Advancing Green Chemistry: Barriers to Adoption & Ways to Accelerate Green Chemistry in Supply Chains

A Report for the Green Chemistry & Commerce Council

GREEN CHEMISTRY & COMMERCE COUNCIL
Business Mainstreaming Green Chemistry

Researched and written by:

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About the Organizations

GREEN CHEMISTRY & COMMERCE COUNCIL

The GC3 is a cross sectoral, business-to-business network of companies and other organizations working collaboratively to advance green chemistry across sectors and supply chains. The GC3 is based in the Lowell Center for Sustainable Production at the University of Massachusetts Lowell. The GC3 commissioned this research to support its efforts to mainstream green chemistry by understanding barriers and opportunities to accelerating green chemistry adoption across supply chains.

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T. FENNELLY & ASSOCIATES, INC.

TFA is a consulting firm focused on helping clients with value creation and market access in the renewable and traditional chemical industry Eighty percent of TFA's work is in specialty and renewable chemicals and their related markets. TFA has over two decades of consulting experience in the evaluation of and strategizing for these areas. Tess Fennelly and Bryan Luftglass were the lead authors on this report:

Tess Fennelly – has over twenty years of consulting experience in specialty chemical and polymer related fields. Tess also has eleven years of industry experience with positions in Sales, Business & Market Development, Marketing & Communications, Strategic Planning, and Mergers & Acquisitions. Her extensive background in traditional and sustainable chemistries includes adhesives, coatings, plastics, specialty fibers and specialty chemicals. She worked for Segetis, Air Products and Chemicals, American Cyanamid (Now Cytec) and Stauffer Chemical Company. Tess has a B.S. in Chemistry from Purdue University and an MBA from Lehigh University.

Bryan Luftglass – has over twenty years of consulting experience related to chemicals, environmental technologies, energy and fuels plus fifteen years in operating companies introducing, developing and growing new products and businesses. He has also focused on work with multi-national chemical companies on programs related to strategy and corporate sustainability. Bryan worked for BOC Gases and Linde, Fuel Tech, Environmental BioScience Corp., CPI Consulting (now IHS Chemical), Chem Systems (now Nexant) and his own consulting firm, Eco Logic Inc. Bryan has a B.A. from Colgate University and a M.S. from the Scripps Institution of Oceanography.

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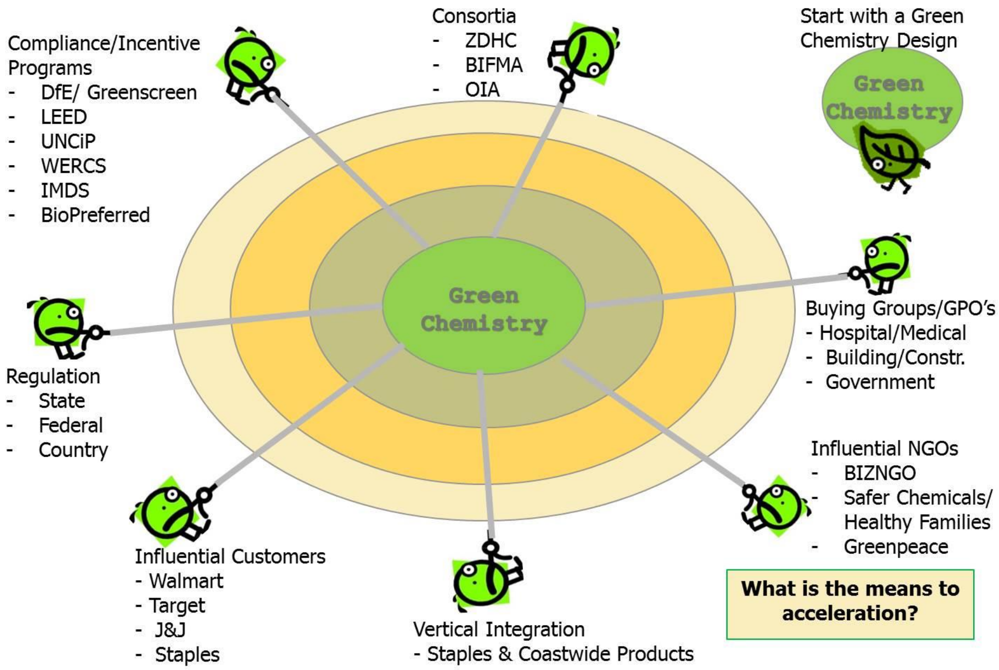
Executive Summary

There continues to be a growing interest and awareness in green chemistry. There are successful cases of adoption of safer alternatives, and scaling of supply, in response to demands from regulators and customers. However, overall progress is slow, measured in decades.

Despite efforts from many stakeholders to accelerate green chemistry use, including those shown on the accompanying figure, adoption rates remain low.

ES Figure I: Current Green Chemistry Efforts



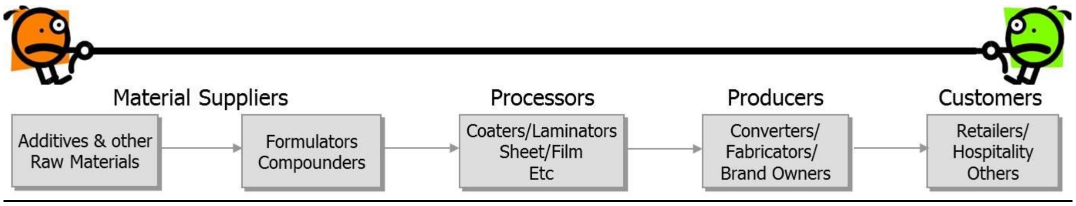
These multiple stakeholder efforts to drive the growth of green chemistry have been slow. So, when there are green chemistry alternatives available

- Why aren't more green chemicals in use?
- What are the barriers?
- What is the means to accelerate adoption?

In the course of undertaking this project and answering these questions, T. Fennelly & Associates, Inc. (TFA) spoke with roughly fifty industry representatives and has considered the entire supply chain from chemicals to processors to fabricators and through to industrial and consumer finished products. TFA identified major drivers and deterrents to growth. The complexity of supply chains is enormous, consisting of thousands of chemicals formulated into literally millions of products. This complexity inherently creates barriers.

Each position in the supply chain provides a different a viewpoint for companies. This is true about many things including green chemistry.

ES Figure II: Supply Chain Positioning Produces Different Vantage Points – Often at Odds



This analysis has identified the factors that have affected the slow growth and availability of green chemistry. Nine key issues were identified that have slowed availability and growth of green chemistry:

1. **Green Chemistry Definitions**
Most industries have not established a unified set of "green chemistry" definitions. It isn't critical to pick a "right" definition. It is **Critical** to be on the same page when initiating and advancing discussions and collaborative efforts involving Green Chemistry. These definitions inherently establish priorities for such efforts.

2. **Supply Chain Complexity**
Supply chain complexity poses enormous barriers to green chemical adoption. Each supply chain position has its own vantage point, a different viewpoint from others in the chain. Complex supply chains create fragmentation of demand by application, volume, specification, customer expectation, geography, etc. In complex supply chains, demand for new innovative technologies is diffuse. This affects the speed of adoption and flow of new, safer, greener chemistries and practices. Often the results are supply chain conflicts and an "us vs. them" mentality between suppliers and customers.

3. **Incumbency**
The existing infrastructure of the established chemical industry is so efficient that it is hard for new entrants, green or not, to compete with the established supply chain.

4. **Confusion**
Conflicting information from studies and research, policy uncertainties and conflicting lobbying efforts continue to confuse the industry. Stakeholders are at times grid-locked, not making a change due to uncertainty about the acceptability of status quo products.

5. **Switching Risk**
There is concern that switching to green chemistry alternatives could lead to market failures such as market loss due to a product's poor performance, brand tarnishing and other hidden costs such as process or equipment or process changes, material incompatibility, workforce training, customer education and others. There is also the risk of switching to a "better bad". This makes stakeholders cautious and slow to make chemical management decisions.

6. Price / Performance

Price/performance was the most cited reason for the slow adoption of green chemistry. Entrenched chemicals of concern (COC's) have set the standard for price/performance. Often there are savings in a total cost analysis such as reduced hazardous waste handling and disposal. This can be hard to quantify for customers focused on $/lb. pricing. Change will continue to be slow without a concerted effort to address the trade-offs between conventional price/performance issues and "green".

7. Supply & Demand

There is often not enough real or perceived demand to make increased production worth the investment. Stakeholders are cautious to move forward to commit to demand or to commit to supply. Supply infrastructure growth will be slow without compromise, partnership and collaboration to increase demand and supply in tandem.

8. Transparency

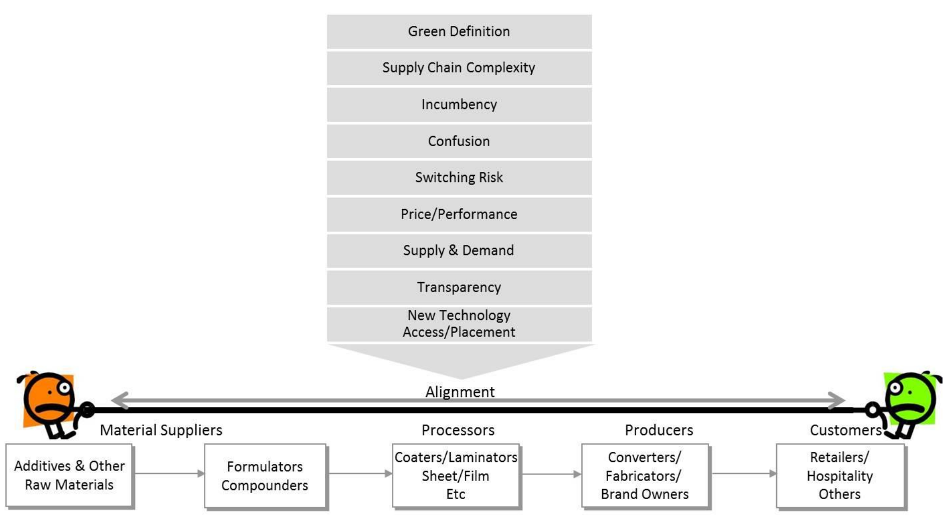
More transparency is occurring, much by force. Suppliers are looking for ways to satisfy customer demands while protecting IP and trade secrets. Customers are frustrated and skeptical of the chemical industry's reluctance to be open and transparent.

9. New Technology: Access and Placement

Finding and vetting green chemistry technologies remains a weak link. Suppliers struggle to identify early adopters. Customers struggle on where to go beyond the traditional supply chain for new technology. The flow is slow, but collaborations and other activities are beginning to open up the flow and access to technology.

The issues that create barriers for broader adoption of green chemistry identified in this report are obvious strong impediments to growth. They can cause misalignment. They have weighed down the flow of new green chemistry adoption.

ES Figure III: Nine Issues That Can Misalign Green Chemistry Supply Chains



Much of the progress to date in advancing green chemistry can be attributed to two main drivers, Government Regulation and Consumer Awareness.

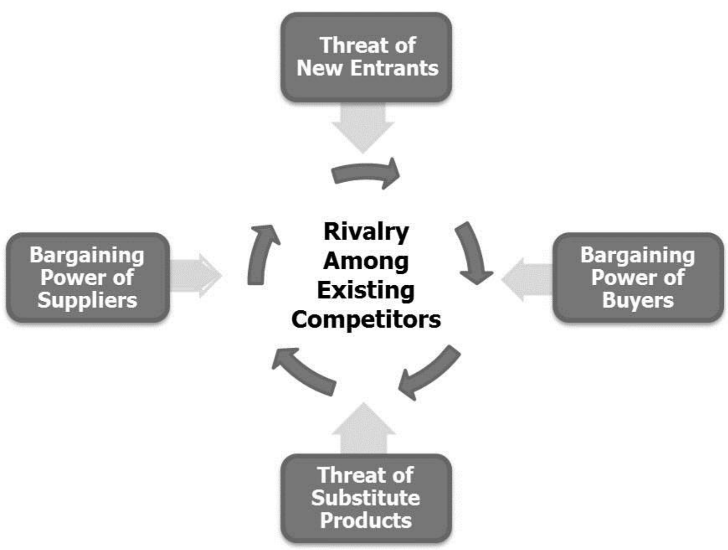
1. **Government Regulation**
Regulatory bans and restrictions have been and will continue to be a big driver for green chemistry. However, the difficult and costly regulatory process for new product registrations and secondary approvals can act as a hindrance to product availability, demand and adoption. For a new chemistry, particularly from a small company with limited toxicology or regulatory support, this can be challenging.

2. **Consumer Awareness**
Aware consumers can force and drive change to greener chemistry. This change occurs independent of legislation or lobbying. "Perception is reality" to the consumer. Consumer education can heighten consumer awareness and accelerate demand for green chemistry.

Acceleration of green chemistry is difficult due to the tug of war between and within pro-green chemistry and entrenched industry "camps". There are basic problems of agreeing to definitions of green chemistry, supply chain complexity and other misalignments between stakeholders across the supply chain. All indications are that these forces will continue to bombard regulators, customers, suppliers and other stakeholders with alternate views that will, in fact, slow related progress. Similarly, this will continue as an "us versus them" tug of war between those who want change and those who prefer the status quo. Pro-green consumers are frustrated and angry at the lack of progress, while industry bemoans that consumers aren't viewing risks rationally.

Many of these issues are compounded by industries functioning within the traditional structure of the supply chain as highlighted by Porter's Five Forces Analysis, developed by Michael E. Porter in the 1970s.This type of analysis is also instructive in assessing the forces at play in green chemistry.

ES Figure IV: Porter's Five Forces



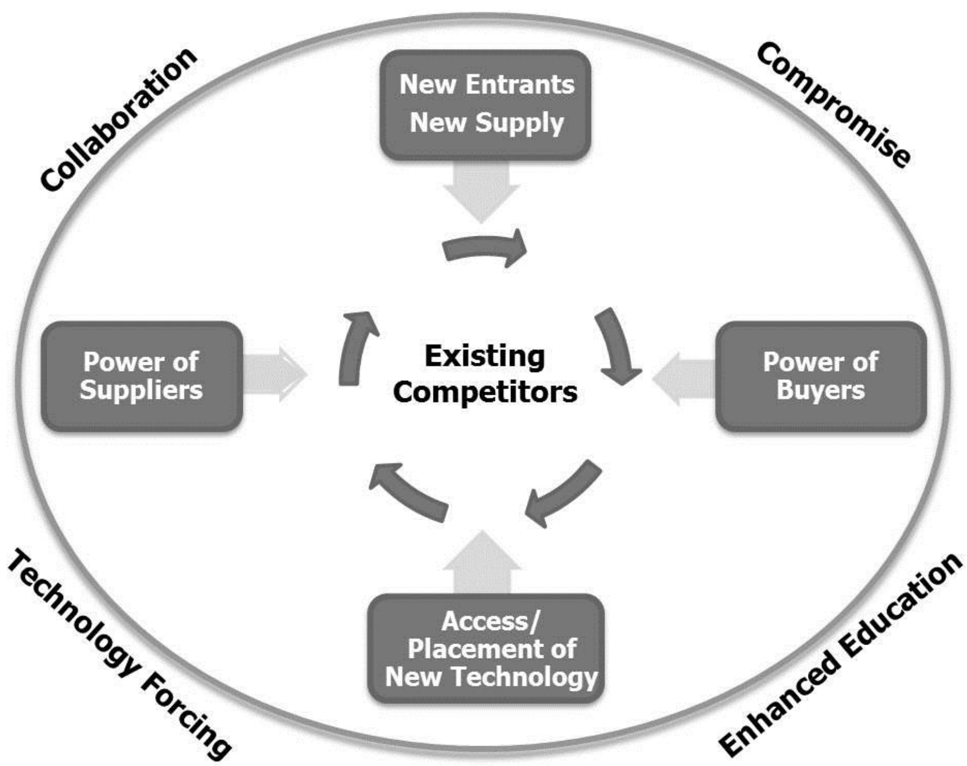
The Five Forces model is a tool companies use to assess their competitive position within industry supply chains to understand where power lies. It is based on a protectionist approach employed to assess and anticipate threats to the business from existing competitors, bargaining power of suppliers and buyers (customers) and the threat of new entrants and new technology. The Five Forces model is a planning tool used to build a position of defense and deflection of these threats. It is not a cooperative or collaborative approach to business positioning.

TFA has concluded that there are four accelerators that can change the current paradigm and create a new paradigm that can lead to faster growth of green chemistry. They are:

- Collaboration
- Technology Forcing
- Compromise
- Enhanced Education

These elements are not entirely new and all exist in some form. However, to transcend the existing "stuck" conditions, they need to be applied both more forcefully and in combination with one another. Individual companies need to be competitive, but there is a way to use the accelerators to modify the traditional Five Forces away from a purely adversarial approach to a more cooperative framework. Adopting this new model can lead to sustainable change when companies commit to this approach.

ES Figure V: Cooperative Five Forces Model



1. Collaboration

Collaboration can lead to projects where green substitutes succeed. It can help overcome the nine identified alignment issues and create alignment and agreement for change. It can help avoid unrealistic expectations and consequent changes

Collaboration through consortium-based approaches can create programs through which change can occur faster, provide a broad perspective from which priorities become more obvious, mitigate the risk of "go-alone" potential hazards.

Collaboration can bring new materials and technology options to market faster, get to larger scale faster and bring the cost and risks down for all.

2. Technology Forcing: Non-regulatory

Marketplace decision makers with considerable "buyer power" force change. In effect, they create de facto regulations. Technology Forcing can, like government regulations, drive change to green chemistry. Large retailers and consumer product companies have a great deal of market power to leverage. Exercising power should involve an appropriate level of collaboration and compromise in order to ensure project goals are appropriately set and met. This includes internal collaboration between the sourcing and sustainability groups at consumer products and retailer organizations to ensure green chemistry and price/performance needs are examined in tandem.

3. Compromise

When compromising, companies can accelerate the adoption of green chemistry by embracing the principle of reasonable trade-offs.

Accepting continuous improvement will accelerate the adoption of greener chemistry. Something "better enough" is better than the status quo. It will not represent the ultimate goal, but provides a step in the right direction. Reducing risks and impacts of COCs, as opposed to their outright replacement, may be an acceptable compromise.

The cost of a green chemical is likely to be higher initially than that of the status quo. Timetables for step change economic improvements can be established. Suppliers and customers can negotiate a short term plan for absorbing or passing along the increase in cost. The performance of a green product may not be identical to that of the status quo. Key performance parameters and expectations can be defined to satisfy all parties and avoid consumer push-back.

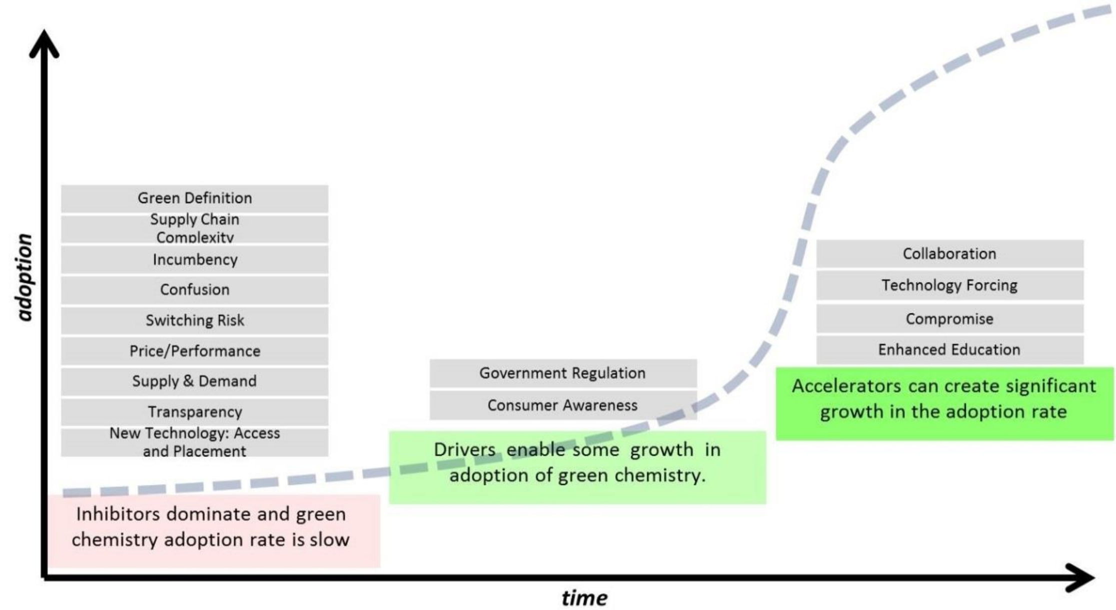
Easing of other business standards is a compromise to fuel the growth of the green chemistry products: inventory turns, supply terms, etc.

4. Enhanced Education

Educated, informed and impassioned consumers can fuel the growth of green chemistry. The easiest way to accelerate the availability and adoption of green chemistry is to start with a green chemistry design by way of an educated work-force. Consumer facing companies can help drive growth by educating consumers about green chemistry.

Applying the four accelerators in a Cooperative 5-forces model can help to diffuse the supply chain inhibitors and fuel the availability and adoption of green chemistry.

ES Figure VI: S - Curve Model of Green Chemistry Adoption



Advancing Green Chemistry:
Barriers & Ways to Accelerate Green Chemistry in Supply Chains

I. INTRODUCTION

A. Background and Project Goal

There continues to be a growing interest and awareness in green chemistry. There are successful cases of adoption of safer alternatives, and scaling of supply, in response to demands from regulators and customers. However, overall progress is slow, measured in decades.

Numerous chemicals of concern (COC's) have been identified: chemicals that are under regulatory or market pressures due to emerging science or consumer concerns. Many of these COCs, which are considered by many to be in need of phasing-out, are still widely used today.

The Green Chemistry & Commerce Council (GC3) commissioned T. Fennelly & Associates, Inc. (TFA) to study factors encouraging and inhibiting broad adoption and large scale use of green chemistry innovations. TFA is a consulting firm focused on helping clients with value creation and market access in the renewable and traditional chemical industry (see Appendix VII).

TFA spoke with leading industry experts and seasoned professionals on the subject. Many chemicals and product categories were screened. Three specific COC s were selected for case study review: Bisphenol A, Formaldehyde and Phthalates. Detailed learnings from those cases were developed as a basis for subsequent research and analysis. TFA utilized the research to identify key barriers, drivers and elements needed to accelerate the market availability and adoption of safer, greener chemistry.

B. Project Objectives

1. Provide insight on why green chemistry and/or safer alternatives do or do not reach scale, displacing chemicals of concern.
2. Identify the role of market forces, incentives, policies, and other factors.
3. Profile three chemicals of concern, where efforts to build demand have or have not worked and identify lessons learned.
4. Outline the elements that can inform the development of a customer or market pull/supply partnership project.

C. Project Methodology

In order to select the 3 COC's to profile, TFA began the project by compiling a list of 33 potential chemicals and/or market segments that are currently being considered for market or regulatory restrictions. A number of relevant, non-chemical examples were included that showed a migration towards more sustainable solutions. These helped to provide a broader perspective on how industrial "greening" practices can occur. After discussion, TFA and principles of GC3 selected 13 of the 33 for brief review.

13 Cases for Mini-Profile and Ranking		
Phthalates Phosphates Halogenated Flame Retardants Arsenic	Tributyl Tin Isothiazalone Dyes & Pigments Lubes/Greases	Polystyrene Bisphenol A (BPA) Formaldehyde VOC Solvents for Cleaning Organic Cotton

TFA prepared a high level profile of the 13 cases that described the following:

- Sector
- Description
- Drivers
- Key Issues/Barriers
- Progress
- Potential for lessons learned

Finally, using co-developed criteria, TFA and the GC3 selected the three chemicals for case study research: Phthalates, BPA and Formaldehyde.

D. Research Methods

Data for this project were gathered from secondary and primary industry sources. All work was conducted by experienced chemical industry and supply chain personnel.

Secondary Research

TFA utilized secondary data sources for background to profile and analyze chemical case studies and as background for subsequent personal interviews.

Secondary Sources Utilized		
Trade journals Published research Industry/trade organizations	Government documents Annual reports Internet sources	Subscription databases Non-confidential TFA files

Primary Research

Direct interviewing of industry participants was conducted throughout the study. TFA relied on this information to a great extent to ensure the quality and reliability of the secondary research and to obtain specific information critical to the GC3. Interview questionnaires were designed to meet the objectives of this study and provide flexibility to obtain additional relevant information. Individual respondents' identities and responses were kept confidential.

TFA started the interviewing process by speaking with a number of GC3 member companies to discuss company experiences regarding green chemistry. The remaining interviews were used to flesh out the case studies and solidify findings.

The following table depicts the number of interviews completed:

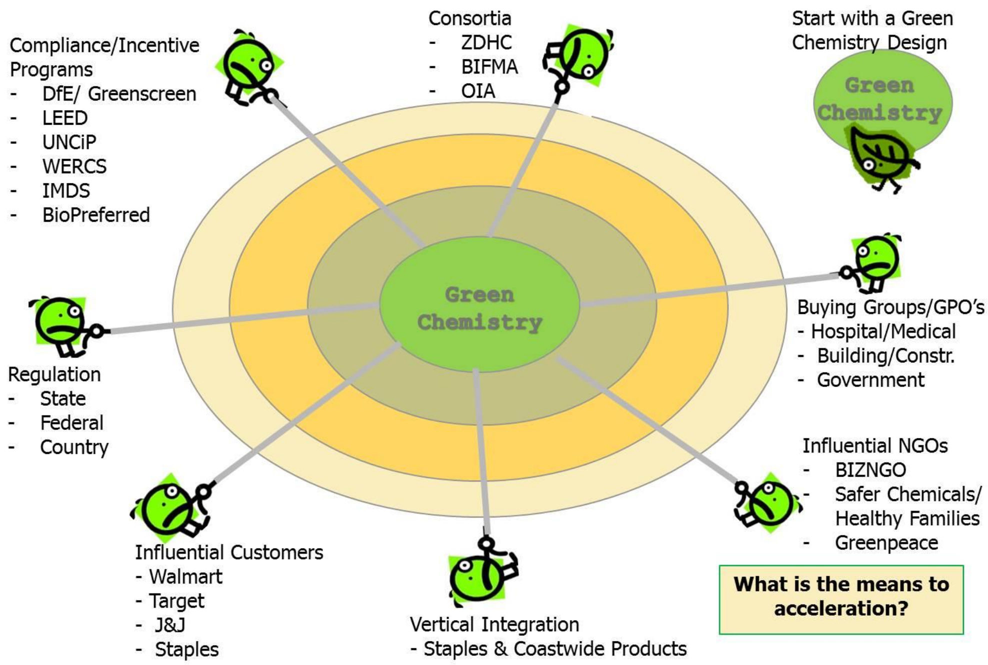
Primary Research	**Calls Completed** Total = 49	**Sampling of Interviewee Titles**
GC3 Member Companies	8	• Director of R&D • Marketing Manager • Program Leader Sustainability • Air Pollution Specialist • Executive VP • CEO • Senior Toxicologist • Director of Sustainability • Chief Sustainability Engineer
Green Chemistry Suppliers	14	
Formulators/Fabricators	11	
Regulatory Experts	6	
Certification Organizations	6	
Industry Experts/Trade Groups	3	
Other Brand Owners/Retailers	1	

II. FACTORS INHIBITING ADOPTION OF GREEN CHEMISTRY

A. Situation Analysis

Despite efforts from many stakeholders to accelerate green chemistry use, including those shown on the accompanying figure, adoption rates remain low.

Figure I: Current Green Chemistry Efforts



These multiple stakeholder efforts to drive the growth of green chemistry have been slow. So, when there are green chemistry alternatives available

- Why aren't more green chemicals in use?
- What are the barriers?
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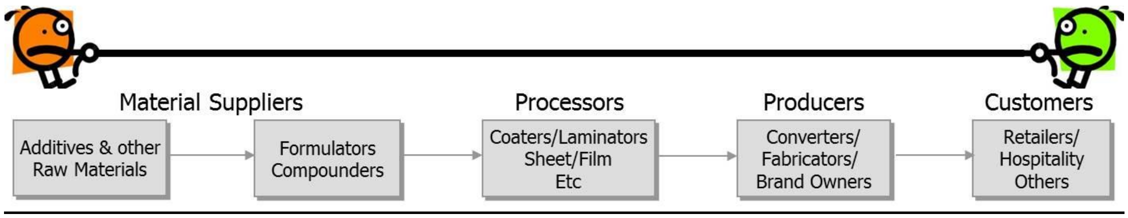
In the course of undertaking this project and answering these questions, TFA has considered the entire supply chain from chemicals to processors to fabricators and through to finished products both industrial and consumer. TFA identified major drivers and deterrents to growth. The complexity of supply chains is enormous, consisting of thousands of chemicals formulated into literally millions of products. This complexity inherently creates barriers.

Each position in the supply chain provides a different a viewpoint for companies. This is true about many things including green chemistry.

Figure II: Supply Chain Positioning Produces Different Vantage Points – Often at Odds



Complex supply chains are connected and woven together with established incumbents. They have developed an optimized and entrenched infrastructure, strong supplier-customer relationships and mature cost positions. As such, the supply chains already have what can be defined as high degrees of internal "alignment". The alignment is a balance of an efficient operating infrastructure within the supply chain. Green chemistries typically upset that alignment. Customer needs are multifaceted at each stage and may resist or not support the demand for green chemistry coming from other points in the chain. A change at one point in the chain may disrupt the established flow and practices of the rest of the chain. For example, a change from a phthalate plasticizer to a new non-phthalate may require a change in processing time, temperature and equipment. If the material is part of a foam layer, it may have different adhesion properties; this could require a change in adhesives and coatings. The final product may have different densities, requiring new packaging, shipment terms, etc. Understanding supply chain positioning/alignment and the implications of change at each point in the supply chain is critical in successful invention, modification, flow and adoption of green chemistry.

These issues can be called simply Supply Chain Misalignments. TFA has concluded that addressing these is required for the successful flow of green chemistry. Nine significant supply chain alignment issues were identified:

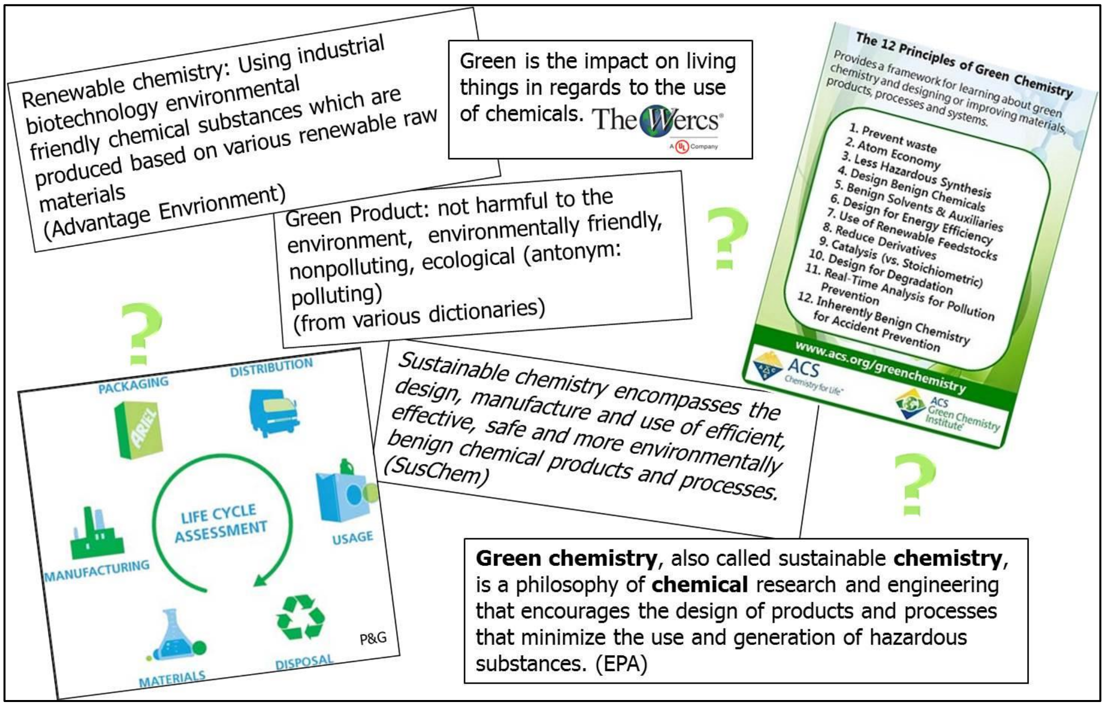
1. Defining Green Chemistry
2. Complexity of Supply Chains
3. Incumbency
4. Confusion
5. Switching Risk
6. Price/Performance
7. Supply & Demand
8. Transparency
9. New Technology: Access and Placement

These are not in order of priority. In interview feedback, Price/performance was cited most often as a barrier to the adoption and flow of green chemistry. However, these alignment issues are inherently linked.

B. Defining Green Chemistry

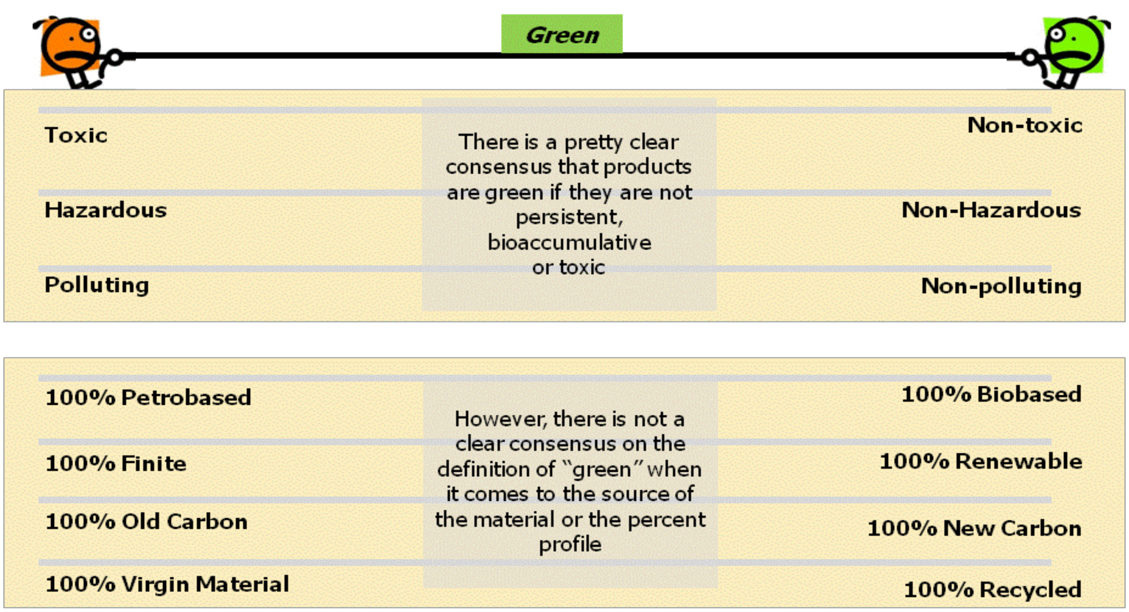
Lack of agreement on how to define "Green Chemistry" can be a hindrance to green chemistry flow and adoption. Although often overlapping, there are many definitions for "green chemistry" in the marketplace.

igure III: Varying Definitions of Green Chemistry



There are no universal metrics for green chemistry. Metrics vary by industry and by company. For example, one company will define green chemistry products as those that are "safer". Another company will define green chmistry as products that are renewable and biobased. Even these metrics are unclear. If products are biobased, must the product be 100% biobased? How much is enough?

Figure IV: What is Green?



Interviewee Feedback on "How do you define Green Chemistry":
"12 principles of green chemistry although renewable may or may not be part of it. Is it taking food off the table?"

"Need to have a perspective on what you are using, when and where. Is it a solvent used to remove benzene from the ground or one to put in a hospital cleaning formulation?"

"Chemicals that don't adversely impact health"

"Green Chemistry is products that are not PBT (persistent, bio-accumulative and toxic)."

"A product that is derived in some percent from plant based renewable feed-stocks, environmentally friendly and does not degrade into bad actors."

Additional Interviewee Feedback on the definition of green chemistry

"Product rating methodologies are flawed and biased. They use a petroleum based lens that has altered the view for novel non-petroleum based technologies."

"A leading polymer producer markets their material as a biopolymer: <40% is bio-derived, >60% is petroleum based. Is this green?"

"Our customer, a fabricator of automotive aftermarket products, said that a retailer wanted more environmentally sound products. We bid with a non-phthalate, non-halogen stabilizer compound. We lost the bid due to price. We analyzed the winning bid product. It was more "environmentally sound" in that it was made from 100% recycled material. However the material was recycled wire & cable jacketing from China which was loaded with DOP phthalates and heavy metals."

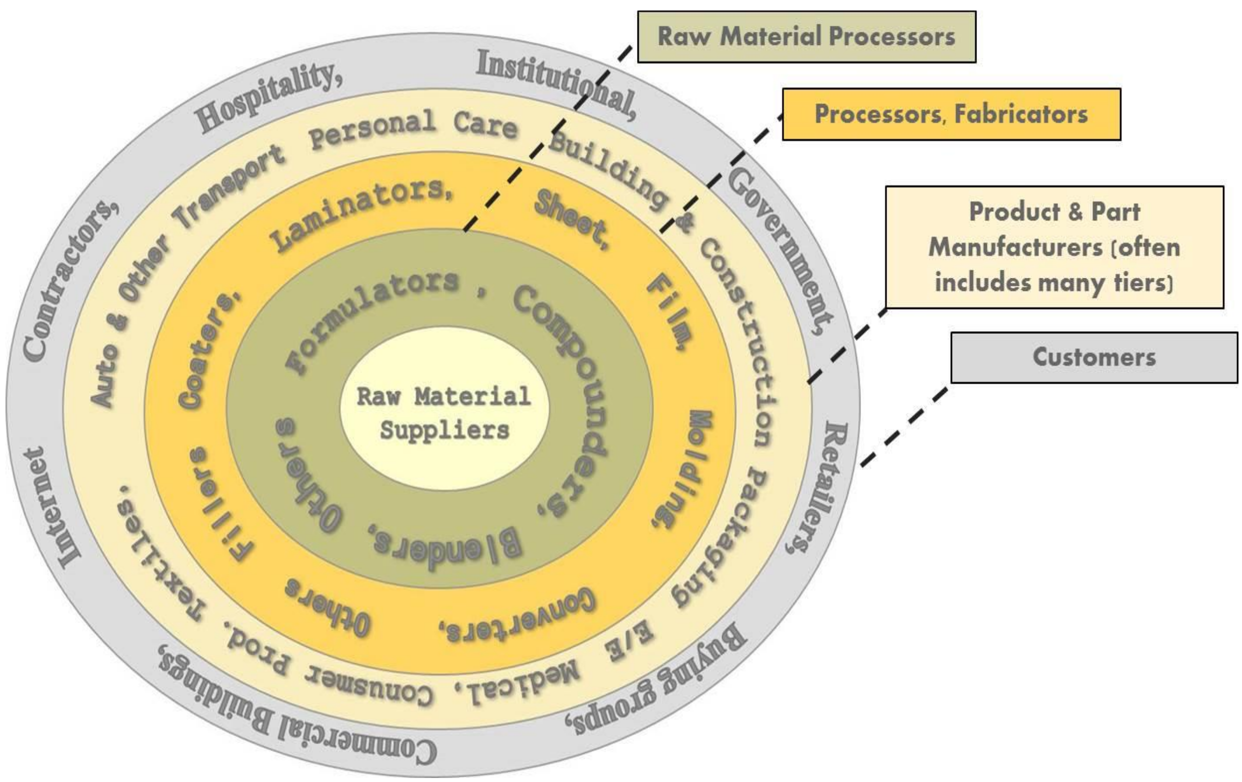
Key take-aways on defining "green chemistry":

1. It isn't essential to pick a "right" definition for green chemistry. It is essential to be on the same page.
2. When starting a discussion, ask "How do you define Green Chemistry" ?
3. Coherent dialogue requires a common defintion of green chemistry. Without this, discussions, messages, and conclusions can and will be misinterpreted.

C. Complexity of Supply Chains

Complex supply chains hinder shifts to new and often safer materials. Material suppliers must respond to a diverse and complex set of needs, requirements, qualifications and demands for their products for the many different applications and end-use markets. Conversely, many final customers like mass retailers must traverse a complex supply chain for the wide array of products on their shelves. Additionally all must conform to industry requirements, standards, regulations and customer perceptions and demands.

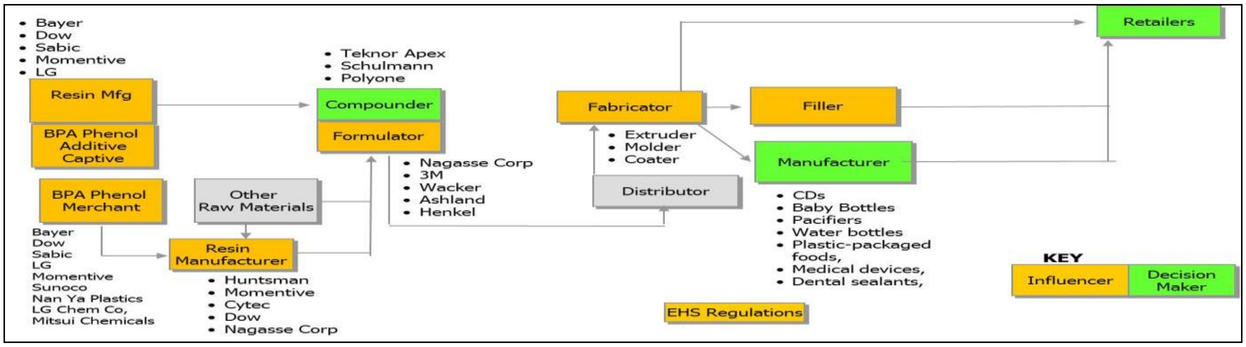
Figure V: Moving Tiers of Complex Supply Chains



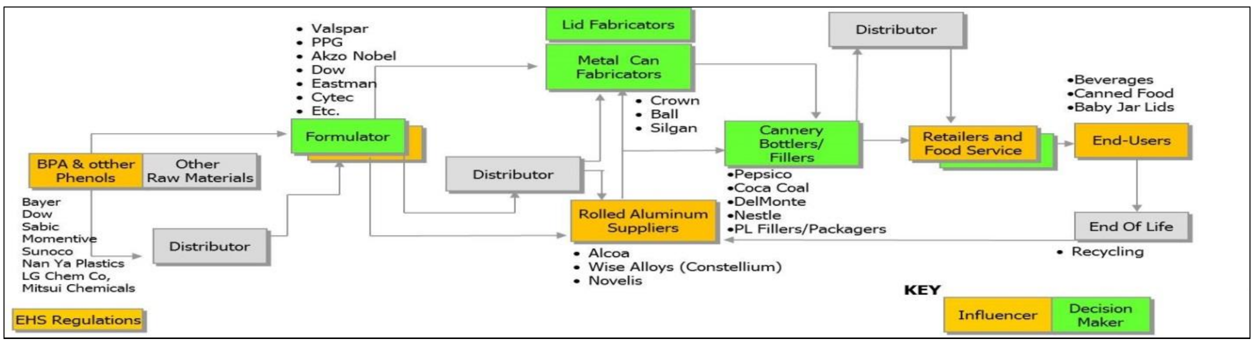
BPA is one of the three COC cases reviewed for this work. BPA is used as an intermediate in ETP (engineering thermoplastic) production for polycarbonate (PC) and structural epoxy thermoset resins; as an intermediate in epoxy coatings and as an additive in developers used in thermal receipts. Each supply chain is different than the others, with a complex network of varying participants (sellers, buyers, and distributors), influencers and decision makers.

Figure VI: BPA Multiple Complex Supply Chains

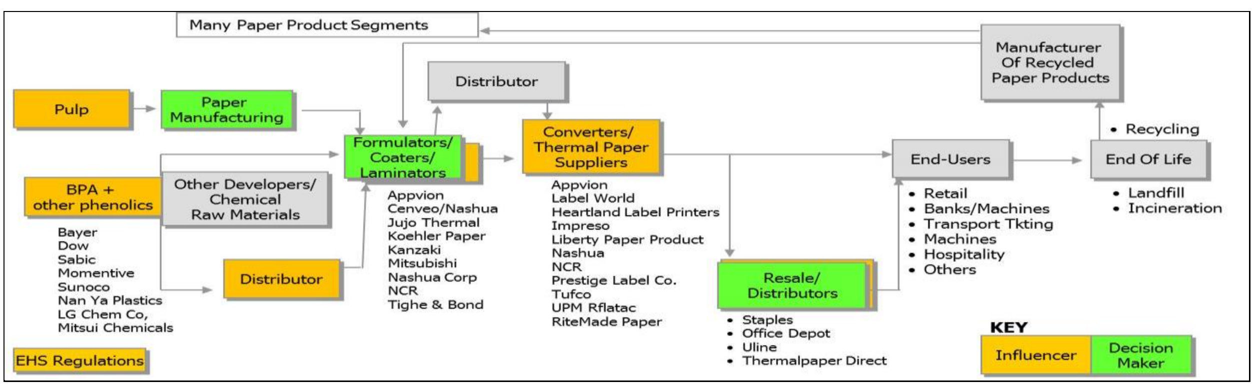
Supply Chain: BPA Resin Intermediate



Supply Chain: BPA Epoxy Can Coating



Supply Chain: BPA Thermal Receipts



Interviewee Feedback on Complex Supply Chains:
"Choose carefully - complex supply chains are aligned; steps are connected; a change in one point of the chain can impact supply dynamics in other parts in the chain."

"Need to strengthen the communication in the middle of the chain. It is very difficult to get materials through. The processors are resistant. "

"Footwear and apparel are archaic industries. The supply chain is very complex and doesn't lend itself to change. When it happens, change is slow. "

"Processors/fabricators have investment in capital equipment that may not work with the new materials/innovation. Re-training is costly too."

"Understand how the products/processes are connected and the channels are woven together."

"Supply chains have always been complex, but now they are more complex with the retailers actively involved, trying to offer what is right for the consumer."

Key take-aways on supply chain complexity:

1. Each supply chain position has its own vantage point, a different viewpoint from others in the chain. Working to understand the complexities and challenges that each set of stakeholders face in the supply chain can improve communication and eventual flow of green chemistry.
2. Complex supply chains create fragmentation of demand by application, volume, specification, customer expectation, geography, etc.
3. Suppliers and customers must be knowledgeable about and work with many different supply chains.
4. In complex supply chains, demand for new innovative technologies is diffuse. This challenges the development and adoption of these innovative new technologies
5. Processors, formulators, part manufacturers and other intermediates in the supply chain often block or cloud communication flow in the channel.
6. Complex supply chains are aligned. Steps are connected. A change in one point of the chain can impact supply dynamics at other points in the chain.

D. Incumbency

The chemical industry is anchored by multi-billion dollar petroleum-based incumbent companies that have built global capabilities. Many have integrated raw material streams and products with optimized and proven process economics, well-understood product performance data, market expertise and established customers. They know how to compete globally. They have multiple production sources for the same product. They have global regulatory registrations. Some capitalize on their country's natural resources, low labor costs and government subsidies or ownership.

Customers know their suppliers and the supply chain. Strong working relationships have been established at many points in the chain: Tier 1, Tier 2, Tier 3 and in some cases back to the raw material supplier.

This infrastructure is a challenge for all new entrants, green or not, to compete with the established supply chain. However, green chemistry has some added challenges such as confusion, risk, price/performance, supply & demand, transparency and access and placement of new technology, which are described below.

Interviewee Feedback on Incumbency:

"Choose segments where you can effect a change. It is an uphill battle to get vertically integrated producers to change." (I.e. particle board producers who harvest wood and also make formaldehyde based binders; polycarbonate producers who produce their own BPA)

"Over 11B lbs. of phthalates are used globally in PVC compounds. "New plasticizer suppliers can't bring us the volume we need globally, price/performance and knowledge of our performance profile."

"A new supplier can't offer us consistent quality volume fast enough or guarantee more than one source."

"PC and epoxy are performance polymers that we can source globally. They have the price/performance profile we need. There are no effective alternatives today and most applications are not concerned about BPA as a production intermediate."

"The overhead is very costly to bring new green chemistry products to market. The incumbents have no incentive to change this. It keeps competition out of the market."

"The existing infrastructure is so efficient that it is hard for new entrants or technologies to catch up. It will take time and often the customers are not willing to wait."

"Large incumbents have the infrastructure, process tweaked, volumes/scale and cost advantage. Green chemistry needs to do some serious economic landscaping to compete with incumbent supply and economics."

Key take-aways on incumbency

1. Incumbency creates enormous barriers to change, barriers include
   a. Entrenched supplier-customer relationships
   b. Low costs, generally facilitated by large scale production and logistical efficiencies
   c. Low total cost of ownership which may be facilitated by manufacturing equipment optimized for the incumbent product
   d. Availability of multiple suppliers and sources that creates price competition and lowers risks of shortages

2. Incumbents will generally resist change out of self-interest. Incumbents don't want their assets to become obsolete.

E. Confusion

Although the term "toxic chemical" produces a universal reaction of "bad", conflicting campaigns are producing widespread confusion about what specific chemicals fall into that category. This uncertainty and confusion has slowed and stalled the adoption of green chemistry.

BPA is an example of this uncertainty. BPA is used in such diverse applications as

- An intermediate in the production of polycarbonate engineering thermoplastics and epoxy thermoset resins
- An intermediate in the production of coatings like food can coatings
- A developer for thermal retail receipts and tickets

Chemically, BPA resembles synthetic estrogen and there is concern that BPA is an endocrine system disruptor. There is a deeply divisive tug-of-war going on today regarding the safety of BPA and BPA substitutes:

- **Studies & Research:** Conflicting safety information has clouded and confused the industry. There are hundreds of toxicological studies and research with diverging results regarding its link to cancer, heart and kidney disease, prenatal development and behavioral disorders.

- **Policy:** There has been a large international and national movement to restrict BPA from baby bottles and children's products, in large part driven by consumer demand. However, the US FDA recently declared that "at current levels of exposure"[1] BPA is safe in all other food packaging. As of January 2015, France banned the use of BPA from food packaging and thermal receipts[2]. But, in January 2015, EFSA (European Food Safety Authority) published its latest comprehensive re-evaluation of BPA[3]. They concluded that exposure and toxicity from BPA poses no health risk to consumers of any age group (including unborn children, infants and adolescents) at current exposure levels.

- **Rigorous Lobbying** for and against BPA's safety and use are clouding and confusing the market.
  - Against Restrictions: American Chemistry Council (ACC) and their website FactsAboutBPA.org, Bisphenol A REACH Consortium, Grocery Manufacturers Association (GMA), North American Metal Packaging Alliance (NAMPA) and others
  - For Restrictions: Japan Metal Industry, American Medical Association, certain brand manufacturers, Healthy Hospitals, other environmental and consumer health NGO's

- **Viable technology and Cost/Performance Substitutes** have not yet been clearly identified:
  - EPA DfE conducted an alternative assessment to BPA for thermal receipts which did not identify clear options as thermal developer substitutes.
  - Infrastructure of thermal printing machines makes replacing with a non-thermal technology cost prohibitive.
  - Polycarbonate and epoxy are work-horse polymers that the industry is reluctant to change.

In another example, there is confusion created by the rigid rating methodologies of some programs. TFA heard from a number of green chemistry interviewees that there is a concern that programs like EPA's Design for Environment Program (DfE), now called Safer Choice, can do more harm to a new technology than good by labeling a type of new green chemistry as a potential hazard based on historical petrochemical data. Interviewees described receiving a Yellow triangle by default based on a chemical functionality. ("The chemical has met DfE criteria for its functional ingredient-class, but has some hazard profile issues."[4])

Interviewee Feedback on Confusion:
"Conflicting toxicology reports & conflicting legislation keeps the industry and those consuming confused. "

"Very partisan and absurd conclusions are drawn by conflicting sides. This confuses everyone in the chain. "

"Consumers have been asking us about epoxy powder coating on our products and exposure to BPA. There Is BPA at the surface and it can come off. We are trying to understand the risk."

"It is not black and white. Hospitals started banning BPA, but it is used in eyeglasses, medical equipment, DVDs, etc. Customers were not willing to give these up, so they went back and relaxed the standards for these areas of less concern."

"The industry is switching to DOTP which is a terephthalate. Isn't that still a phthalate?"

Key take-aways on confusion

1. Conflicting information continues to confuse the industry.
2. Stakeholders are at times grid-locked, not making a change due to uncertainty about the status quo.

F. Switching Risk

There is concern that switching to green chemistry alternatives could lead to market failures such as poor performance, brand tarnishing and other hidden costs such as process or equipment or process changes, material incompatibility, workforce training, customer education and others.
For example:

- A PVC blood tube manufacturer switched to a citrate plasticizer from the phthalate plasticizer; the high migration of the citrate caused the adhesive on the tube clamp to fail.
- A furniture manufacturer substituted traditional fiberboard with a green board to eliminate formaldehyde based binders. When laminated, the green board had inferior impact resistance and dented when heavy objects were placed on it.
- PepsiCo took a chance making their Sun Chip bag with a compostable biopolymer. The brand took a hit when the public pushed back on the "noise" of the bag.
- A metal cleaning operator switched to a greener solvent option, but found that throughput was significantly slowed due to longer dry times.

There is also the risk of adopting a "better bad". Those who switched from DOP to DINP plasticizer are finding they must now switch out of DINP for similar toxicology concerns. Similarly, those who switched to Bisphenol S from Bisphenol A have found there is little toxicological profile improvement.

Interviewee Feedback on Switching Risk
"We asked our supplier to take toluene and other VOC's out of the adhesives for our products. The supplier chose water based system for the construction, but used THF (a known carcinogen)."

"There is always the danger of impacting a product. No one wants to tarnish their brand."

"We are cautious about switching to a non BPA ink developer. We don't want to choose a 'better bad'."

"Big consumer products companies want green, but are very cautious. If they are first in and the supply/technology is a "flash in the pan" they are compromised. The large players are looking for a guarantee of supply longevity to make the switching costs worthwhile. This has slowed adoption."

"We switched away from the DOP plasticizer to DINP. Now DINP is on Prop. 65. "

"For 80 years the industry has formulated in one way and now they are being asked to change. There is a resistance due to the costs, requalifications and potential failure."

Key take-aways on switching risk

1. Stakeholders are cautious to make sure they have the information needed to make sound chemical management decisions.
2. No one wants to adopt a "better bad" or introduce a greener product that fails due to switching risks.
3. This slows the marketplace's drive toward greener chemistries.

G. Price/Performance

Typically a new entrant or new technology introduction is driven by some improvement in price/performance, e.g.:

- Better heat performance, scratch resistance, easier to fabricate, better impact resistance, reduction in processing steps, cheaper raw material stream, regional availability, volume economics, etc.

In contrast, the drive for "green chemistry" is often aimed at displacing a current technology that is working well. The new products may have a better EHS profile, but often are inferior in performance or higher cost. There are added switching costs beyond the price/lb. such as cost-in-use, customer re-qualifications, changes in formulation, changes or investment in processing equipment, throughput, etc. Many of the target products being replaced are commodity materials. Even though long term cost profiles may in fact be better (reduction in hazard handling, disposal costs, intangible benefits like reduced toxic exposure) this can be a harder "sell" as a replacement for the optimized volume-ready commodity.

Although large retailers and brand owners are pushing for green chemistry, there continues to be limited willingness to accept any change in price/performance.

Interviewee Feedback on Price/Performance

"The biggest issue with green chemistry development is a lack of viable alternatives that have the necessary cost/performance."

"We find that the greener products are either poorer performance and/or higher price and the market can't sustain this. It is getting worse with the low oil prices."

"There are not any plasticizers that have the price performance profile of phthalates. This is the biggest reason why there has not been more growth in replacing phthalates with bio plasticizers."

"We haven't been able to eliminate formaldehyde due to cost/performance. The formaldehyde free panels don't have the impact resistance needed."

"There are often savings in using green chemistry: reduction in hazardous disposal, reduction in recovery equipment, water treatment, handling concerns and others. However this total cost solution is a tough to quantify for customers focused on $/lb."

"Even at price/performance parity, selecting a new material is costly: requalification, lab costs, certification costs, processing and equipment changes, training, etc."

"Performance is first; EH&S is next and then sustainable is a nice add-on."

"Retailers act schizophrenic. In one breath they say they want green and in another they want cost/performance and supply parity."

"New materials are not drop-in replacements: UV stability, migration, smell, color and other factors can change the production process and final product performance."

"Many of the biobased solutions are not as good and are $1-$2 more per pound."

"Our customers don't want to pay more. If there were a cost/performance solution out there, we would use it to make formaldehyde-free binders."

"Our new material for cleaners was not a drop in replacement. The product wasn't moving. We discovered that formulators needed formulation suggestions for their micro-emulsions."

Large retailers:
"Say they want a greener product but won't budge on price. Consumers are the same way."

"Green is not their priority- price is"

"When we delivered the requested green solution for a lawn and garden product to our customer (a large retailer), they rejected it in favor of the lower priced phthalate plasticized PVC product."

"The sustainability panels within large retailers work to drive new technology and sustainable solutions. Then the sourcing agents turn the alternative products away because of price. There needs to be alignment and communication within the organization."

"Everyone wants to do the right thing, but we can't be altruistic. Sustainability must be affordable. We are all financially driven. "

"Larger wood companies have stuck with UF because of the speed of curing polyvinyl acetate increased curing time costs too much for large scale wood board production."

Key take-aways on price/performance

- Price/performance was the most cited reason for the slow adoption of green chemistry
- Significant degradation in performance is unacceptable in most cases. On the other hand, there may be room for some compromise on price and performance.
- Often there are savings in a total cost analysis such as reduced hazardous waste handling and disposal. This can be hard to quantify for customers focused on $/lb. pricing.
- Entrenched COC's have set the standard for price/performance.
  - Change will continue to be slow without leadership, a game-changer or catalyst.

H. Supply & Demand

New technology supply and demand is a "chicken and egg" dilemma. New chemical plant investments take years and may cost hundreds of millions of dollars. Material suppliers often find there is not enough real or perceived demand to justify the investment. Conversely, producers and customers expect a new technology to ramp quickly, perform seamlessly, be available from more than one source and meet large volume needs. Uncertain supply and demand commitments can jeopardize timing and investment in the supply, thus slowing the availability of and adoption of green chemistry. These lower volumes mean poor economies of scale that inhibit cost competitiveness with incumbent solutions.

Material suppliers must identify, qualify and quantify the demand needed to invest in new material production, while getting management buy-in and meeting return on investment needs. Often a new technology will require step change improvements, quality modifications and staggered investment to reach scale. Building scale is costly with product development and commercialization costs, environmental and compliance testing and regulatory registrations like TSCA and REACH.

Processors and producers are key to building demand and are often reluctant to change due to concern of sole sourcing and limited or lack of global supply. Incurring transition costs and requalification costs for a source that may not grow is risky. Once the new product is approved or qualified, the fabricators and customers are often impatient at the slow growth of a supply infrastructure and products.

Interviewee Feedback on Supply & Demand

"The products have not delivered the hope of more stable supply and price. Fluctuating price and availability of crops for biobased products have plagued the industry."

"We need millions of pounds of plasticizer for each application. This is a big hurdle for new technology plasticizers. We must have that and a qualified 2nd and 3rd source."

"Finding innovation partners who can provide product globally is difficult"

"New technology coming out of universities takes a long time to commercialize and become a viable supply."

"The new thermal paper is 20% more expensive. The price will come down when we scale, but we need the demand."

"Often the new biobased products also have issues with their starting raw material supply. Without a supply of cost effective raw materials, biobased products will struggle to make headway."

"Often new green chemistry technologies don't have the supply, can't get the funding to build the plant or the process economics don't work. They end up not producing as promised or go out of business. We spend a lot of time and money to test and go through all the hoops to get the new technology to work with a zero outcome."

"Price and commitment to build a new chemical plant is huge. It is a 'trickle-up' demand: build a $600MM plant and then get the sales. This is risky."

"We need to have volume and reliability of supply. The green chemistry feedstock source and production has not caught up."

"Volume and availability are crucial. We cannot switch materials until it is there."

"Customers are reluctant to commit to a new supply that may not grow or may close down."

Key take-aways on supply & demand

1. There is often not enough real or perceived demand to make increased production worth the investment.
2. Stakeholders are cautious to move forward to commit to demand or to commit to supply.
3. Supply infrastructure growth will be slow without compromise and collaboration during the planning process and mutual long-term corporate commitments.
4. Strong partnerships can ensure this occurs.
    - For a sustainable partnership, both parties must see a win/win.

I. Transparency

Transparency includes the full disclosure (visibility) of all ingredients in a finished product. Demanding transparency can stifle innovation. Blocking transparency can create concern and potential liability for the unknown ingredient. It can slow industry acceptance especially in segments or programs requiring transparency. This "us vs. them" struggle has slowed the flow and adoption of green chemistry.

Material suppliers are striving to meet the demands for innovation, greener supply and transparency. Often the need to protect IP and/or Trade Secrets is critical in the positioning and availability of new technology. Releasing this information too early can result in

- Loss to low-cost imports & technology knock-offs
- Loss to large competitors that blanket patent around the new IP and tie up commercialization
- Loss from costly IP battles with larger corporations to defend the new technology
- Loss of competitive position when trade secret formulations are made public

Product manufacturers, consortiums and retail customers are driving transparency. The critical need is to mitigate the risk in handling or selling products with unknown ingredients that could be COCs. They need transparency to

- Eliminate chemicals that can harm human health and environment.
- Identify chemicals that might introduce liability and/or tarnish brand and company image. This also includes avoiding product recalls or disruption in supply and distribution.
- Respond to consumers' demands -"right to know".
- Comply with EHS standards both from a safety standpoint and to meet the global, complex and changing legislation landscape. California Air Resources Board (CARB) and Prop 65 are really driving this in the US.

This need for transparency has fueled a growth in stakeholders issuing mandates based on restricted substances lists or incentives for purchasing or product placement. Some examples include

- Brand Owner Transparency Programs: Nike, Apple, Patagonia, Google and others
- Conventional Trade Organizations Driving Transparency: BIFMA, OIA
- Industry Groups formed to drive Green Chemistry & Transparency: ZDHC, Healthy Hospitals, Bluesign, Personal Care Products Council, Sustainable Packaging Coalition, US Green Building Council (HPDs and EPDs) , others
- Retailer Driven Transparency: Wal-Mart's "Corporate Chemical Policy" and Private Brand DfE (Safer Choice) labeling , Target's "Sustainable Product Standard", others
- Certification Procedures/Databases/Organizations Driving Transparency: Green : GreenScreen from NGO Clean Product Action, Pharos(Building & Construction material evaluation), C2C (Cradle to Cradle)Product Standards, WERCs (GreenWercs, SmartWercs) (assesses formulation chemicals), CleanGredients (from DfE), LEED, Material IQ (via Greenblue), IMDS (Material Data System for Automotive Materials), INCI (Cosmetic Ingredients), Leather Working Group, others
- Government Transparency Programs: Safer Choice, California Safer Consumer Products Legislation, others

These many programs often require different certification procedures, disclosure mandates and testing requirements. Identifying which certifications to pursue and obtain is a costly and time consuming process for suppliers.

In an effort to protect IP and trade secrets, material suppliers have required CDAs (Confidential Disclosure Agreements), MTAs (Material Transfer Agreements) and 3rd party testing or certifications. When programs mandate disclosure, new innovations and technology introduction can be slower as companies look to commercialize in areas that don't require disclosure.

Interviewee Feedback on Transparency Issues

"Emphasis on secrecy is overdone. There's a need for willing partners to get technology out without feeling threatened."

"It is very hard to collaborate with material suppliers. They play the competitor game and will not be transparent. "

"IP is our bread and butter. We try to patent and protect as much as we can, but sometimes a "recipe" is required and we must decide whether to reveal or not. Often certifications ask for our formulae and it can be a problem."

"The demand for transparency is making it hard to survive in the market. Big incumbents are predators. They enter the space and blanket patent and price around our patents and trade secrets. This places a block on the market. It makes it very tough and takes value out of the market."

"We want transparency, but even NDA's with customers don't always work. Customers often don't know everything in their formulations. "

"We go all the way up the line: Tier 1, 2, 3 to the raw material supplier and demand full formulation ingredient disclosure. A high percent will not disclose even under NDA."

"The new CARB requirements are killing us. The 2013 Consumer and Commercial Products Survey compliance date is March 1, 2015. We must report detailed revenue data and formulation information. There is a box to check to keep the information confidential, but the industry is very worried."

"Fragrances are an issue. We don't always know what is in the fragrance formulation going into our products."

"Tests found high levels of formaldehyde in children's clothing from major apparel brands. The levels exceeded industry standards and were not approved by the brand owner. There is an issue with policing the products, even when transparency is in place."

"China has posed problems for us. We have clear ingredient and COC restriction lists, but the restricted chemicals still show up in the products - example: hexavalent chromium. It is very hard to monitor and regulate."

"As a fabricator, we need to eliminate COC's for our product disclosures to our retail customers. Even with NDA's our suppliers don't know the exact ingredients in the formulation."

"Since The Healthy Hospital Initiative, we are getting 1-2 requests/week for transparency in ingredients."

Key take-aways on transparency

1. More transparency is occurring, much by force.
   a. Suppliers are looking for ways to satisfy customer demands while protecting IP and trade secrets. This can result in slower new technology offerings as companies wait to secure IP.
   b. Customers are skeptical of the chemical industry's reluctance to be open and transparent.
2. Transparency conformance and certification programs and agencies abound. This is a costly and time consuming process for suppliers.
   a. Each market has its own NGO/agency or certification requirements – often more than one.

J. New Technology: Access and Placement

Finding and vetting green chemistry materials remains a weak link. Material suppliers struggle to identify early adopters. Customers struggle on where to look for new solutions beyond the traditional supply chain. An additional blockage is the conventional level of secrecy within the supply chain among formulators, compounders and processors (outlined above as a lack of transparency). This search for and identification of a home for new technology can be hit or miss and slows the flow and adoption of green chemistry.

New material suppliers often have limited access to a mature supply chain. Truly new technologies within an existing company can have a slow start, dwarfed by base business or outside current target markets. In both cases these companies struggle to:

- Identify markets, segments and segment leaders
- Identify early adopters
- Choose certifications necessary to enter a segment

Customers, formulators/compounders & processors may want alternatives and access to greener products, but they have limited access outside their established supply chain. These companies struggle to:

- Find alternatives outside the existing supply chain.
- Make decisions to add suppliers or products, when corporate objectives to reduce suppliers or qualify suppliers are barriers.
- Understand the viability and relative attractiveness of the options that are out there. (There are hundreds of eco-labels which can create further confusion.)
- Make the right choice. There is a fear of choosing a "better bad". Also there is "Green fatigue" – i.e., a perception that if everything is green, nothing is green.

Interviewee Feedback on Access/Placement of Technology

"We tried to find a sustainable particleboard formaldehyde free product. We used a wheat board from Dow Bioproducts in Canada. The plant closed. We switched to a soy board from Agristrand in Mankato, MN and they closed. It is expensive to test and approve the products, pass them in the field, commercialize and then start over when products become unavailable."

"Finding new technology is a challenge. We are doing more collaboration with individual suppliers and now with a group of major traditional chemical suppliers, but they don't want to collaborate on a real partnership basis. There is difficulty with the investment and reward."

"Finding a place for our new technology can be challenging - especially finding the early adopters."

"We have a hard time finding new technologies. We have the existing supply chain, Dow, DuPont, BASF, but the flow of truly new innovations is slow."

"If we do go with something really new and the company doesn't have the testing capabilities, we incur high costs to test and we are not an R&D company."

"The EPA BPA alternative assessment program did not uncover commercially viable alternatives. Where are the alternatives?"

"We have "partnerships" with our current suppliers and are protective of that. However, they don't have access to some of the newest technology."

"We have a corporate practice of entering into technology collaborations with new suppliers. Our competitors lay in wait to see what we come up with."

"We rely on our current supply chain to bring us innovation. It's not working so well."

"We look to universities, tradeshows, technology scouts, patent filings and our current supply chain for new technology. It is a slow process."

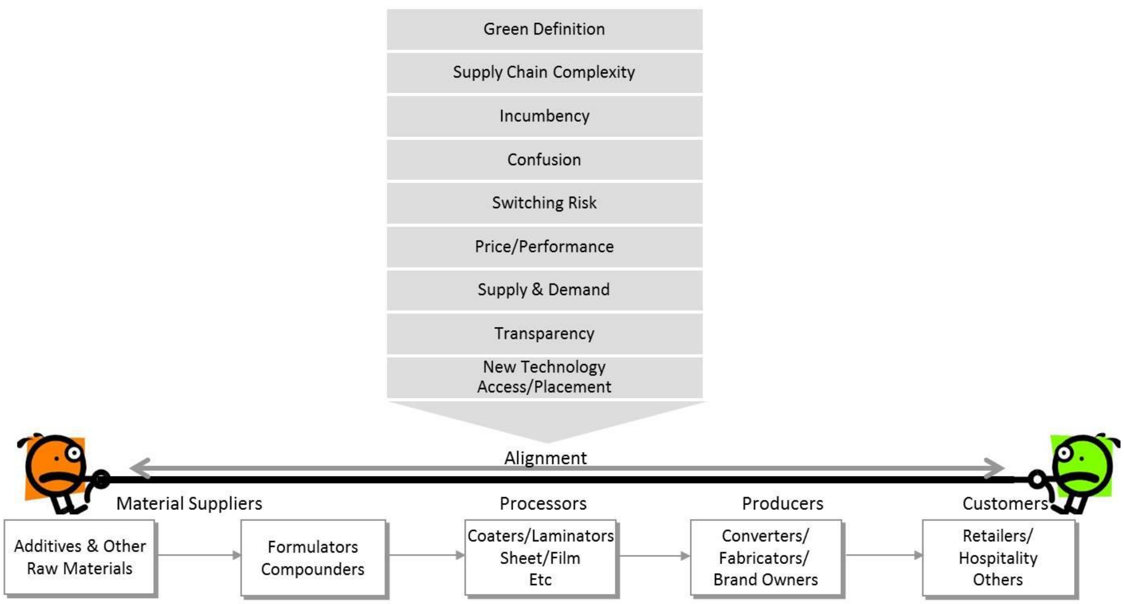
Key take-aways on new technology access and placement

1. Finding and vetting green chemistry technologies remains a weak link.
    a. Suppliers struggle to identify early adopters.
    b. Customers struggle on where to go beyond the traditional supply chain.
2. The flow is slow, but collaborations and other activities are beginning to open up the flow and access to technology.

III. EXISTING DRIVERS FOR CHANGE

The issues that create barriers for broader adoption of green chemistry identified in this report are obvious strong impediments to growth. They can cause misalignment. They have weighed down the flow of new green chemistry adoption.

Figure VII: Nine Issues That Can Misalign Green Chemistry Supply Chains



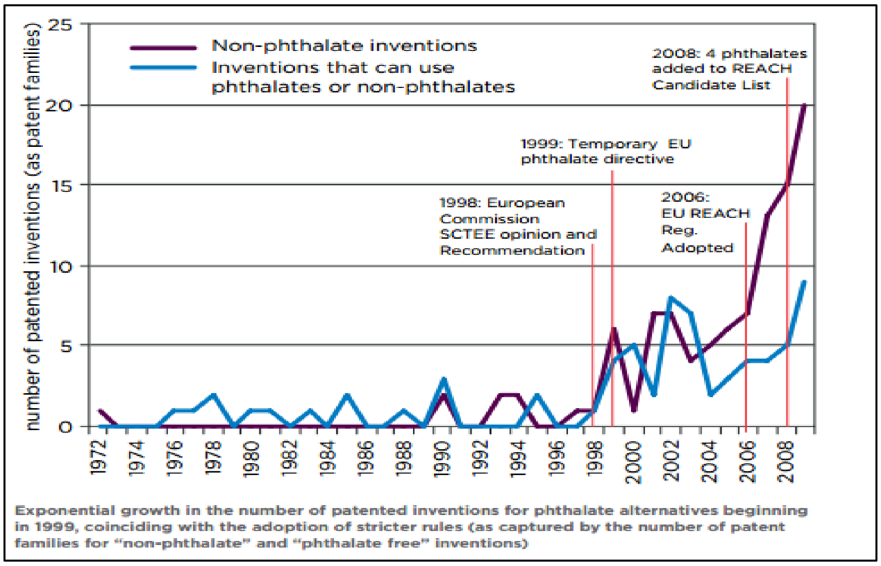
Much of the progress to date can be attributed to two main drivers, Government Regulation and Consumer Awareness. Before evaluating growth accelerators that can be leveraged to create new approaches, it is worthwhile reviewing the existing drivers.

A. Government Regulation

Governmental policies have forced the elimination of certain chemicals of concern, often in specific applications. In other cases they have simply forced reductions to exposure to these chemicals. The U.S. government has also encouraged the use of bio-based products with programs like USDA BioPreferred.

Regulation can drive new technology availability, demand and adoption. In one example from the three subject COCs studied in this project, the Center for International Environmental Law[5] found that there was a spike in patented non-phthalate inventions that correlated with European REACH regulations.

Figure VIII: REACH Phthalate Regulations Correlate with a Spike in Non-phthalate Patents



Source: 2013 Article: Driving Innovation: How stronger laws help bring safer chemicals to market (The Center for International Environmental Law) [5]

In another example, the recent listing of DINP[6] (Diisononyl Phthalate) on California Prop 65 has spurred increased production and demand for non-phthalate plasticizers as reported to TFA during interviews with fabricators.

Although regulations and other government policies (such as purchasing) can drive the development of new chemistries, they can also be a factor in the bottleneck of green chemistry availability. New chemistry triggers new chemical notification and potential regulatory requirements. If the chemical is used as an intermediate in the manufacture of downstream derivatives, this may also trigger new chemical requirements for each of the derivatives. Costly delays due to insufficient models that overestimate hazards can occur. For a new chemistry, particularly from a small company with limited toxicology or regulatory support, this can be challenging.

Regulatory Registration of a New Product:

- In the US, the main law regulating chemical production is TSCA (Toxic Substances Control Act), which is implemented by the EPA. Similar requirements are in force around the world such as REACH in Europe.
- The TSCA Inventory is a list of more than 80,000 chemicals in commercial production and use in the United States. If a chemical is not on it, a company generally must file a pre-manufacture notification (PMN) with the EPA.
- In the absence of chemical testing information (as testing is not required under the PMN process), EPA must use models to predict chemical toxicity and potential exposures. This modeling may overestimate hazards. If the review shows potential concerns, the agency can place restrictions on marketing of the chemical. The PMN process can then be delayed or specific testing or review requirements known as a "SNUR" – significant new use rules may be instituted. Additional secondary approval requirements such as those from the FDA and FiFRA (Insecticides and pesticides) as well as state level reporting requirements on products (WA, ME) may also be required.

TSCA is seen by many stakeholders as flawed, discouraging the growth of newer, safer materials and having fallen behind in its ability to provide for protection against COCs. Appropriate revisions or modifications to EPA's review process for new chemicals might help fast track the review process for green chemistry.

States also have regulatory requirements for chemical use and reporting. They are not harmonized and have varying registrations, standards and reporting requirements. Compliance is an especially heavy cost for smaller companies. California leads the states in its regulatory requirements. One such regulation is the California Safer Consumer Product Regulations intended to improve the health and safety of all Californians by providing the Department of Toxic Substances Control (DTSC) with the authority to control toxic substances in consumer products. The DTSC has identified 1,200 chemicals of concern and is required to identify priority chemical-product combinations for which manufacturers would be subject to conducting alternatives assessment.

California standards are often adopted by other states. California requirements also drive material suppliers to unify their offerings based on California standards. This is referred to as the "California Effect"and is fostering the growth of green chemistry. As mentioned earlier, California standards are also driving transparency in certain areas.

Interviewee Feedback on Government Regulation

"The EPA picked the molecules for a read across in our TSCA submission even when we suggested that was not good comparison. The product was flagged. In order to avoid a SNUR, rework and additional costly tests were required. The 90 day process turned out to be over a year." (Similar comments were mentioned by 3 companies interviewed.)

"Our product has the same chemical structure as the petroleum product; the difference is that we are producing it from biobased, renewable resources. The EPA says we are new chemistry and must file a PMN. This is costly and time consuming."

"We need an efficient and effective regulatory review process that doesn't penalize innovation. We need to be able to more easily commercialize innovative new chemicals that can provide improved and safer products for consumers."

"Companies are struggling to meet all the different state requirements – varying regulations, different country registrations, overhead of the registrations, meeting all the paper-work, costs, keeping up with the standards, and the reporting. It is all very expensive. This makes it extremely difficult for new technology offerings."

"If regulations force us to stop using phthalates, we will. Otherwise it is like pushing string to get our customers to change."

"MN passed the Toxic Free Kids Act in 2009 which bans products like formaldehyde in certain children's products."

"Modify EPA process to fast track green chemistry registrations."

"Reach is driving our textile material choices. It is more restrictive than TSCA and impacts the global supply and compliance of the industry."

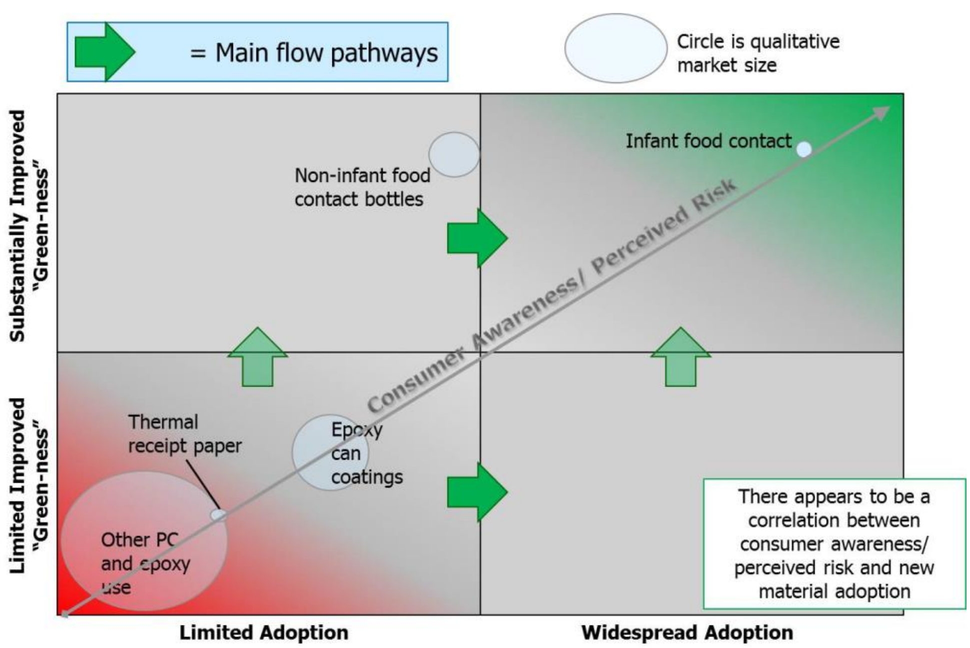
Key take-aways on government regulation:

1. Regulatory bans and restrictions have been and will continue to be a big driver for green chemistry.
2. The difficult and costly regulatory process for new product registrations can act as a hindrance to product availability, demand and adoption.
3. Additional secondary approval requirements (FDA, FIFRA) and state level reporting requirements on products (CA,WA, ME) can add additional challenges to green chemistry products.
4. This can be challenging for a new chemistry, particularly from a small company with limited toxicology or regulatory support.

B. Consumer Awareness

As described earlier, there is a general correlation between end consumer awareness of COCs and their replacement. Concern over endocrine disruption properties of BPA and phthalates fueled consumers' demand for BPA and phthalate replacements. While other industry applications for BPA and phthalate lag in adoption, consumer focused applications have had success in driving green chemistry. These are often called "consumer-centric" segments. The general correlation between awareness and replacement is shown below for BPA.

Figure IX: Consumer Awareness and Demand Drives Green Chemistry Adoption



Research studies and results published can also create an up-tick in new technology demand, even in areas where overall consumer awareness is just starting. For example, a leading thermal paper supplier described an increase in demand for their BPA and BPS free thermal paper: "We have seen a significant increase in requests for our products as a result of the 2014 University of Calgary study."
(The Calgary study reported that both products disrupt normal brain-cell growth and are tied to hyperactivity[7].)

Consumer awareness can be generated by multiple means, but has largely been driven by NGO efforts. Social media, the internet, print and television news journalists have also played a role. This effort is likely to increase in the future. Consumers can force a change.

Interviewee Feedback on Consumer Awareness

"Consumers were concerned about formaldehyde in our personal care products. We have made a commitment to remove them from our formulations."

"We have been receiving an increasing number of inquiries about BPA in food packaging and in our thermal receipts. We have actively been working with suppliers to remove the BPA from the products on our shelves and from our thermal receipts."

"So much is in the power of the consumer. They know lead-free, but have a very simplistic understanding of other chemicals. Education is key."

"We are in the fashion industry. Niche users (consumers) care about sustainability. Others don't know or care as much. A big education effort should take place to drive demand."

"Consumers drove phthalates out of baby items and toys."

"We have started using safer developers in our thermal papers. Consumers are pushing back because the print is lighter than the dark print they get with the BPA developers. The customer base needs to be educated to compromise with a lighter print to get a safer product."

Key take-aways on consumer awareness:

1. Aware consumers can force a change and drive change to greener chemistry.
   a. This change occurs independent of legislation or lobbying. "Perception is reality" to the consumer.
2. Consumer education can heighten consumer awareness and accelerate this green chemistry demand.

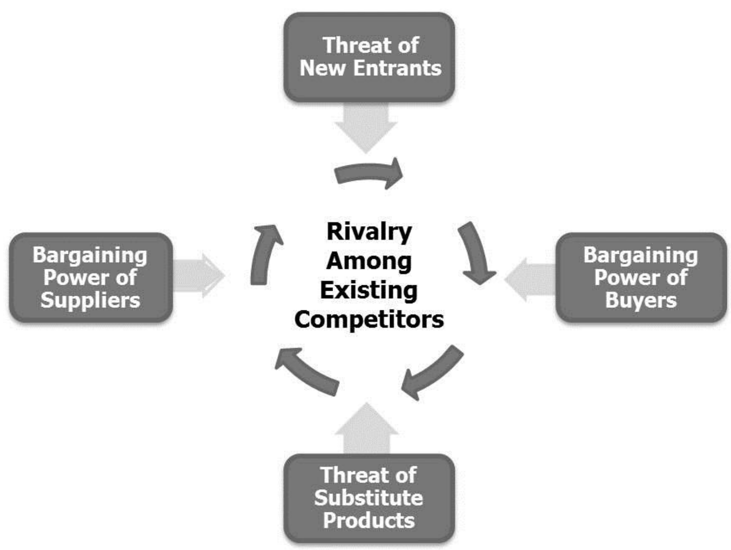
IV. ACCELERATING ADOPTION OF GREEN CHEMISTRY

A. Introduction

Acceleration of green chemistry is difficult due to the tug of war between and within pro-green chemistry and entrenched industry “camps”. There are basic problems of agreeing to definitions of green chemistry, supply chain complexity and other misalignments between stakeholders across the supply chain. All indications are that these forces will continue to bombard regulators, customers, suppliers and other stakeholders with alternate views that will, in fact, slow related progress. Similarly, this will continue as an “us versus them” tug of war between those who want change and those who prefer the status quo. Pro-green consumers are frustrated and angry at the lack of progress, while industry bemoans that consumers aren’t viewing risks rationally.

Many of these issues are compounded by industries functioning within the traditional structure of the supply chain as highlighted by Porter’s Five Forces Analysis, developed by Michael E. Porter in the 1970s.This type of analysis is also instructive in assessing the forces at play in green chemistry.

Figure X: Porter’s Five Forces



The Five Forces model is a tool companies use to assess their competitive position within industry supply chains to understand where power lies. It is based on a protectionist approach employed to assess and anticipate threats to the business from existing competitors, bargaining power of suppliers and buyers (customers) and the threat of new entrants and new technology. The Five Forces model is a planning tool used to build a position of defense and deflection of these threats. It is not a cooperative or collaborative approach to business positioning.

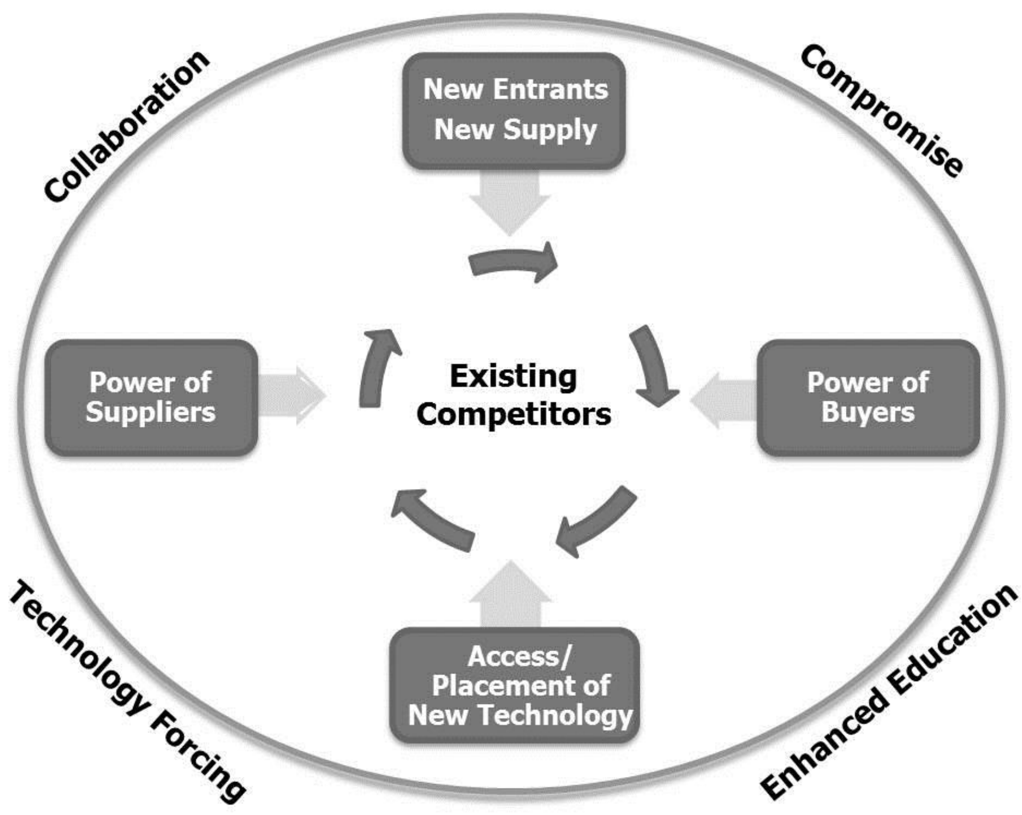
B. Green Chemistry Accelerators

TFA has concluded that there are four accelerators that can change the current paradigm and create a new paradigm that can lead to faster growth of green chemistry:

- Collaboration
- Technology Forcing
- Compromise
- Enhanced Education

These elements are not entirely new and all exist in some form. However, to transcend the existing "stuck" conditions, they need to be applied both more forcefully and in combination with one another. Individual companies need to be competitive, but there is a way to use the accelerators to modify the traditional Five Forces away from a purely adversarial approach to a more cooperative framework. Adopting this new model can lead to sustainable change when companies commit to this approach.

Figure XI: Cooperative Five Forces Model



C. Collaboration

The traditional structure of the supply chain as highlighted by Porter's Five Forces Analysis hasn't enabled fast growth of green chemistry in industry. The traditional focus of competition and bargaining power for customers and suppliers has limited transparency, innovation and availability of cost-effective new materials. Consequently, it's not surprising that collaboration is a key for change.

Strategic alliances, collaborations, co-creation and co-working are transforming the traditional supply chains and working organization. "Coopetition" is a term used as a model to drive competition and innovation. The message is that there are ways to achieve the goal while simultaneously being competitive and collaborative.

Involving a broad range of stakeholders early and sustaining collaboration among them is the first and potentially most important step in a new green chemistry effort. It provides a way to close the gap between what players in the supply chain say they want and their lack of understanding of how each position in the supply chain works.
Collaboration can be beneficial when it occurs in virtually any combination within these five force areas, as well as outside of it as exemplified by NGOs, government regulatory bodies and other influencers.

Collaborative efforts can help lift some of the barriers that have slowed the adoption and flow of green chemistry:

- **Green Chemistry Definitions** are established
- **Price/Performance** trade-offs are reviewed (within appropriate competitive and anti-trust guidelines)
- **Transparency** is addressed
- Expectations of **Supply & Demand** are shared
- A path is paved for **New Technology Access and Placement**
- Some measure of **Risk** sharing is agreed upon.

Interviewees provided a number of current examples of collaboration:
Joint investment
"We have a fund to subsidize green technologies where we see economy of scale factors. We accept the longer term view and give them short term help to grow."

"We realize commitments for volumes are needed. We have an internal innovation fund to invest in new technologies."

"Real partnerships in the investment and production space are a solution."

"We have an 'open innovation' program. We work with companies to help them develop and launch a new technology that is of interest to us both."

Interviewees provided a number of current examples of collaboration (continued):

Technology Sharing

As companies develop tools or technology, they share them with the industry to help speed access to and adoption of green chemistry.

- Personal care company about to… "introduce a testing and measuring product that we will make available to industry."
- A textile company … "sharing IP on a new product and process" to help drive growth in the technology and thus drive economies of scale for pricing and supply volumes.
- Thermal paper supplier, chemical supplier & retailer "plan to share solution found for safer alternative to BPA, BPS" and other thermal developers.

Open innovation programs

- LAUNCH open innovation platform founded by NASA, NIKE, USAID & the US Dept. of State
- Innocentive Crowdsourcing: In an effort to find green chemistry solutions, the GC3, Innocentive and Johnson & Johnson initiated a challenge driven innovation programs or crowd-sourcing to find new green chemistry solutions for preservatives.

Supply Chain Communication Forums

- GC3 was mentioned multiple times as a unique forum to engage conversation along the full supply chain: from the material suppliers through to the brand owners and retailers.
- ACS Green Chemistry Round Tables were cited as another strong forum for supply chain communication: GCI Chemical Manufacturers, GCI Formulators, GCI Pharmaceutical

Consortia as a means to partner & collaborate

- ZDHC: major apparel and footwear brands and retailers made a shared commitment to help lead the industry towards discharge of hazardous chemicals by 2020. Among other things, this group has brought together members of the full supply chain to engage and participate in collaborative discussions and innovation of safer chemicals
- Some corporate cultures are not open to collaboration with competitors and consortia. **This will be a hurdle to some industry collaborative efforts.**
- **Some other NGO organizations have been talking with ZDHC on ways to work together to cross-fertilize ideas and transfer learnings to other industries beyond footwear and apparel.**

Key take-aways on collaboration:

1. Collaboration among individual buyers and sellers along the supply chain can
   a. Lead to projects where green chemistry substitutes succeed
   b. Help overcome the nine identified alignment issues.
   c. Help avoid unrealistic expectations and consequent changes
   d. Create alignment and agreement for change
2. Collaboration through consortium-based approaches can
   a. Engage many stakeholders simultaneously to unify industry acceptance of green chemistry solutions
   b. Create programs through which change can occur faster
   c. Provide a broad perspective from which priorities become more obvious
   d. Initiate projects involving specific chemistries
   e. Leverage broad knowledge base
   f. Mitigate risk of "go-alone" potential hazards
3. Collaboration can:
   a. Bring new materials and technology options to market faster

b. Get to larger scale faster
c. Bring the cost and risks down for all

D. Technology Forcing: Non-Regulatory

As previously discussed under "Government Regulation", governmental bodies have forced technology to change by the elimination of certain chemicals of concern, often in specific applications. In other cases they have simply forced reductions to exposure from these chemicals.

There are strong, non-regulatory forces also driving changes in industry. Marketplace decision makers with considerable "buyer power" force change. In effect, they create a de facto regulation. For instance, it is well accepted that the "big box" stores in various markets (e.g., Walmart and Target for consumer goods, Home Depot and Lowes for building and home improvement products) and others with significant shares of markets (e.g., CVS and Walgreens in pharmaceuticals and personal care products) have considerable market power. They have shown the propensity to demand cost reductions and even require suppliers to change their practices under sustainability initiatives. Brand owners/manufacturers have also effected a change. There are two primary approaches: "red list restrictions" and "incentives".

Interviewees provided a number of current examples of technology forcing:

Retailers Force Change

- "Big Box and retail stores influence/selection of materials depending on the incentives/restrictions they put in place."
- Walmart has launched a program - initially involving 10 chemicals – that requires disclosure of the presence of those chemicals within household cleaning and personal care products sold in stores. Walmart is also targeting DfE (Safer Choice) labeling by starting with this requirement for in-house private label brands.

Brand Owners Force Change

- Tarkett, a global leader in vinyl flooring, made sustainability a corporate pillar and lead the industry by replacing their plasticizers with non-phthalate options.
- P&G announced formaldehyde is being removed from PC products for children and is committed to take them out of adult products by 2015.
- Apple eliminated PVC and phthalates from all wire & cable jacketing.
- Adidas & Nike and many other Brand owners have restricted substances lists.

Consortia/Industry Groups Force change

- OIA Outdoor Industry Association with the Sustainable Apparel Coalition has a chemicals management working group that does assessment and management of chemicals and their potential impacts on humans and the environment across product life cycle.
- BIFMA – provides incentives for being labeled greener.
- Healthy Hospital Coalition- provides buying incentives to eliminate COC's.
- Textile manufacturers are using BlueSign to eliminate COC's at the beginning of the design phase- focused on a positive list and incentives.
- Many others

At its extreme, technology forcing is counter to collaboration. Strong arming does work, especially with companies that have leverage. Yet, it can hinder a path to future solutions, especially if unrealistic expectations are set or if goals are set in a vacuum without appropriate vetting by those that can help deliver the solutions. It creates the burden of discovery and change that is forced sequentially and often slowly all the way “up” the supply chain. Therefore, exercising power should involve an appropriate level of collaboration and compromise in order to ensure project goals are appropriately set and met. During the course of interviewing, a number of material suppliers voiced concern over the conflicting messaging from the sustainability and sourcing groups within consumer product and mass retailer organizations:

- “Mass retailer sustainability groups should work in tandem with their own sourcing groups and suppliers so that realistic expectations are set for green chemistry and economics.”

Key take-aways on technology forcing:

1. Marketplace decision makers with considerable “buyer power” can force change. In effect, they create a de facto regulation.
2. Technology Forcing can, like government regulations, drive change to green chemistry.
   a. Large retailers, especially, have a great deal of market power to leverage.
3. This will work faster and more efficiently if done via a collaborative approach.
   a. Collaboration can help ensure realistic goals are set
   b. Feedback mechanisms need to be created within the technology forcing companies, as well as with those companies subject to force.
4. Internal collaboration between the sourcing and sustainability groups at consumer products and retailer organizations can ensure green chemistry and price/performance needs are examined in tandem.
5. Some level of compromise may be necessary.
6. Success is much more likely if stakeholders are educated, including being provided with answers to the following questions:
   a. “Why are we doing this?”
   b. “What are the benefits?”
   c. “What are the consequences of non-compliance?”

E. Compromise

Compromise is a subsidiary principle of any true collaboration (and may also be applied when technology-forcing approaches are used). It involves the acceptance of continuous improvement. Something “better enough” is better than the status quo. It will not necessarily represent the ultimate goal, but provides a step in the right direction.

Commercialization of new solutions requires passing many rigorous goals and hurdles. Invariably, compromises are involved because a chemical that is “greener” than existing products is likely to have tradeoffs to the incumbent material: price/performance, supply & demand, etc.

Compromise can help lift some of the barriers that have slowed the adoption and flow of green chemistry. For instance compromising in the following manner addresses several key green chemistry adoption issues:

- **Green Chemistry Definitions** are established
- **Price/Performance** trade-offs are reviewed (within appropriate competitive and anti-trust guidelines). These are understood and agreed to before significant decisions are made.
- **Transparency** expectations and requirements are established.
- Expectations of **Supply & Demand** are agreed to by some means. This can be managed via a Memorandum of Understanding (MOU) between supplier and customer(s). While generally non-binding, MOUs do set expectations and guideposts for relationships at functional levels and can enhance support by those at the highest levels of corporations or investors who must approve significant investments.
- This paves a path for **New Technology Access and Placement** and allows for some measure of **Risk** sharing to be agreed upon.

Compromise and non-regulatory technology forcing appear on the surface to be two approaches at odds with one another. They are not if the companies forcing the change and those impacted by the change are able to compromise.

Interviewees provided a number of current examples of compromise:
"Industry needs to be patient: Rome wasn't built in a day. Chemical industry has 50 years of optimizing and it is going to take time to change. Do a phased approach. Compromise."

"Commercialization involving new solutions must pass a set of multiple goals. Compromises are involved."

"Product inventory turns were not meeting the mass retailer standards. The mass retailer eased the velocity rate to keep our sustainable product in stores."

"We couldn't remove all PVC, but we removed it from packaging where it wasn't necessary. This was an easy solution."

"We designed a safer product removing phthalates, lowering VOC content and managing a post-use recycling chain. Using PVC is the right choice now until another effective and sustainable alternative can be widely available on the market."

Interviewees provided a number of current examples of compromise (continued):

"Our customer focused on a trade-off analysis vs a red list since there were not effective replacements for full formaldehyde replacement."

"We compromised with low formaldehyde-emitting laminates. They don't always eliminate the formaldehyde, but yields products that are safer for consumers in all cases."

"The biopolymer isn't GMO free. This will take time. We can start with a GMO biopolymer now and look toward GMO free products in the future."

"We want biomaterials that are not using food-source raw materials. As long as there is a plan to get there we can work with the first generation product."

"We consider practices as well as substitutes. Where we can't change to a "safer solvent" we focused on installing a closed loop system to keep restricted chemicals from being released."

"We had to look at the ways in which a COC can be diffused not just replaced. We targeted layers and multiple solutions regarding BPA in thermal receipts.

Evaluate sustainable new solutions and processes

Limit paper waste- don't print when not needed

Educate not to recycle

Promote e-receipts

TSCA influence in minimizing receipts discarded

OSHA to address worker contact and handling"

Key take-aways on compromise:

1. When compromising, companies can accelerate the adoption of green chemistry by embracing the principle of reasonable trade-offs.
2. Accepting continuous improvement will accelerate the adoption of greener chemistry. Something "better enough" is better than the status quo. It will not represent the ultimate goal, but provides a step in the right direction.
3. Reducing risks and exposures from COCs, as opposed to their outright replacement, may be an acceptable compromise.
4. The cost of a green chemical is likely to be higher initially than that of the status quo.
   a. Timetables for step change economic improvements can be established.
   b. Suppliers and customers can negotiate a short term plan for absorbing or passing along the increase in cost.
5. The performance of a green product may not be identical to that of the status quo.
   i. Key performance parameters and expectations can be defined to satisfy all parties and avoid consumer push-back.

6. Easing of other business standards is a compromise to fuel the growth of the green chemistry products: inventory turns, supply terms, etc.

F. Enhanced Education

Enhanced education is the fourth accelerator. Two elements of education were raised during interviews:

- Consumer Education
- Industry Education

1. Consumer Education

Being green is not enough of a driver. Consumers and customers have demonstrated that even though they say they want green, they will not always (or generally) pay for it. Adoption rates have been successful when consumers and customers are educated and aware of the perceived risk of existing chemicals or materials. At this point they can and do drive change. Empowering consumers with information about chemicals in products they purchase for themselves, friends and family can help drive this change.

Interviewees provided a number of current examples of consumer education:
"Consumers have a simplistic understanding of chemicals and have "chemophobia" thinking chemicals means bad. Education is key."

"Consumers care about sustainability and green in some areas more than others: High interest in cleaning, food, personal care and cosmetic, baby/children; Lower interest in fashion, home goods and transportation. A big education effort is needed."

"Consumers aren't educated enough. This is a huge roadblock. Must be a pull; can't be a push."

"There is limited consumer awareness about BPA in thermal receipts."

"Consumers only seem to generally be interested in knowing that the manufacturer is doing the right thing. They seem disinterested in knowing what the company is doing in sustainability or corporate social responsibility. "

"Consumers are not aware of green chemistry, but they do see 'sustainability'"

"Consumers continue to ask about their exposure to COC's including phthalates, formaldehyde and BPA in their furniture."

"Branding as an integral part of the brand image is helpful with products like 7th Generation, Method, Aveda, but there is still so much greenwashing, that this is not always a reliable source of education."

"Consumers fears or perceptions are reality. Education is needed to help prevent consumer panic. For example, carbon black is hazardous when airborne, not when it is bound in a resin system. "

Many discussions with industry, governmental and NGO personnel during the study identified creating a better educated consumer base as key to successfully increasing the flow of successful green chemicals.

In effect, the message was: Consumers need to know that safer and/or more environmentally friendly chemicals create benefits that may be hidden to them.

2. Industry Education

There is a growing movement toward green chemistry education, but it is pocketed and slow. High schools have limited modules involving green chemistry. The focus is more on environmental studies. Universities tend to offer individual classes in green chemistry. Industry players interested in promoting green chemistry adoption and design have a limited offering of training workshops and tools for design. Much of the training is how to look for and measure COCs vs. green chemistry design.

Interviewee Feedback on Green Chemistry Industry Education

"Green Chemistry education is an add-on."

"Green Chemistry needs to be integrated into the chemistry and engineering programs for the full four year undergraduate program"

"Chemical educational programs in schools don't teach toxicology or green chemistry."

Industry challenges that promote "Designing with Green Chemistry" are changing thinking patterns.

- "Living Building Challenge: launched by Cascadia Green Building Council. It is the most advanced measurement of sustainability. Every credit is required is required for certification."
- "BlueSign is a design and manufacturing software system for sustainable textile production that eliminates harmful substances right from the beginning of the manufacturing process".

Key take-aways on enhanced education:

1. Educated, informed and impassioned consumers can fuel the growth of green chemistry.
    a. Consumer facing companies can help drive growth by educating their customers.
2. Educated and informed customers all along the supply chain can fuel the growth of green chemistry.
3. The easiest way to accelerate the availability and adoption of green chemistry is to start with a green chemistry design by way of an educated work-force.

V. CONCLUSIONS

This analysis has identified key factors that have affected the slow growth and availability of the Green chemistry. Nine supply chain alignment issues were identified that have slowed availability and growth of green chemistry:

1. **Green Chemistry Definitions**
Most industries have not established a unified set of "green chemistry" definitions. It isn't critical to pick a "right" definition. It is **Critical** to be on the same page when initiating and advancing discussions and collaborative efforts involving Green Chemistry. These definitions inherently establish priorities for such efforts.

2. **Supply Chain Complexity**
Supply chain complexity poses enormous barriers to green chemical adoption. Each supply chain position has its own vantage point, a different viewpoint from others in the chain. Complex supply chains create fragmentation of demand by application, volume, specification, customer expectation, geography, etc. In complex supply chains, demand for new innovative technologies is diffuse. This affects the speed of adoption and flow of new, safer, greener chemistries and practices. Often the results are supply chain conflicts and an "us vs. them" mentality.

3. **Incumbency**
The existing infrastructure of the established chemical industry is so efficient that it is hard for new entrants, green or not, to compete with the established supply chain.

4. **Confusion**
Conflicting information from studies and research; policy, and rigorous lobbying continues to confuse the industry. Stakeholders are at times grid-locked, not making a change due to uncertainty about the acceptability of status quo products.

5. **Switching Risk**
There is concern that switching to green chemistry alternatives could lead to market failures such as market loss due to a product's poor performance, brand tarnishing and other hidden costs such as process or equipment or process changes, material incompatibility, workforce training, customer education and others. There is also the risk of switching to a "better bad". This makes stakeholders cautious and slow to make chemical management decisions.**Price / Performance**
Price/performance was the most cited reason for the slow adoption of green chemistry. Entrenched chemicals of concern (COC's) have set the standard for price/performance. Often there are savings in a total cost analysis such as reduced hazardous waste handling and disposal. This can be hard to quantify for customers focused on $/lb pricing. Change will continue to be slow without a concerted effort to address the trade-offs between conventional price/performance issues and "green".

6. **Supply & Demand**
There is often not enough real or perceived demand to make increased production worth the investment. Stakeholders are cautious to move forward to commit to demand or to commit to supply. Supply infrastructure growth will be slow without compromise, partnership and collaboration to increase demand and supply in tandem.

7. **Transparency**
   More transparency is occurring, much by force. Suppliers are looking for ways to satisfy customer demands while protecting IP and trade secrets. Customers are frustrated and skeptical of the chemical industry's reluctance to be open and transparent.

8. **New Technology: Access and Placement**
   Finding and vetting green chemistry technologies remains a weak link. Suppliers struggle to identify early adopters. Customers struggle on where to go beyond the traditional supply chain for new technology. The flow is slow, but collaborations and other activities are beginning to open up the flow and access to technology.

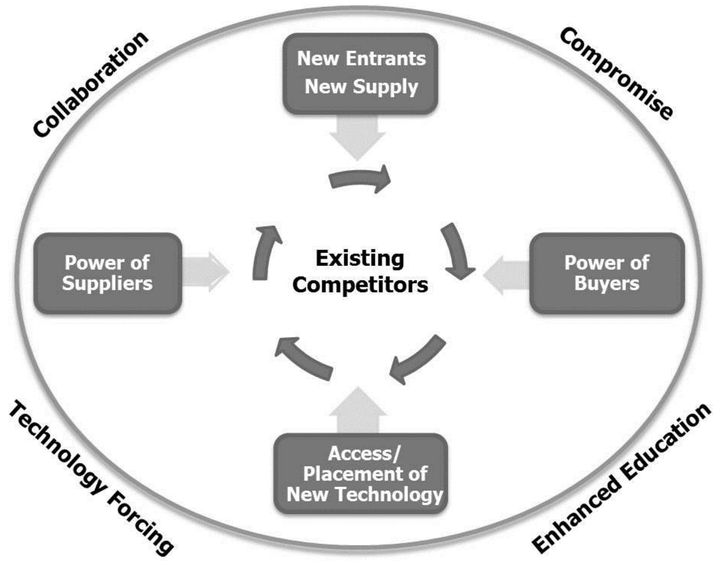
Two significant current green chemistry drivers were identified: Government Regulation and Consumer Awareness. However, the slow adoption of green chemistry to date suggests that future efforts need to better address the impediments to growth.

1. **Government Regulation**
   Regulatory bans and restrictions have been and will continue to be a big driver for green chemistry. However, the difficult and costly regulatory process for new product registrations and secondary approvals can act as a hindrance to product availability, demand and adoption. For a new chemistry, particularly from a small company with limited toxicology or regulatory support, this can be challenging.

2. **Consumer Awareness**
   Aware consumers can force and drive change to greener chemistry. This change occurs independent of legislation or lobbying. "Perception is reality" to the consumer. Consumer education can heighten consumer awareness and accelerate demand for green chemistry.

Four green chemistry accelerators: Collaboration, Technology Forcing, Compromise and Enhanced Education were identified. These underlie the change and creation of a new paradigm from which green chemistry can grow more quickly - a more cooperative 5 forces model.

Figure XII: Cooperative Five Forces Model



1. Collaboration

Collaboration can lead to projects where green chemistry substitutes succeed. It can help overcome the nine identified alignment issues and create alignment and agreement for change. It can help avoid unrealistic expectations and consequent changes

Collaboration through consortium-based approaches can create programs through which change can occur faster, provide a broad perspective from which priorities become more obvious, mitigate the risk of "go-alone" potential hazards.

Collaboration can bring new materials and technology options to market faster, get to larger scale faster and bring the cost and risks down for all.

2. Technology Forcing: Non-regulatory

Marketplace decision makers with considerable "buyer power" force change. In effect, they create a de facto regulation. Technology Forcing can, like government regulations, drive change to green chemistry. Large retailers and consumer product companies have a great deal of market power to leverage. Exercising power should involve an appropriate level of collaboration and compromise in order to ensure project goals are appropriately set and met. This includes internal collaboration between the sourcing and sustainability groups at consumer products and retailer organizations to ensure green chemistry and price/performance needs are examined in tandem.

3. Compromise

When compromising, companies can accelerate the adoption of green chemistry by embracing the principle of reasonable trade-offs.

Accepting continuous improvement will accelerate the adoption of greener chemistry. Something "better enough" is better than the status quo. It will not represent the ultimate goal, but provides a step in the right direction. Reducing risks and impacts of COCs, as opposed to their outright replacement, may be an acceptable compromise.

The cost of a green chemical is likely to be higher initially than that of the status quo. Timetables for step change economic improvements can be established. Suppliers and customers can negotiate a short term plan for absorbing or passing along the increase in cost. The performance of a green product may not be identical to that of the status quo. Key performance parameters and expectations can be defined to satisfy all parties and avoid consumer push-back.

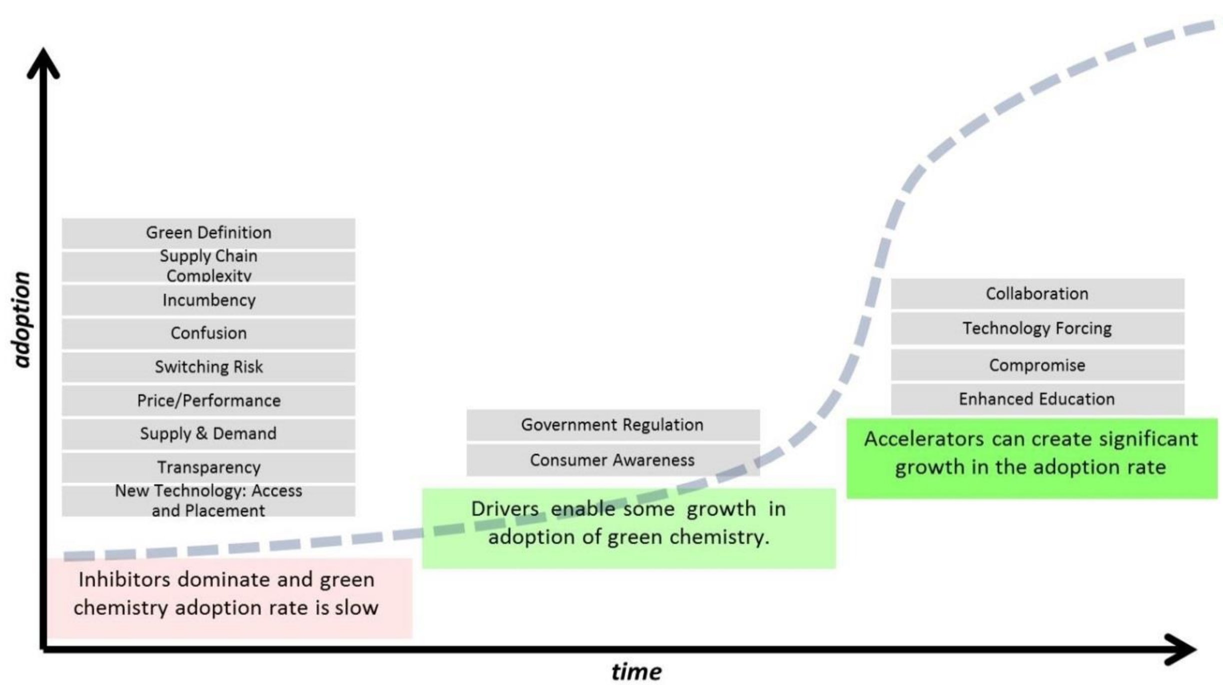
Easing of other business standards is a compromise to fuel the growth of the green chemistry products: inventory turns, supply terms, etc.

4. Enhanced Education

Educated, informed and impassioned consumers can fuel the growth of green chemistry
The easiest way to accelerate the availability and adoption of green chemistry is to start with a green chemistry design by way of an educated work-force. Consumer facing companies can help drive growth by educating consumers about green chemistry.

Applying the four accelerators in a Cooperative 5-forces model can help to diffuse the supply chain inhibitors and fuel the availability and adoption of green chemistry.

Figure XIII S- Curve Model of Green Chemistry Adoption



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VI. APPENDICIES

Appendix A. Potential next steps to help implement the accelerators

Appendix B. What can retailers do to advance green chemistry?

Appendix C. What can chemical suppliers do to advance green chemistry?

Appendix D. What can the GC3 do to advance green chemistry?

Appendix A. Potential Next Steps to Help Implement the Accelerators

During the course of TFA's research, a number of solutions were identified by TFA or suggested by interviewees as potential next steps to accelerate the availability and flow of green chemistry options. While these have not been fully vetted or formulated, these next steps could help guide future dialogue and cooperative efforts to implement the accelerators identified in this report. These solutions are described below.

Potential Next Step to Reduce Confusion in the Supply Chain

Establish a collaborative effort between consortia groups within industries to leverage each group's offerings, bring equivalency of tools to the table, and lighten the burden for industry suppliers by minimizing duplication of efforts. For example, a collaborative effort could be established in the textile, apparel and footwear sectors with groups such as ZDHC (Zero Discharge of Hazardous Chemicals), AFIRM (The Apparel and Footwear International RSL Management Group), the Sustainable Apparel Coalition (SAC) and Outdoor Industry Association (OIA). A more collaborative approach has started in the apparel and footwear industry with the development and piloting of the Higg index by the SAC, which is being adopted by many organizations as a standardized set of tools. (http://www.apparelcoalition.org/higgoverview/)

Potential Next Steps to Drive Access/Placement of New Technology

Establish a collaborative industry technology park funded by key industry players who can benefit from testing and further development of open innovation technologies. There are methods to search for new technologies via open innovation programs and technology clearing houses. Examples of such programs are Innocentive and Nine Sigma. These efforts can be used collaboratively by industry groups to generate a flow of potential new technology solutions. Often the identified technologies need further testing and process development. This can be an expensive and risky approach for a single company to undertake, due to the investment and limited IP from an open sourced technology. A collaborative research park would allow for joint investment to develop the opportunity without placing the burden on any one company. Once new products are developed, partnerships in the investment of production facilities can further extend the opportunity for green chemistry scaling (which would also help with Supply/Demand issues).

An example of such an approach for identifying and scaling replacements for perfluorinated compounds (PFCs) for apparel, footwear and textiles is the "Smart Textiles Initiative" at the University of Borås in Scandinavia. As part of this initiative, partners are working directly on research and development with companies that pool technical innovation.

A second idea is to work with companies that pool technical innovation. These companies can provide a direct access point for both suppliers and customers. Two examples of organizations providing this service for the textile industry are HeiQ Materials AG, Swiss high technology company producing high sustainable technologies for textiles; and Beyond Surface Technologies, a technology scout company offering sustainable performance technologies for textiles.

A third idea is to prioritize efforts by studying coalitions driving sustainable materials in the marketplace (such as the US Green Building Council, Practice Green Health, etc.), restricted substance lists and customers who must meet those demands and develop open-source templates to identify green chemistry needs in other segments.

Potential Next Step to Drive Supply/Demand
Establish a cross industry collaborative effort that would bring the demand scale and power needed to drive new technologies. For example, BIFMA (Business and Institutional Furniture Manufacturers Association) has established sustainability goals to drive application of green chemistry substitutes for chemicals of concern in the products their members sell. This is quite difficult, as office furniture is a small segment and the impact on volumes is small. Automotive is the volume driver for e-coat, powder coating and chrome paints. So, if the Automotive Manufacturers Association and/or the Auto BioCouncil combined forces with BIFMA and other metal coating organizations, they could use their combined purchasing power to find alternatives to chemicals of concern in metal and plastic coatings.

Potential Next Step for Non-Regulatory Technology Forcing
Establish collaborative efforts between major retailers and/or consumer goods companies to accelerate scale of green chemistry alternatives for chemicals of concern for specific applications. Mass retailers or brands banding together can send a powerful message to industry and help accelerate the flow of green chemistry. As an indicator of this, Target and Walmart banding together for the Beauty and Personal Care Sustainability Summit was seen as a significant statement to brands in that sector regarding the need to scale more sustainable alternatives.

Appendix B. What Can Retailers Do?

As a follow-up to this study, TFA was asked by the GC3 Retail Leadership Council to answer the question "What can retailers do to advance green chemistry?" We developed the following recommendations:

Collaborate – Compromise – Educate – Force Technology

- When engaging in conversations, understand the other participant's definition of green chemistry.

- Be educated and open-minded about the supply chain issues and complexity beyond the retailer vantage point.
  - Accept the longer term view and give suppliers the short term to help them grow

- Be clear on the relative need for green chemistry versus price/performance.
  - Internal collaboration between the sourcing and sustainability groups can ensure green chemistry and price/performance needs are examined in tandem.

- Transparency is happening across industry. Collaborate and compromise when possible to drive the flow of green technology faster.

- Embrace the principle of reasonable trade-offs. Accepting continuous improvement will accelerate the adoption of greener chemistry. Something "better enough" is better than the status quo. It will not represent the ultimate goal, but provides a step in the right direction.

- Continue participation in broad supply chain communication forums like GC3 & the ACS Green Chemistry Institute® Industry Roundtables.

- Utilize specific industry consortia as a means to partner and collaborate to drive green chemistry practices: example ZDHC.

- Mass Retailers banding together sends a powerful message and helps accelerate the flow of green chemistry.
  - Target & Walmart banding together for the Personal Care Summit was seen as a significant statement.

- Increase and enhance sharing of relevant information in advertising and at the point of purchase - educate consumers

- Utilize technology forcing to drive green chemistry. If done with some measure of compromise and collaboration during the planning process, it will happen faster.
  - Clearly state demands.
  - Provide incentives, establish restrictions; require certifications.
  - Brand/owner retailers: continue to force a change by voluntary material changes (Apple no PVC/phthalates, P&G eliminating formaldehyde).
  - Compromise on price, especially at early stages when economies of scale are poor and supplier business risks are high
  - Accept continuous improvement/ step change.
  - Ease business standards to fuel growth of green chemistry products: inventory turns, supply terms, etc.

Appendix C. What Can Chemical Suppliers Do?

As a follow-up to this study, TFA was asked by the GC3 Retail Leadership Council to answer the question "What can suppliers do to advance green chemistry?" We developed the following recommendations:

Collaborate – Compromise – Educate – Force Technology

- When engaging in conversations, understand the other participant's definition of green chemistry?
- Be educated and open-minded about the supply chain issues and complexity beyond the chemical supplier vantage point.
- Be clear on material attributes, profile and supply. Keep open communication channels for pertinent updates
  - Price/performance profile and projection for the future
  - Green Profile: C2C data, biobased percent if applicable, EHS attributes
  - Supply profile: current, projections, global availability
  - Registrations, certifications: TSCA, DSL, REACH other registrations timeline. Other important certifications: FDA, DfE, BioPreferred, other
- As new tools or technologies are developed, set up mechanisms to collaborate, share (license, venture, open access, etc.) and invest to help speed access to and adoption of green chemistry.
  - Work to overcome the corporate cultures that are not open to collaboration.
- Transparency is happening across industry. Collaborate and compromise when possible to drive transparency and drive the flow of green technology faster. Be open faster; respond to customer needs and concerns.
- Continue participation in broad supply chain communication forums like GC3 & the ACS Green Chemistry Institute® Industry Roundtables.
- Lead the industry in greener offerings before regulations and consumer pressure. Set sustainability and green chemistry as a corporate pillar.
  - Accept green chemistry as a means to improve competitive positioning and increase growth.
- Utilize consortia as a means to partner and collaborate to drive green chemistry technology: Joint research parks to develop new offerings.
- Listen, communicate and respond to customer needs. Share hurdles, opportunities, progress.
- Respond positively to technology forcing to drive green chemistry. If done in a collaborative fashion, it will happen faster.

Appendix D. What can the GC3 Do?

As a follow-up to this study, TFA was asked by the GC3 to answer the question "What can the GC3 do to advance green chemistry?" We developed the following recommendations:

- Help constituents understand the GC3 vision and ways to implement it.

- Continue to provide a forum for full supply chain communication and learnings.

- Balance membership along the supply chain: chemicals, processors, fabricators, etc.
  - Multiple respondents commented that the GC3 was heavily weighted towards the brand owner/ retailer side.

- Solicit feedback from GC3 members regarding this report:
  - What resonated with them and what didn't. Other feedback, learnings.
  - Discuss ways in which these findings can be turned into actionable efforts.

- Continue to identify barriers to success and means to accelerate green chemistry adoption and work closely with stakeholders who have the interest but not necessarily the means to effect change.

- Facilitate efforts to drive Green Chemistry via the collaborative 5 forces model with cross supply chain focus groups (potentially by segment: personal care, textile, formulated cleaners):
  - Review and discuss the 9 alignment issues and the 4 accelerators in this report
    - Modify as needed
    - Discuss hurdles, opportunities, solutions
  - Review collaborative model suggestions in this report.
  - Brainstorm additional collaborative solutions and ideas for implementation
  - Review and rank the potential models
  - Discuss next steps