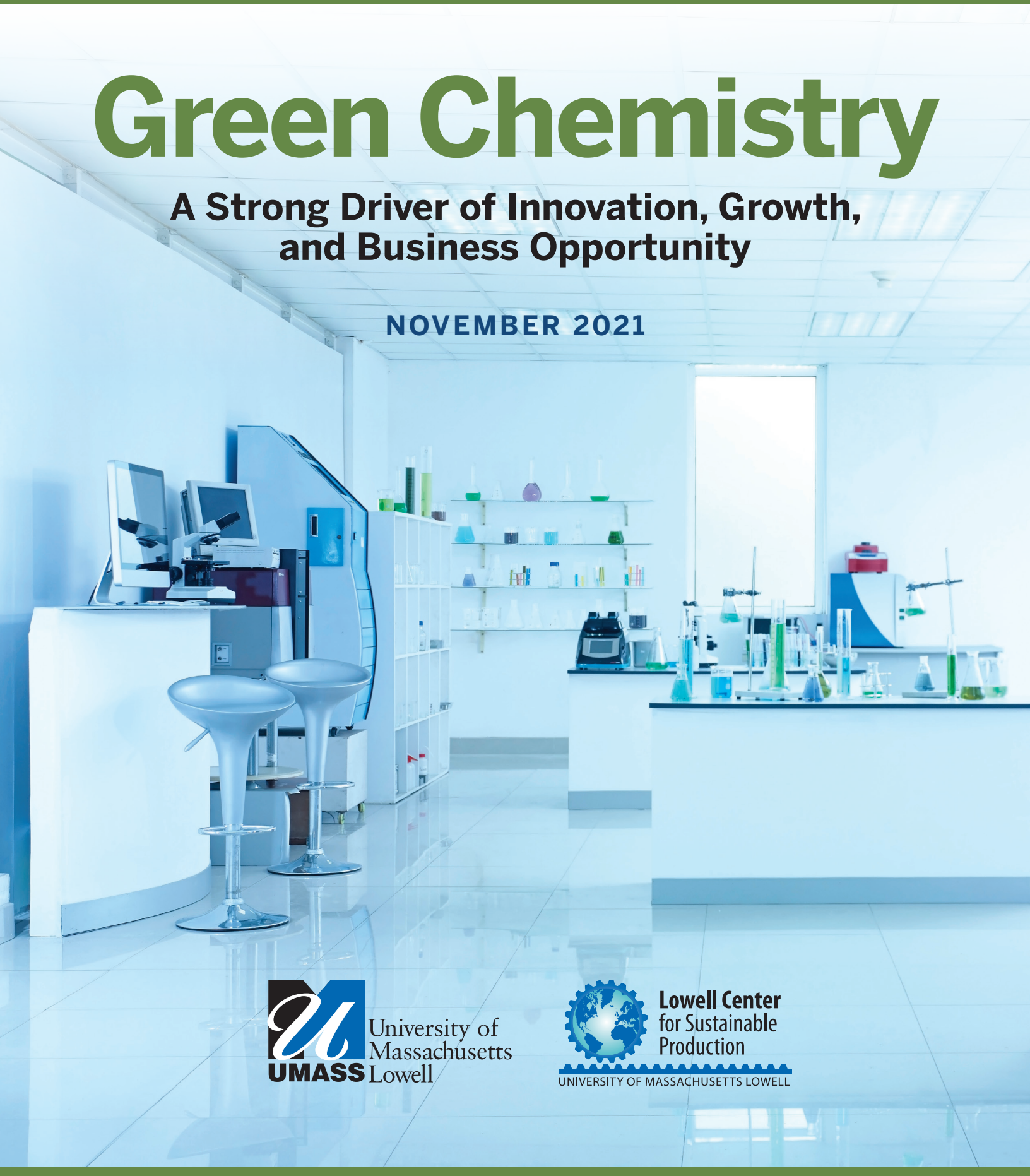
Green Chemistry

A Strong Driver of Innovation, Growth, and Business Opportunity

NOVEMBER 2021



UMASS University of Massachusetts Lowell

Lowell Center for Sustainable Production
UNIVERSITY OF MASSACHUSETTS LOWELL

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A REPORT FOR GREEN CHEMISTRY & COMMERCE COUNCIL (GC3)

GC3 GREEN CHEMISTRY & COMMERCE COUNCIL

PRODUCED BY

UMASS University of Massachusetts Lowell

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UNIVERSITY OF MASSACHUSETTS LOWELL

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The Sustainable Chemistry Catalyst is an independent research and strategy initiative, based at the Lowell Center for Sustainable Production (University of Massachusetts Lowell), focused on accelerating the transition to safer, more sustainable chemistry through research and analysis, and stakeholder engagement with scientists, policymakers, and commercial actors. The Catalyst works to understand barriers and opportunities to commercialization of safe and sustainable chemistry, identifies model solutions and strategies, develops methods to evaluate safer alter-natives, and builds a community of expertise to support the transition to safer, more sustainable chemistries and technologies.

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EXECUTIVE SUMMARY

As investors and manufacturers seek new market opportunities for growth in the chemical sector, one of the portfolios attracting attention is the expanding portfolio of green chemicals. The U.S. EPA defines green chemistry as chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal (Anastas and Warner, 2000).[1] While green chemistry has traditionally represented a very small segment of the broader chemistry industry, there is emerging evidence that this segment is poised to grow rapidly. In this report, we examine the business case for investment in green chemistry on the part of manufacturers, retailers, brands, and R&D teams. We present compelling evidence through a multi-method approach, relying on case studies, consumer product sales trends, economic value-added analysis, and prior research that suggests the green chemicals and products sector is growing rapidly and will likely become a dominant element of major investment portfolios in the near future. The findings presented here build on earlier reports over the last ten years, including by Pike Research (2011), Heintz and Pollin (2011), the Center for International Environmental Law (2013) and the Green Chemistry & Commerce Council (GC3), American Sustainable Business Council and Trucost (2015).

One of the primary drivers of the growth of green chemistry products is growing consumer and retail demands for products that are less impactful and healthier for people and the planet. As an increasing number of Fortune 500 companies commit to carbon neutrality and zero emissions targets by 2030, rational investors are naturally gravitating to the benefits of chemistries that can contribute significantly to these goals, whilst also appealing to a much more aware consumer base that is paying attention to the ingredients list in the products they buy (IFIC, 2021; Investopedia, 2020). Our analysis suggests that significant growth in the last five years has occurred, but also projects that this growth is likely to increase significantly in the next five. Given the urgency to achieve multiple sustainable objectives such as addressing climate change, meeting UN Sustainable Development Goals, reducing the volume of non-degradable plastics in our oceans, and responding to increasing government requirements, we make a compelling case for expanding investments in this sector.

The $4 trillion conventional chemicals segment represents 7.1% of global GDP, making it the fifth largest global manufacturing sector in terms of annual contribution to GDP. The U.S. chemical sector is the second largest in the world after China and produces 15% of the world's chemicals,

1 For the purposes of this report, we refer to green chemicals, green chemistry products, products of green chemistry or sustainable chemistry as chemicals and chemical products that are safer, reduce waste generation and greenhouse gas emissions and/or utilize renewable/biobased feedstocks.

produces more than 70,000 diverse products and is responsible for more than a quarter of U.S. GDP. More than 96% of U.S. goods manufactured in 2016 and used in our everyday lives contained chemical sector products (CISA, 2019). Today, many of these products are produced using chemicals derived from finite and non-renewable fossil and mineral feedstocks. Given the massive footprint of chemicals across multiple product sectors, the replacement of fossil fuel petrochemicals with green chemicals represents a significant opportunity to make an impact on sustainability goals for many industries.

As shown in **Figure ES.1**, the research team developed a multi-method analysis of the recent and projected growth of green chemistry products. First, researchers at NYU Stern School of Business conducted an analysis of IRI point of sales data in the United States. This analysis revealed a remarkable fact: there was more than a 40% market sector sales growth over conventional chemistries in the consumer products segment. Second, we conducted an industry survey that confirmed that the significant projected growth forecast holds not just for consumer products, but across a multitude of segments. Third, we developed an economic analysis using IMPLAN® economic modeling,[2] that suggests that green chemistry will be a major source of job growth in the coming

FIGURE ES.1
A multi-method analysis of the recent and projected growth of green chemistry products.

2 See Appendix section for methods and approach.

decade. Finally, we reviewed extant literature and conducted numerous case studies, which suggest that green chemistry is being adopted and has become a critical component of corporate product innovation strategy across multiple sectors. The case studies we assembled in agricultural products, apparel, sporting goods, consumer electronics, retail, and beauty products all point to the same fact: enterprises are gravitating towards green chemistry for sound business reasons. Together, these multiple sets of analyses all point to the same conclusion: The green chemistry sector is set to become a major investment growth sector, which was confirmed by a major ESG investor that we interviewed as well.

The Five Key Findings

Our analysis provides a clear picture that an increased focus on protecting human health and the environment has become a priority for consumers, policy makers, upstream supply chain investments, and ESG-focused investors alike. The on-going goals for reduced carbon footprints by Fortune 500 companies makes this an important component of a sustainable corporate strategy, given the widespread use of chemistries across multiple industry portfolios.

There are five clear insights that emerge from our study:

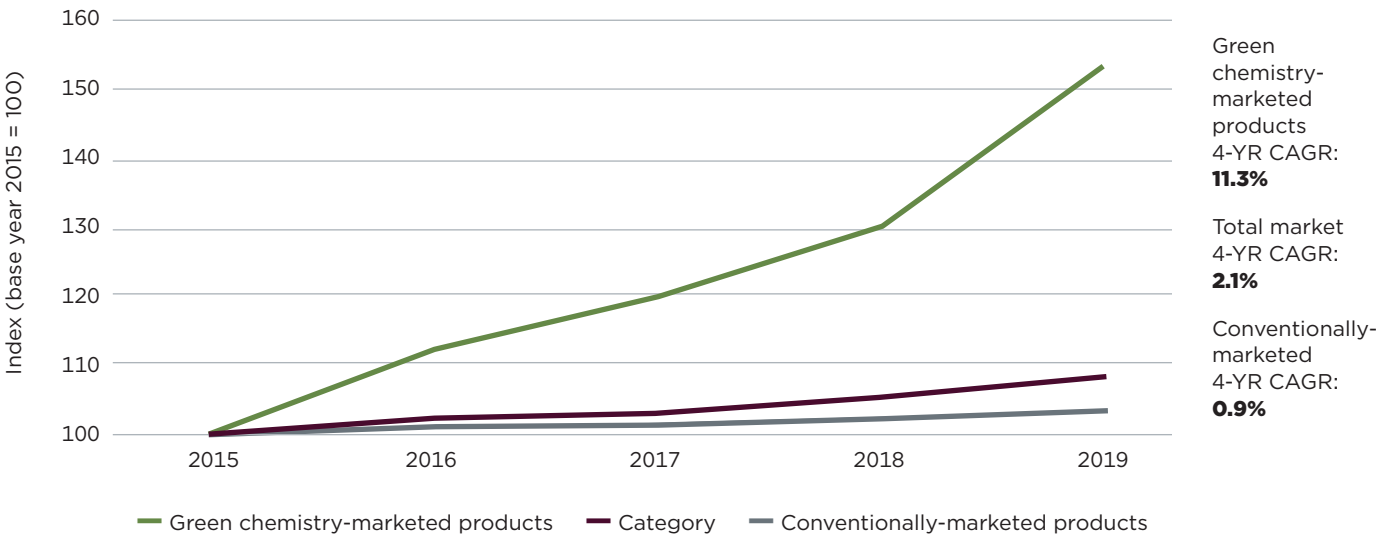
1. Green chemistry-marketed products significantly outperform their conventional counterparts in consumer markets
2. Consumers and institutional buyers are driving demand for green chemistry products
3. Emerging government policies and investor expectations are fueling growth of the green chemistry sector
4. The green chemistry sector will become a strong driver for job and economic growth
5. In response to increasing demands for more sustainable product portfolios, sales, sourcing, and R&D are working hand in hand to drive green chemistry solutions into the future product mix

FINDING #1

Green chemistry-marketed products significantly outperform their conventional counterparts in consumer markets

Researchers at the NYU Stern Center for Sustainable Business conducted an analysis using IRI data which reflects all scanned package goods purchased in measured U.S. outlets including food, drug, mass merchandisers, dollar, and convenience stores between 2015 to 2020. Ten categories were analyzed that included products with green chemistry formulations. As shown in **Figure ES.2** (p. 9), from 2015–2019 (prepandemic) green chemistry-marketed products grew at a much faster rate than their conventional counterparts by 12.6x and faster than the overall market by 5.4x.

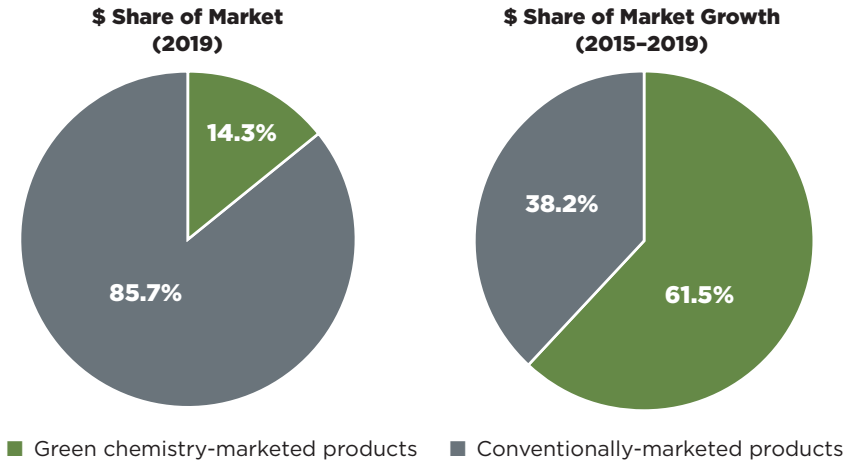
FIGURE ES.2
Growth of green chemistry marketed-products from 2015–2019.



From 2015–2019, green chemistry-marketed products (10 categories examined) grew 12.6 times faster than their conventional counterparts, and 5.4 times faster than the market.

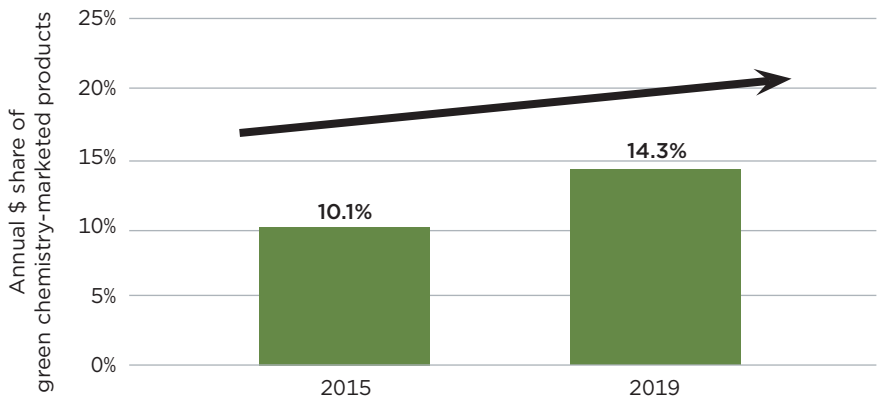
The data tell the story. Between 2015 and 2019, **green chemistry-marketed products represented almost 62% of overall market growth** for the 10 categories evaluated. During the same time, green chemistry products rose to over 14% of the total market share in 2019 using U.S. dollars. **Even the pandemic did not slow down the growth of the green chemistry sector** and the longer-term outlook of analysis of the sector indicates a 6.6%–11.5% compound annual growth rate (CAGR) between 2020–2025.

FIGURE ES.3
Market growth of green chemistry products.



Green chemistry-marketed products (10 categories examined) are 14.3% of the market and delivered 62% of the categories market growth (2015–2019).

FIGURE ES.4
Green chemistry-marketed products continue to climb in 2020, despite the pandemic.



Across 10 categories studied, green chemistry-marketed products account for 14.3% share of market ($) in 2019, up from 10.1% in 2015.

FINDING #2

Consumers and institutional buyers are driving demand for green chemistry products

During winter 2021, the research team undertook a survey of companies across sectors and the value chain. The findings, based on 54 respondents representing 15 sectors and the full value chain, reinforced what we heard from our one-on-one interviews with industry leaders. Although the greatest growth of green chemicals is occurring in consumer-facing industries, such as consumer cleaning products, health and beauty, footwear and apparel, and children's products, we are seeing growth in the B2B sector as well, including paints and coatings, construction materials, packaging, electronics, and other areas. This suggests that both **consumers *and* institutional buyers are responsible for the growth of the green chemistry sector**. Other factors driving growth identified in our survey included:

- C-Suite priorities
- Regulations
- Shareholders and investors
- Advocacy campaigns

The consumer demographics driving the largest growth in demand for products of green chemistry include Millennials (1981–1996); Gen Z (1997–2012); and Higher Income Consumers.

Our case studies also suggest that large brands are leading the way and using their purchasing power as leverage to shape the industry. Companies such as Apple, Unilever, Lowe's, and Nike are all establishing aggressive goals to reduce their chemicals and carbon footprints. For example, in January of 2021, multinational consumer products powerhouse **Unilever, announced that it is committed to making all its cleaning products carbon neutral by 2030**. They will devote more than $1.2 billion to switch to renewable or recycled carbon in its cleaning products.

FINDING #3

Emerging government policies and investor expectations are fueling growth of the green chemistry sector

Our analysis of key trends suggests that strong government policies do indeed make a difference and are driving growth of innovation in green chemistry across multiple sectors. New policies such as the European Commission's Chemicals Strategy for Sustainability, state policies in the United States, and implementation of the Lautenburg Chemical Safety for the 21st Century Act in the U.S. have created strong regulatory signals to the marketplace that are influencing investors. A greater number of investment houses outside of the traditional ESG sector are making significant inroads into the green chemical space, such as Carlyle's acquisition of Beautycounter (discussed in our case studies). Policies that foster increased investments in research and development, preferred acquisition status on government contracts, preferred product placement in retail establishments, and private and public labeling and certification programs that assist consumer and institutional purchasers in identifying safer and more sustainable products are attracting more and more companies to pursue green chemistry objectives. Our previous research indicated that between 2017 to 2019 the growth in the number of products certified by the USDA's BioPreferred Program increased by 93%. More than 2,000 products currently carry the U.S. EPA Safer Choice Label.

Due to investor and consumer pressures multi-national corporations are working on efforts to market more sustainable and green chemistry products including the world's largest retailers Amazon and Walmart. Many brands are driving the green chemistry sector. More than 32 global brands, along with suppliers and others have come together to form the ZDHC, which enables companies in the textile, apparel, and footwear industries to implement chemical management best practice across the value chain to advance a zero discharge of hazardous chemicals.

SHAREHOLDERS DEMAND SAFER CHEMICALS POLICY

In June of 2020, more than 44% of shareholders of retailer TJX Companies, with stores in the United States, Canada, Europe, and Australia (T.J. Maxx, Marshalls, Sierra Trading Post, HomeGoods and Homesense), **demanded the retailer reduce toxic chemicals in the manufacturing of the products it sells in all its stores.**

By February of 2021, the retailer had publicly announced a new more expansive chemical strategy.

SUSTAINABLE INVESTING TO DRIVE GROWTH OF GREEN CHEMISTRY

ESG investments captured $51.1 billion of net new money from investors in 2020—the fifth consecutive annual record, according to Morningstar up from $21 billion in 2019.

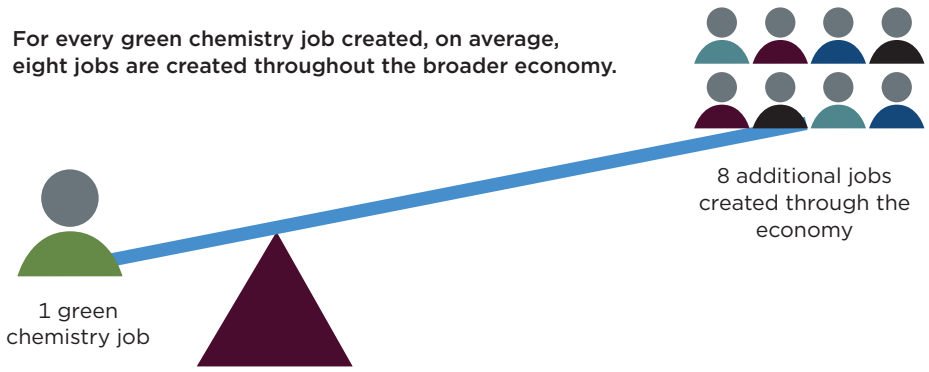
ESG accounted for about a fourth of the money that flowed into all U.S. stock and bond mutual funds last year. New EU rules require fund managers and investment firms to disclose the potential harm their investments could do to the environment and society.

FINDING #4

The green chemistry sector will become a strong driver for job and economic growth

When sales of products of green chemistry increase, jobs in the industry increase accordingly. While such jobs may only be a small part of the industry, our data indicate that growth in this segment is faster than traditional chemistry. While the direct jobs in the green chemistry industry are important to quantify, the indirect (green chemistry supply chain) and induced (restaurants and lifestyle supporting industries) jobs are also a major contributor to employment. The employment multiplier is another metric used to understand the economic impacts of an industry. In this case, **for every job created in the green chemistry industry, on average, 8 additional jobs are created throughout the broader U.S. economy**.

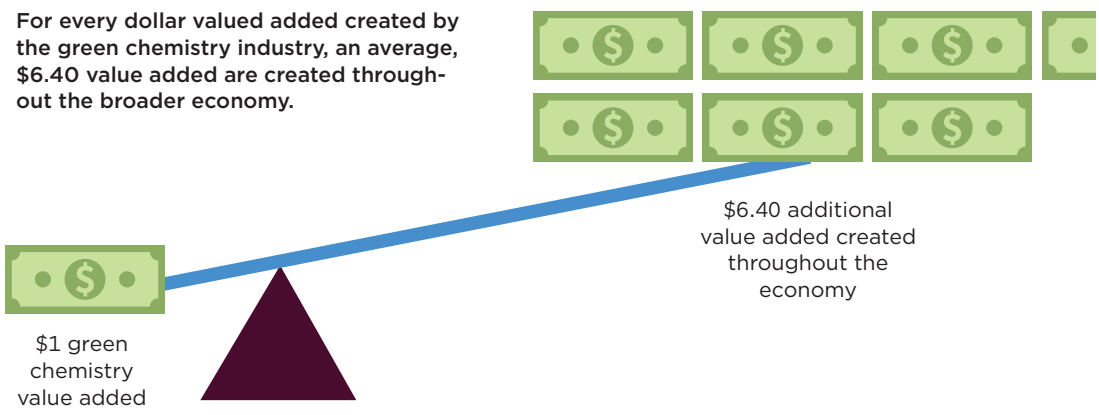
FIGURE ES.5
Green chemistry jobs and economic growth.



The contribution of the green chemistry industry to the overall value added or GDP is another metric to consider in a sector's business case. Based on a million dollars of sales of green chemistry products, on average $1.3 million of value added are created in the U.S. Economy.

The value-added economic multiplier is another important way to consider the economic impacts of the green chemistry industry. This metric relates the green chemistry industry's direct value added to the total value added created throughout the broader U.S. Economy. For the green chemistry industry, on average, for every dollar of value added created, over six dollars of value added are created throughout the broader U.S. Economy.

FIGURE ES.6
Green chemistry value added multiplier.



EXAMPLE: BIOBASED PRODUCTS

A subset of green chemistry industry is the biobased products industry which is a sector with increasing demand and corresponding production of goods. Biobased products are based on plant materials in lieu of petroleum-based and other synthetic raw materials. In 2017, **the biobased industry in the U.S. supported over 4.6 million people and created $470 billion in value added**. This industry as a whole had an economic multiplier of 2.79.

FIGURE ES.7
Biobased products economic impact.

FINDING #5

In response to increasing demands for more sustainable product portfolios, sales, sourcing, and R&D are working hand in hand to drive green chemistry solutions into the future product mix

Almost 58% of the respondents from our survey of business leaders across the value chain indicated that during the period of 2016 to 2020 sales of green chemistry products showed either greater growth (40%) or much greater growth (17.78%) as compared to traditional products.

The survey also shows that 84% of industry respondents have increased investment in R&D of green chemistry products during the last five years and 98% anticipate continued R&D investments in green chemistry products over the next five years. More than 58% of respondents believe that sales growth will be significantly greater in the same period. Specifically, most respondents reported moderate to very strong growth both in the United States (68.43%) and outside of the U.S. (83.93%) during the past five years. Growth is particularly high in packaging, health and beauty, household CPG products, along with toys and footwear/apparel.

Interviews with business leaders demonstrates a strong commitment across sectors, the entire value chain, and companies of various sizes to investment in green chemistry solutions. The following quotes provide a number of key insights into how different organizations are making big shifts in their product portfolios in response to demands for a new generation of emerging green chemistries.

What Industry Leaders are Saying

"We will never be a value brand and recognize that we will never be the lowest price point for chemical cleaners on the shelf. We recognize that consumers expect a range of prices for performance, and we recognize that we will be on the shelf at a higher price than non-renewable chemicals. However, it is our commitment that our products will also perform as a premium-priced product and will be priced comparably to other premium products."
Martin Wolf, Seventh Generation, Inc.

"The basic principle of green chemistry is to minimize the use and formation of toxic substances, and design products in a way that minimizes harm. We want to prevent bad things from happening and prevent harmful substances from being used in the supply chains. We know this can't happen all at once, and there are no perfect chemicals, but that shouldn't stop us from continuously improving our use of green chemistry to reduce our footprint in the supply chain. That is also the message we consistently communicate with our suppliers."
Frank Opdenacker, VF Corporation

"The formulation of a new product often starts on paper...we often have to go back and forth several times until we land on a formula that we both agree on, and this occurs well before the actual formulation stage". The large cosmetic brands produce at large scale, whereas we must bake into our prices the cost of running a full safety team, including an in-house lab that tests every batch of product for heavy metals. We also bear the cost of auditing and sourcing with our suppliers to ensure that there are no human rights violations. These costs are in addition to the premium costs of our safer packaging and raw materials, which renders our costs higher than those of larger brands. But despite these higher costs, we are seeing demand for our products continue to grow."
Lindsay Dahl, Beautycounter

Cargill is a company that will not take price losses to bring a product to market. If we can't become at least price competitive with offerings in a market, we won't sell it. The green chemistry segment today is only about a $60M business and is a fraction of what we earn on a global basis. However, our five-year strategy for the company has earmarked our bioindustrials space as the big area for the future. We see a huge demand for more biobased products in the future. We think that vertical integration from the farmer to the consumer gives us an edge; access to commodities and scale that allow us to be more efficient in production costs in a carbon constrained future.
Marty Muenzmaier, Cargill

"Retailers are asking for increased transparency for products they are putting on their shelves. Target and Walmart are great examples of retailers that have established a green chemistry policy and want to ensure the products are responsible – and are pushing their suppliers to change formulations. I think the change and interest is coming from a lot of different angles."
Emily Lethenstrom, Trillium Asset Management

"I think that we are only beginning to delve into the possibilities for green chemistry at Lowe's. There is a gap to be bridged in consumer understanding, and the difference between simply looking at a list of ingredients in a product, and what it means in terms of the environment. The same goes for our merchandising team, and they are often striving to understand what the "six syllable" chemistry words mean in terms of a better buying decision for our customers."
Chris Cassell, Lowe's Companies, Inc.

FINDING #1

Green chemistry-marketed products significantly outperform their conventional counterparts in consumer markets

"In a nutshell, the green chemistry market is poised for takeoff."

GreenBiz. May 2016

The sentiments reflected in a 2016 GreenBiz article refer to indications of potential growth in the green chemistry sector. The data presented in this report clearly demonstrates that green chemistry's time has finally arrived. In this report, we present actual purchasing data accumulated for the most recent five-year period providing quantifiable results that the green chemistry sector is now achieving the growth levels that proponents and analysts have only predicted in the past.[3]

Green Chemistry Consumer Purchasing Behavior Study

Researchers from the NYU Stern Center for Sustainable Business examined purchasing behavior for growing green chemistry sector in the United States. The team examined ten (10) different product categories as presented below. The data were collected from an IRI Point of Sales database, on measured scanned packaged goods purchased in all in-store U.S. outlets including food, drug, mass merchandisers, dollar and convenience stores.

The 10 product categories included:

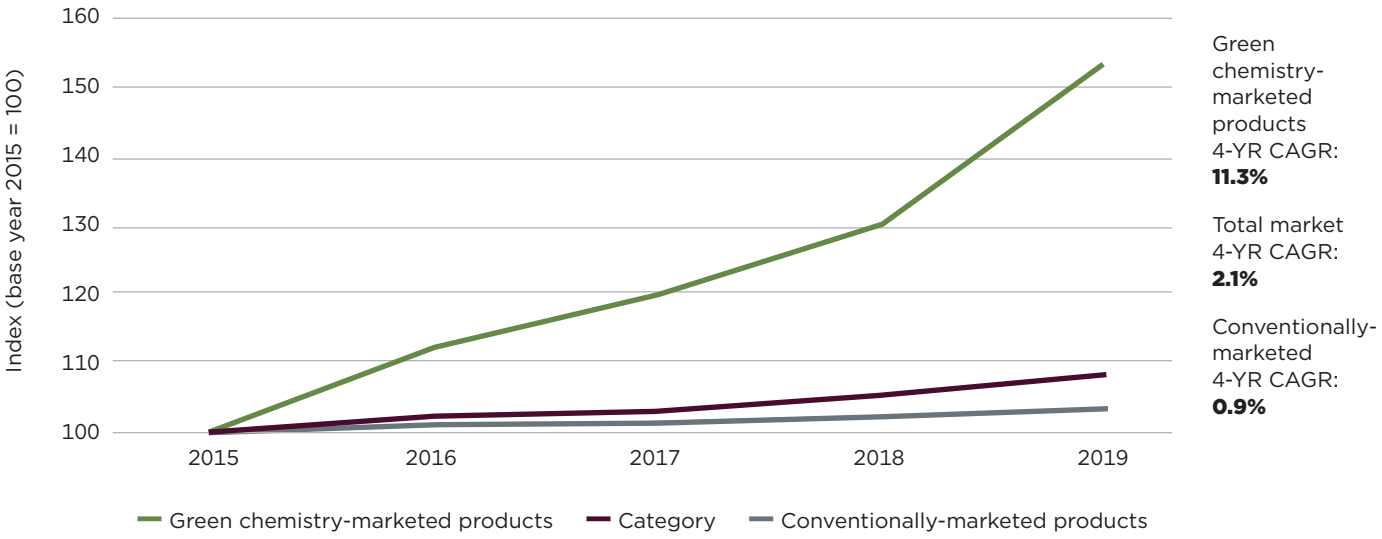
1. Auto wax
2. Dish detergent
3. Floor cleaner
4. Household cleaner
5. Laundry detergent
6. Pavement deicing
7. Pool chemicals
8. Skincare
9. Soap
10. Suntan products

3 For the purposes of this report, we refer to green chemicals, green chemistry products, products of green chemistry or sustainable chemistry as chemicals and chemical products that are safer, reduce waste generation and greenhouse gas emissions and/or utilize renewable/biobased feedstocks.

Products for each category were coded as green chemistry products based on on-package communication including both certifications and claims such as EPA Safer Choice, USDA Bio-Preferred, plant-based, no-phthalates, etc. and were grouped and analyzed in comparison to conventionally marketed products (see **Appendix A**).

The findings of the research clearly demonstrate and document the increasing domestic consumer demand for green chemistry products. Between 2015–2019, the 4-year compound annual growth rate (CAGR) was 2.1% while for green chemistry-marketed products that rate was 11.3% (**Figure 1.1**). For one specific certification, EPA's Safer Choice, between 2015–2019, the 4-year CAGR was 10.4% compared to category performance (the four categories where Safer Choice products were sold) of 1.45%

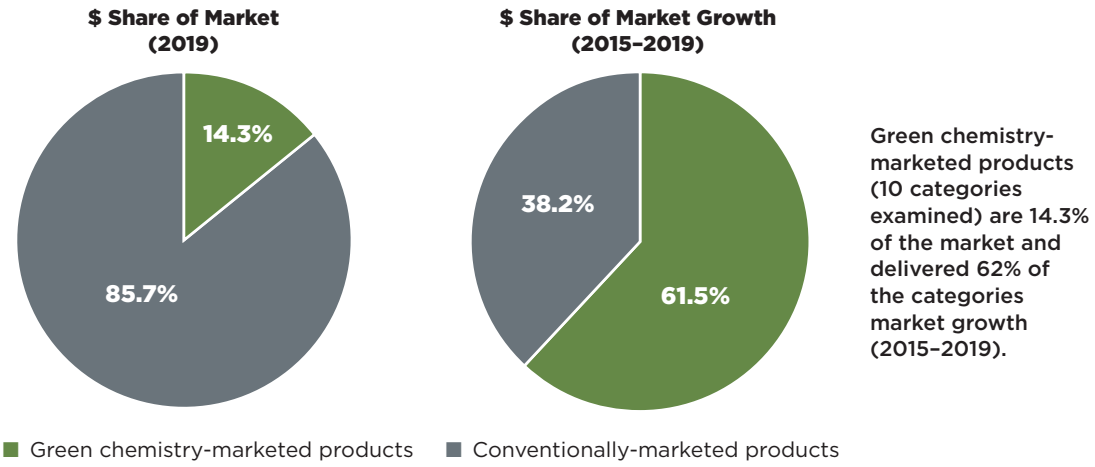
FIGURE 1.1
CAGR growth of green chemistry-marketed products



From 2015–2019, green chemistry-marketed products (10 categories examined) grew 12.6 times faster than their conventional counterparts, and 5.4 times faster than the market.

In fact, while during 2015 to 2019 green chemistry-marketed products were 14.3% of market share for the ten categories, they delivered 62% of the categories' market growth (**Figure 1.2**).

FIGURE 1.2
Market growth of green chemistry products.



Even the pandemic did not slow the growth of the sector as the annual dollar (US) share of green chemistry-marketed products of focus grew as presented in **Figure 1.3**.

FIGURE 1.3
Annual $ share of green chemistry-marketed products.

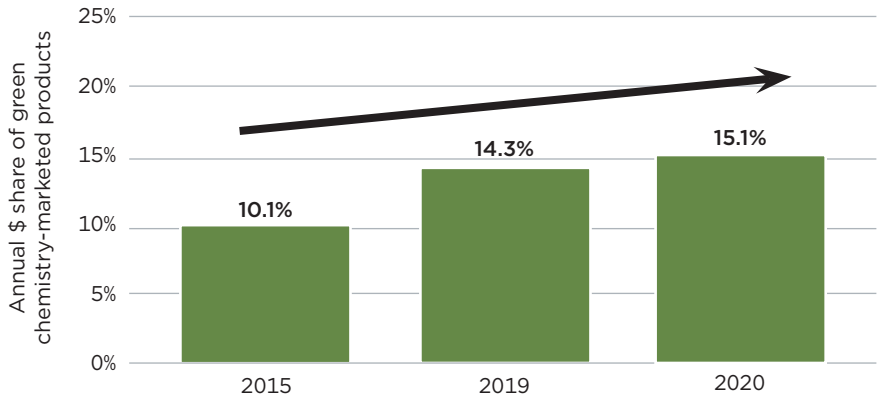
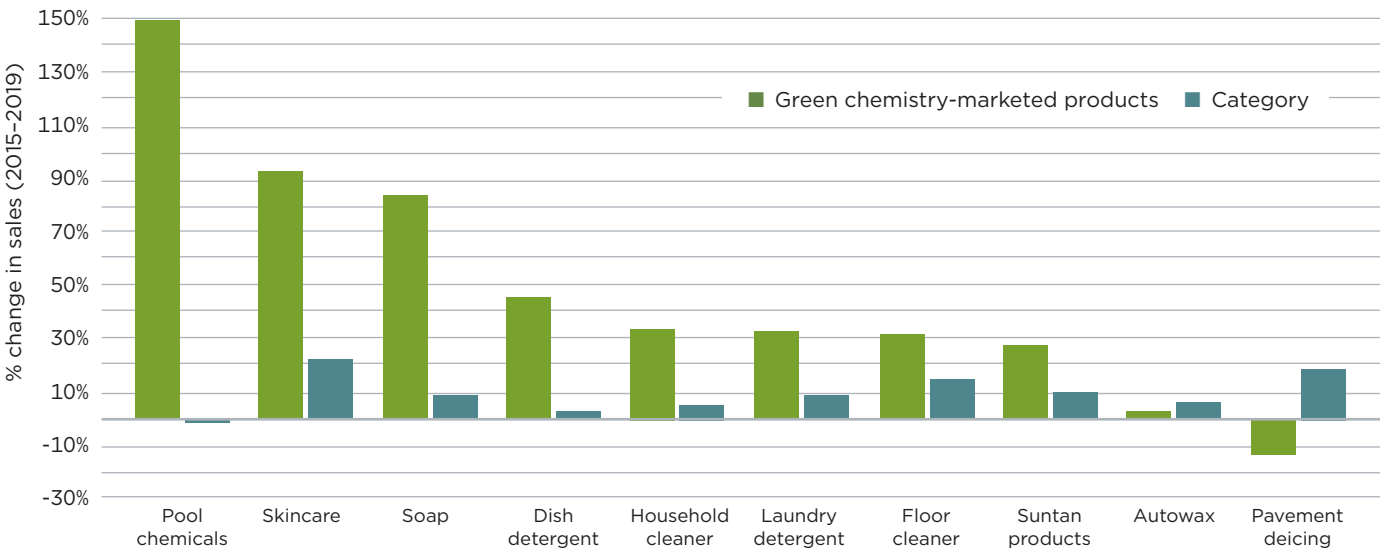


FIGURE 1.4
Category growth of green chemistry products.



In 8 out of 10 categories researched, the growth of green chemistry-marketed products outpaced the growth of their respective categories.

* Note: Actual sales growth for green chemistry-marketed products in pool chemicals from 2015–2019 was 345%

As shown in **Figure 1.4**, green chemistry products outperformed product category growth for all but the pavement deicing and auto wax categories. These results provide additional tangible evidence that consumers are willing to pay what are often premium prices for sustainable products including those utilizing green chemistries, a finding demonstrated in other studies (Accenture, 2019; CGS, 2019). Based on our survey and interviews with companies, we predict significant further growth in sales of green chemistry products in several sectors including cleaning products and health and beauty.

Green Chemistry Industry Experts Survey

During the first three months of 2021, the project team worked in collaboration with researchers at the Lowell Center for Sustainable Production, University of Massachusetts Lowell, to conduct a web-based survey of key industry and other experts, including retailers, brands, and manufacturers. The goal was to understand the drivers for growth, as well as the level of investments being made by companies across the value chain in green chemistry.[4] Fifty-four survey responses were obtained with a breakdown of respondents comprising:

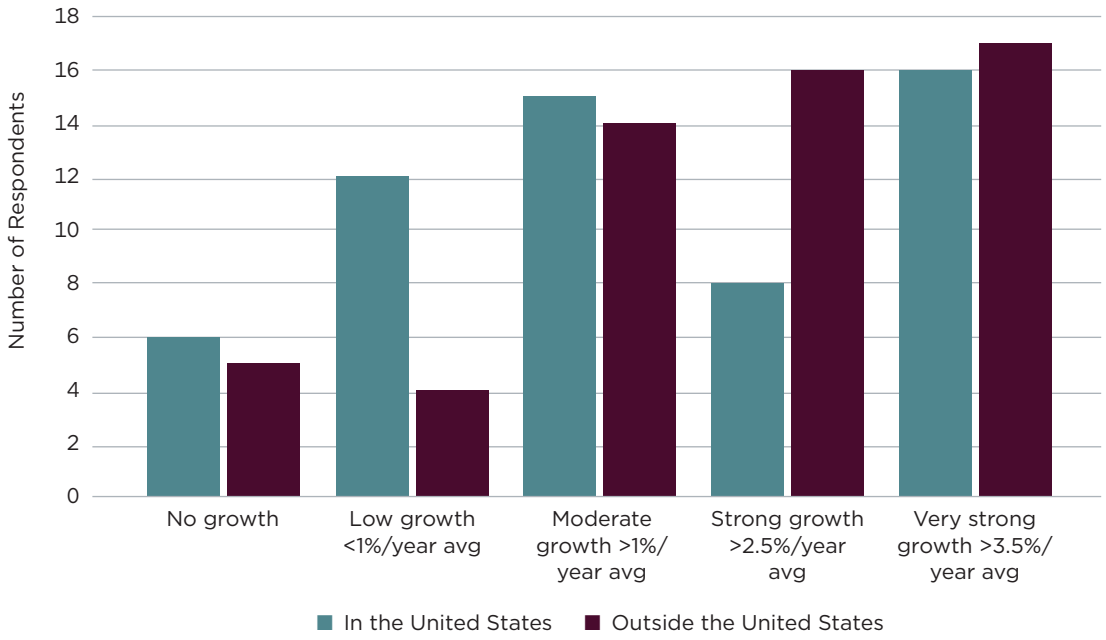
- Chemical Industry = 42.22%
- Brands = 22.22%
- Other Manufacturers = 20.00%
- Retailers = 11.11%
- Industry Consultants = 2.22%
- Other = 2.2%

4 Qualtrics based survey hosted by North Carolina State University-IRB Reviewed

The survey collected insights regarding the current and projected economic growth opportunities for green chemistry in the US and explored trends in company policies, consumer and B-2-B drivers and challenges to growth.

Overall, the survey results suggest a surging optimism for new growth in green chemistry products across several sectors over the last five years. We asked the respondents whether over the period of 2016–2020, "your company observed an increase in domestic and global demand for "green and sustainable chemistry products"? As shown in **Figure 1.5**, most respondents reported moderate to very strong growth both in the United States (68.43%) and outside of the U.S. (83.93%).

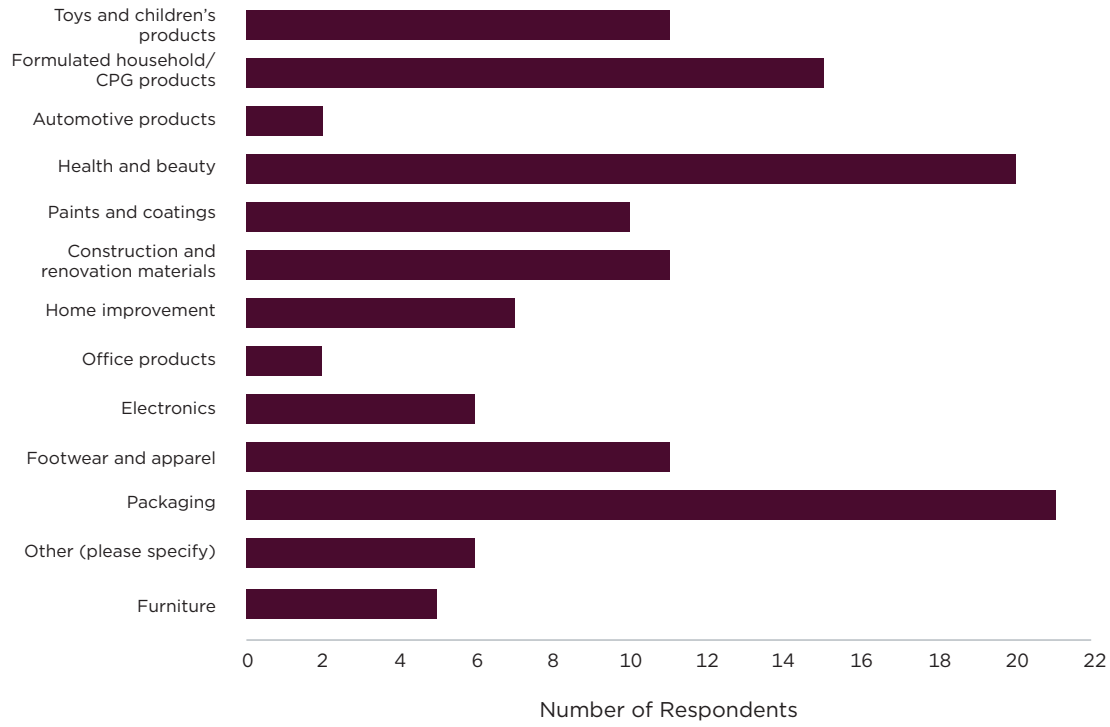
FIGURE 1.5
Observed growth of the green chemistry sector.



The survey also dove into which product categories were providing the largest increase in demand for green and sustainable products. As presented in **Figure 1.6**, packaging, health and beauty, and household CPG products experienced the greatest growth over the last five years along with toys and footwear/apparel. We also observed growth in the construction and home improvement sectors.

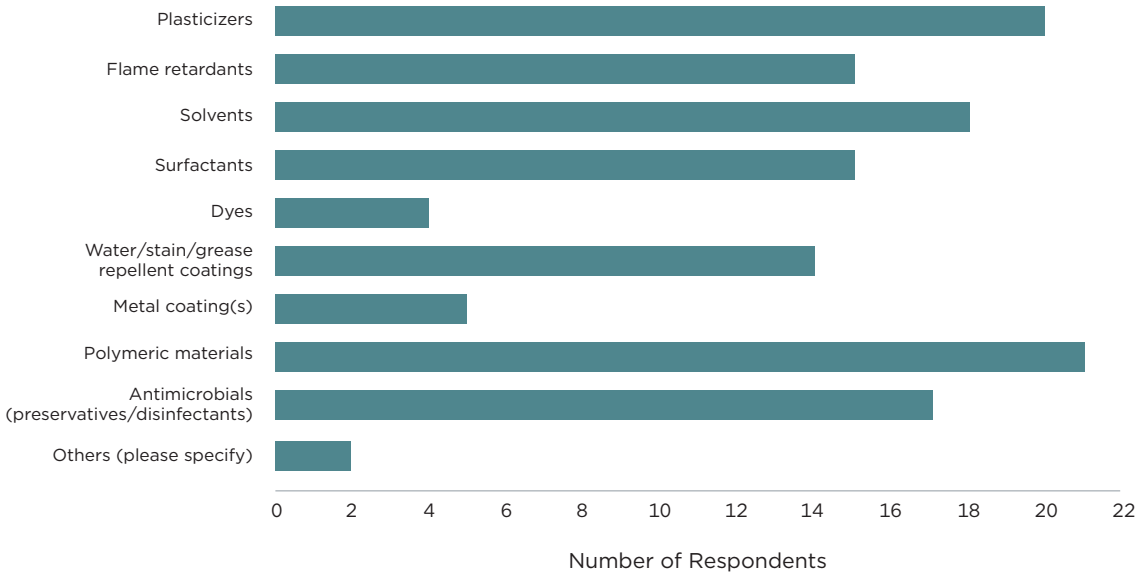
Almost 58% of the industry respondents to our survey indicated that during the period of 2016 to 2020, sales of green chemistry products showed either greater growth (40%) or much greater growth (17.78%) as compared to their traditional products.

FIGURE 1.6
Product categories with observed increased demand for green chemistry.



We also asked participants which green chemistry functions had the largest increase in demand. As shown in **Figure 1.7**, polymeric materials, plasticizers, solvents, and antimicrobials had the largest growth in the last five years. These materials are likely linked to many of the categories with the greatest growth shown in **Figure 1.6**.

FIGURE 1.7
Chemical functions with largest increase in demand for green products.



Industry Confidence

One way to gauge confidence levels of industry leaders is their projected investment in research and development of new products in the green chemistry sector. About **84% of the respondents in our survey indicate their organizations have increased investment** in R&D in green chemistry products over the last 5-years. We are also observing a greater number of startups that are targeting this sector with new products. This suggests we are likely to witness a significant pipeline of new green chemistry products entering the marketplace in the next several years. This trend is likely to expand, with higher levels of investment being dedicated; **98% of industry respondents anticipate continued R&D investments** in green chemistry products over the next five years. This trend was further described by several companies in our interviews, including Cargill, Beautycounter, Seventh Generation, and others.

Market Projections

A number of current projections for growth of green chemistry are presented as a range, based on secondary research conducted by the team. These projections vary due to the rapid integration of green chemistry into several areas of the economy. One of the barriers to estimating growth is a lack of industry specific North American Industry Classification Systems (NAICS) codes administered by the U.S. Government that would us a more accurate measure of the growth of green, biobased, and sustainable chemicals. Further confusion exists about the types of product categories that belong in the "green chemistry" category.

Despite these issues, analysts are unified in the view that over the next 5 to 10 years the green chemistry sector is poised for significant growth (**Table 1.0.**) This growth is largely a result of increased customer awareness of safety concerns, increasing regulatory policies around safer chemicals (especially in Europe), and the impact of sustainability goals being set by many Fortune 500 companies.

TABLE 1.0
Analyst projections for the growth of the green chemistry industry and sub-sectors.

Sector	Analyst Projections	Analyst
Green Technology and Sustainability Market	Compared to $8.3 billion in 2019, the industry is predicted to generate revenue of $57.8 billion in 2030. Additionally, between 2020 and 2030 (forecast period), the market would advance at a CAGR of 20.0%.	Research and Markets
Green Chemistry—Global	Green chemistry chemicals market size is forecast to reach $130 billion by 2025, after growing at a CAGR of 11.5% during 2020–2025.	IndustryARC
Green Chemistry—Global	Will grow to $18.47B by 2030 a 6.6% CAGR between 2020 and 2030.	Prescient & Strategic Intelligence
Green Chemistry	The global marketplace for renewable chemicals is predicted to grow from $51.7B in 2015 to $85.6B by 2020, with a CAGR of 10.6% for the period of 2015–2020.	3rd World Congress on Green Chemistry & Tech.—Oct. 2020 USA
Bioplastics—Global	Will reach $19.93 billion by 2026–a CAGR of 16.2%.	Fortune Business Insights
Bioplastics and Biopolymers—Global	Expected to grow from $13.2 billion in 2015 and reach $7.66B by 2022 with a CAGR of 13.7%.	Stratistics MRC
Bioplastics—Global	Projected to reach $22.1B by end of 2026—a CAGR of 15.6%.	ResearchCMFE

FINDING #2

Consumers and institutional buyers are driving demand for green chemistry products

"Our analysis from one study showed that the likelihood consumers would buy our brand based on our marketing was 6 to 10% higher. If they have heard of the Seventh Generation brand but have not heard of our mission, that likelihood rose to 20–30%. However, once consumers were informed both of our brand AND our mission, the purchase intent jumped up to 50%. The more they learned, the more willing they were to switch to our sustainable brand."

Martin Wolf, Director of Sustainability & Authenticity, Seventh Generation, Inc.

Our survey results suggest that a number of factors drove the observed growth of green chemistry products from 2015 to 2020. The most important drivers identified by respondents included consumer demand (33%), brand requirements (19%), and pressure by business customers for greener products (13.3%). Further, the demographic segments with the most influence on green chemistry product growth include Millennials (55%), Gen Z (43%), and higher income consumers (41%). Interestingly, Baby Boomers are not a strong driver for green chemicals; younger demographics seem to be much more focused on purchasing green chemistry products, as indicated in the Lowe's and Beautycounter case studies. Our results suggest that the most important pathways for communicating green chemistry to consumers include eco- and safety labels, corporate websites, social media, and packaging design.

Eco-Labels

As one walks down the consumer cleaning aisle of any big box retail store, it is immediately clear that there are a growing number of household products with a third-party certification labels promoting the sustainability and/or safety of the product. The value and utility of standardized eco-labels has risen in part due to their utility in simplifying B-to-B purchasing transactions as well as for communicating the sustainability and health benefits of products to consumers. Our previous research indicated that between 2017 to 2019, the number of products certified by the USDA BioPreferred Program grew by 93%. More than 2,000 products currently carry the EPA Safer Choice Label.

FIGURE 2.1
Examples of leading product labels and certifications used for green chemistry products.

U.S. EPA Safer Choice Label
Replaced the former Design for Environmental Label in 2015, has more than 2,000 products

USDA BioPreferred Label
Launched in 2002 has over 1,700 certified products

Green Seal Certified
Global non-profit founded in 1989 provides third-party certification around the world using EPA's third-party certification requirements

UL Program ECOLOGO*
Products, services and packaging are for reduced environmental impact

European Union Ecolabel
Established in 1992, currently over 75,000 products and services on the market, the EU Ecolabel is recognized across Europe

GreenScreen Certified™
Free of thousands of chemicals of concern and use preferred chemistry

VALUE OF LABELS—U.S. EPA SAFER CHOICE

The demand and value of a scientifically robust and respected government certification for safer chemistry was recently emphasized, when on March 15, 2021, a coalition of over sixty diverse stakeholders sent a formal request to newly appointed EPA Administrator Michael Regan to fully staff the EPA Safer Choice Program, after program resources had been cut during the prior presidential administration.

This was followed by a June 24, 2021, letter to Congress similarly asking for funding levels to be raised to support the Safer Choice Program. Over seventy stakeholders signed the letter included a broad spectrum of major corporations, NGOs, and governmental agencies. A partial list is presented in **Table 2.1**.

TABLE 2.1 Partial list of signatories.

Amway	Breast Cancer Prevention Partners
BASF	Environmental Defense Fund
Clorox	Minnesota Pollution Control Agency
Henkel	City of San Francisco
Proctor & Gamble	Oregon Department of Environmental Quality
Levi Strauss & Co.	Natural Resources Defense Council
Reckitt	Mayor City of Tempe, Arizona
National Retail Federation	Washington State Department of Ecology

– CONTINUED –

VALUE OF LABELS—U.S. EPA SAFER CHOICE (CONTINUED)

In their letter, the signatories state:

"Companies across the value chain utilize the Safer Choice brand to advance their individual safer chemical initiatives – from brand owners to retailers to chemical manufacturers. For example, chemical manufacturers have invested in the difficult task of developing safer chemicals now listed on the Safer Choice's Safer Chemicals Ingredients List (SCIL). Having chemicals on the SCIL allows these manufacturers to offer best-in-class safer chemicals to the market that carry the robust third-party verification of the EPA. Brand owners and product manufacturers have invested in Safer Choice by undertaking the similarly resource-intensive effort to reformulate products using the SCIL to obtain Safer Choice certification. Major retailers specify the Safer Choice label as a way to verifiably meet corporate goals laid out in public-facing chemicals policies.

"The Safer Choice Program also provides value to entities outside of the supply chain. Numerous states and municipalities rely on Safer Choice because it is the only third-party program that requires all ingredients to be screened for hazards instead of simply using a restricted substances list."

Industry respondents also indicated which sectors had the highest potential for market growth in green chemistry in the next five years (2021 to 2025) in **Table 2.2**. As shown in this table, packaging, polymers, consumer products, apparel, and biobased products have the highest potential for growth. These are consistent with current areas of greater demand for green chemistry. Building materials is believed to have a high potential growth going forward, as indicated in our Lowe's case study.

TABLE 2.2
Sectors with the greatest potential growth in green chemistry.

1	Packaging
2	Polymers and Plastics
3	Biobased Products
4	Consumer Products
5	Apparel and Textiles
6	Building Materials
7	Pharma and Life Sciences
8	Specialty Chemicals
9	Electronics

These results also point to the importance of increased green chemistry purchasing activity by industrial buyers. Many companies have established aggressive targets for sustainability through 2030, which may include some "stretch goals". The adoption of green chemistries in product lines is an important contributor to sustainability metrics such as The Chemical Footprint Project and reduction of non-renewable content.

For instance, in January of 2021, multinational consumer products powerhouse Unilever, announced that it is committing to make all its cleaning products carbon neutral by 2030. The company will devote more than $1.2 billion to switch to renewable or recycled carbon in its cleaning products (C&EN, 2021). The impact this type of action has on the overall consumer products supply chain is significant. Unilever sources raw materials from over 10,000 suppliers worldwide and up to 100,000 non-production suppliers and has over 400 brands spanning food, beverages, cleaning agents, and personal care products available in over 190 countries (Innovation Enterprise, 2021). This strategic direction was influenced, in part, by Unilever's acquisition of Seventh Generation (see **Case Study**).

Multiple other industry sectors are similarly moving in this direction. For instance, in the apparel sector, large retailers, brands and manufacturers such as Target, Adidas, Gap, H&M, Hugo Boss, ISKO, Lenzing, Nike, Puma, Smart Shirts, and many others are coming together in an organization called the Zero Discharge of Hazardous Chemicals (ZDHC), which has a mission to enable brands and retailers in the textile, apparel, and footwear industries to implement sustainable chemical management best practice across the value chain in order to advance the goal of zero discharge of hazardous chemicals.

Launched in 2011, ZDHC is now a global community with over 160 contributors focused on managing input chemistry. They have created a roadmap to advance towards the zero discharge of hazardous substances.

FINDING #3

Emerging government policies and investor expectations are fueling growth of the green chemistry sector

Government Policy Drivers

The demand for safer and more sustainable products continues to see significant growth globally. In response to increasing scientific evidence and advocacy, governments are advancing bold policy reforms at the national, state, and local level to require product ingredient transparency, phasing out of chemicals of concern, and adoption of safer alternatives. The Safer States Database identifies hundreds of new bills introduced in the last five years addressing chemical transparency and restrictions.

A number of these policy drivers are likely to have the effect of driving the green chemistry sector as presented in **Table 3.1**. International policies, such as those in Europe, will drive the domestic sector as a consequence of trade and exports. Well-designed regulatory policies can have a strong influence in driving innovation and reducing impacts of chemicals (CIEL, 2013). For example, the European Chemicals Agency reports that 12 chemical restrictions are delivering health benefits of at least €2.1B per year-four times their cost (ECHA, 2021). Europe's far reaching chemicals legislation REACH has been documented to have protected millions of people from serious illnesses such as cancers, disorders of sexual development, asthma, and allergies, while also preventing more than 95,000 tonnes of hazardous chemicals escaping into the environment.

TABLE 3.1
Examples of recent chemicals policies internationally.

Government Entity	Policy
European Union	The European Green Deal of 2020 sets the EU on a course to become a climate neutral and circular economy by 2050. The Chemical Strategy for Sustainability (CSS) seeks to lead Europe towards a toxic-free environment, where chemicals are produced and used in a way that maximizes their contribution to society, while avoiding harm to the planet and to current and future generations, through safe and sustainable by design approaches. The CSS builds on experience from over a decade of implementation of REACH.
United States	The Frank R. Lautenberg Chemical Safety for the 21st Century Act of 2016 amended the Toxic Substances Control Act (TSCA), the nation's primary chemicals management law to include: • Mandatory requirement for EPA to evaluate existing chemicals with clear and enforceable deadlines. • Risk-based chemical assessments. • Increased public transparency for chemical information; and • Consistent source of funding for EPA to carry out the responsibilities under the new law.
State of California	CA SB–258 Cleaning Product Right to Know Act of 2017 requires that as of January 1, 2020, all cleaning products sold in California must provide detailed online ingredient reports via the web. This bill follows on other transparency and chemical restrictions legislation including the California Safer Consumer Products program.

As an example of how both Republicans and Democrats see value in driving innovation in green chemistry products, in January of 2021, the U.S. Congress enacted the bipartisan *Sustainable Chemistry Research and Development Act*. The bill is intended to both support American manufacturing and jobs while also protecting human health and the environment through expanded use of sustainable chemistry technologies. The act directs the White House Office of Science and Technology Policy to convene an interagency entity with the responsibility of coordinating and strengthening federal programs and activities in support of sustainable chemistry.

In our survey, we asked industry leaders which public and private policies are likely to have the greatest impact and pull in driving the green chemistry sector. As presented in **Table 3.2**, efforts to address climate change are an important policy driver for investment in green chemistry products followed by policies by institutional buyers for both safer and more sustainable products.

BI-PARTISAN CONGRESSIONAL SUPPORT FOR SUSTAINABLE CHEMISTRY

U.S. Senators Chris Coons (D-Del.), Susan Collins (R-Maine), Amy Klobuchar (D-Minn.), and Shelley Moore Capito (R-W.Va.) introduced the *Sustainable Chemistry Research and Development Act* with the companion bill in the House by Representatives John Moolenaar (R-Mich.) and Dan Lipinski (D-Ill.).

Encouraging innovation, creating new jobs, and improving human health and the environment is something that should bring us all together," said **Senator Coons**.

"Sustainable chemistry aims to improve the efficiency of the chemical production process while reducing risks to human health and the environment," said **Senator Collins**.

"This legislation strengthens cooperation between the federal government, the private sector, and the scientific community to further research and development in chemistry," said **Congressman Moolenaar**. "It will keep our country at the forefront of innovation and help create new products that will benefit all Americans."

TABLE 3.2
Industry views on impact of global drivers that will increase growth of the U.S. green chemical industry.

Rankings of Top Priorities	Policy Recommendation	% Ranked Medium to Very High Impact
1	Increased business and government efforts to address climate change	100.00%
2	Increased demands from retailers for safer and more sustainable products	97.44%
3	Increased business and government focus on the "Circular Economy"	97.43%
4	Implementation of the European Commission's 2020 "Chemicals Strategy for Sustainability: Towards a Toxic-Free Environment"	92.31%
5	Government and industry initiatives aimed at increasing product ingredient transparency	89.48%
6	Increased focus on responding to UN Sustainable Development Goals	84.62%
7	The 2007 European Union Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation	84.21%
8	Increased ESG investor advocacy	76.92%
9	European Union taxonomy for sustainable activities	75.00%

Identified Policy Needs

With the start of the Biden administration and a new Congress, we asked industry leaders what federal-level policies and actions would be most effective in further advancing U.S. based manufacturing of green chemistry products. Twelve specific recommendations were provided to the research team with the following rankings of positive impact provided in **Table 3.3**.

TABLE 3.3
Industry opinion on domestic policy recommendations that can drive the growth of the U.S. green chemistry sector.

Rankings of Top Priorities	Policy Recommendation	% Ranked Medium to Very High Impact
1	Chemical phase outs and/or restrictions	95.00%
2	Federal and state tax policies incentivizing products of green and sustainable chemistry	87.13%
3	Preferential-expedited new chemical review process for green chemistry under TSCA, FIFRA and other laws	82.05%
4	Specific federal purchasing specifications for green chemistry and sustainable products through GSA and DOD	81.58%
5	Increased federal funding for green chemistry and sustainable products R&D and commercialization	80.00%
6	Federal Executive Orders promoting federal government purchasing of green and sustainable chemistry projects including federal purchasing targets	79.49%
7	Enhanced federal recognition programs for green and sustainable chemistry products	76.26%
8	Federal and state streamlining of permitting for green chemistry manufacturing facilities	68.40%
9	Favorable loan lending rates and guarantees for qualified green chemistry and sustainable products	59.46%
10	Providing for U.S. Patent extensions of green and sustainable chemistry products	56.41%
11	Development of NAICS industrial codes covering green chemistry and sustainable products	55.55%
12	Other-not specified	N/A

Role of the Investment Community

We also studied how the financial and investment community has become a much stronger force in the advancement of green chemistry. Investors, already focused on climate impact and ESG governance, are increasingly concerned about the financial risks associated with toxic chemicals as well as the growth potential from investment in companies with innovative green chemistry

solutions. There are clear market opportunities for investing in firms which can meet consumer and institutional buyer growing demands for safer and more sustainable chemistry-based products.

RISKS RELATED TO MANUFACTURE OF CHEMICALS OF CONCERN

After a year of talks, German based Bayer AG agreed to pay up to $10.9B to settle lawsuits in the United States against the company for reportedly causing cancer from exposure to their glyphosate-based Roundup weed killer product (Reuters, 2020). Prior to this decision, the company recognized an almost 30% stock value decrease between June 2018 and the settlement date. The company has announced that it will phase out the use of the product for lawn and garden care by 2023.

Bayer however is not an isolated case. There are numerous other cautionary tales of the financial and shareholder impacts that could have been avoided through the adoption of green chemistry technologies.

U.S.-based Chemours launched in 2015 as a spin-off from DuPont. The Chemours plant in Bladen County, North Carolina is at the epicenter of a major on-going public health investigation. Scientists found unregulated industrial chemicals in the Cape Fear River, the source of their public drinking water. Scientists in 2016 reported finding per- and polyfluoroalkyl substances (PFAS) in that drinking water, despite it being treated by a local utility (Sun et al, 2016).

At the center of the controversy is the chemical GenX, which Chemours made then used as a processing aid in the manufacture of fluoropolymers for nonstick coatings, and other applications. Scientists found that in water, the chemical GenX hydrolyzes into hexafluoropropylene oxide dimer acid (HFPO-DA), which was among the PFAS found in the treated drinking water. Public health studies have shown residents who participated in blood sample studies had 4.4 ppb of PFOA in their blood versus the national average of 1.5 ppb (C&EN, 2019).

One of the results of this incident, global PFAS contamination and a major Hollywood movie, *Dark Waters*, was damage to the company's stock price in 2017, Chemours traded at over $57 per share. In part due to environmental concerns coupled with financial performance, the stock dropped 41% in 2019.

A number of investors are relying on a new tool by the Swedish advocacy group ChemSec called ChemScore which rates chemical companies on their risks of substances of high concern and investments in green chemistry.

ESG and How Institutional Investors Flex Their Strength

Many of the world's largest financial institutions have embraced environmental, social, governance (ESG) investment strategies. As an example, Goldman Sachs, one of the world's largest investment banking enterprises with almost $2 trillion assets under management, garnered global attention with the announcement that had created a new group focused on sustainable investing. Under the merchant banking division, Goldman Sachs rolled out its 10-year commitment to target $750 billion in sustainable financing, investing and advisory (S&P, 2020). In fact, a Forbes (2020) report

"I believe that in general, we are going to be stepping away from our dependence on fossil fuels, and publicly traded companies that produce products that replace fossil fuels will be the focus for not just ESG investors. Those companies that truly want to reduce Scope 3 emissions are putting their money where their mouth is, are having an impact on their product life cycles, and as demand for their products increases and costs go down, they will be recognized in the financial markets and rewarded because their raw material inputs are well regarded and monitored."

Emily Lethenstrom, Trillium Asset Management

stated that the total US-domiciled assets under management employing Environmental, Social and Governance (ESG) investing strategies increased 42 percent over the past two years, to $17 trillion in 2020, up from $12 trillion at the start of 2018.

Additionally, financial investors such as Trillium and Impax Asset Management have adopted a proactive stance to specifically reduce investment in companies that manufacture or use chemicals of concern and support green chemistry innovators. In 2020, the healthy beauty company Beautycounter was acquired by the Carlyle Group and valued at $1B. Beautycounter had raised approximately $100 million in outside funding and was valued at $400 million as recently as 2018.

Investor advocacy groups are increasingly using their influence to directly change corporate policies. For example, Framingham, Massachusetts based TJX has over 4,557 discount stores located in nine countries with over 270,000 employees. At its June 2020 annual shareholder meeting, 44% of its shareholders demanded that the retailer reduce toxic chemicals in the manufacturing of products it sells in its stores (WickedLocal.com, 2020). As a result, the company committed to creating a new chemicals policy.

INVESTMENTS FLOW INTO GREEN CHEMISTRY COMPANIES

Investments in companies producing more sustainable products has never been greater. Just in the last 18 months, **J.P. Morgan** announced they will invest more than $2.5 Trillion over 10 years to Advance Climate Action and Sustainable Development.

Goldman Sachs also announced a 10–year commitment, under which the investment bank will target $750 billion in sustainable financing, investing and advisory activities.

Neither of these cases are in isolation as the ESG (Sustainability) investments captured $51.1 billion of net new money from investors in 2020—the fifth consecutive annual record, according to Morningstar, up from $21 billion in 2019.

ESG accounted for about a fourth of the money that flowed into all U.S. stock and bond mutual funds last year.

Walmart aims to reduce its consumables chemical footprint for Walmart and Sam's Clubs U.S. stores by 10 percent by 2022. This covers approximately 90,000 products from 700 suppliers.

CORPORATE ACTIONS TO REDUCE RISKS IN RESPONSE TO INVESTOR AND OTHER PRESSURES

As a result of increasing consumer pressure, retailers are increasingly establishing bold chemicals policies that increase their portfolios of green chemistry products. The Green Chemistry & Commerce Council's Retailer Leadership Council (RLC) represents 14 major retailers with purchasing power in the trillions of dollars. In 2019, the RLC published a statement outlining its demands for increased chemical ingredient transparency and identifying a set of chemical functions and applications for which retailers would like to see innovation in safer products (GC3, 2019). In 2017, Walmart publicly joined the Chemical Footprint Project which creates a metric for companies to measure their progress in eliminate dangerous substances from their products and investment in safer chemistry. Walmart reports on aggregated information it receives through its own Sustainability Index and the Worldwide Environmental Regulatory Compliance Solutions (WERCS) managed by Underwriters Laboratories (Bloomberg, 2017). Walmart and Sam's Club previously committed to work with suppliers to encourage the incorporation of green chemistry principles in the design of products sold in their stores. In working with suppliers, NGOs, academics, government, and industry stakeholders, Walmart developed its Commitment to Sustainable Chemistry which included the following actions:

- Embracing the 12 Principles of Green Chemistry.
- Going above and beyond legal and regulatory compliance.
- Belief in the public disclosure of their goals and progress.
- Working with credible third-party organizations and leverage regulatory and authoritative resources to guide their approach.
- Expecting their products to meet or exceed performance standards.

FINDING #4

The green chemistry sector will become a strong driver for job and economic growth

Green chemistry product markets are growing throughout the US and global economies as shown in the other sections of this report. This growth in green chemistry-based products has the potential to create jobs and increase the Gross Domestic Product. Not only are jobs created to manufacture the green products but also jobs in supporting industries and within the broader communities where people work and spend their money. It is important to understand the growth of the green chemistry industry and how this growth can affect the U.S. economy and create jobs and elevate the U.S. GDP.

When considering the job creation and impacts to the broader economy, there are several metrics or key performance indicators (KPIs) that are commonly used. In this report, we report "Value added" (a regional version of GDP) and employment. These metrics are the primary indicators for economic impacts used for Input-Output economic modeling.

- **Value added:** Value added describes the new wealth generated within a sector and is its contribution to the Gross Domestic Product (GDP)
- **Employment:** Employment includes full and part time jobs

Within these two economic KPIs, one can further designate where the impacts are occurring. For example, jobs created in the product manufacturing or the supply chain of the green chemistry product. When examining the economic contributions of an industry, the IMPLAN© economic model (see Appendix B) used by the research team generates four types of indicators:

1. **Direct effects:** Effects of all sales (dollars or employment) generated by a sector.
2. **Indirect effects:** Effects of all sales by the supply chain for the industry being studied.
3. **Induced effects:** Changes in dollars or employment within the study region that represent the influence of the value chain employees spending wages in other sectors to buy services and goods.
4. **Total effect:** The sum of the direct, indirect, and induced effects.

An additional important output of economic modeling is the economic multiplier. This is a measure of how increasing jobs or production in one sector impacts the broader economy. For example, creating one job in a high paying industry can create many other jobs within the supply chain and communities surrounding the original job creation. This relationship is referred to as an "economic multiplier."

Modeling Approach

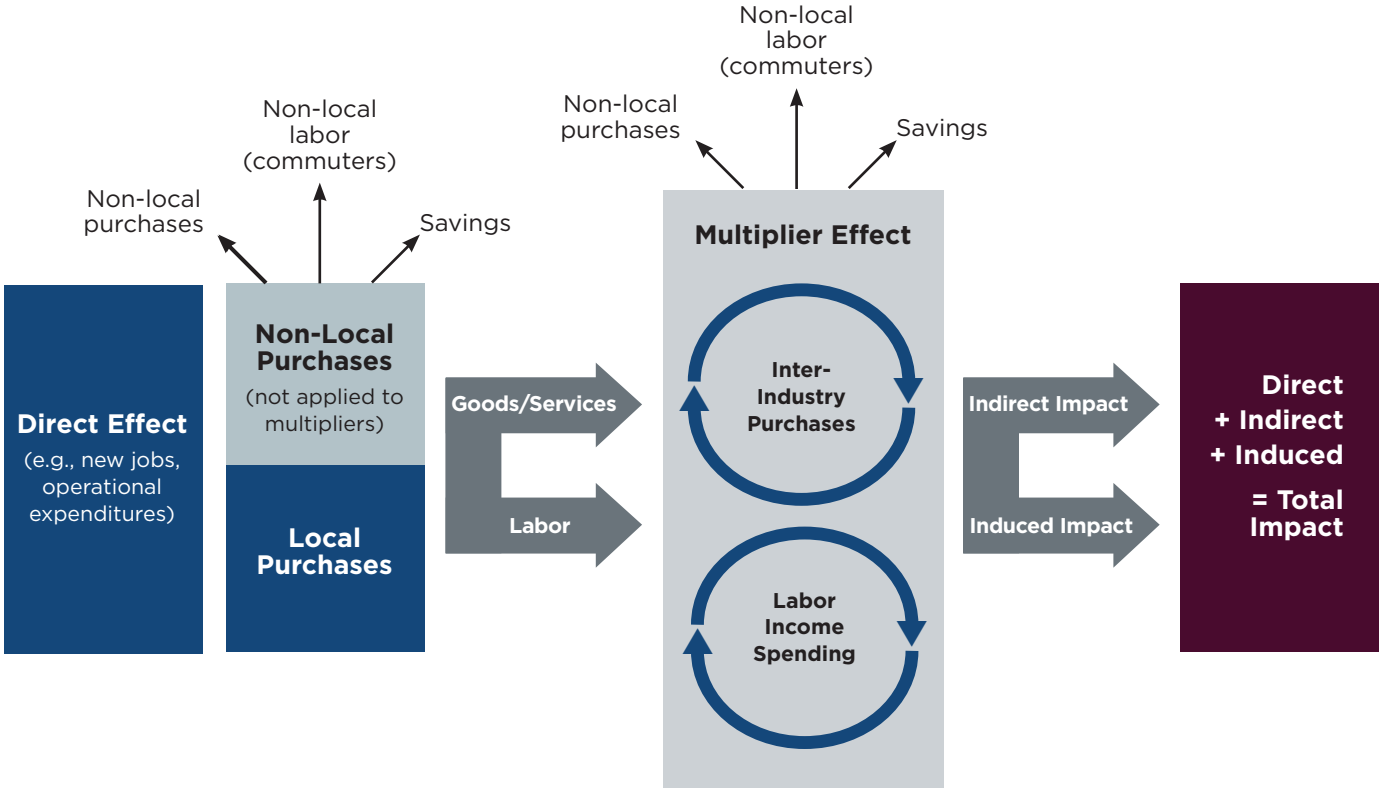
The analysis in this section presents the economic impacts based on the two different sector designations. The first designation is based on the industry survey presented earlier in this report and the second industry designation is based on the retail sales data also presented earlier in the report. These sectors and product categories are ones where green chemistry products are likely to grow significantly faster than incumbents.

TABLE 4.1
Designations of sectors used for the economic impact analyses.

Retail data grouping	Survey industry sector grouping
Auto wax	Apparel & Textiles
Dish detergent	Consumer Products
Floor cleaner	Electronics
Household cleaner	Pharmaceuticals & Life Sciences
Laundry detergent	Polymers and Plastics
Pavement deicing	Solvents
Pool chemicals	Specialty Chemicals
Skincare	
Soap	
Suntan products	

Using these two green product and industry groupings, economic impacts per million dollars of output or production were calculated. This measure does not provide an absolute number of jobs created or supported by the green chemistry product industry; rather, it provides the economic impacts per an increase in sales in green products. **Figure 4.1** provides a visual overview of how a direct effect, for example increase in sales of green chemistry products, impacts the broader economy.

FIGURE 4.1
Visualization of the IMPLAN© economic modeling tool.



Results—Economic Impacts of the Green Chemistry Industrial Sectors

Using the industry grouping from the administered survey, an increase in green chemistry products in the apparel and textile industry will create the greatest number of jobs. **Figure 4.2** shows that every million dollars in increased production of green chemistry-based apparel and textiles will create a total of 4.5 jobs in the apparel industry, 3.8 jobs in the corresponding supply chain, and 4.8 in the broader economy not directly related to the industry activity.

Another way of looking at this data is through the lens of the economic multiplier. Using this metric, one can relate the change in the direct industry to the broader industry. For example, for every job created in the green chemistry-based apparel and textile industry, 1.91 jobs are created in other industries. This number of jobs created in other industries is the type Social Accounting Matrix (type SAM) economic multiplier, reported in **Figure 4.3** minus the direct job in the apparel and textile industry. The green chemistry industry with the highest economic multiplier is the solvents industry where the economic and value-added multipliers were 13 and 7.8, respectively.

FIGURE 4.2
Economic impacts per $1M output.

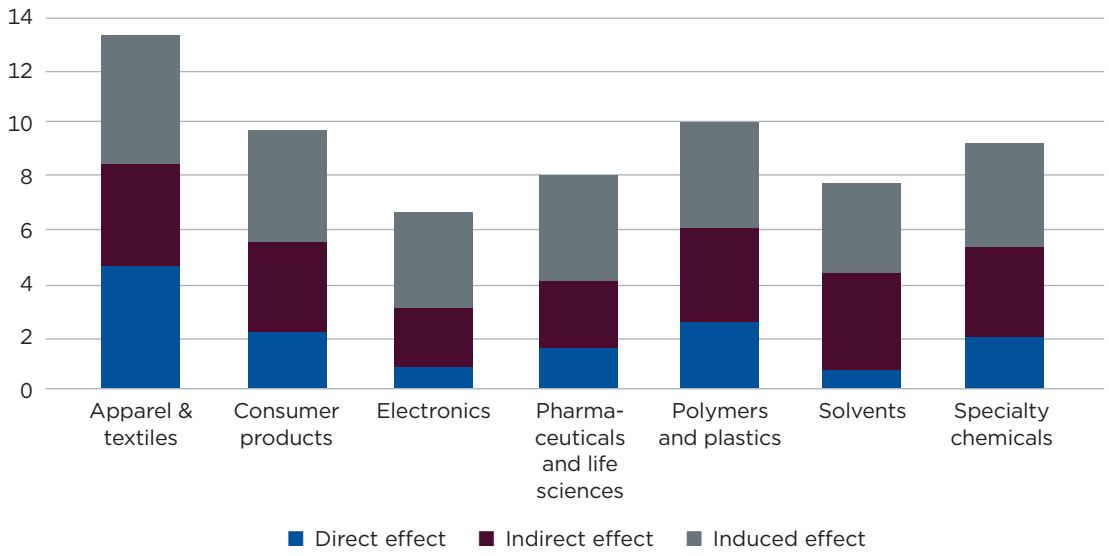
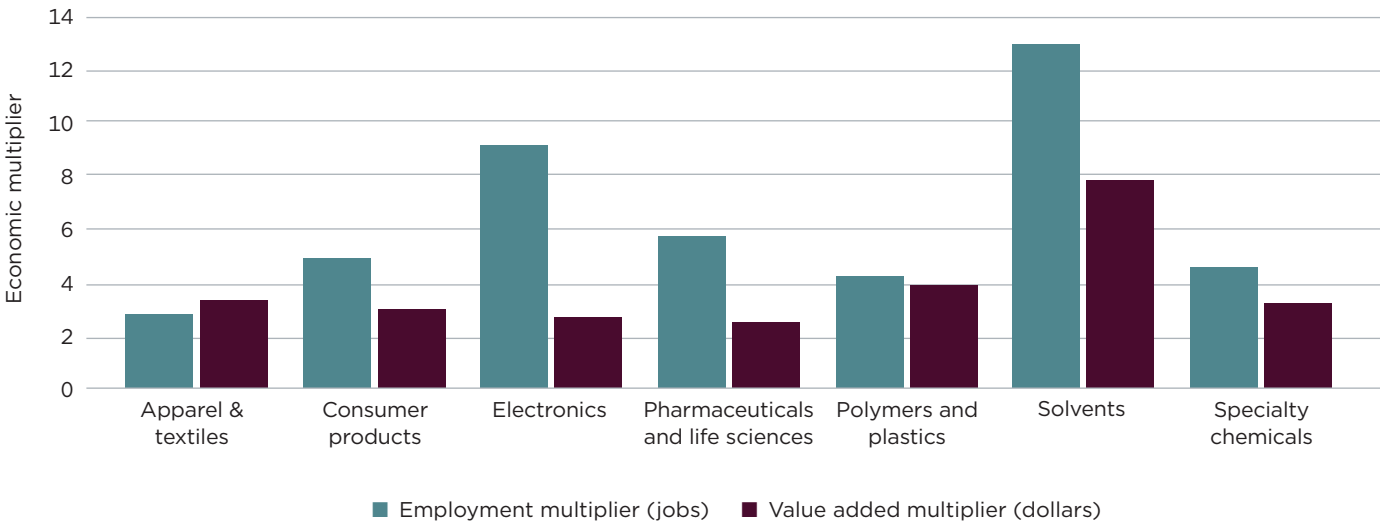


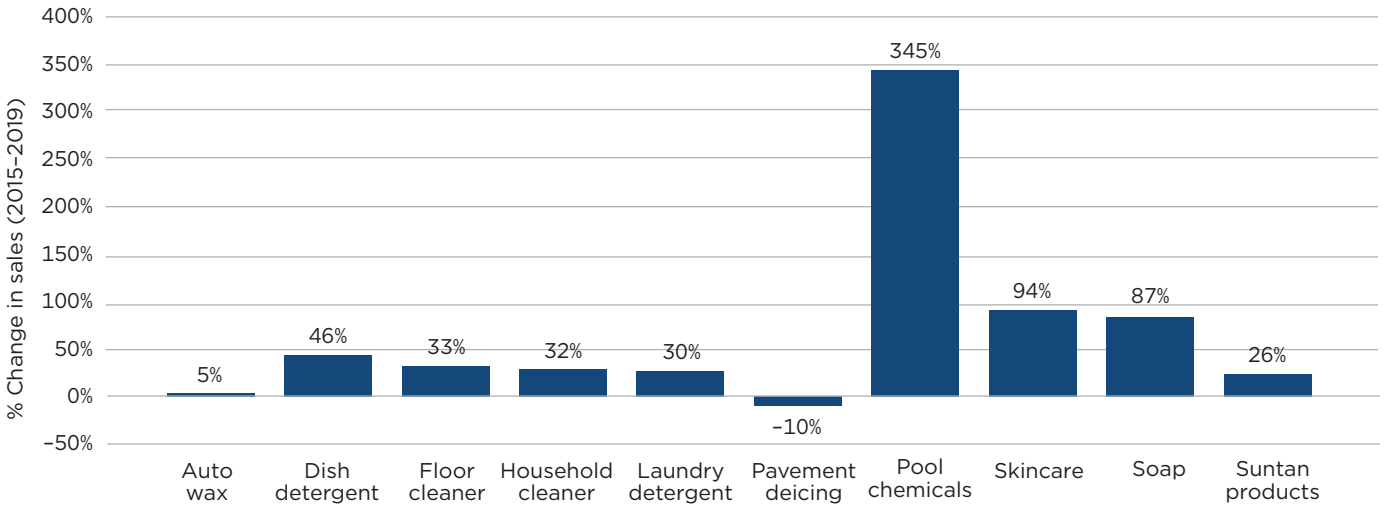
FIGURE 4.3
SAM economic multiplier effect.



Green Chemistry Product Impacts

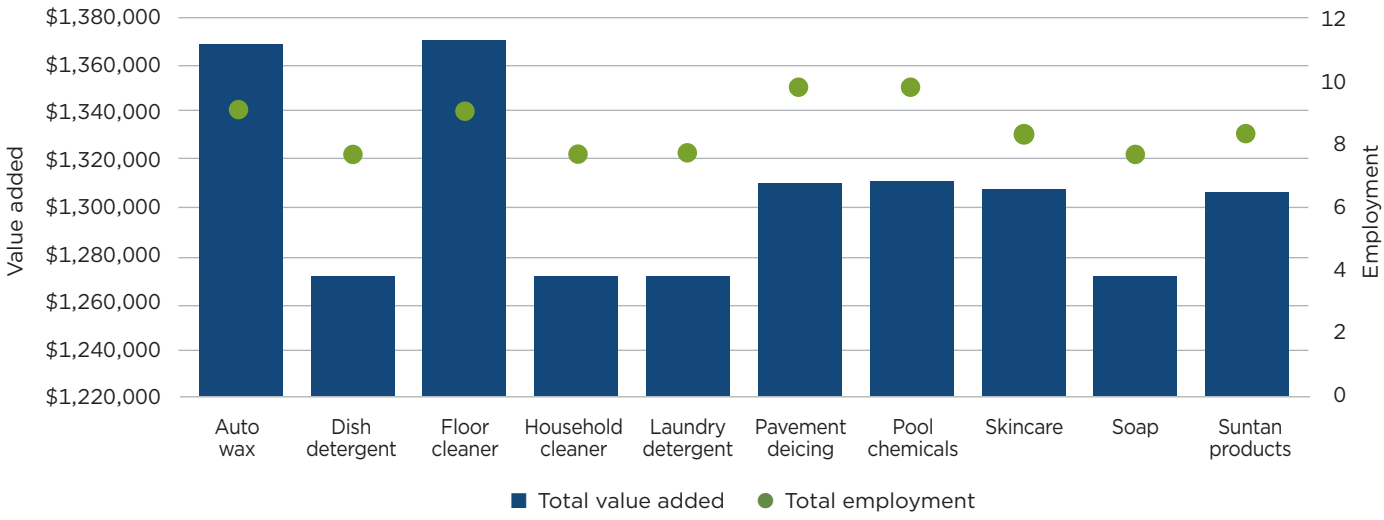
The NYU Stern School of Business analysis discussed earlier indicates significant growth in nine out of 10 green chemistry product categories as presented in **Figure 4.4**. Economic impacts were also calculated based upon sales of products in these categories.

FIGURE 4.4
Green chemistry product sales increases as documented by the NYU Stern School of Business retail sales analysis.



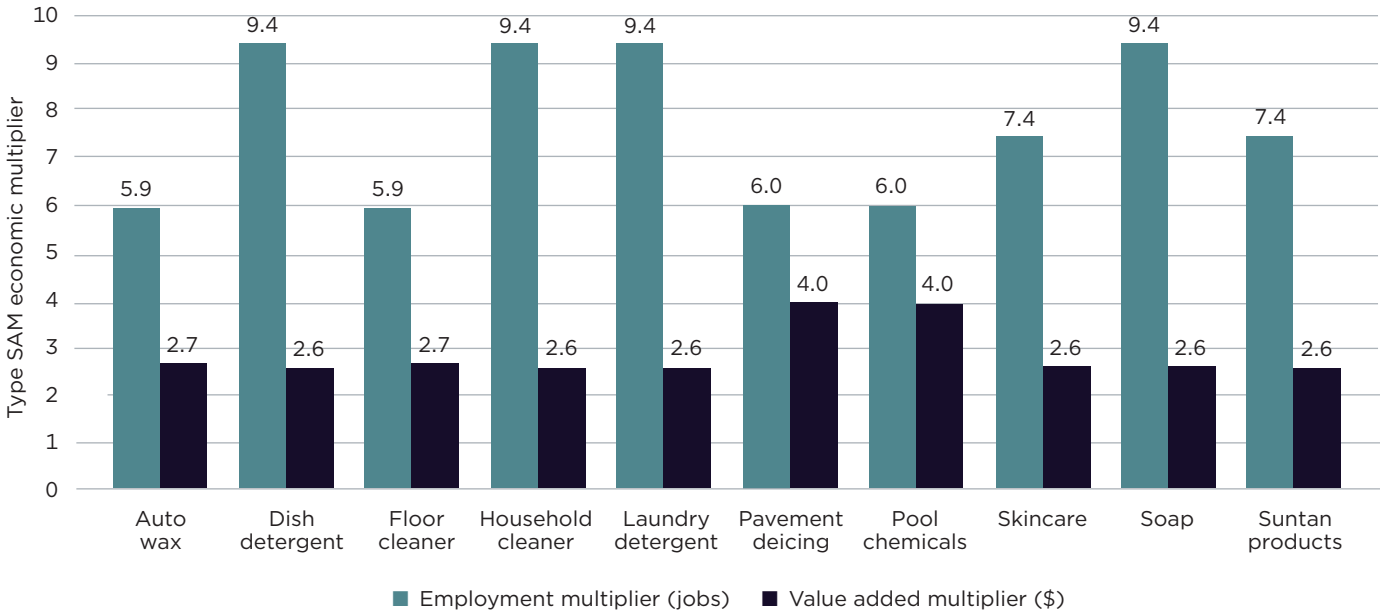
Based on a million dollars of sales in these product categories with the greatest growth in green chemistry products, **Figure 4.5** shows the economic impacts in terms of value added and employment. For every million dollars of sales, the auto wax and floor cleaner categories create the highest value added and employment with $1.367 million of total value added per million dollars of sale and an employment of 8.9. In other words, for every million dollars of auto wax or floor cleaner sold, 8.9 jobs are created in the broader US economy. Of the green chemistry products modeled, the soaps and detergents had the lowest value added and employment per million dollars of sales; however, these values are still relatively high compared to many other industries.

FIGURE 4.5
Economic impacts per million-dollar output for retail data.



Economic multipliers for the green chemistry products analyzed ranged between 5.9 and 9.4 which is relatively high as compared to many other industries, **Figure 4.6**. The type SAM employment multiplier for household cleaners and soaps was the highest with a employment multiplier of 9.4, meaning for every job created in the cleaner industry 8.4 are created in other industries. The type SAM value-added multiplier was the highest for pool chemicals and deicing chemicals, with a value-added multiplier of $4.00.

FIGURE 4.6
Economic multipliers by retail categories.



Example: Economic Impacts of Biobased Products

Biobased products are often made using green chemistry principles, so can be considered a subset of green chemistry products. Previous work from Daystar et al. (2021) determined the size and economic impacts of the biobased products industry. This analysis excluded energy, food, and animal feed. The report concluded that there were over 4.6 million jobs supported by the bioproducts industry in the U.S. Additionally, $470 billion of value added were contributed to the US economy in 2017 as a result of biobased products. The economic multiplier on average for the biobased products was 2.79.

FIGURE 4.7
Economic value added and jobs multipliers for U.S. biobased products sector.

4.6 million
The number of people employed in the U.S. biobased products industry in 2017

→

$470 billion
Value added contribution to the U.S. economy from the U.S. biobased products industry in 2017

→

2.79
The jobs multiplier for every 1 biobased products industry job, 1.79 additional jobs are supported in the U.S.

FINDING #5

In response to increasing demands for more sustainable product portfolios, sales, sourcing, and R&D are working hand in hand to drive green chemistry solutions into the future product mix

"The field of green chemistry will no doubt continue to grow, due to increasing regulation, emerging taxes on certain classes of chemical use in the EU, and very soon, the signals from European Union that will focus on a sustainable and circular economy that is driving the use of recycled material. These elements will continue to escalate and will continue to drive innovation in green chemistry at Nike and others in the footwear and apparel industry."

Renee Hackenmiller–Paradis
Chemistry Center of Excellence in Sustainable Products, Nike, Inc.

We conducted a number of interviews with subject matter experts in leading companies to derive insights on the key challenges, best practices, and business models that have been developed over the last decade around the application of green chemistry in both industrial and consumer-facing supply chains.

We sought to understand new discoveries in which the use or manufacturing of green chemistry products could be more effectively introduced. The experts identified a number of technical and economic obstacles and also shared recommendations regarding how those obstacles can be overcome. Together, they represent a strong business case for corporate, government, and investment decision makers on the importance of investment in green chemistry innovation. The companies include not only recognized brands, but also small innovative companies that have been acquired, as well as investors.

Each of these cases offers a different perspective on the opportunities inherent in green chemistry. High level insights from each case are summarized below.

Apple Inc.

This case illustrates how a major brand can influence and drive increased growth of green chemistry, by virtue of their influence and brand recognition in the industry. Apple is not only proactively making changes to its component chemistries, but also working with suppliers to actively find alternatives.

Beautycounter

Initially starting out as the "lone wolf" in the cosmetics sector, Beautycounter overcame the challenges of being perceived as a niche brand and has emerged as a major player focusing on clean

beauty. The company has banned more than 1,800 unsafe chemicals from its product lines. Their strategy caught the eye of investors at Carlysle, who valued the company at more than $1 billion and acquired them in 2021. This is a testimony to the power of green chemistry as a leading force in one of the most fickle of industries.

Cargill

This large company is a major player in the agribusiness commodities business and has always committed to a carbonless future. It has established a commitment in the C-suite that such a future is inevitable. Although green chemicals are still a small portion of their portfolio, they envision a future where it will become a dominant segment. The company is exploring uses of green chemistries in construction and building materials, in adhesives used in road construction, as well as binders in wood products such as plywood.

Checkerspot, Inc.

This small start-up in Utah found a sweet spot to grow their business, by partnering with backwoods ski manufacturer WNDR Alpine, to create a ski that utilized a green core. This technology appealed to the sustainably minded backwoods skiing community. But it also required rigorous testing and innovation to develop a core that would meet the demands of deep powder skiers. By partnering and working together tirelessly, the company gained a toe hold in a rapidly growing business and landed on a model for growth that other entrepreneurs in the green chemistry space can adopt.

Lowe's Companies, Inc.

Lowe's became aware of the impact of green chemistry initially in its vinyl flooring products and quickly pivoted to address this issue. The sustainability team has since partnered with the Green Chemistry & Commerce Council (GC3) and is making inroads to eliminate unsafe chemicals and source new, cleaner replacements in a number of categories, including cleaners, paint, insulation, flooring, and laundry care. The team developed a framework to systematize the process of assessing chemicals and managing chemical risks, which could include disclosure of chemicals in Lowe's products, reducing or eliminating toxic chemicals from Lowe's products or packaging, better educating consumers on product safety, and/or driving innovation by encouraging suppliers to transition to safer alternatives and green chemistry solutions.

Nike, Inc.

Known as a company that emphasizes "Just Do It", creating green products that meet the rigorous criteria of its athletic customers is a continuous challenge. There is a constant struggle to work with developers on new products that contain new materials that meet Nike's core user requirements. Water resistance and durability are two of the most important features of Nike's outdoor clothing and shoes. One of biggest challenges is dying coloration, which is often very difficult to detect in supply chains that extend across the globe. Nike recognizes that this is an on-going challenge and envisions that it will continue to innovate and create greener chemistries in their products for years to come.

Seventh Generation, Inc.

Once considered a niche consumer brand, Seventh Generation was acquired by the giant consumer goods manufacturer Unilever in 2016. However, unlike what most people feared, it was Seventh Generation that had the greatest influence on Unilever's green policies, not the other way around. The CEO of Unilever came to understand how Seventh Generation was designing their products using green chemistries and made a commitment in January of 2021 to make all of its cleaning products carbon neutral by 2030. The David influenced the Goliath in this case.

Trillium Asset Management

ESG investing is no longer a niche and has become a significant and growing portfolio of many investment companies. Investors, such as Trillium, have recognized that for financial outcomes, the growth is going to be coming from companies that are trying to reduce their SCOPE 3 GHG emissions across their supply chains. Examples include high performing companies like Unilever or SC Johnson, that have made commitments to replace fossil fuel inputs with chemical structures that are biobased. The growth of green chemicals recognizes all of the pressures on the ecosystem and is tapping into consumer's recognition that chemical and fossil fuel inputs are increasingly recognized for their negative effects on environmental health. In the future, these fossil fuels will become increasingly regulated to the degree that those externalities and true costs will be integrated into the financial costs of the product. For this reason alone, investment in green chemicals makes intrinsic sense for long-term investors like Trillium.

VF Corporation

Experts at VF recognized that it is inherently challenging to determine the chemistries that are used in apparel manufacturing. To overcome this challenge, the team collaborated with others in the industry to create a platform that enabled greater transparency into the different chemistries that were being used upstream in the supply chain, which was then opened up to all industry players to drive a standard approach for identifying and removing chemicals of concern across the industry.

We conclude each case with some key takeaways for decision makers in industry, government, and the investment community to consider.

CASE STUDIES

Apple's Green Chemistry Leadership Role

Apple has three priorities when it comes to sustainability: climate change, resources (i.e., finite resources), and smarter chemistry. The last one is a big priority, but so is the goal of becoming carbon neutral by 2030, a goal established by Lisa Jackson, VP of Environment, Policy and Social Initiative (and a former EPA administrator under the Obama administration). All three goals are "big" priorities, and all three are interconnected. The goal on finite resources involves a commitment to produce all products from renewable and recyclable materials. The first two efforts then tie into the need for green chemicals, which can help reach the goal of carbon neutrality and improve renewable material targets. As Jackson notes: "We don't pretend to have all the answers. What we do have are goals to strive for and a global community of businesses committed to doing the right thing by people and the planet."[5]

QUICK FACTS

- Apple was founded in 1976
- Leader in consumer electronics, computer software, and online services.
- Based in Cupertino, California
- Pre-acquisition revenue (2020) of $274.5 billion

Apple has been pursuing greener chemicals for many years. Significant effort involves the supply chain team, which is focused on improving selection of materials, developing safer products and processes, and contributing to worker protection from chemicals. Green chemistry and toxicology play a critical role in many different aspects of any organization's Environmental Health and Safety footprint. The focus is not only on compliance but also a proactive approach to reduce chemicals of concern and finding substitutes.

Green chemistry is a continuous journey that every electronics company is pursuing. One of the major shifts that is affecting the industry is the new set of Chinese Volatile Organic Compounds standards that came into effect on December 1, 2020. These standards cover coatings, adhesives, cleaning agents, and printing inks. Three of these four categories came into effect on December 1, 2020, and the last category (printing inks) came into effect on April 1, 2021. These standards cover almost every type of material used in manufacturing and are impacting many companies and their suppliers in China, including apparel companies, electronics, automotive, and consumer products. The volume of material impacted is also massive, as there are multiple applications of adhesives and coatings. For instance, the adhesives and coatings impact the construction and automotive industry, whilst printing inks impact every industry. To meet these new requirements,

5 https://www.apple.com/environment

the entire manufacturing industry in China has been forced to develop new VOC formulations that contain low levels of hazardous substances. The new Chinese VOC standards are part of the Chinese Blue-Sky campaign, spurred by the environmental conditions in Shenzhen, Shanghai, and major manufacturing hubs throughout the country. The campaign is tied to China's 5-year plan and is focused on improving air quality.

Established in 2013, Apple's chemical management program is designed to help build supplier capacity to manage chemicals safely and to transparently share information with their employees about the chemicals in the workplace, both of which are requirements evaluated in every supplier assessment. The company takes extra care when a new chemical is proposed for use. In 2019, Apple assessed more than 110 new chemicals, which included reviewing product formulation and test reports, understanding the specific circumstances for use, and conducting exposure assessments to proactively eliminate risks to people and the environment as a result of using the proposed chemical.[6]

In 2019, Apple began scaling the adoption of safer cleaners and degreasers beyond Apple's supply chain. They started with tackling the lack of a comprehensive industry-wide standard for defining safer cleaners and degreasers. They worked with Clean Production Action, an independent, non-profit third-party expert on smart chemistry, to create criteria that can be used across the electronics industry to assess safer cleaners. Clean Production Action created a tool called Green-Screen™, which is a chemical hazards assessment framework that looks at 18 different endpoints and creates a benchmark score to allow even someone with no chemistry background to choose smarter chemistry. This enables chemical manufacturers and suppliers to have the cleaners and degreasers they use assessed around the world using a common framework. If a chemical is of concern, the supplier is informed that this is a chemical of high concern and is given the opportunity to reformulate the product. If the supplier does not have the inhouse R&D to find the alternative, Apple will work with them to find a cleaner that has been shown to be effective and less hazardous. The safer cleaners' criteria were also reviewed by Apple's Green Chemistry Advisory Board, a group of the world's leading toxicologists, researchers, and academics focused on integrating green chemistry into Apple's products and supply chain. In 2020, these criteria were shared openly with others to encourage the adoption of safer alternatives and industry standards that can be adopted globally across sectors.[7] For its efforts, Apple recently won the Safer Choice Partner of the Year[8] from the U.S. Environmental Protection Agency, based on their work with suppliers to eliminate chemicals used in manufacturing processes, and making that information available.

Apple collaborates across the industry to scale their chemical management program, driving the elimination of exposure to hazardous chemicals beyond the industry. Apple helped found the Clean Electronics Production Network (CEPN), a network of companies and other experts in the

6 https://www.apple.com/supplier-responsibility/pdf/Apple_SR_2020_Progress_Report.pdf
7 https://www.apple.com/supplier-responsibility/pdf/Apple_SR_2020_Progress_Report.pdf
8 https://www.epa.gov/newsreleases/us-epa-announces-2020-safer-choice-partner-year-award-winners-california

electronics industry facilitated by the Center for Sustainability Solutions at Green America. With Apple as a signatory, CPEN launched its Toward Zero Exposure program, committing to protect workers by reducing exposures to toxic process chemicals, into the electronics industry through substitution.[9] Apple also collaborates with ChemForward to grow the availability of chemical hazard assessments for chemicals used in the sector and has collaborated with the Swedish non-profit ChemSec to make its approach to evaluating alternatives to endocrine disrupting chemicals public, called ChemCoach.[10]

BEAUTYCOUNTER®

Beautycounter: 1,800 on The "Never" List and Counting...

In 2011, Gregg Renfrew learned that the US only banned 30 ingredients from personal care products and that many products contained substances that were potentially harmful. This led her to found Beautycounter, a firm that established a promise to restrict all potentially unsafe chemicals in their formulations. The number of such ingredients continued to go up and is currently at more than 1,800, (which became known as "The Never List"). Renfrew emphasized that "I'd never considered that the products I used on myself, and my kids might not be safe, so I set out to transform the beauty industry by creating clean, high-performing skin care and makeup—while fighting to change the laws that control what can and cannot be used in products, so that everyone has access to safer beauty." Beautycounter has a full product assortment across product categories and is constantly innovating to create new, safer products.

QUICK FACTS

- Beautycounter was founded in 2013
- Leader in clean beauty
- Based in Santa Monica, California
- Pre-acquisition revenue (2020) of $341 million

Decades of studies indicate that serious health issues (including but not limited to asthma, cancer, and infertility) are on the rise and are due in some part to our ongoing exposure to toxic chemicals. There are tens of thousands of chemicals on the market today. Many have limited safety data. This is particularly true for those used in the skin care and beauty industry. The U.S., Canada, and the EU restrict 30, 600, and 1,400 substances in the cosmetic products industry respectively, which gives an idea of how these priorities stack up across countries. What's worse is that the Food and Drug Administration (the agency that regulates cosmetics in the United States) has the authority to remove harmful ingredients from the products we put on our bodies and on our

9 https://www.towardzeroexposure.org
10 http://chemsec.org/chemcoach

kids' bodies every single day, day after day; however, it is difficult to apply this authority, especially when there is no premarket approval required for beauty products (unlike the pharmaceutical industry).

Other chemicals they avoid also have problematic supply chains when it comes to labor practices. A good example of this is the cosmetic chemical known as Mica. This is used to give certain cosmetic powders, like highlighter and eyeshadow, a pretty, shimmery glow. However, sourcing of this mineral has severe problems, including unethical labor practices in the mining and refining process. Beautycounter is now in the process of auditing 100% of their mica suppliers in person, to ensure that they are compliant with ILO practices.

The future of retail and developing a sense of intimacy with customers is a big focus of the company, which is driving some very new experimental marketing approaches with their customers. This is part of the company's efforts to drive innovation in all facets of their business. The new store in Los Angeles, "Live at Abbott Kinney" will also be a place for livestreaming content to interact directly with customers around the world. This interesting approach was documented in a recent Fast Company video.[11] Beautycounter has over 65,000 independent sellers, three stores, and sells directly to consumers. Their independent seller network represents an army of advocates for change in the industry.

Lindsay Dahl plays a critical role at Beautycounter, and is responsible for ingredient safety, quality, sustainability, advocacy, and corporate giving. Her background involves work on state and federal policy around environmental health and ensuring that the right science can be applied to formulations as a way to advocate progressive policies.

The company was initially privately owned, but was recently acquired by the Carlyle Group,[12] and the company was valued at over $1 billion. This was the second largest acquisition in the beauty space and is a testament to where investors believe is the future of beauty products, namely safer and cleaner products that consumers will want to buy. Although Beautycounter was once viewed as a fad and a niche player, their work on safety and sourcing only safe ingredients is making a huge impact in the sector.

When it comes to their supply chain, there are two primary elements associated with Beautycounter's strategy: how they screen for ingredients, and how they assess ingredients into a restricted substances list. In general, the MSDS forms on most chemicals do not reveal a lot of information, so Beautycounter does a lot of their own screening. They begin by examining a lot of third-party research, peer reviewed literature, authoritative lists, research produced by national bodies, and continue to add to the list of 1,800 ingredients that are restricted. For instance, a number of chemicals have potential reproductive toxicity effects or could increase the risk of

11 https://www.fastcompany.com/videos?jwsource=cl

12 https://www.glossy.co/beauty/beautycounter-is-now-a-1-billion-brand-following-carlyle-group-investment

cancer, as well as other hazards. These chemicals can build up in the environment and in our bodies. The team uses a variety of tools but relies heavily on peer reviewed literature to identify chemicals of concern. The assumption in most cases is that the absence of data does not mean the chemical is safe; therefore, it is a screening activity, which only allows safe chemicals to be used.

One of the biggest challenges faced by the team is the difficulty of finding a "drop-in" replacement for a chemical being used in a product, once it is found to be potentially harmful. In many cases, the formulary must be "rebuilt" from the ground up. For example, recently the Beautycounter R&D team was working a skin serum in the company's inhouse lab, and the team proposed the formulation to the screening team. The product development team was subsequently told by the screening team that one of the chemicals which provided excellent product performance had to be dropped. In turn, the development team went back and proposed a new ingredient. Dahl notes that "we often have to go back and forth several times until we land on a formula that we both agree on, and this occurs well before the actual formulation stage." Dahl notes that "cosmetic chemists are very creative people, and there is always a push and pull between us to get it right."

In this manner, the formulation of a new product by the R&D team starts on paper. Once submitted, the screening team will rely on several other tools. One of the most important tools is the SCIVERA[13] database resource, which is a company that works with leading consumer product brands to fundamentally advance chemicals management and sustainable chemistry. This organization provides a database tool (SCIVERA LENS) that can solve some of the most significant problems brands face – obtaining chemical information without the ability to assess, understand, or manage those chemicals.

There are clearly some ingredients that are considered the most problematic. Some of these include:

- **Siloxanes.** Used in a variety of cosmetics to soften, smooth, and moisten. Suspected endocrine disrupter and reproductive toxicant (cyclotetrasiloxane). Harmful to fish and other wildlife.
- **Aluminum.** Toxic metal that can have estrogen-like effects in human systems, disrupting the healthy functioning of the endocrine system.
- **Synthetic fragrances.** Often unknown substances that appear in many cosmetics.
- **Preservatives.** Ones such as parabens, DMDM and urea which may cause joint pain, skin allergies, headaches, hormone disruption, and loss of sleep.

As the clean ingredients movement is growing, people are becoming more aware that many of the products that seem natural are in fact highly unsustainable, are allergenic, and are often not listed

13 https://www.scivera.com

as such on the packaging. There are also differences in targeted markets. For instance, many of the products considered as "high risk" have very high toxicities and are marketed to women of color, such as skin creams, and professional salon use products.

The greatest growth in the clean beauty products segment is the premium category for women in the age group of 30 to 45. The second largest consumer base are the Gen Z and Millennials groups, who are more concerned about sustainable products, but may not understand the safety risks. The other segment of the Gen Z and Millennials demographic follow the "influencers" and are less concerned. It is relatively more expensive to make products clean, which leads to a higher price point; however, more and more people are willing to pay this premium.

A good example of this is with Mica, which became a sourcing issue. Seventy percent of influencers using cosmetics were willing to pay a premium once they discovered that child labor was involved in producing Mica. In fact, Beautycounter's cost of raw materials to produce a similar Mica-free product was higher than what competitors were selling their product for. Dahl notes that "The large cosmetic brands produce at large scale, whereas we have to bake into our prices the cost of running a full safety team, including an in-house lab that tests every batch of product for heave metals. We also bear the cost of auditing and sourcing with our suppliers to ensure that there are no human rights violations. These costs are in addition to the premium costs of our safer packaging and raw materials, which renders our costs higher than those of larger brands."

Packaging is another area that is a focus for Beautycounter. Unfortunately, biobased plastics are good for food, but are not suitable for cosmetics, as the packaging needs to maintain a high stability rate for years in many cases. Agriculture-based materials do not hold up over time, due to their corn-based plastic which has a higher carbon base.

Nevertheless, Beautycounter spends a lot of time on material selection to ensure that aluminum or glass packaging can be recycled and re-used more than once before it reaches the landfill. Many of its products are designed to be refillable, to ensure circularity. Others use a safer-based petroleum plastic that can be recycled. For instance, the majority of the company's deodorant stacks are refillable, and have an outer case of singular plastic that can be recycled or refilled. They also closely audit their contract manufacturers, to ensure that they are meeting their rigorous standards.

Not all Beautycounter's new products are successful when introduced, but they are always used as an opportunity to learn and understand what could be done better next time. If there is no clean alternative, people don't have a choice to shop for safer products. Research and development are all about understanding the opportunity upfront and designing a safer formulation that meets that opportunity. To identify the opportunities, Beautycounter spends a great deal of time marketing and polling people who sell their products. Some sectors (e.g., baby products) are already flooded with clean products, and are very competitive, so the company stays largely within the skin care and body care segments. As they expand their portfolio, they will continue to innovate with new and safer products.

Exploring New Biobased Feedstocks in a Sustainable Products Future

Cargill is a global agribusiness company headquartered in Minneapolis, MN that is focused on bringing consumers and producers of food closer together. Starting with a single grain elevator in Iowa, the company has grown to 155,000 professionals across 70 countries.

Cargill's Bioindustrial Group has a key mission to establish sustainability strategies for the business, which often involves interfacing with customers to understand sustainability opportunities and combining this role with an advocacy role. The customer-facing and advocacy roles overlap, requiring collaboration across product lines and different businesses including the food, and agriculture, food ingredients, animal protein, animal feed, and the grain origination part of the company (its legacy). Cargill's Bioindustrial Group serves industrial markets with agricultural based feedstocks, including performance chemical markets, binders and adhesives, personal care and new emerging markets, among others. Marty Muenzmaier leads sustainability and external affairs for the Bioindustrial Group and his expertise on climate change and sustainability provides a valuable perspective on these issues.

QUICK FACTS

- Cargill was founded in 1865
- Leader in agricultural commodities and transportation.
- Based in Minnetonka, MN
- Pre-acquisition revenue (2018) of $115 billion

Cargill's legacy business has been focused on the grain origination and trading and this continues to remain a core part of their business. However, the company is also committed to sustainability efforts, regardless of the political trends going on throughout its history. Muenzmaier notes that, "even as the U.S. pulled out of the Paris Accord during the Trump Administration, Cargill continued its focus on reducing emissions in our operations and supply chains. We kept going."

There are several areas where Cargill Bioindustrial is focused on sustainable innovation. The first is on construction and building materials, specifically binders and adhesives, as well as rejuvenators used in road construction. For binders, Cargill has been seeking a replacement for formaldehyde, which is used as a binder in wood products such as plywood. These are commonly used by furniture manufacturers and other composite wood companies.

The soy-based asphalt rejuvenator can be used in road construction. Specifically, when an asphalt roadway is on its last legs, with potholes, the rejuvenator can be added to recycled asphalt product to repave the roads in as good or better condition than virgin asphalt roads. This is a big problem in Cargill's headquarters state of Minnesota, where the winters are hard on roads.

Another product that is important to Cargill's portfolio involves dielectric and cooling solutions, which use vegetable oil as a feedstock for transformer oil in place of mineral oil. Dielectric and insulating fluids are primarily used by original equipment manufacturers and utilities, especially in the power utilities space, and is a product Cargill has sold for years.

A fourth part of Cargill's bioindustrial portfolio is in the area of performance chemicals. Cargill produces polyols for foam materials for furniture, including rigid foams used in the transportation sector. Cargill also has a candle wax division that uses vegetable-based wax to replace paraffin petroleum wax, as well as an emerging plasticizers part of the business. Cargill is constantly looking at new ways to employ biobased replacements in the chemicals sector; it is a big and important part of what it does.

In the personal care space, the company is emphasizing naturally-derived products for beauty, skin and hair care, and a variety of inputs such as jojoba, macadamia, red seaweed, and other exotic products which are used in beauty and personal care.

The last major area of focus is one that Cargill's leaders believe will be very important in the future: bio-intermediates. They target key steps within a chemical process to deliver desired attributes using nature-derived chemical intermediates to replace fossil-based chemicals. For example, they will utilize corn to convert dextrose into butane-diol to serve apparel, electronic and automotive sectors.

The green chemistry segment today is a minor portion of what Cargill earns on a global basis. However, the company's future strategy includes a focus on growing the bioindustrials business to meet the growing demand for more biobased products.

What Does Sustainable Growth Look Like?

Cargill provides products that are made with agricultural raw materials that are renewable on an annual basis or even double-cropped in some parts of the world. That is only the beginning of the sustainability value proposition. As the company's customers are seeking more biobased products in the marketplace that are composed of non-fossil materials, Cargill is well positioned to begin to provide those alternatives. Lower carbon profiles are also critical, as marketing experts see a future that is carbon constrained, where customers will seek a lower carbon footprint and a lower carbon intensity for products they buy. Cargill's core competencies can support the production of feedstocks which have sequestration as part of the photosynthesis process and have a lower carbon footprint than the products they are replacing. In fact, Cargill has its own carbon reduction goals to reduce its carbon footprint.

Cargill also has a team to find the right way to discover the application of new green chemicals to finished products. Their bioindustrial R&D lab in Minneapolis works directly with industrial customers to find applications and solutions, and another lab in Europe does the same for its personal care customers.

Cost Competitiveness is Key

Cargill realizes it must be price competitive with offerings in a market; however, if the product has value and is bio-based, there may be opportunities that command a premium, but only if customers understand the value. When the bioindustrial business group was formed, leaders knew their products needed to be price and performance competitive. For example, their asphalt rejuvenator product carries both a price and performance advantage. The repaired road will last longer than re-applying virgin asphalt.

Cargill has identified policy opportunities that could incentivize additional uses of the bioindustrial products it sells. For example, the establishment of a price on carbon could quickly add value to their products which often carry a lower carbon footprint than the fossil-based products it competes with. Cargill is also building its capabilities around the Life Cycle Analysis (LCA) field to gain a firm understanding of the environmental benefits of the production and use of its products in various markets.

Summary

Cargill's future strategic direction reflects the importance of its bioindustrial business as a key part of the future growth of the company. As the world increasingly sees the need to reduce carbon emissions, there will be a closer examination of the benefits that biobased products bring. Cargill is focused intently on meeting that challenge.

CHECKERSPOT

Checkerspot and WNDR Alpine

Scott Franklin had a long career in plant molecular biology, working in the industrial biotechnology sector for 30 years. He and his co-worker, Genet Garamendi, had both observed the tremendous potential that existed in the platform for developing new biotechnology-based materials. Franklin emphasized that, to be successful, it wasn't enough to simply produce bio-based molecules—that a key part of the business is to animate them through a brand. As Franklin notes, "you need to have a focusing mechanism, otherwise you will be scattered in what you are trying to address with the biomolecular platform."

Franklin's company, Checkerspot, approached a noted backwoods mountaineer by the name of Matt Starbenz, to lead a project in winter sports for their advanced biomaterials. The new brand,

CASE STUDIES

WNDR Alpine, focused on incorporating biomolecules in high performance backwoods skis. Starbenz notes:

QUICK FACTS

- Checkerspot, Inc. was founded in 2016
- High performance materials company that designs materials at a molecular level
- Designated a Public Benefits Company
- Based in Berkeley, California

"When I was called upon by Checkerspot, Inc. to lead a project in winter sports for their advanced biomaterials, I knew how much I didn't know. Over the last year, I've learned, grown, led, and helped educate others on the importance of alternative perspectives when it comes to the creation of materials that are vital to our sport, community, and impact on our environment. Granted, skis are not textiles; but they are similarly complex compositions of a variety of synthetic and natural materials. Since the introduction of biobased resins, ski building simply hasn't kept pace with other outdoor categories and adjacent industries. True innovation requires a complete shift of focus while taking a bold step into uncharted terrain. This approach is how we landed on our new Algaltech™ ski materials platform, which has now brought about the Algal Core and the all-new cast PU sidewall application we refer to as Algal Wall."

This development is a critical lesson for innovators in the green chemicals space and a key lesson is that you need to focus on the "so what" of the technology. In the early days of industrial biotech many people were creating a molecule and hoping they would know what to do with it. Franklin notes that "The big ah-ha moment for us was when we realized we needed to focus on what is possible with the new molecules using a three pillared approach: 1) the right chemistry 2) the material science, and 3) the actual fabrication of the product. This approach allowed us to create a virtuous learning cycle and animated what is possible in green chemistry. It is more than simply replacing ABS plastic with a new material that is not petroleum based, but to create a momentum by sharing this approach with others."

There are three major components to the Checkerspot chemistry that produced the WNDR Alpine products:

1. The molecular foundry, which is the starting raw material. This is a triglyceride oil, produced from a single cell developed through permutation and purified just like a vegetable oil. The foundry tailors the oil output and changes the raw material that feeds into new materials.
2. The polymer chemical science, which takes the raw materials from the foundry and performs chemical conversion into the chemistry of new materials, which are then tested to assess changes in physical properties in a new polymer.
3. The SLC or fabrication involves animating and deploying the new material in an application that has an end consumer use (the skis).

Checkerspot took some time to get started in this direction. Franklin notes that "as a start-up we had a lot of inertia. You can go shop your molecule to manufacturers, and the first issue you

encounter is your price. They always want something cheaper. There is a huge amount of infrastructure capital dedicated to making monomers, so if you come up with an alternative—they are not going to displace that infrastructure. That means that I have to run my polyethylene plant more efficiently to compete with that kind of investment. So, we learned right away we had to take a different route, which involved going to a brand and "animating" the technology in such a way that we could connect directly with consumers. Once we connected, this allowed us to go to adjacent industries and show them directly what we can do with the platform. We could make skis with materials produced from algae!"

Industrial biotechnology includes a lot of large players invested in permutation assets and who are focused on utilization of those assets. Many of these players also control feedstocks and want to develop molecules that utilize those feedstocks and assets. Many partners understand industrial biotech and are looking to develop materials that source sugar for these new biomolecules and partner with those companies who want to utilize their assets and help them operate more efficiently. This is equivalent to working with the petrochemical industry, but with the sustainable component of the industry.

Franklin notes that "One of our biggest partners is DIC, a Japanese company that started out very narrow on a triglyceride derived monomer and then and blossomed into a lot of additional derivatives based on that initial monomer. In order for us to address cost, we need partners who can work on permutation assets to minimize cost. Cordeon is another partner with assets in Brazil with sugarcane mills, that are very efficient and produce at a large scale for the types of permutations we do. The materials we focus on are high density foam used in skis and a cast used in components in the ski build. Both of those are the Alpine brand for a 2021 ski manufacturing process that involved a lot of tech transfer for foam development and cast for additional part applications in a ski. The challenge when animating molecules through a brand is that you take on a lot of the manufacturing aspects for the polymer; that is part of the challenge, but also the reward. You will never appreciate the challenges larger companies will have when working with your material, unless you see first-hand the limitations of your material. We also have partnerships with Beyond Surface Technologies and Patagonia/Gore which involve the same starting raw material but involves doing some additional chemical modifications and a lot of polymer chemistry for these textile finishes."

"One of the exciting things about working with a brand like WNDR Alpine is that the ski and outdoor sports industry have their own social networks, and credibility is huge.[14] One of the key elements that we brought was recruiting the general manager of WNDR Alpine, Matt Starbenz. They have done a lot on their website and marketing videos to discuss the sustainability of the product to the end user community. WANDR is an outdoor brand, and every one of the products —the snow board, the jacket, the cap—are touch points to animate our technology. These are

14 https://www.youtube.com/watch?v=NXI7sC9fRJU

all consumers who care about the environment and the materials in products really matter. Performance is also critical, as you can't have failure of the materials when you are in the back-country! The general managers have thus become our brand ambassadors, as they are world class skiers promoting our brand and we get a lot of inbound queries, which in turn has led to other application developments for other brands like K2, Salomon, and Burton's. All of this validates our thesis—if you animate the technology through a brand, and build value through a brand, other will take notice of what you are doing."

"One of the biggest problems we encountered initially is that the price of the raw material was often the end of the conversation when we approached large companies. Our monomer is $6, and the industry's is $3. However, by animating through the brand we are able to earn our margin for the product – and are making money on every pair of skis sold. Animating the technology leads eventually to scale, and the cost of the raw material eventually comes down. There are concentric rings of scale that allow us to progressively move out into other industries that demand lower prices, and we anticipate eventually talking to Ford, GM, and automotive companies as we prove the value of the molecule. Eventually we will be able to build a big plant and produce material at lower cost; but it all starts by animating the technology and proving its usefulness at a smaller scale. You can't start by building the plant and then hope to fill it up with volume... "

Patagonia, Gore, and DST are all participating in the development, testing, and validation of Checkerspot's materials. There are discussions with The North Face, but it takes a lot of inbound conversations and months to get to an agreement. Checkerspot has a very clear point of view on how they will build out the company, by bringing partners along to show them what they are able to achieve the performance outcomes. Animating that technology is important to the consumer when raising money and bringing other partners along and not just talking about that performance, but showing them that you can actually do it leads to the right conversations.

Lowe's Home Improvement: Putting Green Products In The Home

Lowe's Home Improvement grew from a one small-town hardware store into an international seller of home improvement materials, selling everything from appliances, to lumber, to lighting, paint, and other products. The Senior Director of Sustainability, Chris Cassell, leads a small team of four individuals, who focus on a wide variety of different sustainability initiatives, including reporting, disclosures, and among others; green chemistry engagements are led by Cassell.

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He notes that "I think that we are only beginning to delve into the possibilities for green chemistry at Lowe's. There is a gap to be bridged in consumer understanding and the difference between simply looking at a list of ingredients in a product and what it means in terms of the environment. The same goes for our merchandising team, and they are often striving to understand what the "six syllable" chemistry words mean in terms of a better buying decision for our customers."

QUICK FACTS

- Lowes was founded in 1921
- Leader in consumer hardware retailing.
- Based in Mooresville, NC
- Pre-acquisition revenue (2020) of $72.1Bn

Lowes' efforts in green chemistry were first prompted by concerns in 2014 about phthalates in vinyl flooring. Lowe's worked with several stakeholders, including advocacy groups, suppliers and trade associations, to better understand the potential human health impact of certain phthalate chemistries contained in vinyl flooring. To address those concerns, the team worked with suppliers to remove ortho-phthalate plasticizers from all residential vinyl flooring products by the end of 2015. This was considered a major issue, as small children are often crawling on floors, and the off gassing from chemicals could impact them. Other products for which actions have been taken include:

Product Category	Commitment
Insulation	• All fiberglass insulation products are free of brominated flame retardants, halogenated flame retardants, antimony trioxide, formaldehyde, and added heavy metals
Flooring	• All vinyl flooring is free of ortho-phthalates • All indoor wall-to-wall carpet is free of triclosan, organotin, orthophthalates, vinyl chloride, nonylphenol ethoxylates, coal fly ash, formaldehyde, added heavy metals • All indoor residential carpet and rugs are free of PFAS chemicals
Lawn & Garden	• All of Lowe's live good suppliers have discontinued the intentional use of neonicotinoids in their operations, unless required by law • All outdoor pesticide products, except Tree and Shrub Care, will be neonicotinoid-free by 2022 • Lowe's will continue to work with its suppliers to explore alternative Tree and Shrub Care chemistries that do not rely on neonicotinoids
Paint	• All paint remover products are free of methylene chloride and N–Methyl–2-Pyrrolidone (NMP) • All interior and exterior water-based paints are free of triclosan, isocyanates, formaldehyde, lead, and heavy metals
Fabric Care	• All fabric protection sprays are free of PFAS chemicals

When Cassell arrived in 2015, a few of these products were already in the portfolio, but he recognized the benefit of engaging with advocacy groups that already had a position on green chemicals. Recognizing Lowe's sells many products containing different chemicals, the sustainability team joined the GC3 to become better informed and begin considering alternative, safer options without sacrificing quality, efficacy, and affordability. This collaboration started in 2015 and has expanded into an active engagement on the GC3 Retailer Leadership Council team.

An important component of Lowes' green chemicals strategy was to focus on the intersection of products of concern, where the exposure to unsafe chemicals was highest. One of the challenges in the industry at large involves simply understanding what chemicals are present in the more than 2 million products Lowe's stocks on their shelves for customers. Many of these products do not have the chemicals listed. Cassell made an important decision: "We could come up with a list of 100 unsafe chemicals that we are restricting in our products and put it out there; but the challenge is, if you don't have actual access to the information on the content of these chemicals, you can't really stand by that commitment. We took the position that if you say you are doing something, and will get rid of a certain chemical, you need to actually follow-up with that action." Lowe's thus went after the most important chemicals first. The team was able to highlight the worst chemicals by engaging with multiple NGO's, other retailers, conversations with suppliers, and the GC3 Retailer forum. This approach is defined in Lowes' formal green chemistry action plan.[15]

- Lowe's will develop a framework to systematize the process of assessing chemicals and managing chemical risks. Chemical risks can be managed in several ways and may include requiring disclosure of chemicals in Lowe's products, reducing, or eliminating toxic chemicals from Lowe's products or packaging, better educating consumers on product safety, and/or driving innovation by encouraging suppliers to transition to safer alternatives and green chemistry solutions.
- Lowe's will take a collaborative approach to understand and manage chemicals in the products Lowe's sells, including utilizing inputs from third-party subject matter experts, internal and external stakeholders, supply chain partners, and consumers. Lowe's has been working with trusted partners, such as the Green Chemistry & Commerce Council (GC3) to continuously support green chemistry initiatives as well as participating in the GC3 Retailer Leadership Council to better align the retail sector. Lowe's will also continue to partner with credible NGOs, associations, and industry partners.

In engaging with suppliers, when Cassell asked them about a particular chemical of concern, they very often responded that they were already aware of the problem, and if they hadn't already phased out the product, they were planning to do so in the next 6–12 months. In committing to getting unsafe chemistries out of their products, key suppliers ensured that such chemicals would not find their way into other products as well. A timeline for doing so was established, and discussions around different alternative chemistries became a discussion of focus.

15 https://corporate.lowes.com/our-responsibilities/corporate-responsibility-reports-policies/lowes-safer-chemicals-policy

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One of the challenges in leading the green chemistry team is the challenge of working with the merchandising (purchasing) team. Merchandising is a very large team (>400 people) spread out across multiple categories. Many of them are constantly moving between product categories, and it is rare to have someone working in a single category for any length of time and to have the ability to develop a deep understanding of the green chemistry issues at stake. So, it is often up to the small sustainability team to be on the front line of scanning and prioritizing green chemistries, and to flag areas where changes need to be made. This led to the sequence of prioritized process analyses, involving picking out chemicals and product categories of priority, and engaging with key suppliers to remove chemicals of concern.

Many of Lowes' suppliers have dedicated chemists and toxicologists on staff. NGO's often have dedicated chemists looking at products, and federal regulators also have them on staff. Lowe's does not have dedicated chemists on staff, which puts them in a difficult spot. However, by relying on NGO input, as well as customer feedback and federal science, the team is able to convince the merchandising team to make changes to their supplier portfolio. Cassell notes that "We are not qualified to make decisions based on science, so my approach is to collect information from all sides. If there is a clear indication of unnecessary risk associated with a particular chemistry, we will make a move. Also, if there is a clear alternative chemistry, it makes it a lot easier to have that conversation. In some cases, if we don't have good signals and the EPA has not found definitive links to safety concerns, it is difficult to make decisions to remove a product which consumers believe is effective. There are often many different sides to the story, so our preference is to stick to the federal regulations and look at where that decisions lands.

One of the product categories seeing the greatest growth in green chemistry is the cleaning products segment. Cassell believes that the customer focus on green chemicals is moving in proximity to their bodies—starting with organic food, and next in healthcare and beauty products, and finally into cleaning products, where people have to breath in fumes. PFAS-free carpets are another high growth area which is being driven by the proximity rule, as suppliers, retailers, and regulators work together to make the safest decisions for the consumer and for society.

Developing a retail green chemicals strategy is a two-pronged approach for Cassell's team: first, is to do what they have been doing—trying to eliminate the unsafe chemicals from their product portfolio. This is currently happening through the process of elimination currently underway. The second approach, which is occurring in parallel, is to introduce a greater number of good, safer products. This means introducing suppliers who are innovating and developing natural and organic products, and to grow their market share of certain product categories. This second prong involves helping to educate Lowes' merchandisers on the types of products with chemistries they should be seeking out, and to introduce them to suppliers to have that conversation. This will lead to getting more eco-friendly products on the shelf.

One of the biggest shifts that is driving the push for safer chemicals in products is the generational shift in home ownership. Millennials represent the largest share of new home purchases,

and this trend will likely continue. Both Millennials and Gen Z home buyers are more aware of sustainability in the products they buy, and that is a big driver in Lowe's decisions.

The other dimension is the socioeconomic factor. If green products are sold at a premium, a good segment of the population may choose not to purchase those products. It is thus imperative to be able to scale up volume to be able to offer green chemistries at the same price as others on the market. Anecdotally, Cassell sees that these products currently carry a premium, which may be on the order of 10 to 15% more expensive. The customers that really care about product safety will pay that premium, but it is going to be something that will need to be worked out over time.

Nike's Chemistry Center of Excellence: Innovating the Chemical Supply Chain

The Nike Chemistry Center of Excellence (COE) is part of Nike's overall global sustainability team and is focused on coordinating sustainable chemistry across the business to drive the scaling of green chemistry. Day to day, the team spends a lot of time coordinating with key partners throughout Nike on the phase out of PFC's, dimethyl formamide (DMFa), and other priority chemicals from the supply chain. A core principle of the priority chemistry work is to avoid "regrettable substitutions" by replacing one hazardous chemical with another hazardous chemical. The COE utilizes their chemistry assessment process which is a hazard-based screening process that helps to understand the impact of chemistries being used in the supply chain.

QUICK FACTS

- Nike, Inc. was founded in 1965
- World's largest supplier of athletic shoes and apparel
- Based in Beaverton, Oregon
- Over 76,000 employees and revenues exceeding $37.4B
- Has over 1,100 retail stores around the globe

There are many examples of how Nike is working to render their products more environmentally friendly as a function of green chemistry initiatives. For instance, the U.S. EPA's 2010/2015 PFOA Stewardship Program focused on reducing long chain (i.e., C8 or greater) perfluorinated chemicals (PFCs) and PFOA emissions, since existing data shows that shorter chain compounds have a lower potential for toxicity and bioaccumulation. Nike began moving away from C8 PFC's in their water-resistant products and switched to C6 chemicals to provide water repellency. After spending a lot of time moving from C8's to C6's, the regulatory landscape began to shift, and the team realized that in the short to near term, PFC's as a class of chemicals were not favorable. This led the team to begin pursuing the complete elimination of fluorinated chemistries from all water-resistant treatments. As Nike's moved out of fluorinated chemicals,

they used their chemistry assessment process to not only move out of PFCs but to use materials that were substantially better from a sustainability perspective.

Driving the adoption of green and sustainable chemistry requires ongoing research and study. Every new material or chemistry introduced at Nike must go through chemistry assessment which includes a toxicology review and a regulatory assessment review. This process yields a list of approved products, which has become the rule. Any new product which is not on this approved list cannot be used in any product within Nike's supply chain. This is a very high bar. The chemistry assessment methodology has been shared with other brands in the sector. For instance, Nike is collaborating with other companies such as Levi Strauss & Co., H&M, and C&A as part of the Zero Discharge of Hazardous Material foundation to create an aligned chemical screening tool.[16] This type of innovation and inter-brand collaboration is essential to moving towards a common goal of zero discharge of hazardous chemicals.

Compliance with government regulations on restricted substances is a foundational aspect to Nike's culture. Most major footwear and apparel brands meet and often exceed the guidelines provided by industry tools such as the AFIRM Restricted Substance Lists (RSL)[17] and ZDCH Manufacturing Restricted Substance List (MRSL).[18] Nike affirms publicly their conformance to these requirements. However, compliance is just the baseline, foundational expectation. Nike works on going "beyond compliance" and actively invests in research that can keep up with the changing regulatory landscape. The EU was clearly ahead in setting chemical and sustainability related regulations, and this became the yardstick for many of Nike's beyond compliance processes that have been put in place. Global regulation became the driver, and there was an increasing recognition that Nike could reduce their overall chemical footprint in all areas of business, whether it is wastewater impacts or the overall impact to all people on the planet.

One ongoing public relations challenge Nike faces is that chemistry is difficult to talk to consumers about. It became difficult for Nike to publicly state that they are not using a particular hazardous chemical, unless they were absolutely sure that no one in the supply chain was using it. The phase out work of the Center is not often publicly discussed, but the group has become much more open recently about its goal for 2025. Like many other companies, the goal is to eventually eliminate all hazardous materials from the supply chain, and there is an expectation that this will occur. The roadmap to achieving that vision of "Zero Discharge of Hazardous Chemicals" is still evolving. Two of the biggest challenges to knowing how to achieve that vision are 1) lack of full information about where, how, and what chemicals are used continues to be an ongoing challenge; and 2) unavailability of better, more sustainable choices.

16 https://sourcingjournal.com/topics/raw-materials/zdhc-brands-screened-chemistry-programs-135075

17 https://www.afirm-group.com/afirm-rsl

18 https://mrsl.roadmaptozero.com

For example, dimethyl formamide (DMFa) is on Nike's RSL, but it is still used in isolated parts of the supply chain. The team is actively looking for an alternative to DMFa that is inherently better and will still meet the performance requirement demanded by customers. The team has put a call out to the chemical industry to announce that they are looking for a greener alternative, and that they are willing to work in partnership on a more sustainable replacement. However, finding the right chemical is like finding the golden goose for certain types of chemistries.

In some cases, alternative chemistries are available, but at a higher cost. In such cases, Nike can leverage its buying power to render it as economically efficient as possible. For instance, in the area of synthetic leather, the DMF phase out will be a transition as part of a larger material consolidation. This is an important step in moving Nike closer to their target. The phase out took an enormous amount of work with the procurement and material teams, a lot of convincing, and a bit of a leap of faith. Everyone got on board once it became clear that sustainability was the common enterprise-wide goal that drove the hard work and the heavy lift.

Nike is also evaluating biobased materials and exploring some products that are incorporating these elements. One of the challenges identified is that biobased materials are not always better from a life cycle perspective, particularly when one begins to look at energy use and feedstocks. The full impacts of biobased materials and their life cycle carbon footprint, as well as the short-term and long-term tradeoffs, is an area of future growth and research but will begin by ensuring that "the right questions" are being asked.

This challenge of measurement extends to other areas as well. One current area of emphasis is on "greening" the use of organic solvents and moving to more water-based solvents. But there may be limits in transitioning to water-based as water-based increases energy use, since it can lead to longer drying times. So, there is a question of whether the chemistry-based benefits aren't overshadowed by the increase in energy use. Nike has made commitments on all three fronts: energy, water, and chemistry, and sometimes the choices involve trade-offs between these three commitments, making the decision more complicated. For instance, not using a specific chemical can have a knock-on impact on water use, and not using a particular chemistry can result in more energy required to produce the final material or product.

These types of tradeoffs are very complicated—particularly for a company that produces more than a billion shoes in factories around the world producing thousands of products. However, the more information that is gathered over time, the better the choices are going to be. The field of green chemistry will no doubt continue to grow, due to increasing regulation, emerging taxes on certain classes of chemical use in the EU, and very soon, the signals from European Union that will focus on a sustainable and circular economy that is driving the use of recycled material. These elements will continue to escalate and will continue to drive innovation in green chemistry at Nike and others in the footwear and apparel industry.

The Green Premium in Consumer Products

Seventh Generation was one of the very first consumer brands to focus on sustainable products, when it was founded more than 30 years ago in 1988 as a mail order catalog business. At that time, its founders believed in creating a company whose values were as important as the products it makes, and they established a mission statement to transform the world into a healthy, sustainable, and equitable place for the next seven generations.[19] During the last two years the company has experienced 20–30% growth due to the effects of COVID and the increasing demand for cleaning and disinfecting products.

QUICK FACTS

- Seventh Generation, Inc. was founded in 1988
- Leader in natural household products
- Acquired by Unilever in 2016 for $700M
- Based in Burlington, Vermont
- Pre-acquisition revenue (2015) of $200M

Martin Wolf is a chemist by training, and after graduating from the Worcester Polytechnical Institute, he began working as an agricultural chemist at Ceiba Geigy (known as Syngenta today). After working at Thermo Electron he decided to start up his own lab—Cambridge Analytical Associates, which eventually went public and merged into a larger company. As a consultant for the chemical industry, one of his clients was Seventh Generation, and they finally invited him to join the company in 2002 and move to Burlington, Vermont, the location of its headquarters. At that time, Seventh Generation was a $1M company, with half a dozen buyers in New York and a fulfillment center in Vermont, and his initial job was to screen any products sold in the catalogue to ensure they were complying with the environmental claims on their labels, including validation of claims on recyclable materials, biobased materials, and other claims.

Today Wolf's primary role at Seventh Generation as Director of Sustainability is to derive frameworks for more sustainable products and to explore alternative ingredients for packaging. Wolf notes that "I am constantly trying to figure out how to make our products more circular and more sustainable, and how to work with our supply chain partners and our employees to do so. If we are to be successful, we have to think like a B-Corp, and if our commerce is not sustainable, our business cannot be." Wolf works with the America Cleaning Institute, the American Sustainable Business Council, and state regulators to create a more sustainable system of commerce which can thrive.

19 https://www.seventhgeneration.com/insideSVG/mission

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How is Seventh Generation Using Green Chemicals?

There are two primary approaches that are used to ensure that green chemicals are used in Seventh Generation's products. First, Wolf ensures that stringent raw material standards are in place, and with the exception of microbial preservatives, all chemicals have to be *biobased* and *biodegradable* and also *non-toxic*. All companies selling products to Seventh Generation must complete a 27-page screening document that ensures their materials are compliant. A second approach involves having Seventh Generation's formulation chemists introduce new products with replacements to standard petroleum-based chemicals using biobased components. For example, a common surfactant is SLS which uses a petroleum or Ziegler catalyst, and chemists may decide to replace this with a surfactant that is made with palm kernel oil.

Chemists will look at the non-renewable chemical, determine what is available in the biobased range, and determine if the product can accommodate the new molecule. In other instances, a new chemical supplier may approach Seventh Generation, noting how they have done some formulary research and have arrived at some suggestions on how to formulate and create a new product using a biobased technology to replace a non-renewable chemical. The result may lead to collaboration and further exploration of this new potential "drop-in" molecule.

The Unilever Buy-Out and the Archimedes Effect

In 2016, Seventh Generation became a wholly owned subsidiary of Unilever and became publicly listed under Unilever's share price for the first time in its history. Its revenues at the time were roughly in the $300M–$500M range, and the idea of being swallowed up into a massive global consumer conglomerate was daunting at first. Paul Pullman, the CEO of Unilever at the time, visited the Seventh Generation headquarters, and made a speech to the entire workforce. His message to the employees was very straightforward: "We acquired you because of who you are. We don't want you to change! In fact, we want you to teach us what you are doing!" Seventh Generation had to adapt to Unilever's IT systems and other shared services such as human resources, hiring practices, procurement, etc., but were largely left to continue to pursue their mission to develop their products as they saw fit. And then, two things happened.

The first is what people now call the "Archimedes Effect", so called because the Greek scientist first proved the law of the lever and is claimed to have shouted "Give me a lever long enough and a fulcrum on which to place it, and I shall move the world!" Seventh Generation now had a very large Unilever, and over time, the smaller company has been influencing and changing the mammoth consumer goods company. Wolf notes that "We are seeing them change as they are adapting to our views. Our view of why it is important to be biodegradable and biobased has influenced Unilever, and they have made a commitment to *completely eliminate fossil fuels in their cleaning products by 2030*."

Wolf went on to note that "Our packaging was 80% PCR (Post-Consumer Recycled) when we were acquired, and only 2% PCR at Unilever. We showed them how to begin to use more PCR in their

packaging, and today they are north of 25% PCR and are committed to move to 100% PCR in their packaging. This is a public commitment that they have made—it appears that we have infected the host with our commitment to sustainability!"

The Cost Obstacle

Like all companies in the CPG industry, cost remains a compelling challenge… always. However, Wolf emphasizes that "a company has many levers to pull to be able to get their product on the shelf at a given cost target". For instance, he notes that Seventh Generation's material costs tend to be higher due to the lack of established capital infrastructure for many biobased chemicals, but he notes that there are ways of adjusting packaging and distribution, and working with retail customers, to enable their products to be on the shelf at a competitive target cost. He also notes that "We will never be a value brand and recognize that we will never be the lowest price point for chemical cleaners on the shelf. We recognize that consumers expect a range of prices for performance, and we recognize that we will be on the shelf at a higher price than non-renewable chemicals. However, it is our commitment that our products will also perform as a premium-priced product and will be priced comparably to other premium products." For instance, Seventh Generation's laundry cleaner seeks to be comparable to Tide in price and performance and is not going to compete with lower value brands like Arm & Hammer. The same goes for dishwashing liquid, which is priced at the same level as Palmolive and Dawn, which are also higher priced products. Seventh Generation is also working with retailers to discover other ways to take cost out. For instance, they are working with dollar stores and Walmart, using a hub and spoke model of distribution, to ensure their product arrives on the shelf at a lower total cost, using a variety of levers to do so, recognizing at all times the consumers' expectations and where your product fits on the spectrum of price and performance.

"Our market research has shown that some consumers are willing to pay a small premium for a sustainable product—perhaps no more than 10 to 15%. But not all consumers are willing to do so, but if they are skeptical about the performance of our product and they try it and discover it is comparable to a premium brand, then the added benefit of being biobased is a deciding factor in our favor. But it can be tough to get them over this initial hurdle. Our analysis from one study showed that the likelihood consumers would buy our brand based on our marketing was 6 to 10% higher. If they have heard of the Seventh Generation brand but have not heard of our mission, that likelihood rose to 20–30% likelihood. However, once consumers were informed both of our brand AND our mission, the purchase intent jumped up to 50%. They more they learned, the more willing they were to switch to our sustainable brand."

Sustainable Products: Not Just a Passing Fad Anymore

The marketing team at Seventh Generation is seeing consumers' preferences moving towards sustainable products as more than just a passing trend in the cleaning products and personal care industry. Consumers are increasingly aware of the need to use biobased, natural products, and products that are free from toxicants and use safer chemistries. They recognize that they have the choice to use biobased and safer products.

The growth of biobased cleaning products is much faster than non-renewable products in the same category. This is a trend that has not been lost on competitors. Wolf notes that "More chemical companies like Dupont, Dow, and BASF realize that making commitments (the latter with the purchase of Kognis) toward increasing their offerings of biobased materials is a shift that must be made. There is increasing pressure on fossil fuel energy suppliers to move towards renewables, and this will result in increasing constraints on petrochemical feedstocks and a general shift towards biobased materials."

Challenges Ahead

Wolf notes that we will need to be careful with increases in biobased materials sourcing. "At some point we may see headwinds regarding the conversion of land issue, particularly relative to greenhouse gas emissions, deforestation, and food vs. feedstock concerns, as the competition for starches and carbohydrates may compete with the ability of nationals to feed people. We are also seeing concerns on deforestation in Malaysia, Brazil, and Indonesia, which is driven by poor government oversight over cheap, underutilized land that they are seeking to put to productive use."

"There are major cultural challenges that exist in many executive suites. What I saw happen at Unilever was that as we presented to their executive suite who we were as a company, they quickly were able to see that what we were doing was the right thing to do, and subsequently issued statements on their intention to change from the top down. This is essential, as people who work in R&D and the supply chain are so cost focused in CPG, that they will use a cheaper non-renewable over 50 basis points!"

Looking to the Future

Wolf emphasizes that "We are staying where we are because we understand the market. Our biggest focus is on creating more sustainable packaging, and how to deal with plastics to make them less harmful to the environment, as well as the functional ingredients in our products. We know that we are not a big enough player that we can make a huge difference in the market, but that may be changing as Unilever also pursues this journey over the next ten years. They are large enough that they could provide enough revenue to drive exclusive agreements with new suppliers producing new safer, biobased materials. Today our innovation process is more arms-length with our suppliers. We have a very rigorous material standard and require our suppliers to meet that standard, either through a current molecule or modification of a molecule so it is compliant. As we have grown in size, Seventh Generation has more leverage with suppliers to adapt molecules to their requirements. Seventh Generation is also beginning to have more leverage through its growth with major retailers such as Amazon, Walmart, Target, CVS, Walgreens, dollar store chains, and others. The company prides itself on always being at the front of the pack when it comes to setting cleaning product standards and bringing the entire industry along through efforts such as the Sustainability Consortium, the Ellen MacArthur Foundation, the UN Environmental Program, and other forward-thinking groups."

Trillium Asset Management, LLC: Driving Growth of Sustainable Chemistry through an ESG Portfolio

Since 2007, Emily Lethenstrom has worked as an ESG specialist. In 2015 she took on the ESG role Trillium, with a goal of helping to shepherd ESG materiality analysis with Trillium's sector analysts. Their work involves identifying key issue areas for each of the 11 economic sectors covered across the ESG portfolio and diving deep into that analysis, identifying the key ESG issues, and determining what companies are doing to manage those risks.

QUICK FACTS

- Founded by Joan Bavaria in 1982 who is considered the "founding mother" of Socially Responsible Investing
- HQ is in Boston, Massachusetts
- Over $4 billion in assets under management
- 1st investment manager to file a shareholder resolution in 1995 (Johnson & Johnson)

In addition, Lethenstrom analyzes companies for the Trillium ESG Global Equity Fund, a mutual fund which has been around since 1999. Originally known as the Portfolio 21 Global Equity Fund, it was purchased by Trillium. That fund has 27 environmental criteria against which companies are evaluated—and they are broad in nature, including issues such as raw material supply chain, leadership at the firm, factory improvements, and other issues.

Traditionally, one of the sectors she works in is the Global Equity Green Strategy, which involves an analysis over time that examines what chemical companies are doing to contribute to sustainable outcomes. Traditionally, chemicals have had a pretty negative overall life cycle picture. However, the onset of green chemicals and chemistry has created many more attractive invest-ments for an ESG portfolio, and more companies are recognizing this trend and are beginning to position themselves to replace fossil fuel inputs, driven by consumer demand.

Letherstrom notes that this trend is definitely occurring. More consumers are becoming self-educated about human and environmental health impacts of products they consume such as food products, food packaging. But many haven't thought about chemicals before. Increasingly individuals are asking "what do green chemicals mean for me as an individual and the environ-mental health of our communities?" Many consumers are definitely paying attention to this shift. For instance, there are safer chemistries that perform equally as well as their more harmful incumbents—and that over time have proven themselves. The other driving force is that retailers are asking for increased transparency for products they are putting on their shelves. Target and Walmart are great examples of retailers that have established a green chemistry policy and want

to ensure the products are responsible—and are pushing their suppliers to change formulations. She notes that the change and interest is coming from a lot of different angles.

Traditional investors that don't consider sustainability are different than the ESG sustainable and socially responsible investors. The growth of green chemicals recognizes all of the pressures on the ecosystem and is tapping into consumer's recognition that fossil fuel inputs are increasingly recognized for their negative effects on environmental health. In the future, these fossil fuels will become increasingly regulated to the degree that those externalities and true costs of using fossil fuels are integrated into the financial costs of the product.

We are already starting to see this in Europe with the Registration, Evaluation and Authorization of Chemicals (REACH) legislation passed in 2006. This was a huge undertaking that allowed companies in Europe to begin measuring and monitoring chemicals and highlighted the impact of Substances of Very High Concern (SVHC's). Lethenstrom notes that regulation has an important role to play by recognizing those higher toxic chemicals that are produced from fossil fuels and showing that there are substitutes that are far less toxic and made from renewable inputs that are not as impactful. This is especially true when you look at the life cycle of a chemical.

In terms of financial outcomes, the growth is going to be coming from companies that are trying to reduce their SCOPE 3 GHG emissions across their supply chains. Examples include high performing companies like Unilever or SC Johnson, that have made commitments to replace fossil fuel inputs with chemicals that are biobased. A lot of companies that are producers of biobased inputs as a replacement for fossil fuels are seeing increased demand from companies and the connection to climate change will help push this.

Many companies see a business case a business case from green label certifications recognized by consumers and that give the consumer a level of confidence that what they are buying won't impact the larger environment. And as long as the label is reputable, consumers are becoming more educated and willing to spend more money.

VF Corporation and the Application of Chem–IQ^{sm} in the Supply Chain

VF Corporation is a global apparel conglomerate and owns many big brands including Vans, The North Face, Timberland, JanSport, Eagle Creek, and others. Frank Opdenacker and Harsha Chenna are two PhD's in chemistry who have been active in the safer chemicals world for a long time while working at the VF Corporation. VF's green chemicals team is based in Belgium, Switzerland, Hong Kong, and Denver, Colorado, and the team is focused on compliance-related activities in all aspects of chemistry, including product, chemical management, safety, labor, and marketing compliance. The compliance team is focused on ensuring that the company seeks to replace chemical formulations with safer alternatives, which are safer to consumers, operators, and producers, while minimizing the negative impact on the environment. The reach of the compliance team extends out to tier 3 and 4 suppliers, seeking to improve community development, traceability, and transparency.

QUICK FACTS

- VF Corporation was founded in 1899
- Global apparel and footwear company
- Over 50,000 employees and revenues exceeding $13.8B
- HQ is in Denver, Colorado
- Has over 300 brands categorized into Outdoor, Active and Work including The North Face, Vans, and Timberland

One of the proudest achievements of Opdenacker and Chenna is their involvement in helping to develop and shape the Chem–IQ program. This is a program that screens chemicals and auxiliaries at their point of use in the supply chain. Opdenacker notes that "Chemical management is okay, but unfortunately there is not enough information on all of the chemicals that are used in the supply chain. Many producers don't know which chemicals went into their products at earlier stages upstream in the supply chain. In 2011 the REACH regulations came into play in Europe, which requires that chemical manufacturers collaborate with their supply chains to disclose chemical uses. We knew that if we only relied on information provided by chemical suppliers or their MSDS sheets, the information would not fully identify what chemicals were used. Even if you were off by 0.1%, it would not be okay, because chemical substance levels down to the level of Parts Per Million (PPM) really matter!"

Opdenacker then relates what happened. "So, a group of us chemists were sitting around back in 2011 and we started to dream. One of us asked 'Wouldn't it be great to have a way to screen the chemicals that go into our apparel products, and we'd know right away if we have an issue with

water, air emissions, solvents, or whatever? We started to brainstorm on how to develop such a thing. We envisioned some type of a "litmus paper in solution" approach, which automatically shows a color that indicates the analysis results. We then started to think about what analytical technology would tell us what is in the product, which would allow us to make a decision based on the result. This led to a Gas Chromatography[20] Mass Spectrometry (GCMS) screening program that could provide information on the chemistries present in a product. At this point, a group of chemists began working with the University of Leeds and others to develop the system and we decided the best place to start would be to begin by looking at our own factories and our own chemicals."

Once this group of chemists began using GCMS to examine their own products, they very quickly found chemicals that they realized should be replaced. "We wanted to avoid a lot of substances in our products, including chemicals of concern, those identified in Proposition 65,[21] and many others. This led to the identification of thresholds for different chemicals. For instance, if a particular chemical registered at 5 to 7 PPM, it was deemed to be "yellow," where if it exceeds 7 PPM it was labeled "red." This resulted in a simple screening of different chemicals. Anytime one saw a red result, the action required was to contact the chemical supplier to improve on or find an alternative, which would lead manufacturers to produce a safer and better product. In many cases trade-offs had to be resolved. Many people wanted the solution to be as cheap as possible. If a safer solvent alternative increased the cost by $10 per kg, perhaps raising the product cost by 20 cents, then no one would want to use the safer solvent. But at least this began to raise the issue and we could begin to have the dialogue."

Fast forward ten years and VF decided to take the lead in developing a Restricted Substance List (RSL), which identifies prohibited or limited substances for all products and is overseen by their Product Stewardship Team.[22] The key to this approach was the development at VF of CHEM–IQ —a unique proprietary chemical management system that prevents substances of concern from entering VF's supply chains. Through CHEM–IQ, chemists at VF have identified and removed more than 400 tons of non-preferred chemicals from their supply chain. CHEM–IQ doesn't limit chemistry creativity but is viewed as an enabler to accelerate product innovation in line with VF's green chemistry principles, reducing hazardous waste from product design to final production. In 2017, VF made the CHEM–IQ Program Manual available to other manufacturers so they could share its breakthrough benefits. Many players in the apparel sector are now using CHEM–IQ and VF to explore new ways to extend its use throughout the textile supply chain.

20 Gas Chromatography is an analytical technique in which a complex mixture of compounds is injected onto a column and is separated based on their relative boiling point and affinity for a chromatographic column.

21 The list contains a wide range of naturally occurring and synthetic chemicals that are known to cause cancer or birth defects or other reproductive harm. These chemicals include additives or ingredients in pesticides, common household products, food, drugs, dyes, or solvents. Listed chemicals may also be used in manufacturing and construction, or they may be byproducts of chemical processes, such as motor vehicle exhaust. https://oehha.ca.gov/media/downloads/proposition-65//p65list12182020.pdf

22 https://www.vfc.com/sustainability-and-responsibility/chemistry

CASE STUDIES

CHEM–IQ has also served as a means for continuously improving the levels of green chemicals in VF's supply chains. The system measures chemicals at their point of use and leads to chemists searching for ideas to create better chemistry. The development team began by seeking to eliminate all the products that had known identifiable issues. They screened some 40,000–50,000 chemical formulations and found that about 10% had major issues, and another 30% had minor issues. These changes could not be implemented over night, so the goal is now to maintain a consistent approach to continuous improvement, with the goal of eventually removing all non-sustainable chemicals and replacing them with better chemicals. Every year VF's supply chain gets better and moves on to the next tier of chemical improvement.

Opdenacker notes that "The basic principle of green chemistry is to minimize the use and formation of toxic chemical substances and design products in a way that minimizes harm. We want to prevent bad things from happening and prevent harmful substances from being used in the supply chains. We know this can't happen all at once, and there are no perfect chemicals, but that shouldn't stop us from continuously improving our use of green chemistry to lower our footprint in the supply chain. That is also the message we consistently communicate with our suppliers." VF's list of unsafe chemicals is up to 420, but there is concern that it is not VF's role to manage the governance of this list. Opdenacker believes that the assessments and maintenance of this list belongs in the domain of NGO's and universities.

Oddly enough, if VF identifies materials in the supply chain that are non-compliant and notifies their suppliers, the suppliers are happy to hear from them. In many cases suppliers were unaware of the problem and are keen to address VF's concern. Replacing an unsafe chemical is a value-added activity, as it might be helping the supplier avoid non-compliance fines of hundreds of thousands of dollars versus what the original chemical cost. In some cases, chemical suppliers approach VF with a problem and note that to reach a specific level of purity, investments will be required for the specific equipment. In other cases, there was no prior knowledge that the chemical of concern was present, and substantial design work will be needed which may incur costs. However, if all suppliers are involved together to pursue safer chemicals, increased volume usage will drive down costs and equalize the playing field. Not all suppliers can afford significant investments in new equipment, etc. for green chemicals, but in 95% of the cases changes can be made to clean up the supply chain. The CHEM–IQ solution provides an ability for all suppliers to screen their products for green chemistry.

The use of green chemicals in the apparel supply chain is increasing significantly. Large companies like VF, Nike, ASICS, Adidas, Decathlon, Gap, H&M, and others are coming together in an organization called the AFIRM Group,[23] whose mission is to reduce the use and impact of harmful substances in the apparel and footwear supply chain. This is a good forum for bringing together 27 major apparel and footwear brands to drive scale in green chemicals by working together towards common standards. There is significant consensus among the top brands regarding the

23 https://www.afirm-group.com

non-compliance issues that leading to increased scale and volume growth of green chemicals. Each brand publishes the methods that they are using for different types of chemicals, to share best practices. This is not a competition, but rather a way for brands to use their footprint to focus on the top harmful chemicals that comprise the largest volumes currently in use to compete horizontally as an industry to promote green chemistry.

Most apparel suppliers when they develop new products focus on screening of chemicals. More and more are relying on the CHEM–IQ screening tool, as it provides information that they would never have known unless they had gone and conducted an analysis on every chemical in their product. VF acknowledges that a screening is the not the perfect analytical method but is useful for understanding if potentially problematic chemicals present are in a range that is acceptable. There is significant variation in chemical that are typically produced in batches, and there may be differences in the amount of harmful chemicals present. So, from a statistical perspective the screening is not perfect, but is intended to provide a lot of useful information to reduce the footprint of harmful chemicals overall.

A good example is Alkylphenol ethoxylates (APEOs—often called alkylphenols or alkylphenols) which are surfactants that have an emulsifying and dispersing action, so they have good wetting, penetration, emulsification, dispersion, solubilizing and washing characteristics and have been in use for more than 50 years. However, there are concerns that they can affect aquatic organisms and are slow to biodegrade and tend to bioaccumulate. Europe has mandated that APEO's should be limited to around 50 PPM, and one of the applications of greatest concern is spinning oil, which is used in the weaving process. The oil is often present in a fabric because of its use in the supply chain. Screening for APEO's allows brands to go beyond the management of chemicals used in their own factories and can trace whether the chemical exists in processes that occur within the end-to-end supply chain. VF screened for APEO's but did not find any in the tier 1 or tier 2 supplier facilities though were able to find it using CHEM–IQ with a knitting and spinning supplier upstream and drove them to change the use of this oil in the process.

Other examples include the movement from a C8 chemistry to a C6 chemistry used in water and stain repellencies, as well as movement to restrict some silicone-based chemistries. There are many opportunities for improving chemistries, but the CHEM–IQ screening tool starts to drive the right behaviors up and down the supply chain. The tool will also help to educate more consumers, who will push brands to answer more questions about the use of green chemistries in their products. There will always be a push-pull relationship between regulators and consumers for change, but the CHEM–IQ screening solution provides an objective way to identify problems and work towards continuously improving them over time.

CONCLUSIONS AND INSIGHTS

Together, these cases along with the other analyses in this study provide a compelling picture of the powerful forces that are driving a strong business case for investment in green chemistry. The discussions with the individuals interviewed as well as the consumer analysis, the Economic Impact analysis, industry survey, and other research bring out some common themes that are important for all stakeholders in the industry to note. Policy, market, and consumer drivers for green chemistry products are increasing. Products of green chemistry are outperforming incumbents in the same product category in terms of sales. Companies are investing more in green chemistry solutions across sectors. And the job creation and economic benefits of green chemistry investments (in addition to the environmental and health ones) are significant. But significant barriers stand in the way of investment and growth, which must be overcome in the future.

Some of these relate to the incumbency of existing, highly capitalized, cost-effective chemicals integrated into complex global supply chains. Others relate to limited data—for example on chemical manufacture and use and on cost savings or return on investment—that allow a comprehensive evaluation of the growth and economic value of green chemistry in the marketplace. And yet others relate to the limited investor and C-suite understanding of the risks associated with continued use of chemicals of concern and benefits of investment, which results in green chemistry not always being considered a material issue for companies across sectors and the value chain. Additional targeted research and development of clearer metrics for evaluating green chemistry investments will be needed to needed to establish a stronger case for decision-makers.

Investors, supply chain managers, R&D teams, scientists, CFO's, sustainability officers, regulators, industry organizations, and NGOs should all be aware of these insights, that together, weave a powerful business case for change and movement towards a green chemistry future.

- **Consumers are demanding green chemistry solutions and accountability.** North American consumers are following in the footsteps of European customers and are questioning the chemicals in their food, in their homes, in their beauty products, in their apparel, and in other products. Organizations need to be a step ahead of these consumers and provide them with tangible evidence that the chemicals used in the products they buy are safe and from renewable feedstocks and sources.
- **The demand for safer products has advanced beyond toys and baby products and is increasing especially in products that come into direct contact with consumers.** Green chemistry is becoming increasingly important in beauty products but is also becoming critical in cleaning products to which people cleaning are exposed, product packaging

for food, apparel that touches the skin and feet, home flooring and insulation that are in the homes we live in, and for specialized demographics such as mountaineering and hikers. This awareness is likely to continue to increase and those that are more aware of these changes will gain market share.

- **Green chemistry is having a big impact on store shelves.** Consumers are willing to pay slightly more for green chemistry products and are acting with their pocketbooks. This is becoming evident not just in grocery stores, but in home improvement, sporting goods, apparel, and electronics. Companies are acting in response to consumer preferences and are paying attention.
- **ESG investment is growing, and the number of investors who are paying attention to green chemistry is increasing.** As investors become savvier and look beyond a company's "code of conduct" website, they are looking for tangible evidence that companies are making a concerted effort to address their carbon footprint, reduce climate and toxicity risks and are rewarding these companies with major investments and driving up their share price. This is a powerful investment force that is growing and is no longer a niche area.
- **In response to growing demands for safer, more sustainable products, Fortune 500 companies like Unilever, Lowe's, and Apple are making significant commitments to cleaner futures, safer chemistry, and zero carbon emissions.** Reaching these targets by 2030 is not going to be easy, and companies are looking for green chemistry technologies that can make both big contributions to carbon reduction goals as well as safer products goals, especially by working with innovative new suppliers and using screening tools to replace chemicals currently in use in the supply chain.
- **Advancing green chemicals in product lines is a process of continuous improvement.** Many products do not have a lot of information on the chemicals used in their production processes. A proactive approach is needed to ferret out harmful chemicals and identify safer options. This requires investing in a team of chemical engineering and chemistry experts, who are continually seeking replacements for such harmful materials. Procurement personnel must also be involved to work proactively with suppliers and drive innovation.
- **Green chemistry requires innovation and persistence.** There are not always easy "drop ins" for every type of harmful chemical in every application. However, major companies have dedicated their futures to the application of green chemistry in areas of our economy that we would never imagine are ripe for its application, including road construction, building construction, manufacturing processes, home improvement, and many other areas. The possibilities are endless—but that will require investors, governments, companies, and people are dedicated to this goal.

Policy makers, the investment community, and corporate leaders are well positioned to leverage these trends to drive growth of green chemistry solutions in the future.

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APPENDIX A

TOP PRODUCT CERTIFICATIONS AND CLAIMS BY PRODUCT CATEGORY

Claim	Share of Average Annual Dollar Sales of Green Chemistry-Marketed Products 2015–2019	Share of 2015–2019 Growth of Green Chemistry-Marketed Products
Pool Chemicals		
All Natural	45%	54%
Organic	55%	46%
Non-Toxic	55%	46%
Soap		
Paraben Free	63%	59%
Phthalate Free	68%	55%
Sulfate Free	17%	26%
Micro Bead Free	15%	6%
Triclosan Free	12%	8%
Skincare		
Paraben Free	61%	77%
Phthalate Free	54%	45%
Micro Bead Free	20%	0%
Sulfate Free	19%	24%
Formaldehyde Free	14%	1%
Household Cleaner		
Plant Based	29%	48%
Biodegradable	23%	12%
Phthalate Free	21%	37%
Safer Choice Certified	18%	8%
Natural	8%	-6%
Floor Cleaner		
Plant Based	22%	-7%
Natural	22%	-7%
Green Seal	1%	4%
Biodegradable	8%	21%
Phosphate Free	8%	21%

Claim	Share of Average Annual Dollar Sales of Green Chemistry-Marketed Products 2015–2019	Share of 2015–2019 Growth of Green Chemistry-Marketed Products
Dish Detergent		
USDA Bio Based Product	31%	43%
Phosphate Free	30%	35%
Biodegradable	25%	23%
Phthalate Free	21%	44%
Paraben Free	20%	41%
Laundry Detergent		
Plant Based	86%	82%
USDA Bio Based Product	44%	100%
Biodegradable	35%	48%
Safer Choice Certified	32%	56%
Synthetic Fragrance Free	31%	54%
Suntan Products		
Reef Friendly + Safe	45%	54%
PABA Free	46%	46%
Oxybenzone Free	37%	19%
Paraben Free	30%	5%
Mineral Sunscreen	25%	41%
Auto Wax		
Silicone Free	97%	100%
Petroleum Distillates Free	97%	100%
Biodegradable	2%	-12%
Formaldehyde Free	1%	-68%
Phthalate Free	1%	-68%
Pavement Deicing		
Salt	81%	-9%
Natural	36%	27%
Enviro Friendly	22%	-40%
Safer for the Environment	4%	3%
Eco Seal	6%	-28%

APPENDIX B

IMPLAN METHODS AND APPROACH

The Economic Input-Output Model

IMPLAN is an economic impact modeling system that uses input-output analysis to quantify economic activities of an industry in a predefined region. IMPLAN was designed in 1976 by the Minnesota IMPLAN Group Inc. under the direction of the U.S. Forest Service to help meet the reporting requirements for Forest Service land management programs. IMPLAN is now widely used to quantify the economic impacts of various industry activities and policies. The IMPLAN system is now managed by IMPLAN Group LLC of Huntersville, North Carolina.

IMPLAN quantifies the economic impacts or contributions of a predefined region in terms of dollars added into the economy and jobs produced (IMPLAN Group LLC 2004)[24] Data are obtained from various government sources. These include agencies and bureaus within the Departments of Agriculture, Commerce, and Labor.

The IMPLAN system's input-output model currently defines 536 unique sectors in the U.S. economy (which are North American Industry Classification System [NAICS] sectors, except in some cases where aggregates of multiple sectors are used) and uses its database to model inter–sector linkages, such as sales and purchases between forest-based industries and other businesses.

When examining the economic contributions of an industry, IMPLAN generates four types of indicators:

1. **Direct effects:** effects of all sales (dollars or employment) generated by a sector.
2. **Indirect effects:** effects of all sales by the supply chain for the industry under study.
3. **Induced effects:** A change in dollars or employment within the study region that represent the influence of the value chain employees spending wages in other sectors to buy services and goods.
4. **Total effect:** the sum of the direct, indirect, and induced effects.

Model Output

- **Value added:** Value added describes the new wealth generated within a sector and is its contribution to Gross Domestic product (GDP).
- **Employment:** full and part time jobs

24 IMPLAN, Computer Software, IMPLAN, IMPLAN Group LLC, http://www.implan.com

Economic Multiplier

Economic multipliers quantify the spillover effects, the indirect and induced contributions. The Type I multiplier describes the indirect effect, which is described by dividing the direct effect into the sum of the direct and indirect effects.[25] A Type I employment multiplier of 2.00 for example, means for every employee in the industry of interest, one additional person is employed in that sector's supply chain.

Type II multipliers are defined as the sum of the direct, indirect, and induced effects divided by the direct effect. Type II multipliers differ by how they define value added and account for any of its potential endogenous components. A particular Type II multiplier, the Type SAM multiplier, considers portions of value added to be both endogenous and exogenous to a study region. These multipliers indicate to what extent activity is generated in the economy due to the sectors under study. A Type SAM value added multiplier of 1.50, for example, indicates that for every $1.00 of value added produced in an industry under study, $0.50 of additional value added would be generated elsewhere in the economy by other industries.

Modeling Details

Table B.1 and **B.2** provide the IMPLAN modeling details matching industry categories to one or more of the IMPLAN industry codes. When multiple IMPLAN codes bridged to survey categories, a custom model was created in IMPLAN for each grouping of industry codes to generate new economic multipliers.

TABLE B.1
IMPLAN industry grouping bridge to retail data grouping

Retail data categories	IMPLAN Code	IMPLAN Description
Auto wax	180	Polish and other sanitation good manufacturing
Dish detergent	179	Soap and other detergent manufacturing
Floor cleaner	180	Polish and other sanitation good manufacturing
Household cleaner	179	Soap and other detergent manufacturing
Laundry detergent	179	Soap and other detergent manufacturing
Pavement deicing	187	Other miscellaneous chemical product manufacturing
Pool chemicals	187	Other miscellaneous chemical product manufacturing
Skincare	182	Toilet preparation manufacturing
Soap	179	Soap and other detergent manufacturing
Suntan products	182	Toilet preparation manufacturing

25 U.S. Department of Commerce Bureau of Economic Analysis 2013

TABLE B.2
IMPLAN Industry grouping bridge to survey green chemistry categorization

Survey categories	IMPLAN Code	IMPLAN Description
Apparel & Textiles	114	Narrow fabric mills and schiffli machine embroidery
Apparel & Textiles	115	Nonwoven fabric mills
Apparel & Textiles	116	Knit fabric mills
Apparel & Textiles	117	Textile and fabric finishing mills
Apparel & Textiles	118	Fabric coating mills
Apparel & Textiles	119	Carpet and rug mills
Apparel & Textiles	120	Curtain and linen mills
Apparel & Textiles	121	Textile bag and canvas mills
Apparel & Textiles	122	Rope, cordage, twine, tire cord and tire fabric mills
Apparel & Textiles	123	Other textile product mills
Apparel & Textiles	124	Hosiery and sock mills
Consumer Products	179	Soap and other detergent manufacturing
Consumer Products	180	Polish and other sanitation good manufacturing
Consumer Products	182	Toilet preparation manufacturing
Consumer Products	183	Printing ink manufacturing
Consumer Products	191	Laminated plastics plate, sheet (except packaging), and shape manufacturing
Consumer Products	377	Mattress manufacturing
Electronics	301	Electronic computer manufacturing
Pharmaceuticals & Life Sciences	173	Medicinal and botanical manufacturing
Pharmaceuticals & Life Sciences	174	Pharmaceutical preparation manufacturing
Pharmaceuticals & Life Sciences	175	In-vitro diagnostic substance manufacturing
Polymers and Plastics	166	Plastics material and resin manufacturing
Polymers and Plastics	167	Synthetic rubber manufacturing
Polymers and Plastics	168	Artificial and synthetic fibers and filaments manufacturing
Polymers and Plastics	188	Plastics packaging materials and unlaminated film and sheet manufacturing
Polymers and Plastics	189	Unlaminated plastics profile shape manufacturing
Polymers and Plastics	192	Polystyrene foam product manufacturing
Polymers and Plastics	193	Urethane and other foam product (except polystyrene) manufacturing

Survey categories	IMPLAN Code	IMPLAN Description
Polymers and Plastics	194	Plastics bottle manufacturing
Polymers and Plastics	195	Other plastics product manufacturing
Polymers and Plastics	196	Tire manufacturing
Polymers and Plastics	197	Rubber and plastics hoses and belting manufacturing
Polymers and Plastics	198	Other rubber product manufacturing
Solvents	165	Other basic organic chemical manufacturing
Specialty Chemicals	125	Other apparel knitting mills
Specialty Chemicals	163	Synthetic dye and pigment manufacturing
Specialty Chemicals	164	Other basic inorganic chemical manufacturing
Specialty Chemicals	176	Biological product (except diagnostic) manufacturing
Specialty Chemicals	177	Paint and coating manufacturing
Specialty Chemicals	178	Adhesive manufacturing
Specialty Chemicals	181	Surface active agent manufacturing
Specialty Chemicals	186	Photographic film and chemical manufacturing
Specialty Chemicals	187	Other miscellaneous chemical product manufacturing

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Dr. Golden received his Ph.D. in Engineering from the University of Cambridge, and he received his Master's degree in Environmental Engineering and Sustainable Development from a joint program of the Massachusetts Institute of Technology and the University of Cambridge.

In 2009, Dr. Golden was presented the Faculty Pioneer Award by The Aspen Institute for his leadership in the field of sustainability education and research, and he was named by Ethisphere as one of the 100 Most Influential People in Business Ethics.

Golden was appointed to the Board of Scientific Counselors to the U.S. EPA where he continues to serve and was previously on the UN Lifecycle Management Task Force. He was named an AT&T Industrial Ecology Fellow. Dr. Golden consults extensively for companies and governments around the world.

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Dr. Rob Handfield is the Bank of America University Distinguished Professor of Supply Chain Management at North Carolina State University, and he is the Executive Director of the Supply Chain Resource Cooperative (*http://scm.ncsu.edu*). He also serves as Faculty Lead for the Manufacturing Analytics group within the International Institute of Analytics, and he is on the Faculty for Operations Research Curriculum at NC State University.

Prior to this role, Dr. Handfield served as Associate Professor and Research Associate with the

Global Procurement and Supply Chain Benchmarking Initiative at Michigan State University from 1992––1999. He received his Ph.D. in Management from the University of North Carolina at Chapel Hill.

Dr. Handfield is the author of several books on supply chain management, the most recent among them being The LIVING Supply Chain, Biopharmaceutical Supply Chains, Supply Market Intelligence, Supply Chain Re-Design, and Introduction to Supply Chain Management (Prentice Hall, 1999, 25,000 copies sold, and translated into Chinese, Japanese, and Korean).

He recently led a global study on the Emerging Procurement Technology: Data Analytics and Cognitive Analytics for CAPS Research, Procurement Analytics for IBM, Global Logistics Trends and Strategies for BVL International in 2013, and a report entitled "Future Buy: The Future of Procurement," published by KPMG.

Dr. Handfield is focused on digital supply chains, sustainable procurement, and he is a co-author of two prior biobased reports. He has worked with over 25 Fortune 500 companies on different aspects of supply chain management sustainability and digital analytics.

JESSE DAYSTAR

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Dr. Jesse Daystar is an Adjunct Assistant Professor at the Nicholas School of the Environment at Duke University and at the Department of Forest Biomaterials at North Carolina State University. He also serves as the Chief Sustainability Officer and Vice President of Sustainability at Cotton Incorporated. Dr. Daystar has Ph.D. and M.S. degrees in Forest Biomaterials, and he has B.S. degrees in Chemical and Pulp & Paper Engineering from North Carolina State University.

Dr. Daystar is a leader in the field of life cycle assessment of agriculture, textiles, forest biomaterials, and cellulosic biofuels. He has published extensively in these fields in leading peer reviewed journals and wrote a book chapter on life cycle assessment. Beyond publishing research, Dr. Daystar contributes to the academic community by serving on the USDA Biomass Research and Development Initiative (BRDI) awards review panel. He also serves on the Metrics Committee at the Field to Market which convenes diverse stakeholders to work collaboratively to define, measure and advance the sustainability of food, fiber, and fuel production in the United States.

At Cotton Incorporated, Dr. Daystar develops and implements sustainability strategies working with industry, academia, and NGOs across the entire cotton supply chain to drive systemic changes towards more sustainable apparel production.

RANDI KRONTHAL–SACCO

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Ms. Randi Kronthal–Sacco is a Senior Scholar of Marketing and Corporate Outreach at the NYU Stern Center for Sustainable Business. Ms. Kronthal–Sacco leads CSB's research in the areas of marketing and brands including the Sustainable Market Share Index™ and is responsible for corporate outreach.

With over 25 years of packaged goods and pharmaceutical experience, Ms. Kronthal–Sacco most recently was the Chief Marketing Officer at Rodan + Fields®. Ms. Kronthal–Sacco spent over 18 years as a Senior Executive at Johnson & Johnson®, where she served as Worldwide Vice President on two of the company's most important franchises, Johnson's Baby and Women's Health. Prior to her role at Johnson & Johnson, Ms. Kronthal–Sacco served in various product management capacities for 8 years at Kraft Foods including Director, Desserts Division.

Ms. Kronthal–Sacco currently serves as a member of the Board of Directors at GlobeScan.

Ms. Kronthal–Sacco holds a Bachelor of Business Administration in Marketing from Emory University and a Master's in Business Administration in Finance from NYU Stern School of Business. Her research has been cited in Harvard Business Review, Fortune, GreenBiz, among others.

JOEL TICKNER

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Dr. Joel Tickner is a Professor of Environmental Health in the Zuckerberg School of Health Sciences at the University of Massachusetts Lowell. He is leading researcher and strategist in making chemistry safer for people and the environment. His research focuses on the development of innovative scientific methods and policies to implement and accelerate the design and application of safer products and manufacturing processes.

His research has led to the establishment and growth of the field of chemical alternatives assessment, the process of comparing alternatives for chemicals of concern. He is the founding Executive Director of the Association for the Advancement of Alternatives Assessment (A4), a professional association dedicated to advancing the science, practice, and policy of alternatives assessment and informed substitution. Tickner also founded the Green Chemistry & Commerce Council (GC3). Tickner is also Co-Director of the Massachusetts Toxics Use Reduction Institute (TURI), which provides resources and tools to help businesses, municipalities, and communities in Massachusetts find safer alternatives to toxic chemicals. He has a Doctor of Science Degree in Occupational and Environmental Health from the University of Massachusetts Lowell.

Green Chemistry

A Strong Driver of Innovation, Growth, and Business Opportunity

As investors and manufacturers seek new market opportunities for growth in the chemical sector, one of the portfolios attracting attention is the expanding portfolio of green chemicals—chemical products and processes that reduce or eliminate the use or generation of hazardous substances from manufacture through disposal. While green chemistry has traditionally represented a very small segment of the broader chemistry industry, there is emerging evidence that this segment is poised to grow rapidly. In this report, we examine the business case for investment in green chemistry on the part of manufacturers, retailers, brands, and R&D teams. We present compelling evidence through a multi-method approach, relying on case studies, consumer product sales trends, economic value-added analysis, and prior research that suggests the green chemicals and products sector is growing rapidly and will likely become a dominant element of major investment portfolios in the near future.

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