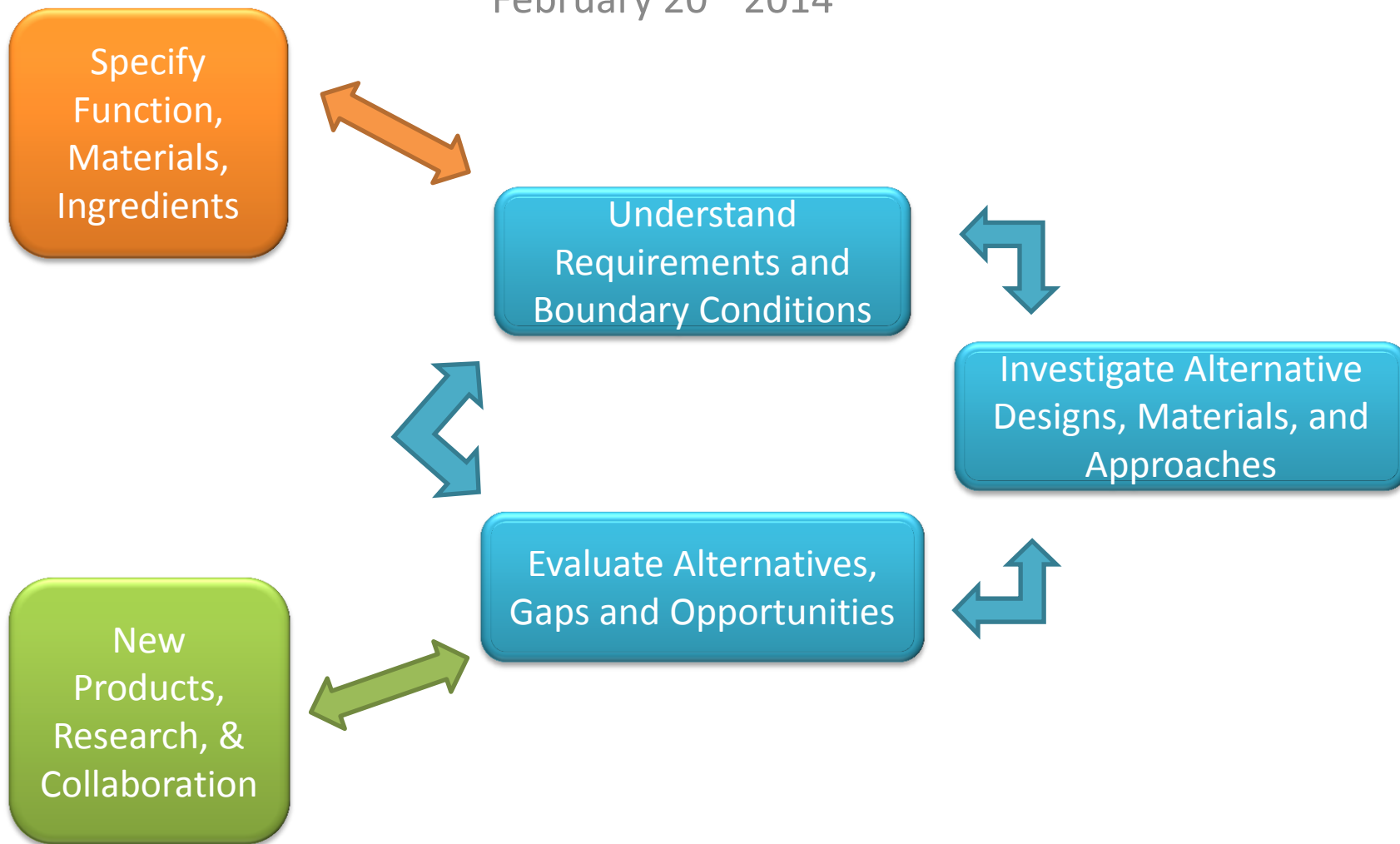


# Panel 2: Systems Approach to Greener Design

Marty Mulvihill, Berkeley Center for Green Chemistry  
February 20<sup>th</sup> 2014



Sharing experience and approaches to collaborative research projects aimed at identifying and promoting greener materials.



BERKELEY CENTER FOR  
GREEN CHEMISTRY

A collaborative center aimed at understanding  
and improving the materials basis of society.

**Haas School of Business**

*Characterizing the Business drivers*

Manufacture

**Labor and Occupational  
Health Program**

*Implementing understanding*

**College of Engineering**

*Developing more efficient  
processes*

Processing

Maximize safety  
and efficiency of  
materials and  
chemical processes

Use

**School of Public  
Health and  
Toxicology**

*Ensuring safer  
materials selection*

**College of Chemistry**

*Using more efficient  
and less impactful  
chemicals & process*

Extraction

Disposal/  
Recycle

**College of Natural Resources**

*Understanding the impacts of chemical  
products on the environment*

# Disciplines look at different parts of the supply chain

Discipline	Basic Research	Development	Implementation	Evaluation
Chemistry	High	Moderate	Low	Moderate
Chemical Engineering	Moderate	High	High	Moderate
Toxicology	High	Low	Low	High
Environmental Science	High	Low	Moderate	High
Public Health	Moderate	Low	Moderate	High
Business	Low	Moderate	High	Moderate
Public Policy	Low	Moderate	High	High
Sociology	Moderate	Low	High	Moderate
Science and Technology Studies	Moderate	Low	High	High

**Basic Research:** Research aimed at the discovery of new quantifiable phenomena that could lead to technology development.

**Development:** Research aimed at creating new technologies with specific outputs.

**Implementation:** Research aimed at elucidating the drivers and barriers for the adoption of new technology in industrial and societal settings.

**Evaluation:** Research aimed at determining the effects of new technology on society, health, and the environment.



## BERKELEY CENTER FOR GREEN CHEMISTRY

*One of the nation's leading centers for interdisciplinary studies in green chemistry*

Mission: To bring about a generational transformation toward the design and use of inherently safer chemicals and materials.



### Education

Integrate the chemical sciences, environmental health sciences, and the study of public and private governance into a cohesive **interdisciplinary educational program**.



### Research

Develop a **world-class research program** that designs novel chemical processes and materials and investigates new approaches to toxicity testing, exposure analysis, and alternatives assessment.

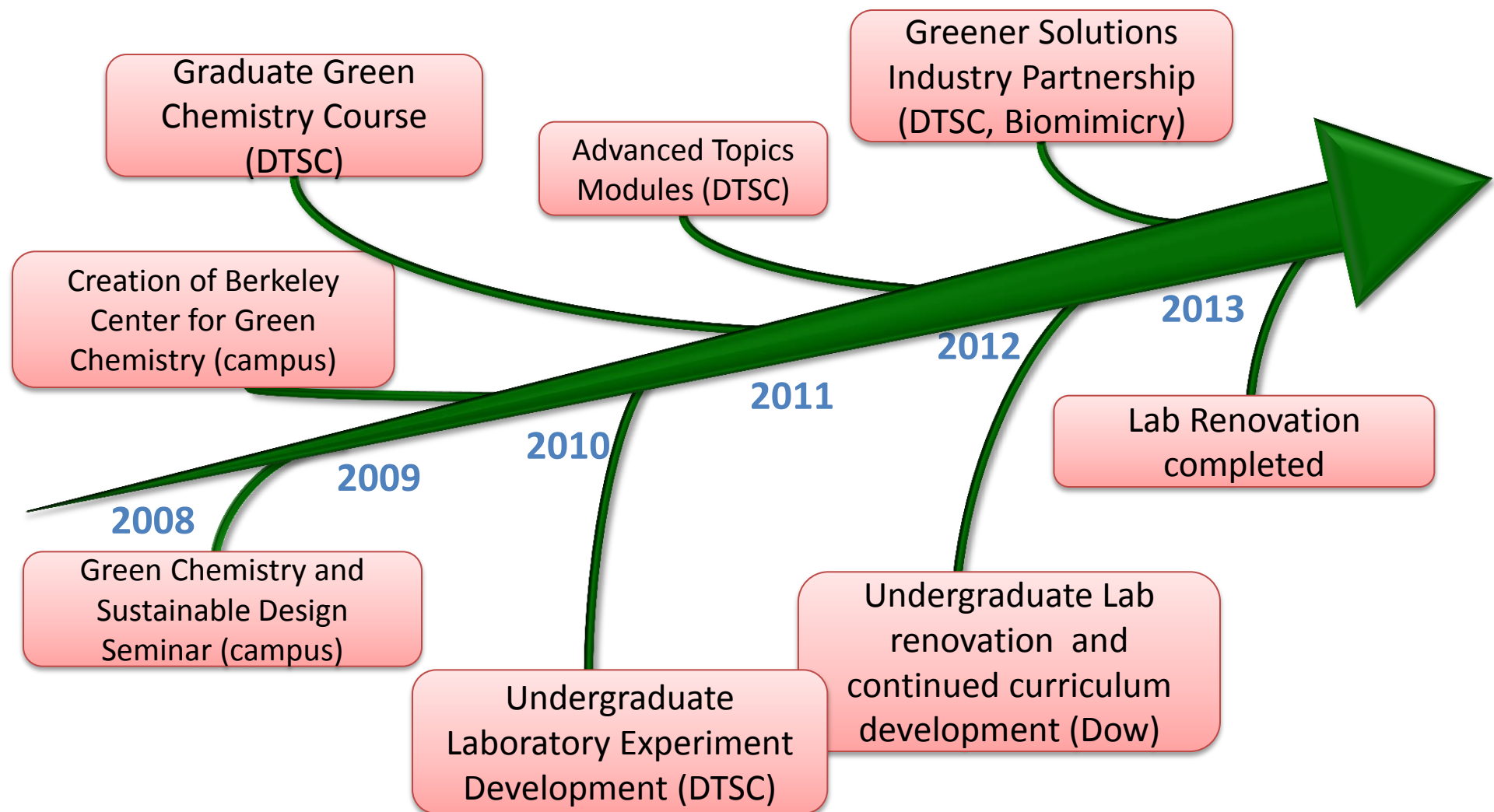


### Engagement

Provide **technical support** to decision-makers, workers, community organizations and businesses working to **advance green chemistry**.

# Evolution of Green Chemistry Courses at UC Berkeley

- Undergraduate curriculum reaches over 2500 students/year
- Increases interest in chemistry on campus
- Helps fund new equipment and lab space



# New Undergraduate Labs Broaden the scope of Chemistry Education



## Example Module Biofuels

- Multi-week modules for research-like experience
- Rigorous chemistry
- Give students a valuable learning context.

### Week 1



#### Ecotoxicity Assay:

- Dose-Response  $LD_{50}$
- Standard Dilution
- Concentration nomenclature
- Data Analysis

### Week 2



#### Biodiesel Synthesis:

- Balancing reactions
- Density
- Separations

### Week 3



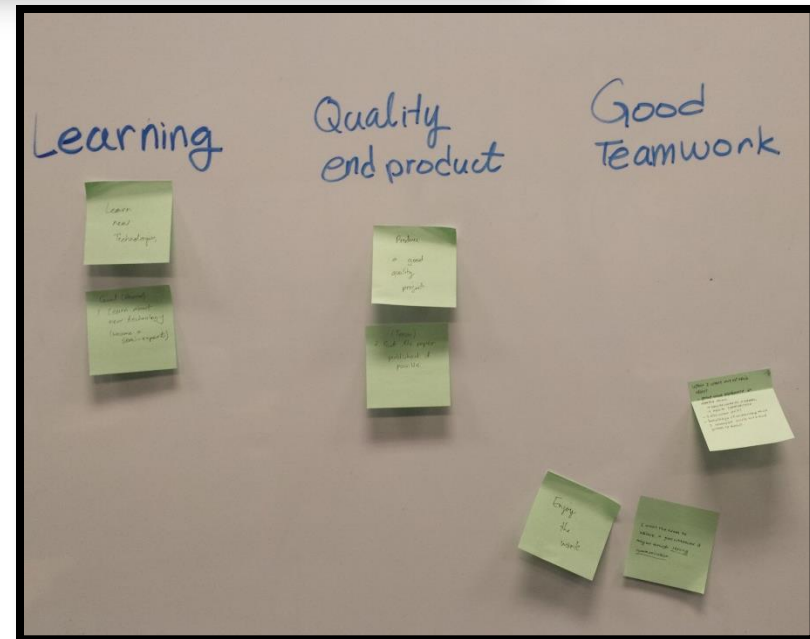
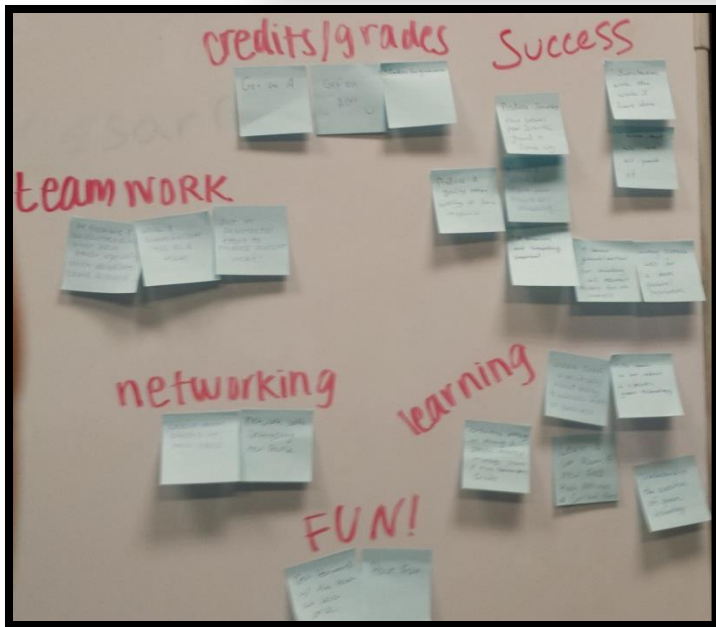
#### Fuel Calorimetry:

- Heat of Combustion
- Efficiency
- Energy Density
- Mixtures

**Students discover the practical nature of Green Chemistry**



# A different model for graduate education



# Our research interests range from the molecular to the society level analysis.

## RECEPTION AND POSTER SESSION

**Julle Chaves** "Application of Alkalinity and Salinity to Cyanobacteria Isoprene Production"

**Heather Buckley** "Understanding Marine Oil Spills: Improving Decision Making and Identifying Key Research Needs"

**Antony Bum Kim** "Post-Occupancy Evaluation on the Effects of Light on Human Health"

**Shuk Han Chan** "Sustainable Manufacturing: At the Intersection of Health, Materials, and the Built Environment"

**Ben Greenfield** "PCB Patterns in San Francisco Bay Forage Fish"

**Noah Kittner** "Greenhouse Gas Benefits of Building-integrated Photovoltaics in Thailand"

**Jennifer Lawrence** "Bioremediation of Aqueous Film Forming Foams"

**Emily Morse** "PRI Pesticide Product Evaluator for LEED Credit: A Simplified Approach to Integrated Pest Management"

**Hurik Muradyan** "Calcium Stearate as Water Resistant Additive in Sustainable Roofing Panels Made from Recycled Materials"

**Avi Ringer** "Barriers to the Diffusion of New Technologies: Theory and Cases from Biobased Chemicals"

**Leah Rubin** "Electrochemical Reactivity of Organic Hydrogen Storage Carriers with Ferrocenyl Redox Mediators"

**Jessica Zelgler** "Development of Early Transition Metal Corrole Complexes for CO<sub>2</sub> Activation"





# NSF-IGERT to Support Graduate Education and Research



## Systems Approach to Green Energy

With support from the NSF, we offer two year graduate fellowships to students interested in conducting interdisciplinary research related to green energy.

Students will collaborate with experts from across campus to create sustainable solutions to energy challenges.

### We are supporting:

- **12 graduate students**
- **International Experiences**
- **Collaborative Research**
- **Partnerships with Industry, Government & NGOs**

Learn more at:

<http://sage-bcgc.berkeley.edu>

# Our outreach activities support government decision makers, local schools, NGOs, and businesses

Researchers in the BCGC are called upon to provide testimony to the California Legislature, and to serve on advisory boards, including:

- Green Ribbon Science Panel (Cal/EPA)
- Biomonitoring Science Guidance Panel (Cal/EPA)
- Cumulative Impacts and Precautionary Approaches work group (Cal/EPA)
- Green Chemistry Commitment , an NGO, university & government collaboration to advance green chemistry education.



- Support undergraduate volunteering in classroom. (See Your Future)
- Participate in local ACS outreach events (National Chemistry Week)
- Science communication through (EHN)

*National Chemistry Week Event Photo- Barnes*

Greener Solutions became a way for us to more effectively interact with diverse stakeholders, while providing our graduate students with real-world challenges and experience.



BIOMIMICRY 3.8



KAISER PERMANENTE®

LOHP  
LABOR OCCUPATIONAL  
HEALTH PROGRAM



CHANGE



BEAUTYCOUNTER



**2012**

6 students

Hewlett Packard

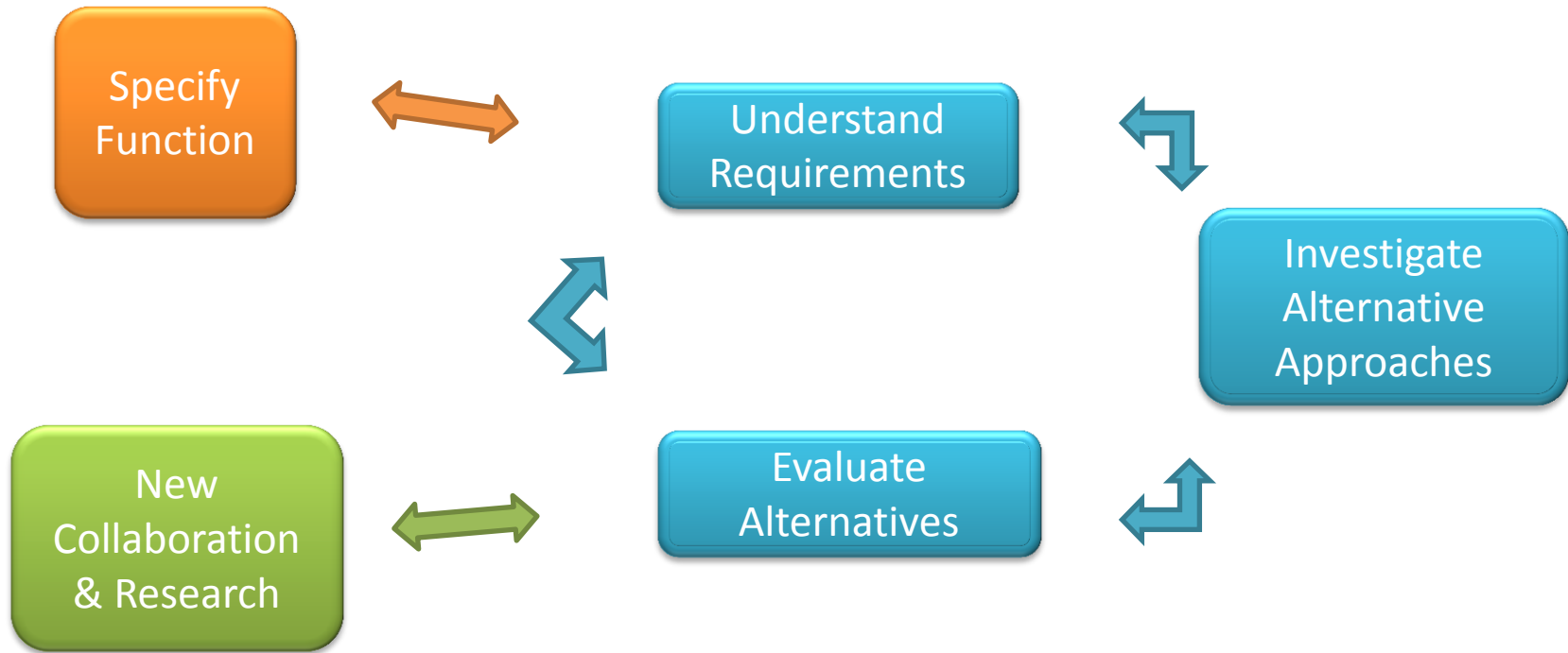
**2013**

10 students

LS&Co, Biomimicry

**2014 and Beyond?**

# non-CBI Challenges with broad cross-sector impact



***Students evaluate the opportunities for innovation***

**Incremental**  
Minimal Investment  
Quick Adoption

**Disruptive**  
Significant Investment  
New Markets are needed  
Long term shift in company structure

# Quotes from Partners and Students

“Wow, this is really cool! I just reviewed the papers and am really excited to see the depth of knowledge and research the teams displayed in their work.” –Karl Palmer, DTSC

“Again, good work on the presentation yesterday! Would some of you be willing to present it again via webinar early next semester?” –Curtis Wray, HP

“Most courses teach facts that I then easily forget. This course taught me skills, the "how to" of performing research and communicating findings to non-academics.” –Student

“I have never done this much research for a science class--and it was really fun! Overall, I would recommend this class to any student.” –Student

“The mandate to produce something that is of value beyond the course itself is not only very motivating, but also provides for a real-world background against which to test and refine the abstract lessons learned in lectures.” –Student

“Although other academic classes have been enlightening and interesting, this class was extremely valuable comparatively because it was the first time that I could develop significant practical skills in the class that will help in a potential future career. “ –Student



An aerial photograph of a city and bay, likely San Francisco, with a large white text overlay in the center. The text reads "Thank You!". The background shows a dense urban area with a large body of water and a bridge in the distance. The sky is blue with scattered white clouds. The foreground shows a residential area with houses and trees on a hillside.

**Thank You!**



# Help Us Achieve our Goal

We seek to bring about a generational transformation in the design, production, and use of chemicals, materials, and products. We are building a foundation to safeguard human health and ecosystems by embedding the principles of green chemistry into science, engineering, business decision-making, and public policy. We are working to realize this goal through basic research and applied innovations. We cultivate partnerships with organizations who share this vision and want to invest in the next generation of chemistry and materials.



# Greener Solutions Collaboration



BEAUTYCOUNTER



BIOMIMICRY 3.0



Systems Approach  
to Green Energy

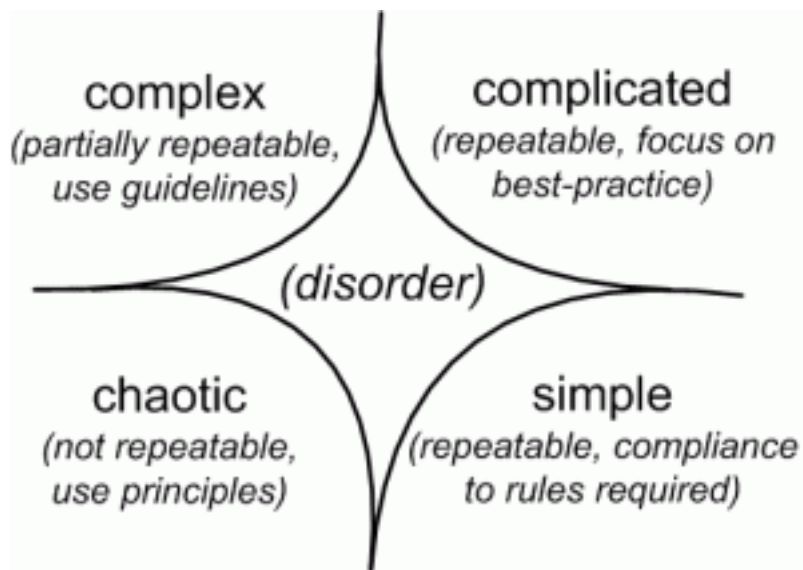


Department of Toxic  
Substance Control

We teach problem-solving and collaborative approaches.

We build on the tools and expertise of graduate students content areas.

We are not creating “green chemists” we are teaching students from how to collaborate and solve materials sustainability challenges.



### Complex

the relationship between cause and effect can only be perceived in retrospect

*probe – sense - respond*

**emergent practice**

### novel practice

no relationship between cause and effect at systems level

*act – sense - respond*

### Complicated

the relationship between cause and effect requires analysis or some form of investigation and/or the application of expert knowledge

*sense – analyze - respond*

**good practice**

### best practice

the relationship between cause and effect is obvious to all

*sense – categorize - respond*

# Our Approach: Building Research out of Class Projects

- A natural place to scope new projects
- Students are general excited about interacting outside of their disciplines
- Green Chemistry is best taught within the context of examples

