10th Annual GC3 Innovators Roundtable Session Summaries

Tuesday, April 28th

Welcome and Opening Remarks

Joel Tickner, University of Massachusetts Lowell
John Frazier, Nike

Joel Tickner, director of the GC3, provided a ten-year perspective of the GC3, its impacts, and how the world and the field of green chemistry has evolved over the past decade. His children, who were 3 and 5 when the GC3 was founded, provided a metaphor for the growth of the GC3 over the past ten years. Like children, organizations and movements need nurturing and support as they develop their own unique personalities. Sometimes they take longer to mature than one hopes, but constant attention, process, and vision are critical.

Tickner outlined the significant changes in the marketplace with greater consumer and purchaser attention to safer chemistry; in policy with European and some U.S. state policies; in the development of new scientific fields such as alternatives assessment and green toxicology; and in the number of energetic green chemistry efforts that have been established in government, industry, and academia. Despite these drivers and momentum, green chemistry is still a marginal consideration in chemistry research, is not reflected in government priorities, and is much neglected from the supply side. Tickner reflected on the barriers to green chemistry raised ten years ago by companies and how many are similar to ones we face today. Despite this, significant efforts have occurred to improve supply chain transparency and industrial partnership toward solutions. Green chemistry is no longer viewed as a “far out there” idea.

Tickner reflected on the successes of the GC3 over the past 10 years in supporting mainstreaming of green chemistry through its efforts on:

- enhancing information flows through supply chains,
- expanding green chemistry education,
- accelerating innovation,

- engaging retailers in green chemistry,
- building supply chain partnerships,
- supporting networking and collaboration, and
- education and outreach activities.

He concluded that while green chemistry may not be mainstream yet, the processes and structures to make it happen are evolving. This is a unique time to take green chemistry toward the mainstream by: building incentives for R&D, adoption, and scale; enhancing green chemistry education; growing the scientific base; accelerating collaborative supply chain partnerships to solve problems, and communicating the success stories. The ultimate goal is to build a stronger, more vibrant, integrated green chemistry community.

Opening Keynote

John Frazier, Nike

Nike is a company built on innovation. The challenge for Nike is how to push better chemistry innovation through the supply chain and the sector. Nike has invested in tools such as Blue Sign in order to support safer chemistry through the supply chain, and partnered with USAID, the State Department, and NASA on the LAUNCH Innovators program to accelerate innovation in the green chemistry sphere. Nike also shares its best practices and innovations with other brands to promote green chemistry across the apparel and footwear sector, participating in initiatives such as the ZDHC and sharing their green rubber, color dry, and supercritical CO_2 technology. Internally, Nike is creating tools to enable designers to make safer choices using the results of chemical research. Collaboration is crucial to speeding the adoption of better chemistry—both within and outside of the firm.

Session I

Ten Years Back and Ten Years Ahead: Green Chemistry and the GC3

Sean Cady, VF Corporation
Tammy Ayers, Steelcase
James Hutchison, University of Oregon
Monica Becker, Monica Becker and Associates *(moderator)*

In the past decade, the industrial landscape has evolved with the rise of green chemistry. While increasingly complex supply chains are difficult to manage, the involvement of brands and retailers in the R&D process has created a pull for green chemistry at all levels, and a strong demand for supply chain transparency. Technical expertise within the supply chain will be a critical need in coming years. Collaboration between brands and other stakeholders is anticipated to increase as successful partnerships are publicized, and brands will also play a bigger role in green chemistry R&D in the coming years. The last decade has seen an explosion in the availability of tools for hazard assessment and green chemistry, and harmonization of these tools is becoming a critical need in order to reduce the complexity of green chemistry efforts. As the green chemistry community expands, benchmarking and sharing of best practices is becoming increasingly important. Better communication surrounding the value of green chemistry solutions will enhance their adoption.

Opportunities for Safer Chemicals and Products

- Implementation of green chemistry throughout supply chains
- Brand and retailer participation in green chemistry demand and R&D
- Harmonization of tools and metrics
- Design for disassembly/end-of-life
- Communication of value of green chemistry

Key Drivers for Green Chemistry

- Regulatory and NGO pressure
- Retailer requirements
- Consumer awareness
- Demand for transparency
- Trend towards holistic health and well-being

Challenges for Implementation

- Complexity of marketplace and supply chains
- Lack of harmonized tools
- Lack of clear metrics
- Gap between academia and marketplace
- Lagging progress towards green chemistry education
- Disconnect between academic/"white paper" research and implementation
- Slow pace of green chemistry R&D

Helpful Actions

- Collaboration across industry
- Common metrics for green chemistry performance and progress
- Industry-academia partnerships
- Communicating market needs to academia
- Green chemistry workshops to speed education
- Increase visibility of progress towards green chemistry
- Identify real problems that need green chemistry solutions

Role for the GC3

- Matchmaker facilitating cross-industry collaborations & academic partnerships
- Promote systems thinking
- Bridging gap between industry and academia; communicate market needs
- Communicate issues surrounding green chemistry

Session II

Moving Forward on Mainstreaming

Ray Garant, American Chemical Society
Tess Fennelly, T Fennelly & Associates, Inc.
Libby Bernick, Trucost
Amy Perlmutter, Perlmutter Associates
Joel Tickner, University of Massachusetts Lowell *(moderator)*

Green chemistry policymaking began in the 1990's with voluntary programs (awards and conferences) that capitalized on the energy surrounding the new field. Beginning with discussions about federal green chemistry research and development legislation, in 2010, the America COMPETES legislation was passed supporting the establishment of the SusChem green chemistry programs at NSF. Confusion over definitions of sustainable vs. green chemistry as well as what green chemistry policy should include (incentives/disincentives) is an issue in federal legislation and in emerging state policies.

Tess Fennelly and Associates (TFA) identified 9 key issues that are slowing green chemistry adoption (see "Challenges for Implementation" below). TFA also identified "accelerators" to overcome these barriers, and speed the adoption of green chemistry. By utilizing collaboration, compromise, technology forcing, and enhanced education, the mainstreaming process can be advanced.

Trucost analyzed the business case for green chemistry. Some trends are: Considerable market growth for safer products and growing investment in green chemistry R&D on the part of chemical companies. Regulations, enforcement, and liability are putting business value at risk when green chemistry is neglected. Improved metrics and communication around the value of green chemistry, as well as further quantification of societal and economic benefits, should help accelerate the mainstreaming movement.

The GC3 has developed an Agenda for Mainstreaming Green Chemistry based on input from GC3 members, a Mainstreaming Steering Committee, Roundtable discussions, interviews with thought leaders, and original research. The Agenda identifies drivers, barriers and an action plan to accelerate mainstreaming. The Agenda will be finalized, publicized, and implemented over the next several months.

Opportunities for Safer Chemicals and Products

- staying ahead of regulations—being proactive rather than reactive
- avoiding fines and cleanup costs
- taking advantage of new technologies

Key Drivers for Green Chemistry

- innovation potential
- conferences and awards
- legislation incorporating government funding
- European regulatory restriction via REACH and RoHS

- consumer awareness and market demand

Challenges for Implementation (many of which from the Tess Fennelly and Associates report)

- lack of cohesive definition of “green chemistry”
- complexity of supply chains
- technology incumbency
- confusion over what chemistries are problematic
- switching risk, where alternatives may perform poorly or have risks of their own
- price/performance
- supply & demand
- transparency in supply chains of information
- new technology access/placement in complex supply chains

Helpful Actions

- enhanced education
- collaboration
- compromise, where supply chain actors share risk of green chemistry solutions
- technology forcing from decision makers with buying power
- quantify societal/economic benefits
- improve metrics and communication around business value of green chemistry
- enhanced education

Role for the GC3

- finalize, publish, and implement Agenda for Mainstreaming Green Chemistry
- continue pursuing education of consumers and businesses

Keynote II

Bob Kumpf, Elevance

Contextual intelligence is key to accelerating innovation and green chemistry. Elevance has developed an approach to drive innovation: demonstrate (the ability to perform innovative reactions—metathesis—beyond the laboratory), build, apply, and embrace. It is important to move from “it’s green, but…” to “it’s green, and…” to communicate the added value of green chemistry solutions.

Context and megatrends are critical to alignment if a company wants to be successful in this space. Some important megatrends and their consequences include:

- manufacturing matters — the viability of biobased materials must be demonstrated at commercial scale using local feedstocks;
- advanced materials are important and growing — materials are desirable for their performance and innovation, not just their biobased nature;
- the new energy economy is growing (petroleum is likely on the decline) — importance of energy-saving materials is growing; and

- the consumer is emboldened — it is important to leverage the heterogeneous population of informed consumers.

Elevance created the concept of "renewicals" as a way to communicate the dual benefits of chemistries and materials made from renewable feedstocks. These are innovative molecules that are desired for their performance (not just petroleum feedstock replacements) and they have the added benefit of being environmentally friendly, demonstrating the success of the "It's green, and…" approach.

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Keynote III

Eric Beckman, University of Pittsburgh

Over the last two decades, green chemistry has evolved greatly, as has toxicology, life cycle analysis, and the clean technology sector. Future eco-innovation must focus on solving customer's problems. The customer and desired outcome should be kept in mind at every step of development, especially the concept formation, when 80% of costs are locked in. Green thinking and sustainability should be included throughout the process, and it is important to consider alternative solutions for the desired function, instead of just making incremental improvements to existing technology.

Evolving technology is creating new possibilities for design, including integrated molecular design, process simulators, computationally-supported product design, and distributed manufacturing. Distributed chemical manufacturing may be an interesting possibility to scale green chemistry innovation in the future. Academia needs to explore integrated design and support entrepreneurship with multidisciplinary curricula. In order for education to keep pace with rapid industrial innovation, industry needs to be actively involved in curriculum development.

Session III

Thinking Outside the Box: Innovative Business Efforts to Accelerate Green Chemistry

Matt Dwyer, Patagonia
Rey Banatao, Connora Tech
Ken Geiser, University of Massachusetts Lowell *(moderator)*

Patagonia is driven by their goal of building the best product and causing no unnecessary harm. They consider people in their supply chain as well as materials. Patagonia has set up a venture fund to invest in sustainable/environmental technology. They are committed to reducing the impact and toxicity of their textile finishes. These directives come from Patagonia's C-suite, which is committed to proactively doing environmental good.

Connora is attempting to make reversible, recyclable thermosets. While thermoplastics are highly recyclable, thermosets are typically designed to be permanent for high-performance applications. Connora's Recyclamine technology creates thermosets with programmable cleavage points which can be "unzipped" by light or pH changes, allowing the components to be reused and value recaptured. The cost of the production process is currently prohibitive, but Connora is working with the sporting goods industry and epoxy manufacturers to license and improve their technology. It has established small scale, niche product models – for example in mini surf boards – to show proof of concept and gain a strong following.

Opportunities for Safer Chemicals and Products

- textile, apparel, and sporting goods industries have complex supply chains with many opportunities for improvement

Key Drivers for Green Chemistry

- businesses are interested in safer products
- customers desire greener products

Challenges for Implementation

- complex supply chains
- desire for IP can slow or block collaborative efforts
- lack of interest from high up in organization

Helpful Actions

- partnering with suppliers and committing to buy green solutions
- understanding and commitment from high up in corporate ladder
- brands using their power to "pull" supply chain
- supply chain aligning with green chemistry
- identify toxicity early on in development

Role for the GC3

- bring different levels of supply chain together at the table
- create collaborative efforts that avoid IP issues
- provide tools for educating/convincing C-suite

Session IV

Are We Succeeding? Measuring Progress in Green Chemistry

Ann Blake, Environmental and Public Health Consulting
Andrew Dicks, University of Toronto
Gabe Wing, Herman Miller[2]
Sally Edwards, University of Massachusetts Lowell
Amanda Cattermole, Cattermole Consulting *(moderator)*

While the definition of green chemistry has been mostly solidified, metrics are all over the map, with many being proxy measures. We have an opportunity to think intentionally about green chemistry metrics at different levels—molecular, product, company, and so on. "Preferred" lists of ingredients/processes are important to accelerate progress. To move toward the triple bottom line of protecting the economy, people, and planet, we need to build on existing work and develop improved metrics and tools at every level.

Process mass intensity (PMI) is a useful green chemistry metric in industry due to its front-end, proactive approach. However, the most common sustainability metrics are still carbon footprint, CO_2 production, water usage, and life cycle assessment. Tools such as Sanofi's ID cards allow evaluation of a chemical's hazards, physical properties, cost, and possible substitutions, but there are multiple such guides which are not always in agreement. Other important process considerations include energy usage, process safety, and product degradation potential. Often, there is insufficient toxicity data to make an informed decision.

Herman Miller develops goals that create movement within the company. In addition to company-wide goals such as zero waste, reduced water and energy use, they have created eco-inspired product scorecards which account for ease of disassembly, materials toxicity, recycled/biobased content, LCA, and more. Herman Miller has encountered challenges in creating their metrics, including scalability, data gaps, keeping up the speed of production, and ensuring that the goals are really worthwhile and embedded within the company.

The Chemical Footprint Project is a corporate-level tool to evaluate systems for chemical management. It is focused on public benchmarking and recognizing leadership in safer chemistry, and designed to work alongside related tools. A "chemical footprint" is defined as the total mass of high-concern products sold by a company or used in its manufacturing operations and by its suppliers. The framework of the CFP includes management strategy, chemical inventory, progress measurement, and public disclosure. A beta version of the tool will go online in June. The Green Chemistry Checklist can also help companies elevate green chemistry within their firm.

Opportunities for Safer Chemicals and Products

- metrics are currently all over the map; need unification/simplification
- metrics for bio-based materials

Key Drivers for Green Chemistry

- company desire for sustainability and safer products/processes
- investors could potentially choose green chemistry oriented companies

Challenges for Implementation

- complexity of product manufacturing makes universal metrics challenging
- sustainability metrics are distinct from green chemistry; potentially confusing

Helpful Actions

- unifying metrics at each level
- making it easy for companies to implement green chemistry policies

Role for the GC3

- connecting companies at different stages of metric implementation
- publicizing helpful metrics and tools

Green Chemistry Problem Solving

See attached appendix

Session V

What Makes Partnerships Work? Lessons from the Real World

Jason Wadsworth, Wegmans
Roger McFadden, Staples
Martin Mulvihill, UC Berkeley Center for Green Chemistry
Kaj Johnson, Method
Johanna Brickman, Oregon BEST *(moderator)*

Staples and Wegmans have partnered in an effort to find a safer alternative to BPA-containing thermal paper. The impetus for the partnership was concern about the harmful effects of BPA from a local consumer advocacy group, who asked Wegmans about the ingredients in their register tapes. Wegmans reached out to Staples, who communicated with their supplier, improved transparency, and discovered that the thermal paper did contain BPA. Roger McFadden and Jason Wadsworth have worked together for 3 years to find an acceptable safer alternative, agreeing to avoid regrettable substitutions by thoroughly evaluating potential hazards of replacements. Roger reached out to the EPA's DfE team, who identified 14 alternatives, all of which unfortunately had unacceptable tradeoffs. Staples then reached out to chemical suppliers, and is currently in the process of investigating two safer alternatives—a drop-in developer replacement, and a process that creates a thermal image without the use of a developer. Next steps in the project involve Staples confirming performance and compatibility of these candidates, selecting one, and finalizing a business relationship with the supplier in order to present a new alternative to Wegmans. Wegmans will then test the new product in stores.

The Berkeley Center for Green Chemistry is pioneering a new model for business-to-academic partnership in its graduate Greener Solutions class. The class teams students from different scientific disciplines and partners them with industry to solve real problems with green chemistry solutions, both in the short- and long-term. The executive director of the BCGC, Marty Mulvihill, looks for business collaborations that include domain-specific technical expertise, pre-competitive challenges that affect the entire sector, a willingness to share results, and funding to support the class. A biomimetic approach is preferred, and students should not have to sign a non-disclosure agreement.

The most recent company to collaborate with the BCGC Greener Solutions class is Method, which has been searching for a safer way of preserving aqueous cleaning products. The GC3 and multiple personal care companies have participated in and benefited from this collaboration, and the USDA has provided lab space, resources, and microbiology experts to assist. Kaj Jonhson of Method feels the students bring a fresh perspective and creative nature-inspired ideas as they assist in identifying functional broad-spectrum preservatives using a rapid-screening approach. This process is generating interesting data, and could potentially be used in many other applications.

Opportunities for Safer Chemicals and Products

- consumer-facing products such as register receipts
- safer preservatives in personal care and cleaning products

- specific business problems that can be solved more quickly with collaboration

Key Drivers for Green Chemistry

- consumer demand for green chemistry
- increasing desire for safer chemistry from brands and retailers
- students interested in pursuing green chemistry careers

Challenges for Implementation

- supplier resistance to transparency
- balance between rapid response and careful assessment of alternatives
- lack of trust across supply chain
- lack of immediately-available safer alternatives

Helpful Actions

- increase transparency across supply chain
- define and understand challenges and opportunities
- take an orderly and prudent approach
- form partnerships across organizational "silos", sectors, and disciplines
- engage students for fresh ideas
- develop rapid screening methods to accelerate R&D

Role for the GC3

- foster partnerships across sectors as well as within
- increase trust across supply chain
- encourage transparency universally
- engage more universities and students in business partnerships

Thursday, April 30th

GC3 Project Group Breakout Sessions

See attached appendix

Session VI

Rethinking Reuse: Green Chemistry Transforms Waste to Goods

Molly Morse, Mango Materials
Scott D. Allen, Novomer
Ramaswamy Nagarajan, University of Massachusetts Lowell
David Constable, ACS Green Chemistry Institute *(moderator)*

The transformation of waste into goods is under development in many sectors and industries. Ramaswamy Nagarajan is a professor at UMass Lowell who focuses on transforming pre-consumer waste into usable chemicals. One technology converts citrus peels and other food waste into pectin-based polymer surfactants to replace nonylphenyl ethoxylates (NPEs or Triton-X). These macromolecules work in a fundamentally different way than traditional surfactants, making them equally effective, but far less toxic. Another project involves bio-based flame retardants synthesized from the cardanol in cashew nut shell liquid—a very cheap waste feedstock from the cashew industry. The resulting oligomer is as effective as some halogenated flame retardants, but far safer. These technologies show great potential for future use in industry, but are still under development.

Mango Materials is a startup company incorporated in 2010. They are using microbes to transform waste methane into polymers (PHA) that can biodegrade in a natural environment. This can be used to replace many existing plastics—for example, aquatically biodegradable PHA could be a safe alternative to microbeads. With waste methane feedstocks around the country, e.g., from landfill gas, and relatively simple production facilities, Mango Materials could easily decentralize production. This technology could contribute to a closed-loop plastics economy, in which plastics return to the landfill and degrade into methane, which is then collected to make more plastics. Mango is currently looking for PHA buyers as well as methane-producing partners.

Novomer was founded in 2004 on two core technologies: conversion of CO_2 to polymers and CO to fine chemicals. The Novomer catalytic technology was spun out of an academic lab at Cornell, and funded initially by an SBIR/STTR. After overcoming start-up problems such as manufacturing issues, shipping, and EH&S, Novomer has achieved commercial scale production of their primary CONVERGE® polyol products—4 basic polyols and 4 formulated products (adhesives and flexible foams). Novomer's flexible foam products are stronger and more load-bearing than conventional foams, while also having lower calorific value and thus requiring less flame retardant—a great demonstration of the "it's greener, AND…" principle.

Opportunities for Safer Chemicals and Products

- waste streams comprised of high-value chemicals
- many chemistries currently in research labs that could solve industrial problems

Key Drivers for Green Chemistry

- cheap, sustainable feedstocks
- side benefits (e.g., performance) from bio-based/green technologies
- researchers who are passionate about their green technology

Challenges for Implementation

- scaling new technologies can be very challenging
- scientists are not educated as entrepreneurs
- new technologies are often more expensive than traditional
- life cycle must be considered—could have regrettable trade-offs

Helpful Actions

- nurture and accelerate new technologies to scale
- incorporate business education into science curricula
- increase funding for tech transfer/small businesses

Role for the GC3

- advocate for entrepreneurial education in schools
- make connections between start-ups and large industrial partners, funders
- publicize funding sources for green technologies

Closing Remarks

Joel Tickner, University of Massachusetts Lowell

Joel Tickner, director of the GC3, presented the key outcomes of the project group discussions and the next steps each group initially outlined. He identified some of the key messages from this year's roundtable including:

- the need for supply chain and sectoral partnerships to accelerate green chemistry,
- being clear about the problems we are trying to solve with green chemistry,
- moving from green chemistry as an add-on consideration ("It's green, but…") to an integrated performance consideration ("It's green, and…"),
- looking at new ways to think about scale from a distributed economy perspective,
- developing shared language to talk about green chemistry, and
- understanding and embracing the complexity of supply chains and finding alignment.

Ultimately, the success of green chemistry will be about building transferrable models that overcome barriers and show pathways to success. There is no lack of energy in the green chemistry community. The challenge is channeling and focusing that energy towards common goals. In closing, Tickner reflected on what changes the next ten years will bring and the unique opportunity to accelerate the adoption of green chemistry and build a much larger, more impactful movement.

Appendix: Green Chemistry Problem Solving

Session 1: Technical Solutions

This was a small breakout session designed specifically to brainstorm solutions to challenges facing two companies. The goals of the session were:

1. To provide potential technologies and connections for each challenge that may need further investigation.
2. To provide strategies to consumer-facing companies to help them find solutions to technical challenges they are currently facing.

Challenge 1: Community Playthings

Community Playthings is looking for a mattress that will meet flammability standards for children's bedding while being safe for consumers. They would like to keep using polyurethane foam due to its inherent comfort; polyester alternatives were found uncomfortable. They are currently using wool linings, but these are uncomfortable for babies.

Technical ideas included:

- SABIC may have flame retardants that meet the requirements
- Inman Mills has a wide cotton knit product treated with a non-toxic flame retardant that is fast to washing, but not chlorine bleach
- Coir is a coconut fiber used for mattresses in India

Challenge 2: Method

Method is looking for safer preservatives for its home cleaning products.

Technical ideas included:

- Boat paints need biocide—talk to Valspar about their acrylic boat paints
- Oxygen and UV light
- Surface modifications such as sharkskin texture
- Enzymatic approach
- Look at alternative manufacturing solutions, e.g. techniques used to reduce contamination during manufacturing in clean room environments

Overall Strategies

- Be very clear about your challenge. Create a needs statement.
- Work with other industry partners to find a solution; they often use the same suppliers. "Seatbelt approach" – good for everyone if safest possible solution exists.
- Align on standards to simplify and harmonize
- Change the regulation/policy (i.e. flammability standard)
- Join and work with good trade association
- Identify short-term solution, such as a drop-in substitute
- Identify long-term approach to meet desired functions by potentially different approach

Session 2: Overcoming Barriers

This session was intended to discuss barriers in the adoption of green chemistry in industry, and how best to overcome them using the resources of the GC3 and its members.

Supply Chain Hurdles

- Common language and metrics—often struggle with definitions
- Lack of transparency—especially with complex supply chains; communication gaps between initial supplier and final brand/retailer
- Customers don't know what question to ask; retailers don't know how to answer
- Cost of greener options
  - could be offset by alternative benefits, true cost
- Established local relationships—often cannot change suppliers easily
- Lack of consistent messaging to suppliers
  - could be solved with better intra-organization communication
- Supply chain bears cost of decisions made by brands/retailers
  - supplier should be involved in decision-making process
  - can be advocates if asked
- Adding new suppliers can conflict with corporate commitments to simplify supply chain

Collaborative Efforts

- New materials raise barriers—difficulty of integration, manufacturing changes
- Scale-up is expensive and requires collaboration
- Competitive vs. pre-competitive can cause problems
  - Tap into broad network of problem-solvers
- Cross-sectoral collaboration to move towards circular economy
  - One waste stream = other company's feedstock
  - Need a safe space to discuss potential of waste streams without being vilified
- Apparel sector has effective chemicals management
- Brands could create lists of common needs to spark innovation
- Systems mapping (e.g. roadmap to ZDHC)
  - What groups should be engaged?
  - Bring together existing maps from multiple industries
- Integrating sustainability into business practices—major challenge
  - Education across departments, targeted at different specialties
- Peer motivation: genuine efforts from GC3 members excite other companies
- Increase visibility of tools/maps across industries
  - Solicit open feedback about these tools at conferences to make them more useful in the real world
- Education on data visualization and communication (Edward Tufte)

Compromise

- "Compromise" assumes knowledge of trade-offs, which is difficult in GC
  - stepwise is the only way forward
- Wegmans started out saying "no" to PLA, but changed to "yes" after visiting Natureworks and learning about technology
- Standards and certifications must compromise between simplicity for consumers/formulators vs. complexity of science

Role for GC3

- Bring suppliers to the table and help involve them in GC decision-making
- Connect problem-solvers with problem-havers
- Provide safe space to discuss potential of waste streams

- Bring brands together to create lists of common GC needs for each sector
- Collect existing systems maps from across industries
- Share successful GC efforts from member companies to inspire peers
- Increase visibility of GC tools across industries; compare capabilities
- Provide opportunities for education re: data visualization

Session 3. Bio-Based Feedstocks

This session was meant to explore how to grow the market for bio-based feedstocks and overcome factors limiting their uptake. BASF described their current challenges in developing a market for bio-based butanediol, and these as well as broader challenges were discussed.

Factors Limiting Uptake of Bio-Based Feedstocks

- Scaling is costly; senior management wants brand owner commitment first
- Customers expect chemical supplier to absorb costs; supplier's management wants to charge premium to cover costs and potential risks
- Larger chemical companies have gutted R&D departments; acquire small companies once their innovations are proven

Challenges for Business Case in Low Oil Price Market

- Volatile market. Low costs of non-renewables don't account for externalities
- Customers switch to bio-based if cheaper, or new properties, or marketing opportunity
- Chemical mindset is based on 120 chemicals from petroleum

Overcoming Barriers

- Provide bio-based materials at/below 10-yr average of petro-based commodity for fixed period of time
- Look for customers with strong sustainability propositions
- Use waste as feedstock to gain cost advantage (get paid to remove waste)
- Focus on specialty chemicals rather than drop-in commodity replacements
- Change mindsets of chemists/chemical engineers, rather than customers
- Differentiate by changing name of chemical (some disagreement on this)

Sharing Cost and Risk Throughout Supply Chain

- Difficult to control other companies' asking prices/premiums
- Chemical companies must talk to customers, customers' customers, and so on to explain value proposition and promote bio-based materials

Role for GC3

- Promote members that are providing sustainable materials through the GC3 Innovation Portal—list of companies with green materials, ability to post requests
- Create website with entire value chain and names of companies at each level
- Point to individual companies' portals
- Help develop business case
- Ask member companies to encourage supply chains to attend GC3 events

Session 4. Defining Green Chemistry

This group addressed the issue of a unified definition of green chemistry—how useful this is, how to arrive at one, and how to disseminate it.

Aligning on Single Definition

- Easy between partners in a collaboration, more difficult at large scale
  - Language depends on where you are in the value chain
- Is it helpful? Perhaps embracing heterogeneity and exploring different concepts is better
  - Clear definition is important in policy
  - Definitions are useful for metrics
  - Flexibility leads to creativity
- Map out components of green/sustainable chemistry to create linked set of concepts that strengthen each other
  - Map tools and definitions, compare performance

Guides vs. Definitions

- Could we work on using principles as a guide?
  - Evolution of principles over time?
  - No discussion of whether principles are inhibiting, how to implement
- State directionality of where we'd like to be rather than concrete principles/definitions
  - Chemicals that are less toxic, material intensive, energy intensive, etc.
- GC is innovation throughout lifecycle
  - Mulvihill et al paper can serve as model

What Makes Chemistry Green?

- Overall improvement without any one category worsening?
- Minimal criteria or baseline?
- Tool like LiDS wheel might be helpful to show where improvements are taking place
- Green chemistry alone cannot solve all problems

Next Steps

- Build relationship map of GC vs. sustainability/lifecycle concepts
  - Identify unique value and position of GC

Appendix: Project Group Breakout Sessions

Innovation Group

The goal of this session was to discuss two ongoing innovation projects which are expected to continue into the coming year, and gather feedback and suggestions for improvement.

Ongoing Project: Green Chemistry Innovation Portal

Online platform for growing and connecting the green chemistry community and solving green chemistry challenges

- partnered with ACS Green Chemistry Institute
- forum component on ACS Network to facilitate connections and partnerships, encourage sharing of expertise and information
  - could we include links to green chemistry journals? (*Green Chemistry* is RSC journal, not ACS)
  - include regulatory information? (this is already covered by IC2)
  - appropriate level of management will be determined as forum evolves
  - potential for crowd-sourced tracking of GC innovations (but must keep barrier to entry low—could "sticky" this thread to top of forum)
  - needs robust search function – ACS built-in search function is not sophisticated
  - ability to "tag" posts should be included, possibly with guidelines
- map component on Kumu to introduce outsiders to community, identify research groups in green chemistry, help companies find technical partners
  - could GCEdNET be incorporated? (GC educators)
  - people cannot be included due to complexity, but viewers interested in personal connections (provide GC3 contact, also point to forum)
  - logistical demands of updating could be time-consuming
  - user profiles for self-updating? Not realistic to expect people to commit to update these
  - fillable form for companies to add themselves
  - can expand the map by networking, asking companies who they work with

Ongoing Project: Collaborative Innovation for Safer Preservatives

Sector-wide collaboration to accelerate commercialization of safer preservative systems for personal care and household cleaning products

- creating new model of pre-competitive collaboration for development and scale-up of green chemistry technologies
- currently developing list of criteria for ideal safer preservative, to be distributed to guide and encourage R&D
  - funding for R&D? Crowdsourcing? IP issues?
  - lessons to be learned from this work as it scales?
  - GC solutions require systemic changes

Education Group

The goal of this session was to get feedback about ongoing education projects, as well as brainstorm ideas for future projects that the GC3 could undertake to further green chemistry education.

Ongoing Project: Education Portal

Online portal allowing easy access to GC3 Education Series webinars, designed for education of professionals and students around green chemistry-related topics.

- Beta version is now live and improving based on feedback
- Features include presenter bios, hyperlinks to each presenter's talk, suggested prerequisites, additional reading
- Webinars are members-only for the first year, then publicly available
  - Metrics on engagement?
- Additional topics?
  - More business examples
  - More GC assessment tools for synthetic chemists (LCA intro, alternatives assessment intro, list translators, etc.)
  - Supply chain management/communication

Ongoing Project: Fellows Program

Summer internship program intended to provide training for next-generation workforce, provide students with industry experience and industry with desirable future hires.

- One company participating in this year's pilot
- Fellows from 2015 and 2016 will attend 2016 Roundtable to learn about industry
- No unpaid internships; would like to standardize stipends if possible
  - Non-profits would like to participate, but have difficulty finding funding
  - Universities (e.g. OSU) might be able to provide funding for students to be paid for non-profit internships. Look into this on case-by-case basis

Ongoing Project: Policy Statement on Green Chemistry in Higher Education

Statement calling on higher education institutions to integrate green chemistry and sustainability principles into chemistry, engineering, science, and business curricula.

- currently signed by 30 GC3 organizations
  - would like more signatories, preferably all GC3 members
- needs more power/influence
  - metrics for demonstrating that companies are following commitment
  - students need to see how green chemistry can give them an advantage
  - GC3 companies could track student hiring over the next 5 years and report
  - Ask signatories to put GC in job descriptions, monitor how many people with GC experience make it to the interview

Project Idea: Outreach Education Webpage

Short stories of member outreach successes, example activities, links to resources

- Tools for companies looking for a starting point in outreach
- List of speakers willing to talk about green chemistry topics? Ex: EPA had list of speakers and topics

Other Ideas/Comments

- Nike interested in collaborative real world engagement project with schools
- Case studies from mainstreaming document

- Could be examples for students, but would need solid data
    - Need science case studies as opposed to typical economic ones
    - Examples of GC being implemented in companies, tell stories and show impact – could be helpful to professors
    - Expand case studies with multiple angles—engineering, business, toxicology, public health—to break down disciplinary "silos" for students
- Influence textbook companies to incorporate/embed green chemistry in chem textbooks – e.g. case studies that are woven throughout
    - Can GC3 or members apply pressure here? GC3 could provide case studies
- Many US schools use ACS standards, which don't include green chemistry
- Short videos with definitions of GC from major industry players?
- Certification in GC/chemical stewardship at UW now available online
- Consider idea of Summit for Green Chemistry in Education
- Need more advocates within companies
- Companies don't market sustainability enough
    - Shouldn't need to add GC in job descriptions because it would be obviously embedded in mission statement
    - Large companies are more conservative about this; don't want to spend time responding to complaints about not doing enough
- Need "green chemistry" to be included in job descriptions
    - GC3 posting jobs?
    - Can GC3 ask companies to post their job opportunities to the GC3 LinkedIn page?
- GC3 should ask companies with green chemistry related press releases to send them to GC3 for promotion

Mainstreaming Group

The goal of this session was to start a discussion about what mainstreaming green chemistry will look like when the industry is mature, and what various steps along the way to get there might be. The purpose is to help identify where the GC3 and its members can focus efforts to accelerate green chemistry, and be able to track progress.

Maturity Ladder of Green Chemistry

The concept of a maturity ladder was introduced, and several models discussed. In a maturity ladder, the top rung of the ladder is the end goal, with lower rungs as the steps to get there. The first model presented, from Johnson & Johnson, is used by that company for improving their safety culture and includes the following five major steps:

1. Broken
2. Beginning
3. Improving
4. Succeeding
5. Leading

Relevant to this maturity ladder, participants felt the current state of green chemistry is probably in the "Beginning" stage for industry, and perhaps the "Broken" stage for education.

The group then reviewed the Industry Sector Maturity model for mainstreaming global supply chain sustainability from the IDH Monitoring Protocol which included the following 4 major steps:

1. Initiation
2. First mover
3. Critical mass
4. License to operate

A final model from International EcoCity was also shown, looking at steps from an unhealthy city to a "Gaia" type city.

Thoughts regarding indicators and outcomes for mainstreaming green chemistry:

- Need something quantitative
- Elimination of environmentally induced diseases
- Indicators: 30,000 chemicals in commerce are green
- Indicators should include product- and company-related quantitative goals
- Need a change in culture, mindshift—this is difficult to measure
- Green chemistry is not a checkbox, it is a way of thinking, so is not always easy to measure

Drivers required for mainstreaming green chemistry education:

- Increased hiring in green chemistry
- Increased R&D funding for green chemistry

Some key points/questions brought up in the discussion:

- What would be the impact if environmental regulatory groups in all 50 states took this same approach?
- Change is discontinuous, there are probably tipping points where major progress will occur
- What levers should we focus on?

Michigan Ecology Center Green Chemistry Checklist

The group looked to the Michigan Ecology Center Green Chemistry Checklist: A Guide for Business. This is a tool that industry can use to track their progress in green chemistry. It includes four areas—Education, Hiring, Support & Communication, Design & Innovation—with specific steps for each area. Discussion focused on this framework, expanding hiring to include workforce development.

The group started a brainstorm around education, looking at potential rungs:

- Initial rung: green chemistry class offered at each school
- Other potential rungs:
  - Bridging green chemistry to engineering
  - Outreach and education to high school teachers on GC
  - Educating the public on green chemistry
  - Editorial policy in professional journalism
- Ultimate rung: every school teaches green chemistry as chemistry; the 12 Principles are embedded

Vision statements were proposed for Hiring & Workforce:

- GC is fully valued in the chemical profession and the subsets of related professions
- GC principles are embedded in the requirements for hiring chemists/engineers

As well as Design & Innovation:

- 100% of chemistry related R&D (firm and government) is going towards projects with green chemistry as a core element

Retail Leadership Council

This workgroup focuses on engaging retailers in the push to promote safer chemicals, materials and products across retail supply chains.

Areas of Agreement

- RLC/Chem industry group is excellent forum to participate in conversations not normally had—helps understand needs, issues and each other's businesses
  - Build understanding between B2B businesses and B2C businesses
  - Find leverage points on both sides to help upstream and downstream decisions
  - Create demand at the retail level for safer chemicals and products and then safer chemicals and products will be "pulled through" the supply chain, starting with the chemical manufacturers
- Brand owners need to be involved—when and where should group be going?
- Convergence work needs to be done. Mapping needs to be done to identify opportunities for convergence. Create a "turbo-tax" of chemicals.
- Need to get ahead of regulations
- Need to continue and increase case studies: include lessons learned (successes and failures)
  - Evaluate/update on the 2008-2010 case studies. Where are they now?
- Significant need for consumer education. How to do this?

Areas of Disagreement or Lack of Conclusion

- Varied need for access to updated database on chemical regulations and ingredient disclosures. Large companies/retailers have internally; smaller companies want help.
- Expand the GC3 newsletter?
- GC3 as a conduit for tools: Pharos, Greenscreen, etc. Where are they going? What is on the horizon? Peer reviews of tools.

Suggested Next Steps for the GC3

- Continue work of Retailer Leadership Council
- Map related initiatives to identify opportunities for convergence
- Develop new case studies to share retailer progress in chemicals management
- Provide basic education on materials and functional uses of chemicals
- Provide education at merchant/supplier interface and with consumers
- Provide access to updated database on chemical regulations (it was noted that IC2 manages such a database – see http://www.theic2.org/chemical-policy)