↓ 3.8%	↑ 5.3%
$	U.S. GDP	↓ 6%	↑ 4.1%
	U.S. trade	↓ 16.4%	
	U.S. chemical exports	↓ 14.5%	↑ 10.9%
	U.S. chemical imports	↓ 19.1%	↑ 11.9%
	U.S. chemical production	↓ 9.3%	↑ 12.3
	U.S. employment in chemical industry	↓ 3.6%	

The COVID-19 pandemic has resulted in an increase in demand for personal protective equipment (PPE), disinfectants, plastics used for ventilators, and other chemicals used to fight the pandemic.

American Chemistry Council (2020)

MARKET DISRUPTION AND ECONOMIC DOWNTURN

Petrochemical production and investment has been increasing over the years, revealing opportunities in emerging economies.

HISTORIC MARKET GROWTH (pre-COVID)

Capital investments into new plants and equipment have increased since 2014, and **foreign direct investments** into the U.S. have increased since 2009.

The **U.S. production of natural gas** grew by 10% between 2018 and 2019.

The volume of **natural gas exports** has increased over five consecutive years; in 2019, the U.S. continued to export more natural gas than it imported.

*Developing economies represent **opportunities** for the petrochemical industry, as demand for plastics and packaging continues to increase with greater urbanization.*

American Chemistry Council (2020)
U.S. Energy Information Administration (2020)

Market disruptions and issues of supply pose a threat to the industry.

Market Disruptions

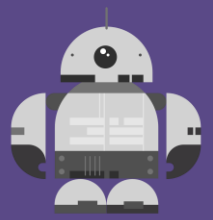
2019 saw a **slow-down in world trade**. Tariffs on U.S.-Chinese goods negatively affected international supply chains, particularly resin producers and downstream manufacturers in both countries.

In recent years, the industry has experienced issues of **oversupply,** eroding the value of petrochemicals.

- This lower-than-expected demand is partially attributed to restrictions or **bans on single-use plastics** by China, Canada, the EU, and other countries.

PERMIAN BASIN, 2019: Producers burned off an estimated **810 million cubic feet of natural gas per day** as the market price of gas did not offset the cost of transportation.

Schlanger (2020)



ACCELERATING AUTOMATION OF CHEMISTRY

Artificial intelligence (AI) and machine learning are increasingly being used in data mining and chemical manufacturing.

Lab-based research is more commonly being outsourced.

Clean energy is a motivator for technological advancements.

Automation has security and workforce implications.

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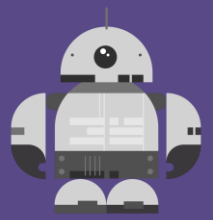


ACCELERATING AUTOMATION OF CHEMISTRY

Artificial intelligence (AI) and machine learning are increasingly being used in data mining and chemical manufacturing.

- Machines are able to mimic human cognition to detect patterns in datasets which allows for predicting outcomes and developing hypotheses.
- “Smart manufacturing” continues to grow, offering increased productivity and efficiency.

Lab-based research is more commonly being outsourced.

- Material informatics platforms are able to digitally model product or process outcomes, replacing lab-based experimentation.
- Such platforms allow for faster research.

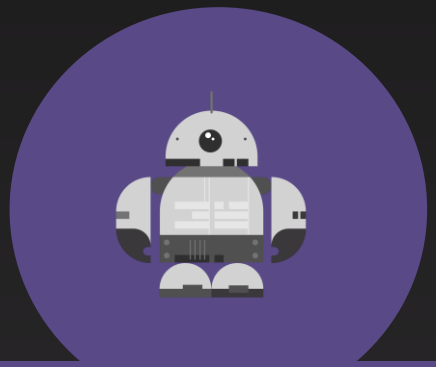
Clean energy is a motivator for technological advancements.

- Firms are using renewable energy sources and investing in “green” technologies.
- Recycling chemical products has financial benefits for firms.

Automation has security and workforce implications.

- Increased digitization may require the industry to further prioritize cybersecurity efforts.
- Automation has the capability to supplement human labor.

Contact strategicplan@acs.org for more information.



ACCELERATING AUTOMATION OF CHEMISTRY

Artificial intelligence (AI) and machine learning are increasingly being used in data mining and chemical manufacturing.

DATA MINING

Using processes that mimic human thinking, machine learning technologies are able to **mine data and detect patterns,** evaluating importance while weighing context and conflicting evidence at a much faster rate than humans.

Such technologies are being used to help **predict outcomes of reactions,** to **find gaps in existing scientific literature** and **assist in developing hypotheses.**

SMART MANUFACTURING

"**Smart manufacturing**" is a continued trend as chemical production facilities embrace AI, machine learning, the Internet of Things (IoT) and other advanced technologies to **increase efficiency and productivity** and **minimize risk and energy loss.**

Lab-based research is more commonly being outsourced.

The process of discovering and developing new chemicals has traditionally been **lab-based**, requiring substantial **time, effort, and money**.

Now **lab-based research is more commonly being outsourced to material informatics platforms.**

Can run computer simulations and experiments that **digitally model** product or process outcomes	Allows chemical companies to keep up with the **pace of change** in the marketplace	**Large, for-profit entities** outsource more commonly than universities and small labs

Dickson, et al. (2020)

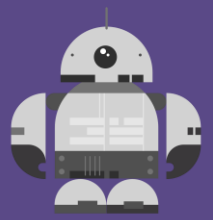
Projected Growth of IoT in the Chemical Industry Market

2019		2024
$48.9 billion	→	**$77.9** billion

Business Wire (2020)

*In August 2020, the National Science Foundation announced a **$100 million investment** in the creation of five AI institutes.*

Laboratory for Nuclear Science (2020)



ACCELERATING AUTOMATION OF CHEMISTRY

Clean energy is a motivator for technological advancements.

GREEN INVESTMENTS

Firms are turning to **renewable energy** sources and investing in "green" technologies that help **reduce carbon dioxide emissions and minimize energy waste**.

CIRCULAR ECONOMY

Emphasis on the economic benefits of a **circular economy** are also driving technological advancements as there is a **$120-billion market opportunity** in the US and Canada alone for plastics and petrochemicals that can be developed by recovering waste plastics. *Deloitte (2020)*

Research has shown that consumers expect companies to provide products designed to be reused and recycled and are willing to pay more for such products.

4D printing is appearing as a disruptive technology that could allow manufacturers to program printed materials to **self-assemble** if damaged.

*IBM has recently launched a free AI service, **RoboRXN** for Chemistry, aimed at predicting chemical reactions remotely.*

Automation has security and workforce implications.

Increasing digitization of the industry may require that chemical firms or departments further **prioritize cybersecurity efforts**.

Recently, there has been an **increase in cyber attacks** on chemical industry information technology and production assets as hackers have exploited vulnerabilities created through the shift to remote-work amidst COVID-19.

CYBERSECURITY

Machine learning and advanced automation have the capacity to **supplement or replace human labor**.

WORKFORCE

STRAINED PIPELINE AND CHANGING WORKPLACE

The economic downturn, academic budgetary constraints and immigration restrictions pose challenges for the chemistry workforce pipeline.

The face of chemistry is changing, as Millennials and Gen Z will soon make up 59% of the global workforce.

Advancements in technology may address workforce shortages but will require new skills of employees.

Workplaces and meetings have shifted to being increasingly virtual.

STRAINED PIPELINE AND CHANGING WORKPLACE

The economic downturn, academic budgetary constraints and immigration restrictions pose challenges for the chemistry workforce pipeline.

- Denials of work visas have risen over the years; currently, policies are in place to suspend the entry of immigrants under certain work and student visas in response to the COVID-19 pandemic.
- University freezes on hiring and declines in admissions pose challenges for PhD and postdoctoral students.

The face of chemistry is changing, as Millennials and Gen Z will soon make up 59% of the global workforce.

- Gen Z will bring unique qualities to the chemistry pipeline, including racial diversity and expertise with digital technologies.
- Gen Z and Millennials value workplace flexibility, affecting projected demand for remote work.

Advancements in technology may address workforce shortages but will require new skills of employees.

- Scientists will have room to focus on tasks that require more higher-level thinking but will also need to develop strong technological literacy.
- Workers should seek out ongoing skills training to remain competitive with the fast-changing landscape.

Workplaces and meetings have shifted to being increasingly virtual.

- Benefits include the capacity to engage more people, the elimination of travel restrictions, reduced carbon footprints and increased sponsorship value.
- Challenges include difficulty connecting with others.

Contact strategicplan@acs.org for more information.

STRAINED PIPELINE AND CHANGING WORKPLACE

The economic downturn, academic budgetary constraints and immigration restrictions pose challenges for the chemistry workforce pipeline.

Unemployment within the chemical industry has risen substantially in 2020; however current employment stands lower than that of the total labor force.

Unemployment rate in the U.S.*
Chemical manufacturing industry: **5.3%**
Total labor force: **6.9%**

** as of Oct. 2020. Bureau of Labor Statistics (2020)*

Many academic institutions have reduced or halted admissions and hiring through 2021.

- Research for postdocs is largely on hold, affecting their ability to win and maintain grant funding, publish papers, and find employment.
- Competition will increase over the next few years as the backlog of applicants grows.
- Many postdocs are turning to other fields or seeking industry jobs.
- Postdocs whose visas are expiring may have to leave the U.S. before finishing their research.

INTERNATIONAL WORKFORCE

Foreign workers fill a crucial need in the U.S. labor market, especially for STEM jobs. However, **denial of H-1B work visas rose** under the Trump administration

from **6%** FY 2015 to **21%.** FY 2019

American Immigration Council (2019)

INTERNATIONAL STUDENTS

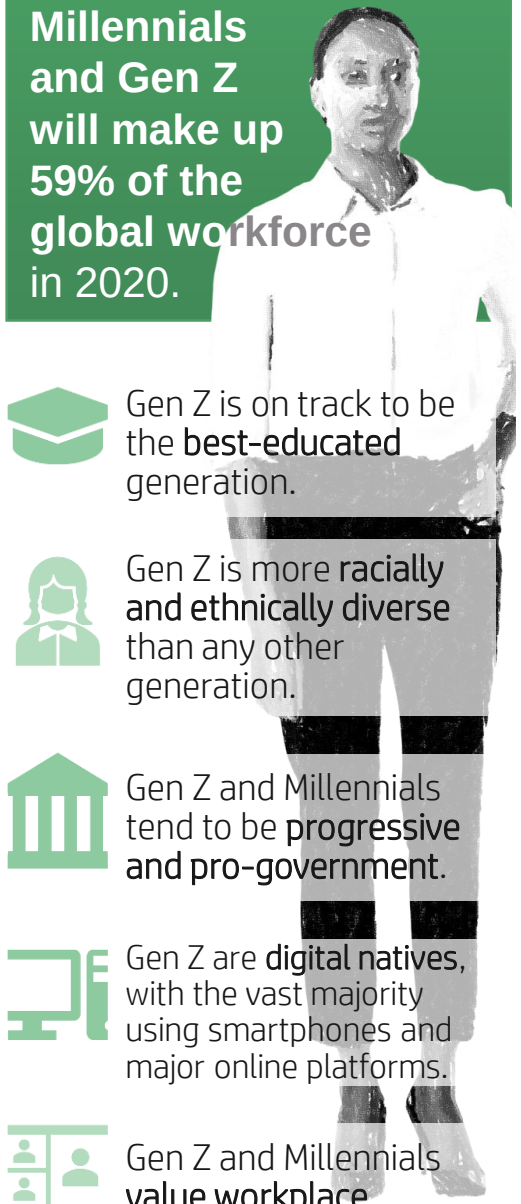
Foreign-born students continue to **pursue STEM degrees at higher rates** than students born in the U.S.

36% Foreign-born students *compared to* **20%** U.S.-born students

Current policies prevent students from obtaining F-1 student visas, which has the potential to bar up to 325,000 individuals from entering the U.S.

Duke University (2019)

According to the World Economic Forum, **Millennials and Gen Z will make up 59% of the global workforce** in 2020.



- Gen Z is on track to be the **best-educated** generation.
- Gen Z is more **racially and ethnically diverse** than any other generation.
- Gen Z and Millennials tend to be **progressive and pro-government**.
- Gen Z are **digital natives**, with the vast majority using smartphones and major online platforms.
- Gen Z and Millennials **value workplace flexibility**.

Fry (2018), Wiles (2020)

STRAINED PIPELINE AND CHANGING WORKPLACE

Advancements in technology may address workforce shortages but will require new skills of employees.

Since machine learning is more efficient than manual labor and can mimic higher-level cognition, such technologies address workforce shortages by **supplementing or replacing human labor**. Experienced workers may be expected to train smart machines before retirement.

As automation continues to supplement hands-on work, scientists will have more space to focus on tasks that require **higher-level thinking**.

The existing and future workforce will need to build **strong technological literacy** to be able to utilize advanced technologies in their workplaces.

Employees will need to be "lifelong learners" to remain competitive, as the **average shelf-life for most technical skills is 18 months**.

Fischer (2019), Stempel (2017), Winterhalter (2020)

We are living in an increasingly virtual world.

In light of the COVID-19 pandemic, the **vast majority of workplaces have moved remote**, forcing employers to embrace digital tools that support virtual work and collaboration.

Scientific meetings have moved to being **completely or mostly virtual**.

BENEFITS

- Ability to engage more people
- No travel-related restrictions
- Reduced carbon footprints
- Increased sponsorship value

DRAWBACKS

- Difficulty networking

Projected Growth of the Global Microlearning Market

2019		2024
$1.5 billion	→	**$2.7** billion

41% of companies plan to adopt microlearning *as a way to support employees within the next year.*

Market Data Forecast (2020)
Association for Talent Development (2017)

Demand for Flexible Work Environments

In a 2020 Deloitte study of white-collar professionals, 94% reported benefiting from work flexibility.

A 2018 Gallup study found that 42% of millennials would switch to a job that allows them to work independently.

By 2030, demand for remote work is projected to increase by 30% due to Gen Z fully entering the workforce.

Wiles (2020)

CONTINUED GLOBALIZATION OF CHEMISTRY

Asia is rapidly prospering and becoming the focus of the scientific enterprise.

Foreign investment into Asia continues to grow.

Concerns around research quality in developing markets persist.

Recent years have seen particularly acute and intensifying geopolitical tensions.

Contact strategicplan@acs.org for more information.

CONTINUED GLOBALIZATION OF CHEMISTRY

Asia is rapidly prospering and becoming the focus of the scientific enterprise.

- Asia's GDP and middle class are rapidly growing.
- Asia continues to invest more in research and development, with China emerging as a top competitor to the U.S.

Foreign investment into Asia continues to grow.

- Foreign mergers and acquisitions into China have reached record highs.
- America and Europe have driven most mergers & acquisitions (M&A) activity

Concerns around research quality in developing markets persist.

- Emerging markets continue to face issues with fraud, corruption, and lack of transparency, which poses challenges to scientific research quality.

Recent years have seen particularly acute and intensifying geopolitical tensions.

- Examples of recent geopolitical tensions include U.S.-China trade conflicts, Brexit negotiations, and military strikes.
- Such tensions pose a certain level of continued economic uncertainty for the industry.

Contact strategicplan@acs.org for more information.

CONTINUED GLOBALIZATION OF CHEMISTRY

Asia is rapidly prospering and becoming the focus of the scientific enterprise.

By 2040, Asia is expected to account for **over 50 percent of global GDP** and for 40% of the world's total consumption.

Urbanization is fueling economic growth and raising living standards, as the **Asian middle class will soon reach three billion**.

Asia now accounts for almost **half of global investment** in areas such as AI, virtual reality, and robotics.

Tonby, et al. (2020)

Asia is excelling in terms of research and development.

Preliminary data from 2019 suggests that **China surpassed the U.S. in R&D spending**, which would make it the global leader. This year, **China surpassed the U.S. as owning the largest share of scientific papers.**

Viglione (2020), Koshikawa (2020)

Along with China, **Japan and South Korea** were among the top five countries with **highest expenditure on R&D** based on 2018 data.

Congressional Research Service (2020)

Singapore, South Korea and Taiwan boast high researcher density, and South Korea has the most researchers in East Asia.

Noorden (2018)

Foreign investment into Asia continues to grow.

Between January 2019 to June 2020, **foreign mergers and acquisitions** (M&A) **into China reached levels that were higher than they have been over the last decade**. Despite political tensions, most recent M&A activity has been driven by American and European firms.

Hanemann (2020)

In 2019, Asia was home to more than one-third of global start-ups valued at more than $1 billion.

Tonby, et al. (2020)

China

- Spends a greater portion of R&D on experimental research
- Publishes on materials science, chemistry, engineering, computer science and mathematics

U.S.

- Spends a greater portion of R&D on basic research
- Publishes on clinical medicine and basic life sciences

*China's **Belt and Road Initiative** (BRI) is a massive infrastructure project that would stretch from East Asia to Europe. Universities have invested millions of dollars into BRI science and technology projects, shifting where low- and middle- income countries are drawing scientific support.*

Chatzky (2020)

CONTINUED GLOBALIZATION OF CHEMISTRY

Concerns around research quality in developing markets persists.

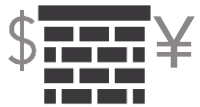
As developing nations increase their research and publishing efforts, concerns around research quality persist due to fraud, corruption, lack of transparency and other ongoing issues.

Corruption Perceptions Index

COUNTRY	GLOBAL RANK	SCORE
U.S.	23	69 /100
China	80	41 /100
India	80	41 /100
Vietnam	96	37 /100

Transparency International (2020)

Though geopolitical risks are not new to the chemical industry, the past couple of years have seen particularly acute and intensifying tensions.



TRADE WAR

Ongoing trade tensions between the U.S. and China have had a significant negative impact on the economies of both countries. **Tariffs affect over $25 billion worth of chemicals and plastics** in the U.S. and China, limiting U.S. growth and export potential. Some countries have benefitted from trade diversion effects.

BREXIT

The United Kingdom left the EU on January 31, 2020. Both parties are negotiating on terms for their future relationship, which includes everything from trade, immigration, aviation, security and access to fishing waters.

SAUDI ATTACKS

The attack on the Saudi Arabia oil distribution and refining infrastructure in September 2019 **impacted supply for major chemical feedstocks** by 16% to 50% depending on the affected site. Chemical production in Japan, South Korea and Thailand were also affected as those countries rely most heavily on refining light grades of Saudi oil.

IRAN AIRSTRIKES

Military strikes between the United States and Iran in January 2020 resulted in a temporary **spike in oil prices**.

Given ongoing geopolitical tensions, a certain level of economic uncertainty will be commonplace.

Deloitte (2020)

CHEMISTRY AND SOCIAL RESPONSIBILITY

Chemistry has room to be more diverse and representative.

Investment in diversity, equity, inclusion, and respect (DEIR) is growing.

Consumers have higher expectations for safe, ethical, and transparent practices in the chemical industry.

The industry continues to move towards a “greener” future.

Contact strategicplan@acs.org for more information.

CHEMISTRY AND SOCIAL RESPONSIBILITY

Chemistry has room to be more diverse and representative.

- Black or African American and LatinX or Hispanic individuals make up a disproportionately small percentage of chemistry students.
- Underrepresented groups in STEM more commonly report experiencing racial discrimination at work

Investment in diversity, equity, inclusion, and respect (DEIR) is growing.

- Firms and associations are spending more money on integrating DEIR practices which is associated with greater profitability.

Consumers have higher expectations for safe, ethical, and transparent practices in the chemical industry.

- Expectations around Corporate Social Responsibility (CSR) have risen to include social justice demands.
- Common CSR focus areas include sustainability, transparency, and DEIR.

The industry continues to move towards a “greener” future.

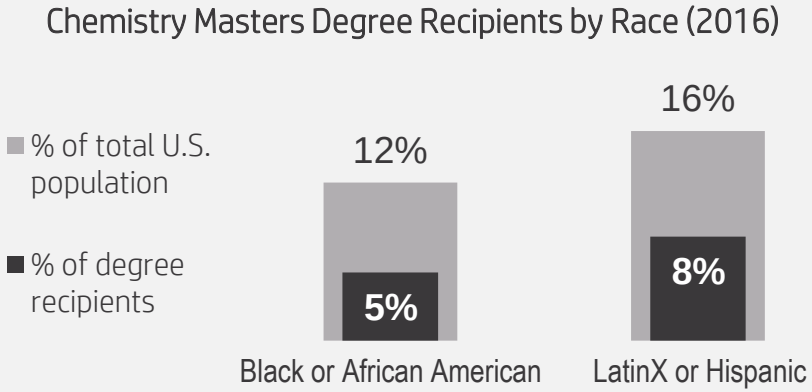
- Consumers value environmentally-friendly practices from firms.
- Investing in “green” technologies has economic benefits for firms.

Contact strategicplan@acs.org for more information.

CHEMISTRY AND SOCIAL RESPONSIBILITY

Chemistry has room to be more diverse and representative as underrepresented groups face continued discrimination and obstacles to career growth.

In 2016, Black or African American and LatinX or Hispanic individuals made up a **disproportionately small percentage** of U.S. chemistry Masters students.



National Science Foundation (2019)

A 2018 Pew Research study found that underrepresented groups in STEM jobs were more likely to say that they have experienced **racial discrimination at work**, particularly Black individuals (62%) compared to White individuals (13%).

Funk (2019)

Academics cite that addressing systemic racism in science first requires acknowledging the racist history of scientific research, confronting racial biases and recognizing the contributions of Black and other minority scientists.

Ileka (2020)

Investment in DEIR is growing.

Investment in diversity, equity, inclusion and respect is increasing on the part of firms and associations. Not only is such an investment associated with **greater profitability**, but it is in **greater demand** from consumers and employees.

COVID-19 has revealed race and ethnicity are risk markers for other underlying conditions that affect health, including socioeconomic status, access to health care, and exposure to the virus related to occupation.

CDC (2020)

Through the #ShutDownSTEM strike, chemists sought to bring awareness to systemic racism in STEM, pointing to a lack of inclusivity in academic environments, including a lack of Black mentors for students.

Snabes (2020)

CHEMISTRY AND SOCIAL RESPONSIBILITY

Consumers have higher expectations for safe, ethical, and transparent practices in the chemical industry.

Support for **Corporate Social Responsibility** (CSR) has increased since 2018, as consumers are increasingly expecting more from employers.

Heightened by recent social justice movements, consumers now value **Corporate Social Justice** which centers the focus of any initiative on "the measurable, lived experiences of groups harmed and disadvantaged by society."

Common Trends in CSR Practice

- Increasing transparency
- Adopting green technology
- Acting locally
- Increasing DEIR efforts

Investopedia (2020), Zheng (2020), Extance (2018)

The "Mind the Store" campaign revealed significant improvements among retailers between 2016 and 2019 around adopting safer policies, reducing/eliminating chemicals of high concern (CHCs) and increasing transparency.

Four major retailers leading the group in 2019:

Walmart, Apple, Target, IKEA

Mind the Store (2019)

The industry continues to move towards a "greener" future.

Corporate Changes

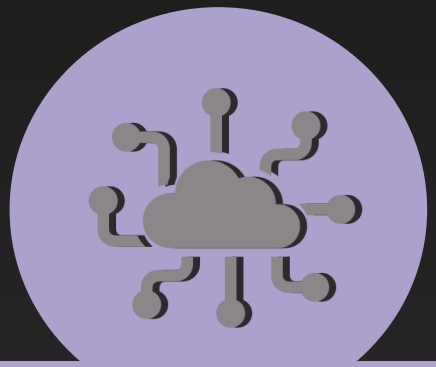
To meet consumer expectations, maximize profitability and champion responsible practices, chemical firms are expanding efforts to reduce their contribution to climate change.

Consumer Insights

Research has shown that consumers expect companies to provide products designed to be reused and recycled, and that half are willing to pay more for such products. *Accenture (2020)*

Federal Action

In July 2019, the U.S. Senate passed the **Sustainable Chemistry Research and Development Act** which seeks to more formally characterize and assess sustainable chemistry, coordinate Federal R&D support, and more. The Act is predicted to support job growth, protect human health and the environment, and help the U.S. realize innovation and market potential of sustainable chemistry technologies. *Quinn (2020)*



EMBRACING OPEN SCIENCE

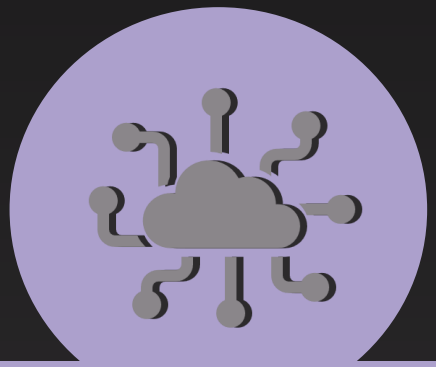
Many influential funders and policy makers support open science and require open access to articles and data.

Revenue from open-access publishing comes at the expense of traditional subscriptions. Payments now come from funders as well as libraries.

Preprint publishing is a growing means by which chemistry research is disseminated. Citizen science gains some traction as a democratized means of conducting research.

The COVID-19 pandemic has spurred calls for open science.

Contact strategicplan@acs.org for more information.



EMBRACING OPEN SCIENCE

Many influential funders and policy makers support open science and require open access to articles and data.

- A group of European research funders are instituting an aggressive open-access publishing mandate and the U.S. has been considering expanding current requirements.
- China offers verbal support, but has not pushed OA as strongly as Western Europe or the U.S.

Revenue from open-access publishing comes at the expense of traditional subscriptions. Payments now come from funders as well as libraries.

- Publishers offer new OA-based publishing options for institutions and funders as legal and illegal use of technology widens the availability of free alternatives to subscriptions.
- The most widely used open access platforms are run by large, commercial publishers.
- Authors rarely pay for OA publishing out of their own pockets.

Preprint publishing is a growing means by which chemistry research is disseminated. Citizen science gains some traction as a democratized means of conducting research.

- Preprints allow for the faster dissemination of research results, but raise quality concerns.
- The Federal government passed the Crowdsourcing and Citizen Science Act of 2017 to support citizen science efforts.

The COVID-19 pandemic has spurred calls for open science.

- Preprint publishing, especially for COVID-19 related research, has increased.
- Most publishers have made COVID-19 articles freely available.

Contact strategicplan@acs.org for more information.

EMBRACING OPEN SCIENCE

Many influential funders and policy makers support open science and require open access to articles and data.

In 2018, a **consortium of mostly European research agencies** and funders announced Plan S, an open-access initiative requiring that articles reporting on research they underwrite be posted in **open-access platforms by 2021**. Supporters include the Gates Foundation and the World Health Organization. *Schulson (2020), Plan S*

The **U.S. has been considering expanding open-access publishing requirements** for federally funded researchers to require immediate open-access publishing, driving a significant increase in OA-publishing..

Brugger (2020)

Legal and illegal use of technology creates alternatives to subscriptions.

Unpaywall is a browser extension that tracks down free versions of articles. Use has expanded and the extension is being incorporated by Scopus, an Elsevier abstract and citation database.

Sci-Hub is an illegal platform that offers access to published articles for free, relying on compromised credentials to acquire copies of articles. It continues to be used by many and poses an ongoing threat to the legitimate scholarly communication ecosystem.

Revenue from open-access publishing comes at the expense of traditional subscriptions. Payments now come from funders as well as libraries.

While open-access advocates support the notion of journal articles being free to the public, only the most extreme propose that no one should pay to make them open. Debate and negotiation continue about what constitutes sustainable OA publishing. At present, the most common source of payment is from grant funds. Other models to support OA publishing, e.g. advertising, membership fees, and subsidies, have been proposed but not gained traction.The most heavily used open-access platforms are run by large, commercial publishers.

Commonly Proposed Open-Access Funding Sources

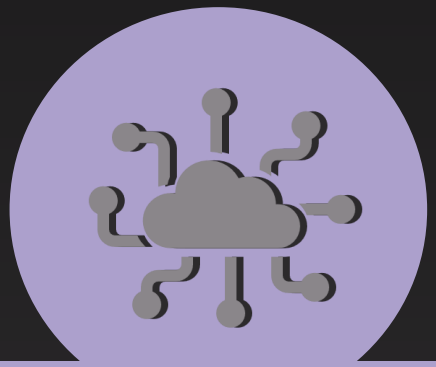
Researchers use grant funds to pay

Sponsored Advertising

Membership fees

Subsidies

Schulson (2020),



EMBRACING OPEN SCIENCE

Preprint publishing is a growing means by which chemistry research is disseminated. Citizen science gains some traction as a democratized means of conducting research.

Citizen science remains a common means by which nonprofessionals can fill a need in the scientific community by gathering data and conducting research in collaboration with scientists. Federal support of citizen science can be seen through the Crowdsourcing and Citizen Science Act of 2017.

Bowser (2020)

Since the launch of multiple preprint services in 2017, the **number of preprints in chemistry has continued to increase** with more and more researchers posting their manuscripts online prior to peer review.

Coudert (2020), Kubora (2020)

PREPRINTING

BENEFITS

- Allows for the rapid dissemination of research reports
- Can result in greater visibility

DRAWBACKS

- Possible spread of low-quality or flawed research, which may be particularly harmful in health-related fields

The COVID-19 pandemic has spurred calls for open science.

Open Access	In light of the COVID-19 pandemic, most publishers, including ACS, have made COVID-19 related research freely available.
Preprint Publishing	Major **preprint servers** have been flooded with thousands of crucial studies related to COVID-19 since the onset of the pandemic. In response, servers are **strengthening their screening** process to safeguard against the spread of poor-quality work.
Record Participation	Many existing **citizen science projects have shifted towards responding to the COVID-19 pandemic** and have seen record participation levels since the onset of stay-at-home orders. Further, Massive Open Online Courses **(MOOCs) have seen a drastic uptick** in participation after the onset of COVID-19. New registered users for top MOOC provider Coursera stood at 8 million in 2019 and increased to 20 million in 2020.

Kwon (2020), Lohr (2020), Johnson (2019), Mir (2020) , Bowser (2020)

SCIENTIFIC DOUBT AND POLARIZATION IN THE U.S.

Americans are divided on key scientific issues and have differing levels of trust in scientists.

Common online sources of scientific information are unsubstantiated.

U.S. policy has reflected a shift away from scientific research and towards deregulation, particularly with regards to environmental protections.

Contact strategicplan@acs.org for more information.

SCIENTIFIC DOUBT AND POLARIZATION IN THE U.S.

Americans are divided on key scientific issues and have differing levels of trust in scientists.

- Polarizing scientific topics include spending on scientific research, scientists' role in public policy, climate change, and COVID-19.

Common online sources of scientific information are unsubstantiated.

- Popular-science social media pages prioritize practical applications of science over new discoveries and explanations of concepts.
- Students have been found to struggle with critically assessing scientific information found online.

U.S. policy has reflected a shift away from scientific research and towards deregulation, particularly with regards to environmental protections.

- The current administration has rolled back over 80 environmental rules or regulations, which the upcoming administration may choose to reverse.
- Congressional support and appropriations for federal research agencies has been predictable and sustainable despite significant cuts proposed in this Administration's annual Presidential Budget Request.

Contact strategicplan@acs.org for more information.

SCIENTIFIC DOUBT AND POLARIZATION IN THE U.S.

Americans are divided on key scientific issues and have differing levels of trust in scientists.

While most Americans have at least a fair amount of confidence in scientists, the likelihood that someone has a “great deal” of confidence differs based on their political affiliation. Americans also disagree about the degree to which scientists should participate in policy debates, with opinion differing again by political affiliation.

Funk, et al. (2019)

America is becoming increasingly polarized.

Partisan Topics

Spending on Scientific Research

Climate Change

COVID-19

Given the urgent need for care, a vaccination program will be most successful with bipartisan confidence in the safety and equitable distribution of the vaccine.

Pew Research Center (2020, 2016), Funk (2019), Schwartz (2020)

Common online sources of scientific information are unsubstantiated.

A Pew Research study found that popular science-related Facebook pages more commonly posted about “news you can use” or advertisements over new discoveries or explanations of concepts.

Hiltin (2018)

Studies show that students struggle to critically assess information from the Internet and are often influenced by unreliable sources. Critical evaluation of online information is particularly important today as scientifically inaccurate information about COVID-19 and other topics is widespread.

Johannes Gutenberg Universitaet Mainz (2020)

SCIENTIFIC DOUBT AND POLARIZATION IN THE U.S.

U.S. policy has reflected a shift away from scientific research and towards deregulation, particularly with regards to environmental protections.

The U.S. has seen considerable deregulation over the past four years. The current presidential administration has **reversed, revoked, or otherwise rolled back over 80 environmental rules and regulations,** including...

- Weakening limits on carbon dioxide emissions from power plants
- Loosening regulations on toxic air pollution
- Pulling back on regulating toxic and hazardous chemicals

2021

The next presidential administration may choose to reverse the current course of regulation roll-backs in order to reach stated goals for reduced greenhouse gas emissions.

Research and development (R&D) funding

- Over the past four years, the presidential administration has **continued to propose cuts** to research and development, proposing a 9% cut for 2021.
- However, the administration has proposed an **increase in funding for artificial intelligence and quantum information**.
- Lawmakers in recent years have largely rejected proposed cuts, leaving funding largely **unchanged** for major scientific agencies.

DISCUSSION GUIDE

Assessing and Applying the Change Drivers to your Work

DISCUSSION GUIDE

- You can use this discussion guide individually, or as a group, to evaluate the Change Drivers and then determine how your work should respond or be adapted based on those Change Drivers.
- The first step is to review the Change Drivers and then triage them in terms of which are the most relevant for your group or team.
- Next, consider how the prioritized Change Drivers should inform your goals, work, and outcomes.
- Finally, your group or team should update your plans based on those decisions.

HOW TO USE THE CHANGE DRIVERS

1

Review

Understand changes going on in the environment around the chemical enterprise.

2

Orient

Triage the Change Drivers for the most relevant to your work and how they are impacting or will impact your goals.

3

Plan

Decide how to adapt and revise your plans based on these Change Drivers.

4

Act

Take action with your plans as informed by the Change Drivers.

5

Iterate

Review and reassess Change Drivers and your plans every six months or during major planning exercises.

A CLOSER LOOK AT STEP 2: HOW TO TRIAGE THE CHANGE DRIVERS FOR YOUR WORK

Review the three tiers of relevant importance for the Change Drivers on the following slide, then discuss:

- ✓ Which Change Drivers are most relevant/impactful for the audiences or constituents we serve?
- ✓ Which Change Drivers highlight opportunities for us? Which show the greatest challenges?
- ✓ Are there intersections among Change Drivers that are significant for us and our work?
- ✓ Sort into Driving, Significant, and Monitoring Change Drivers.

Driving Changes

- The most relevant and critical Change Drivers to consider in decision making and planning over the next three years. When volunteer leadership bodies and staff consider the operating environment for ACS and chemistry, these Change Drivers should be the strongest influences from the study.

Significant Changes

- Important Change Drivers but they are not identified as the top drivers. They should be considered in planning and decision making and used opportunistically when they align closely with particular programs or issues being considered.

Monitoring Changes

- Important Change Drivers to chemistry and ACS yet they are not considered to be driving or significant. They should be monitored and assessed on an ongoing basis but will not drive decision making unless it is determined they should be promoted.

To sort the Change Drivers into each of their respective buckets, consider using a voting tool, such as polleverywhere.com to gauge which topics your group views as the most pressing and critical to their work (driving), important but not top of the list (significant), and ones that are important to keep track of but not consequential to your work at the moment.

PLANNING

Driving

- How should these driving changes guide our work?
- What are the greatest opportunities they represent and how can we prepare to achieve them?
- What challenges do they represent and how do we address them?

Significant

- Among these significant changes, what factors intersect in a meaningful way with our selected driving changes?
- Are there specific elements of these changes we should take into account in our work?

Monitoring

- What elements of these Change Drivers should we be sure to monitor?
- What kind of change would move us to consider moving one of these Change Drivers to a higher priority?

TAKING ACTION

How will these changes impact the work of our group?

How will we need to reallocate resources, change the content of our programming, or other actions?

Review the Change Drivers at least once a year, or whenever conducting planning, to see if anything has evolved in your work that might necessitate a change or new approach.

Stay in touch with the ACS Office of Strategy Development to get updated research and new Change Drivers.