Green Chemistry Education Webinar Series

Green Chemistry – Benign By Design

July 21, 2015

GREEN CHEMISTRY & COMMERCE COUNCIL

Business Mainstreaming Green Chemistry

Today's Speakers

JOHN WARNER

President & CTO,
Warner Babcock Institute for
Green Chemistry

Green Chemistry: Benign by Design

John C. Warner
President and Chief Technology Officer
Warner Babcock Institute for Green Chemistry, LLC

warnerbabcock
institute for green chemistry

beyondbenign

Today's Talk:

- Green Chemistry
- Product Design
- Zero and Big Numbers
- How it fits together
- Examples from WBI

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The Washington Post
EPA Is Reconsidering D
The New York Times
Child obesity is link
to chemicals in plastic
TIME
The Poisoning of America
The Japan Times
Oceans awash in toxic seas of plastic
THE WALL STREET JOURNAL.
Yes, Bisphenol-A Does Enter the Body from Plastic Bottles
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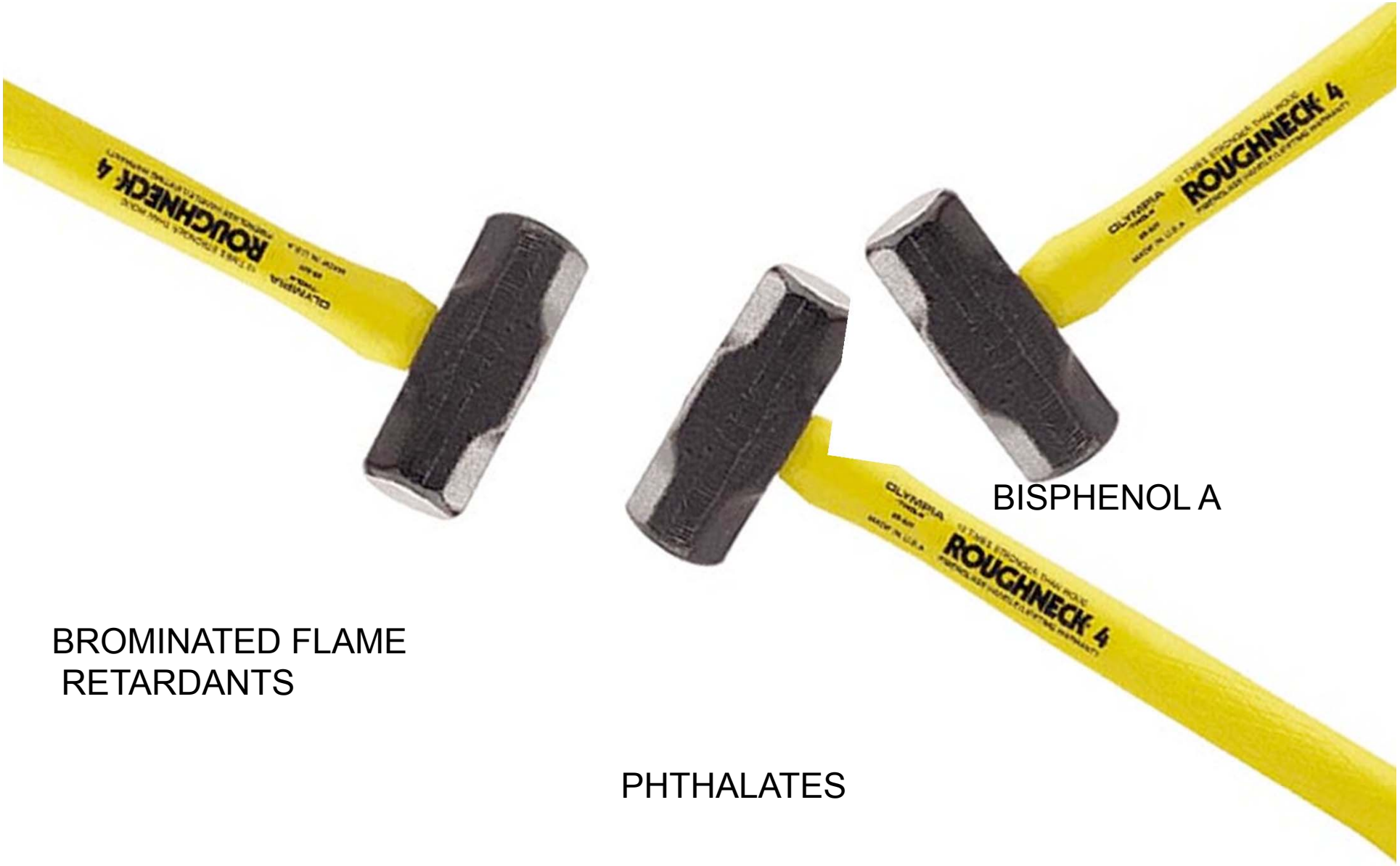
erious contaminati
from Africa's m
USA TODAY
5,000 evacuated after
hazardous Pa. acid spill
Chicago Tribune
Chicago's Toxic Air
THE SUNDAY TIMES
Household Dust Contains Highly Toxic Chemicals


WHACK A MOLE!



BISPHENOL A

BROMINATED FLAME
RETARDANTS

PHTHALATES

Asking the Right Questions

Why would a chemist make a hazardous material?

How do we train chemists?

Every Year: (United States)

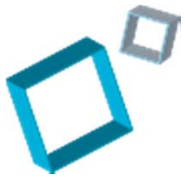
Chemistry and Chemical Engineering Graduates

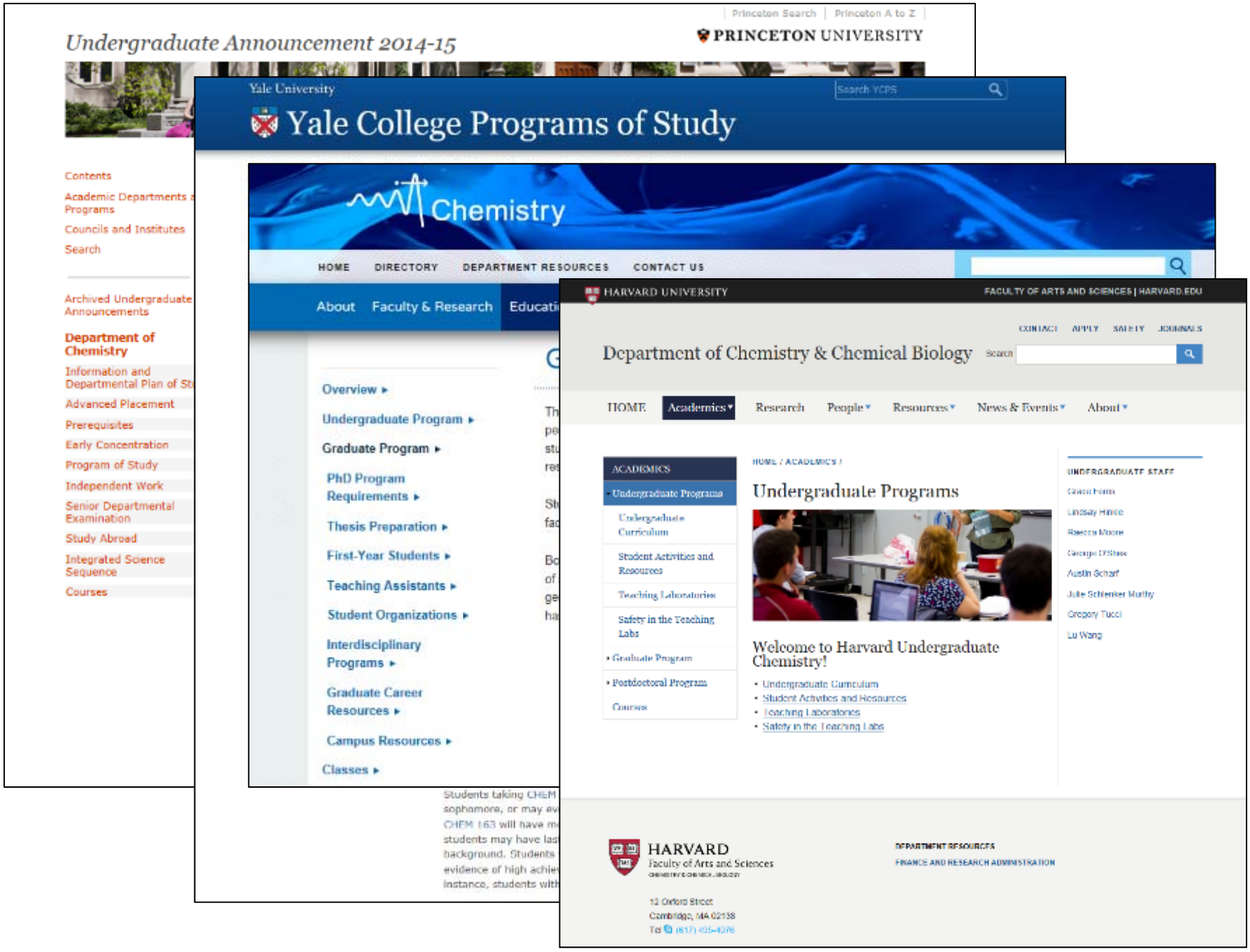
15,000 Undergraduate Degrees

3,000 Masters Degrees

3,000 Doctoral Degrees

50.9 % Women Undergraduate Degrees (2004)

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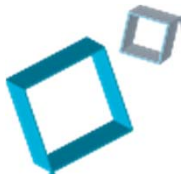
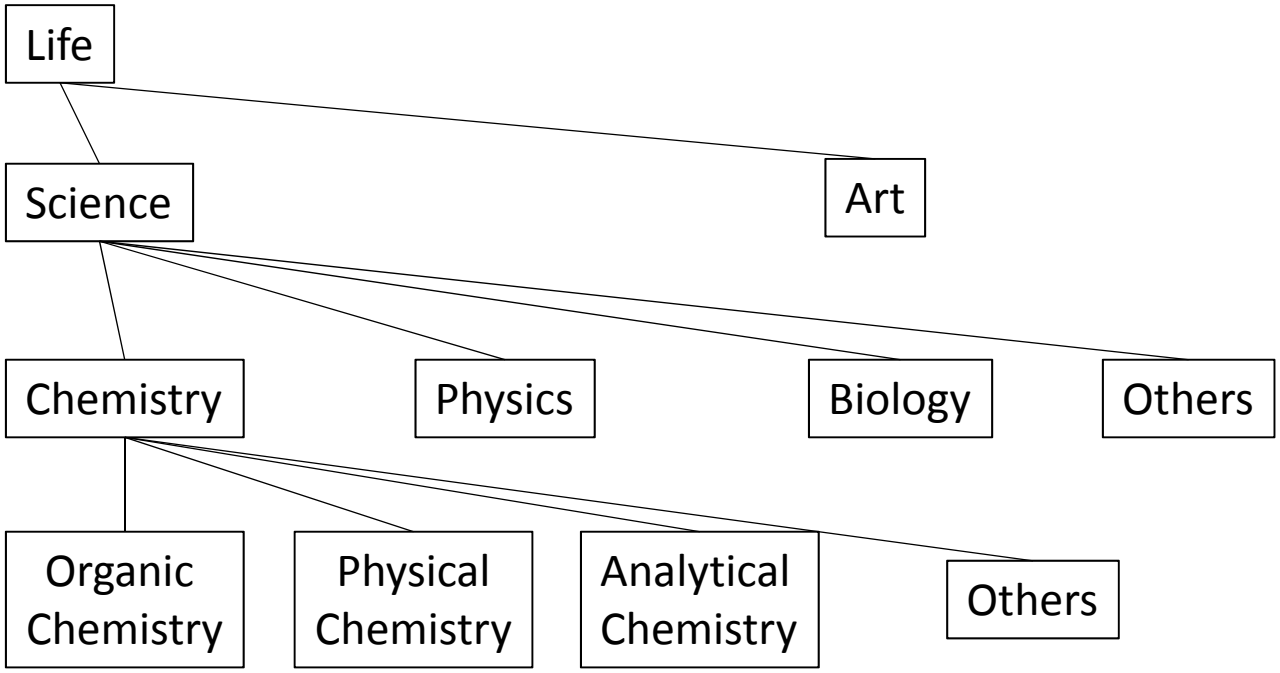
DEPARTMENT RESOURCES
FINANCE AND RESEARCH ADMINISTRATION

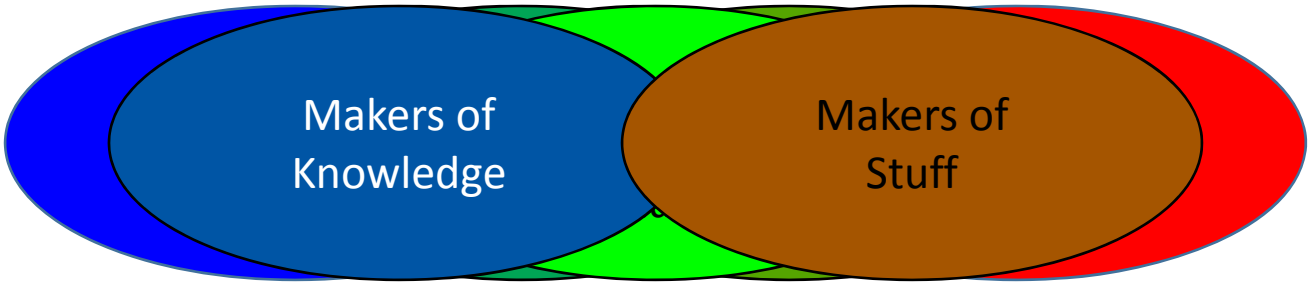
To get a degree in Chemistry…

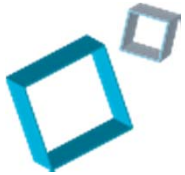
No universities require any demonstration of knowledge regarding toxicity or environmental impact!



This is not part of an
“epic battle of good and evil”


Life
Science
Art
Chemistry
Physics
Biology
Others
Organic Chemistry
Physical Chemistry
Analytical Chemistry
Others


Makers of Knowledge
Makers of Stuff



Green Chemistry is the *design* of chemical products and processes that reduce or eliminate the *use and/or generation* of hazardous substances.

The Twelve Principles of Green Chemistry

1. Prevention. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Atom Economy. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Synthesis. Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals. Chemical products should be designed to preserve efficacy of the function while reducing toxicity.

5. Safer Solvents and Auxiliaries. The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. Design for Energy Efficiency. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

7. Use of Renewable Feedstocks. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

8. Reduce Derivatives. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible .

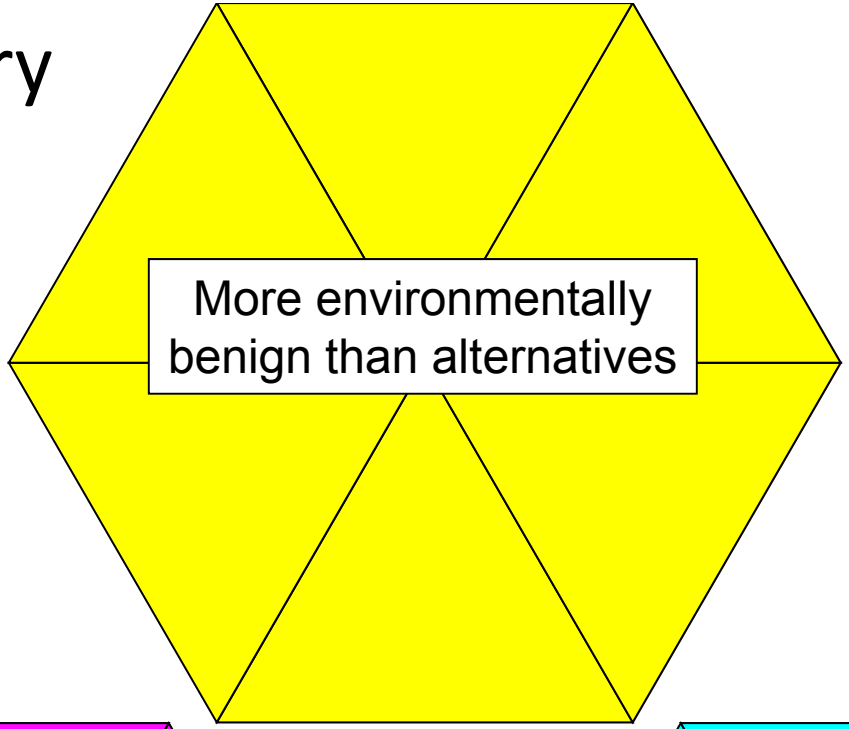
9. Catalysis. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

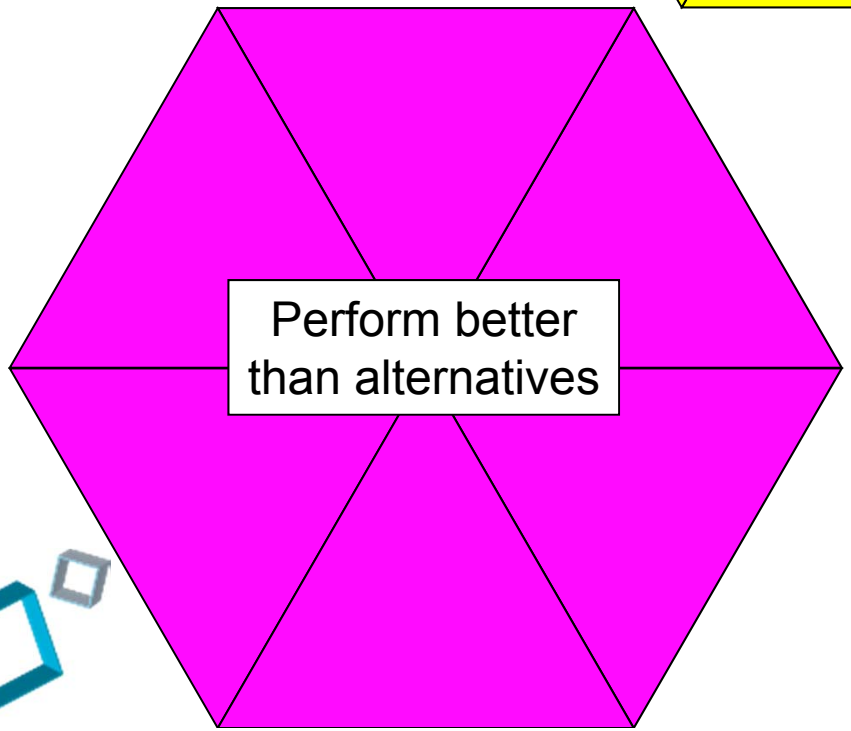
10. Design for Degradation. Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

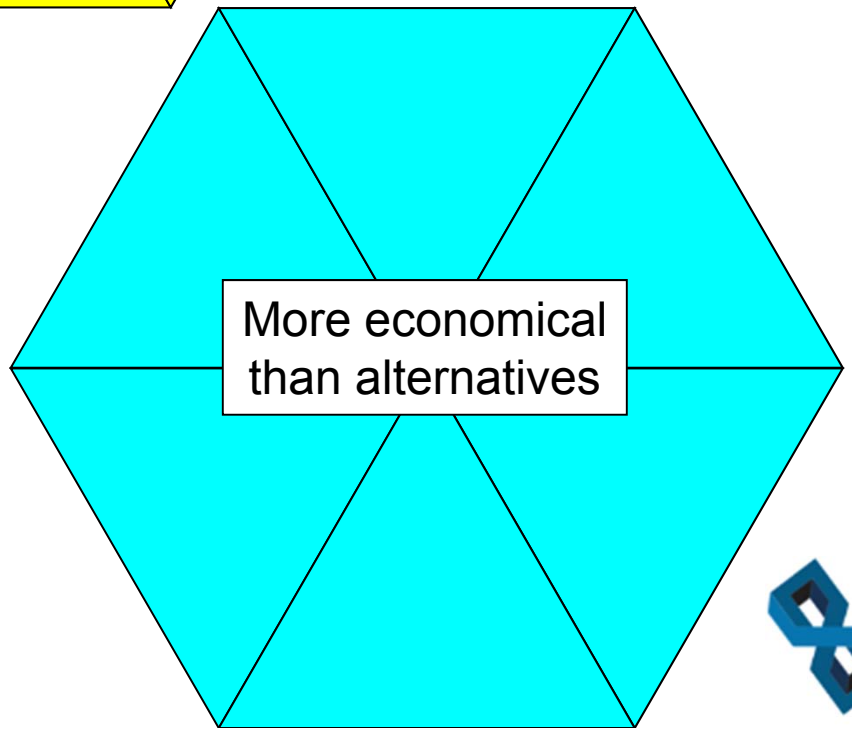
11. Real-time Analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention. Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

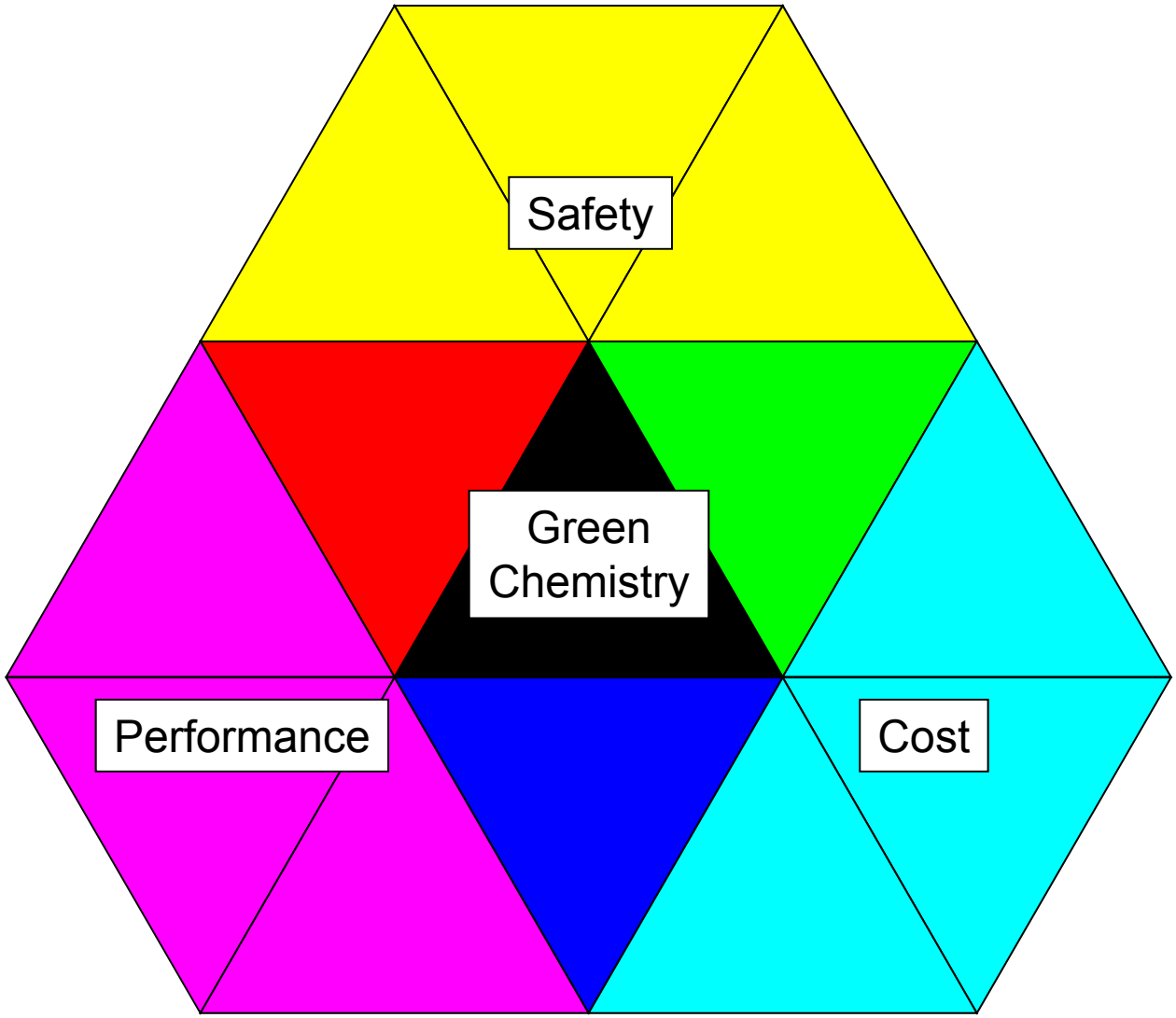
Green Chemistry







Green Chemistry

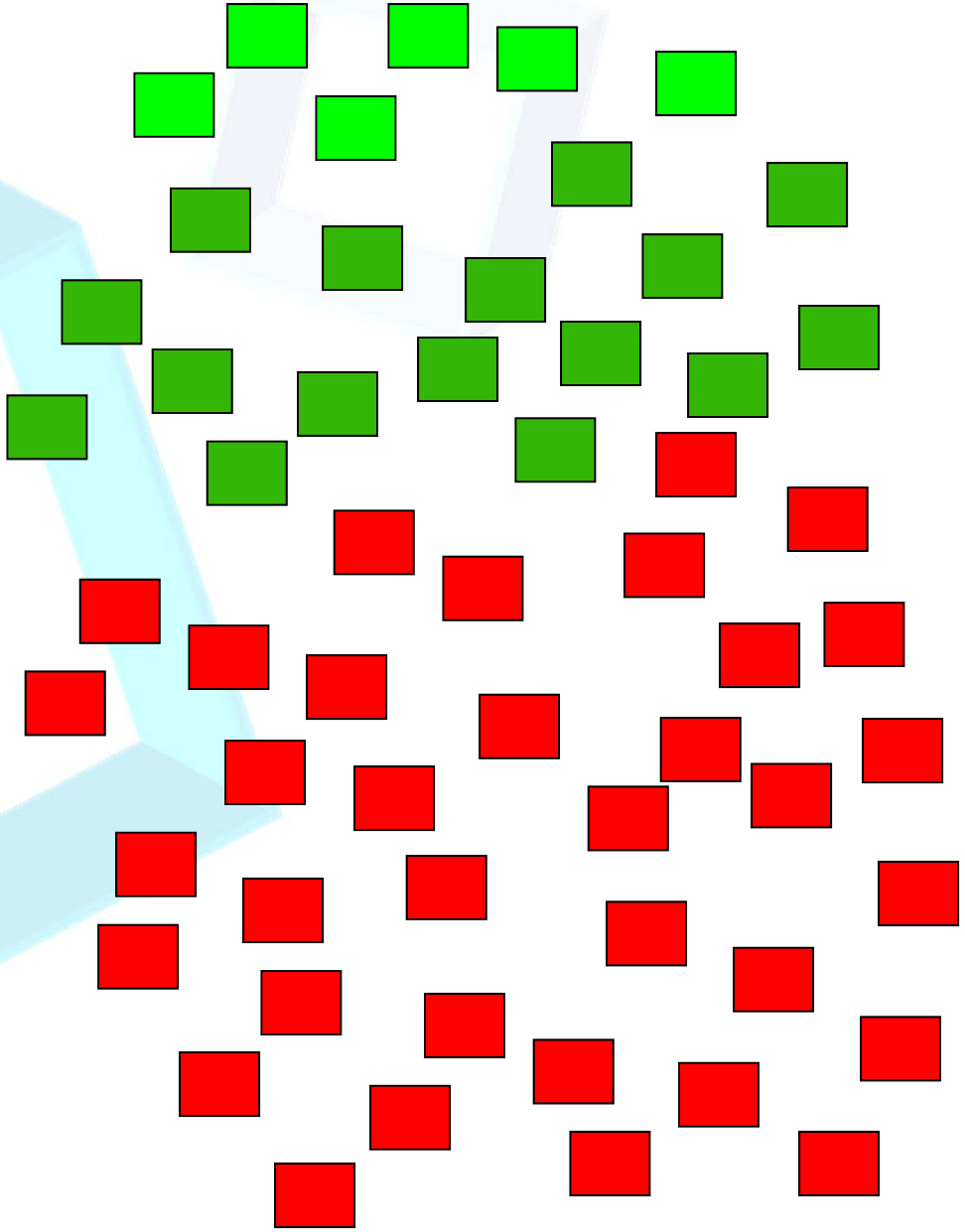


Of all the products and processes…

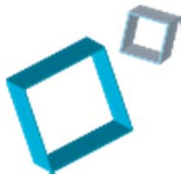
Maybe 10% are benign…

Maybe 25% have alternatives available…

65% Still have to be invented!



How does Green Chemistry fit into the big picture of Sustainability.



United States
Environmental Protection Agency

Learn the Issues | Science & Technology | Laws & Regulations | About EPA

Green Chemistry

Basics of Green Chemistry

On this page:

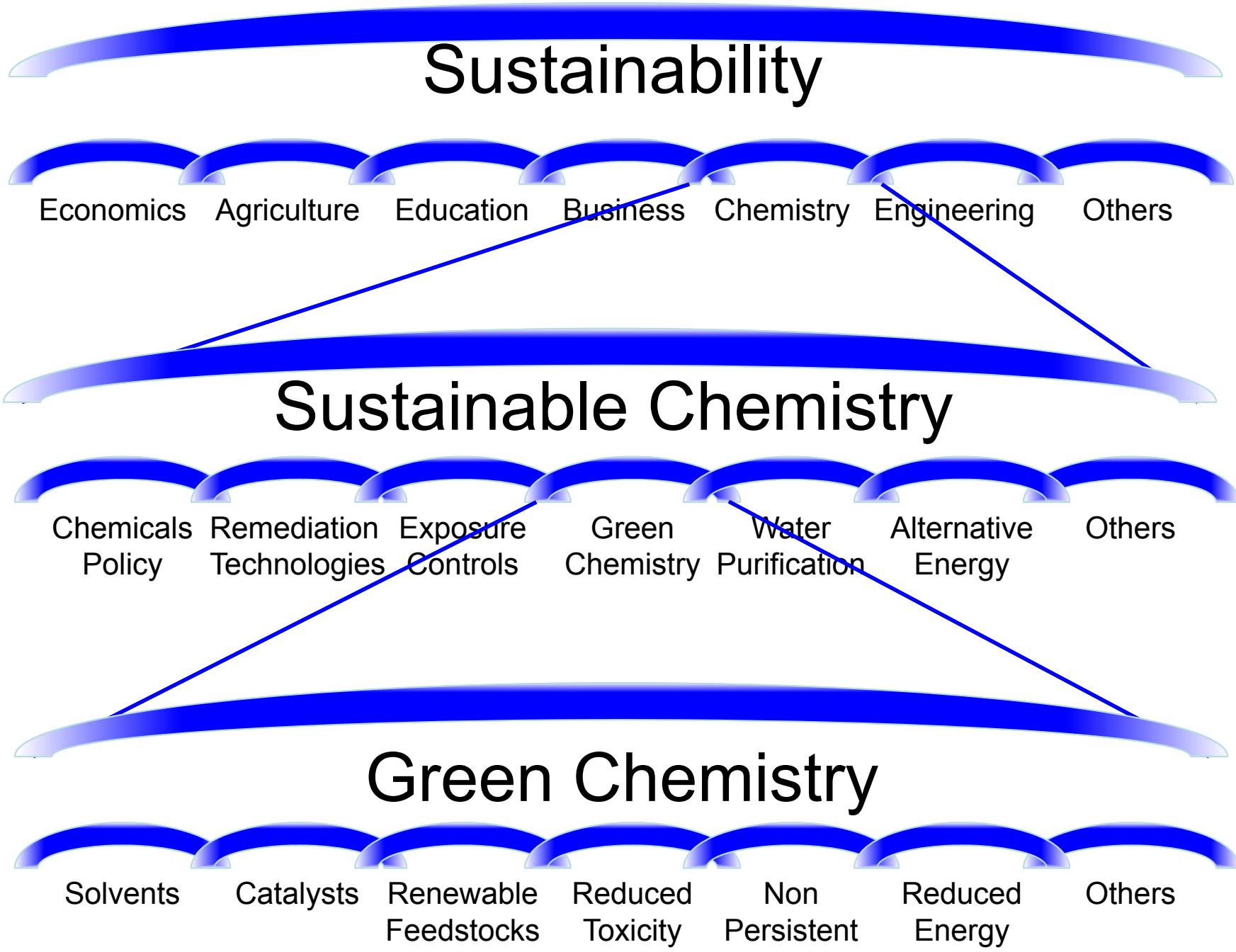
- Definition of green chemistry
- How green ch
- Green chemis
- Twelve princi
- Green chemis

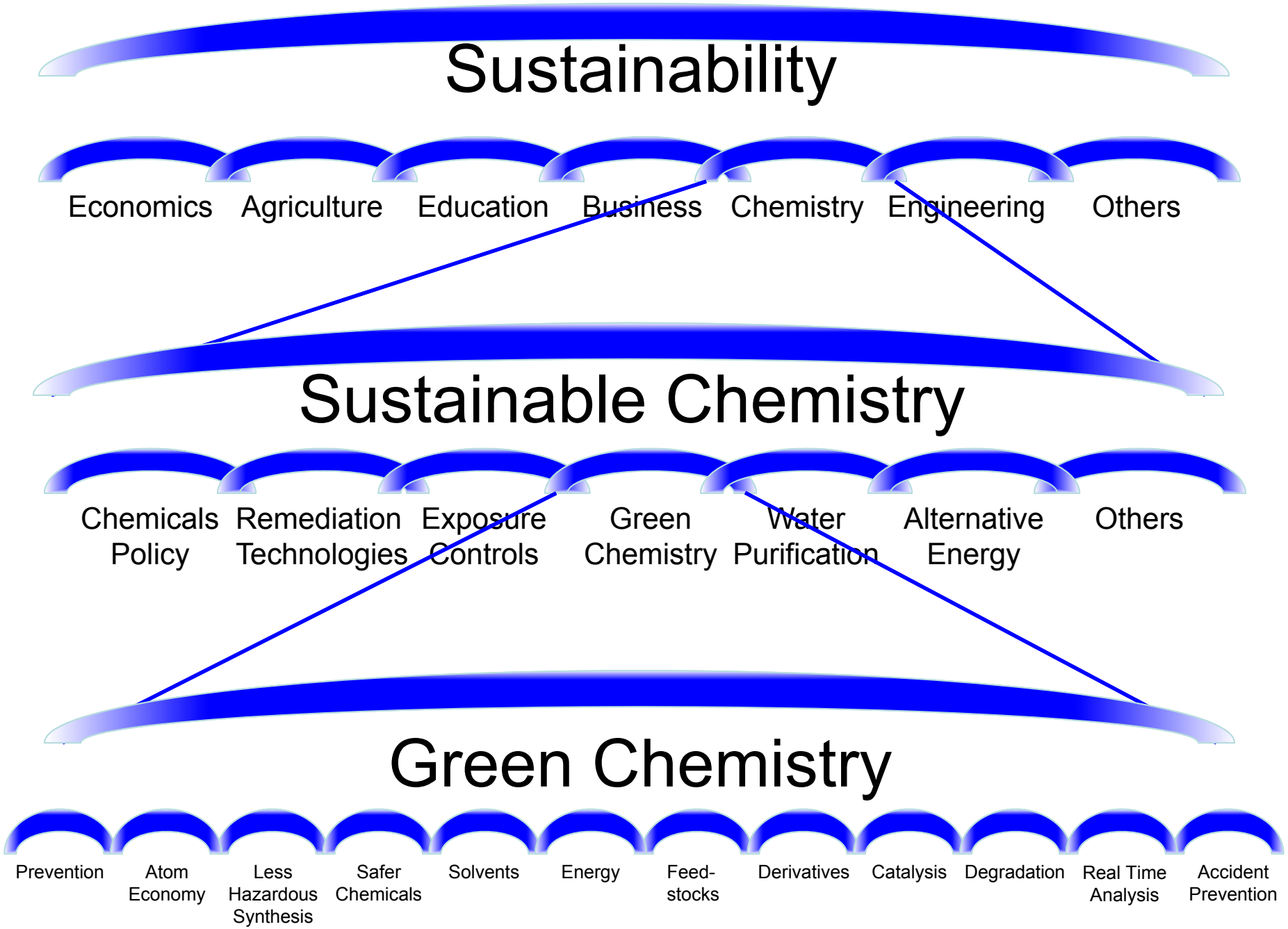
Green Chemistry is also known as sustainable chemistry.

Definition of green chemistry

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. Green chemistry is also known as sustainable chemistry.

Green chemistry:


Sustainability
Economics
Agriculture
Education
Business
Chemistry
Engineering
Others
Sustainable Chemistry
Chemicals Policy
Remediation Technologies
Exposure Controls
Green Chemistry
Water Purification
Alternative Energy
Others
Green Chemistry
Solvents
Catalysts
Renewable Feedstocks
Reduced Toxicity
Non Persistent
Reduced Energy
Others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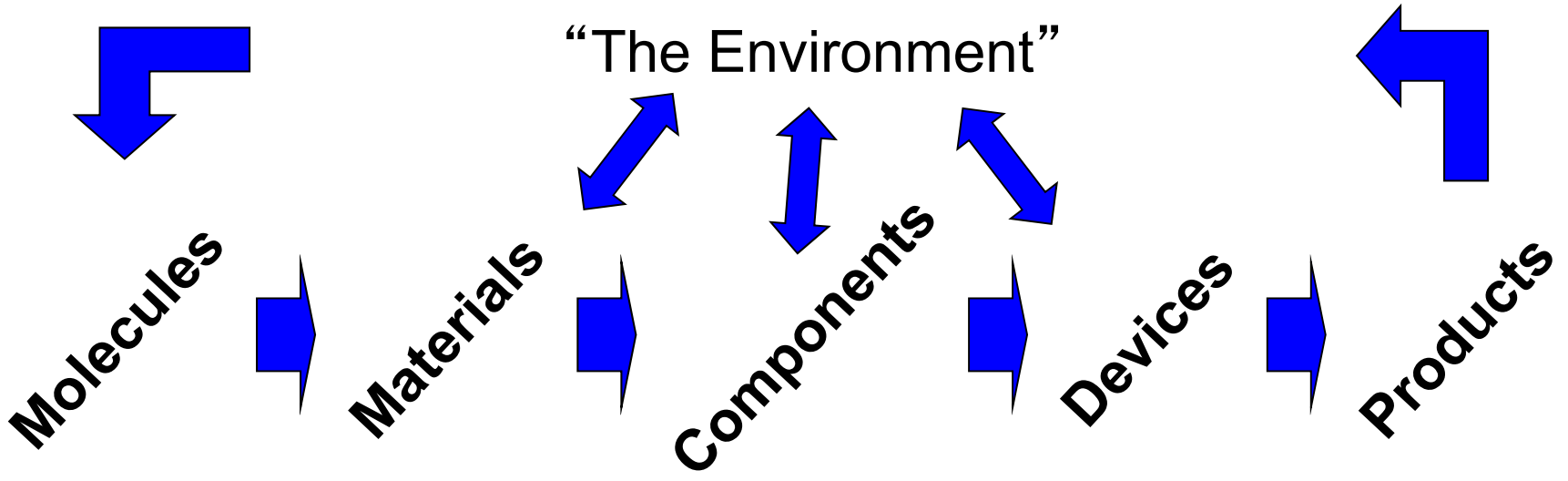
Green Chemistry
Water Purification
Alternative Energy
Others
Green Chemistry
Prevention
Atom Economy
Less Hazardous Synthesis
Safer Chemicals
Solvents
Energy
Feed-stocks
Derivatives
Catalysis
Degradation
Real Time Analysis
Accident Prevention

Where do products come from?



Basic Research

Applied Research

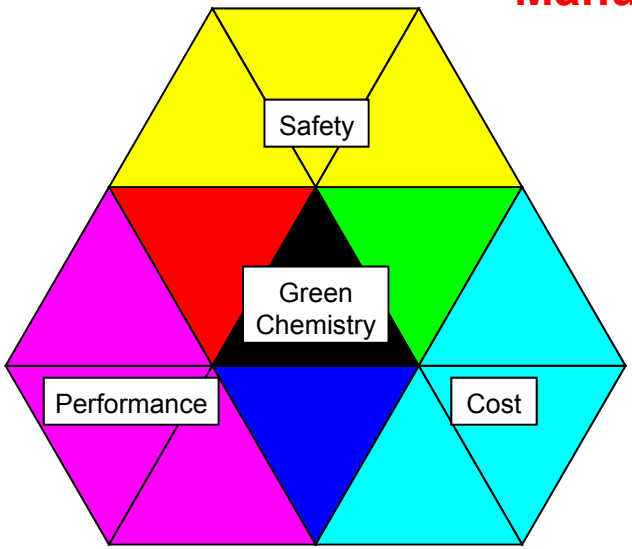
Development

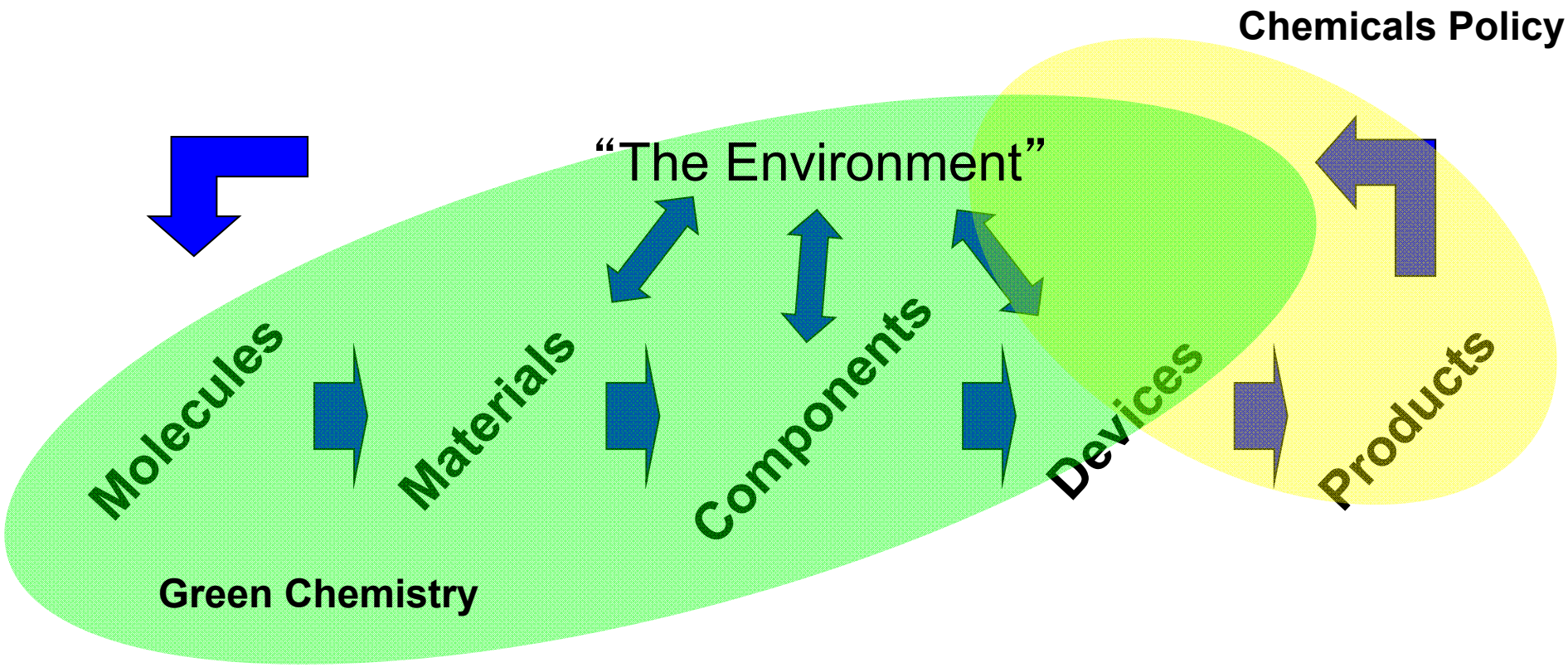
Manufacturing

Performance

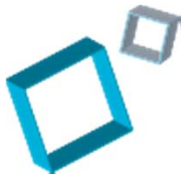
Economics

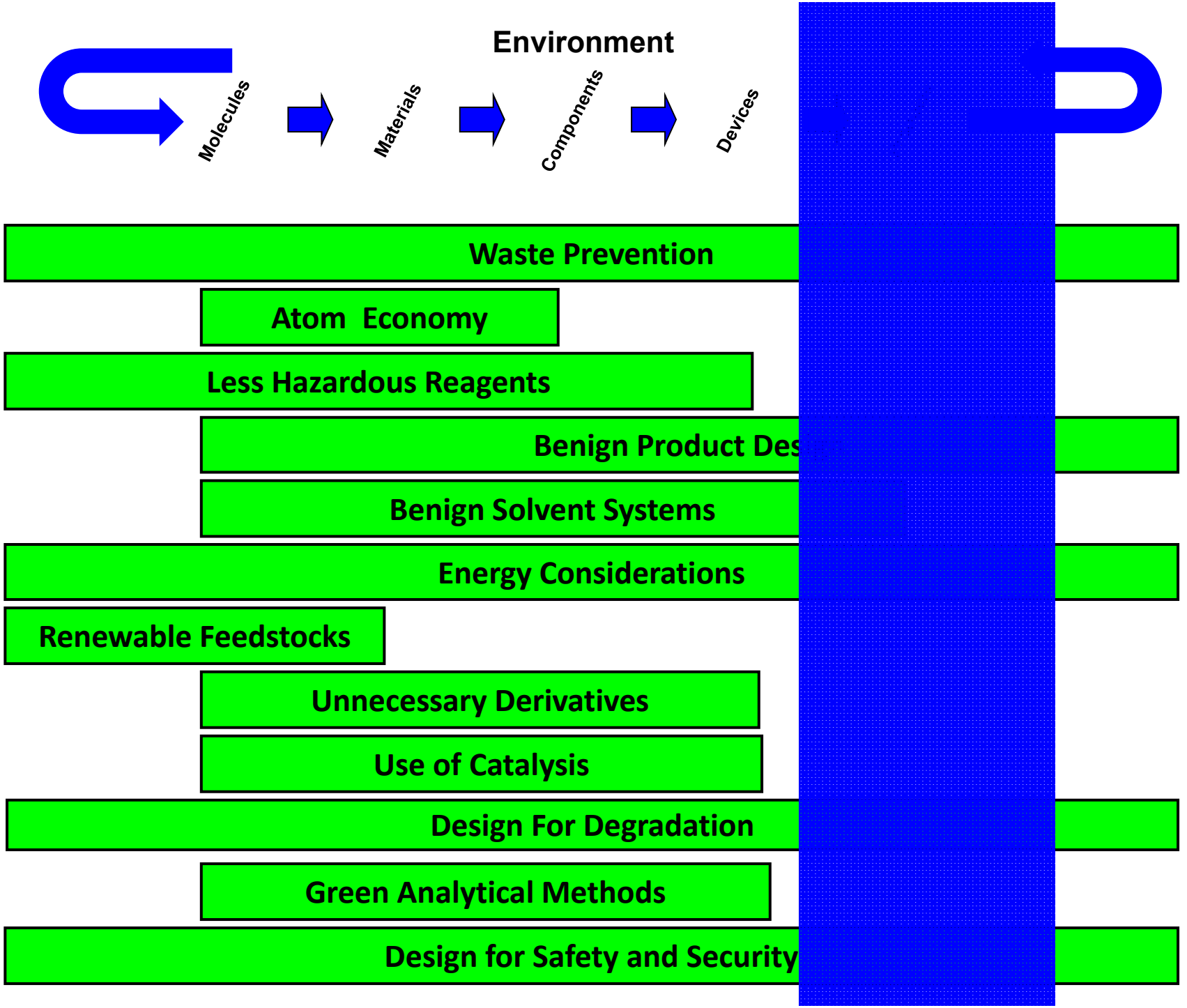
Social Implications

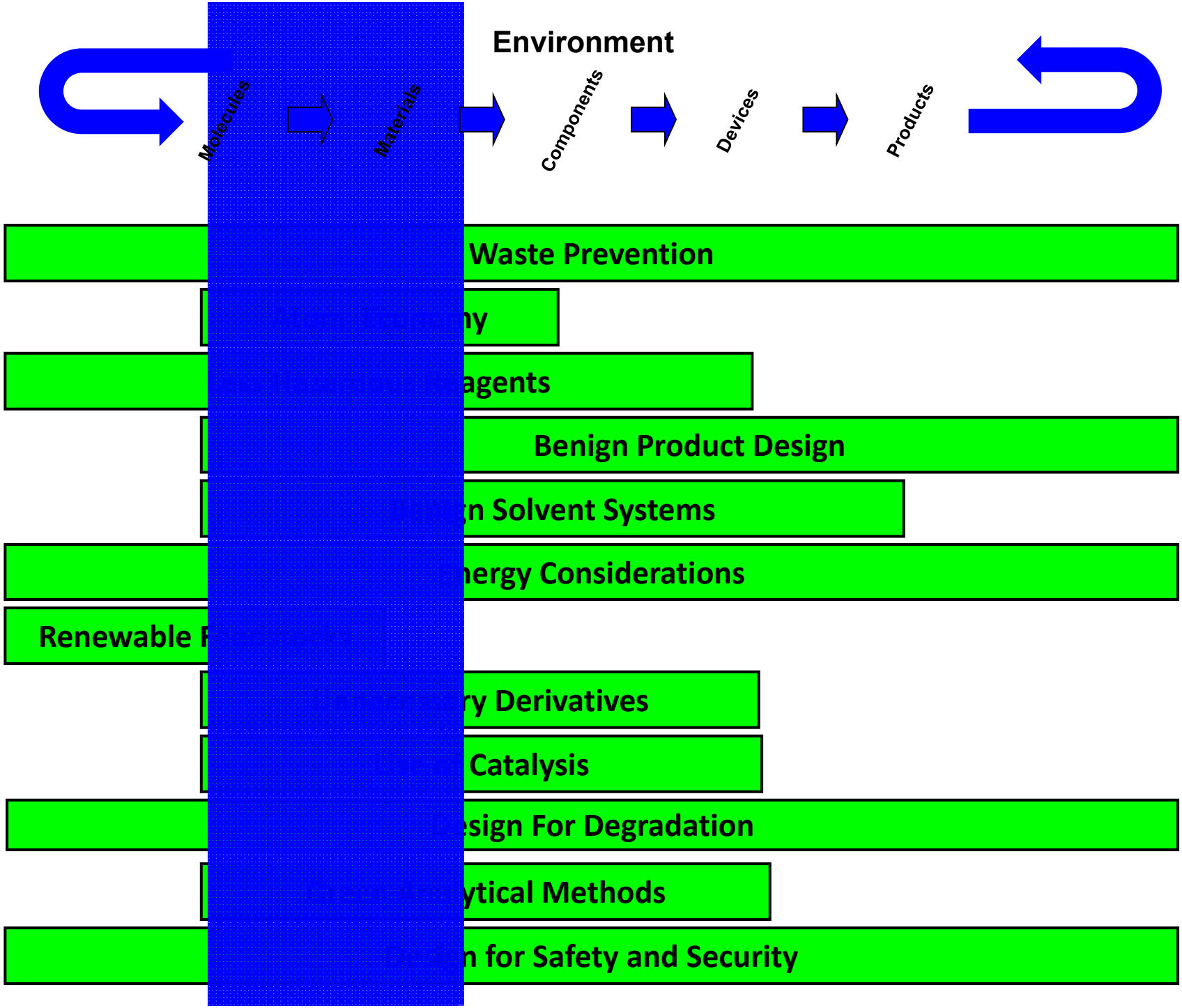



Chemicals Policy
"The Environment"
Molecules
Materials
Components
Devices
Products
Green Chemistry

How does Green Chemistry relate to Life Cycle Analyses?




Environment
Molecules
Materials
Components
Devices
Waste Prevention
Atom Economy
Less Hazardous Reagents
Benign Product Des
Benign Solvent Systems
Energy Considerations
Renewable Feedstocks
Unnecessary Derivatives
Use of Catalysis
Design For Degradation
Green Analytical Methods
Design for Safety and Security


Environment
Molecules
Materials
Components
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Products
Waste Prevention
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agents
Benign Product Design
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Renewable F
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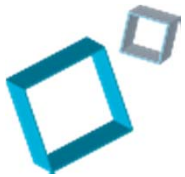
Catalysis
esign For Degradation
ytical Methods
n for Safety and Security

Chemists have ALWAYS cared about Human Health and the Environment.

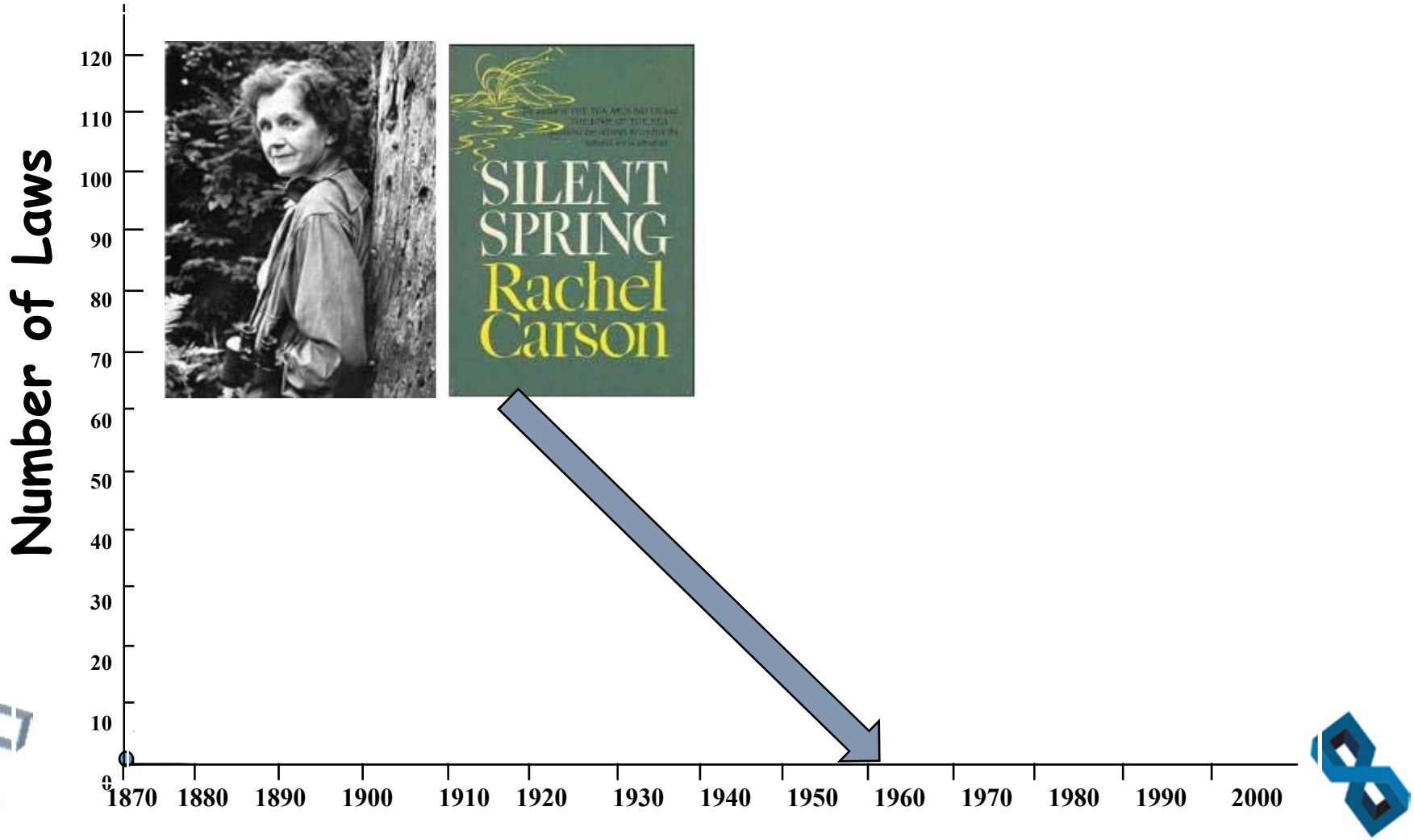
Risk = Exposure x Hazard

The cost of using hazardous materials:

Storage
Transportation
Treatment
Disposal
Regulatory Costs
Liability
Worker Health and Safety
Corporate Reputation
Community Relations
New Employee Recruitment



Environmental Regulations



Traditional Processes

Green Alternatives

Today's Talk:

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- Product Design
- Zero and Big Numbers
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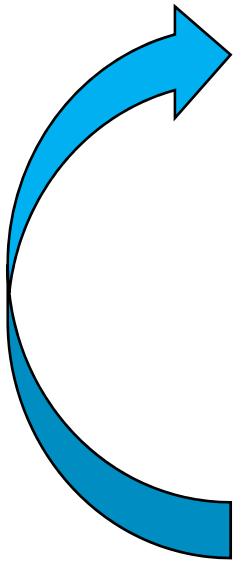
- Examples from WBI

Product Design



Identify and prioritize key attributes

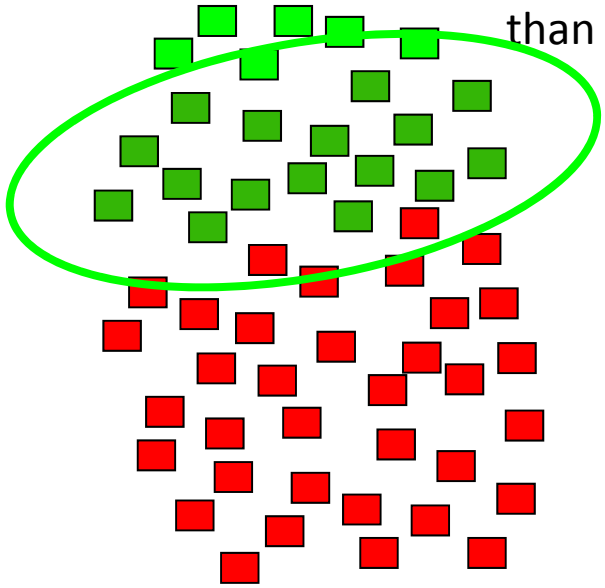
Design/plan metrics and tools to evaluate

Identify possible existing materials

Measure/Quantify performance of materials

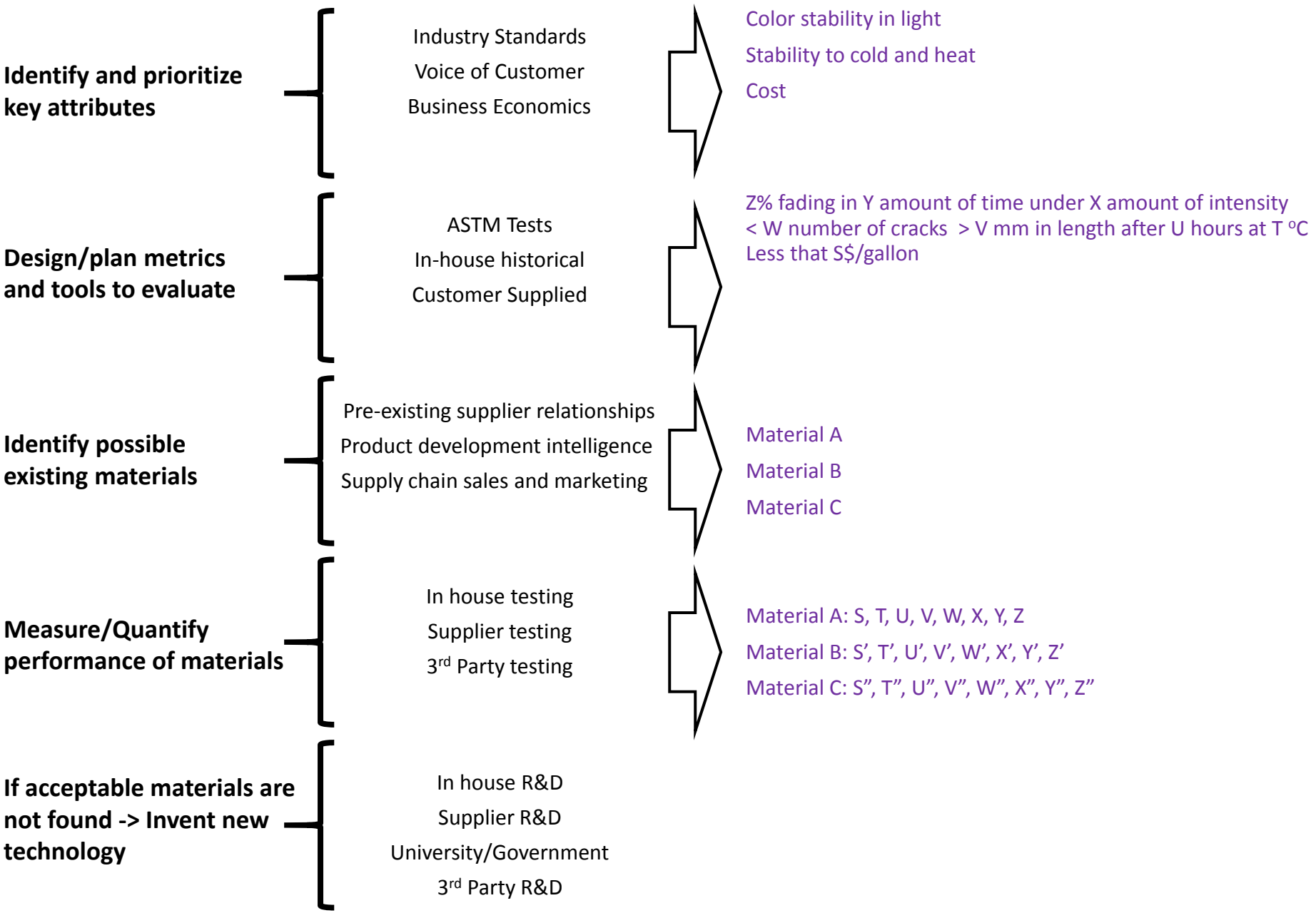
If acceptable materials are not found -> Invent new technology

If acceptable materials are found –> Make Product

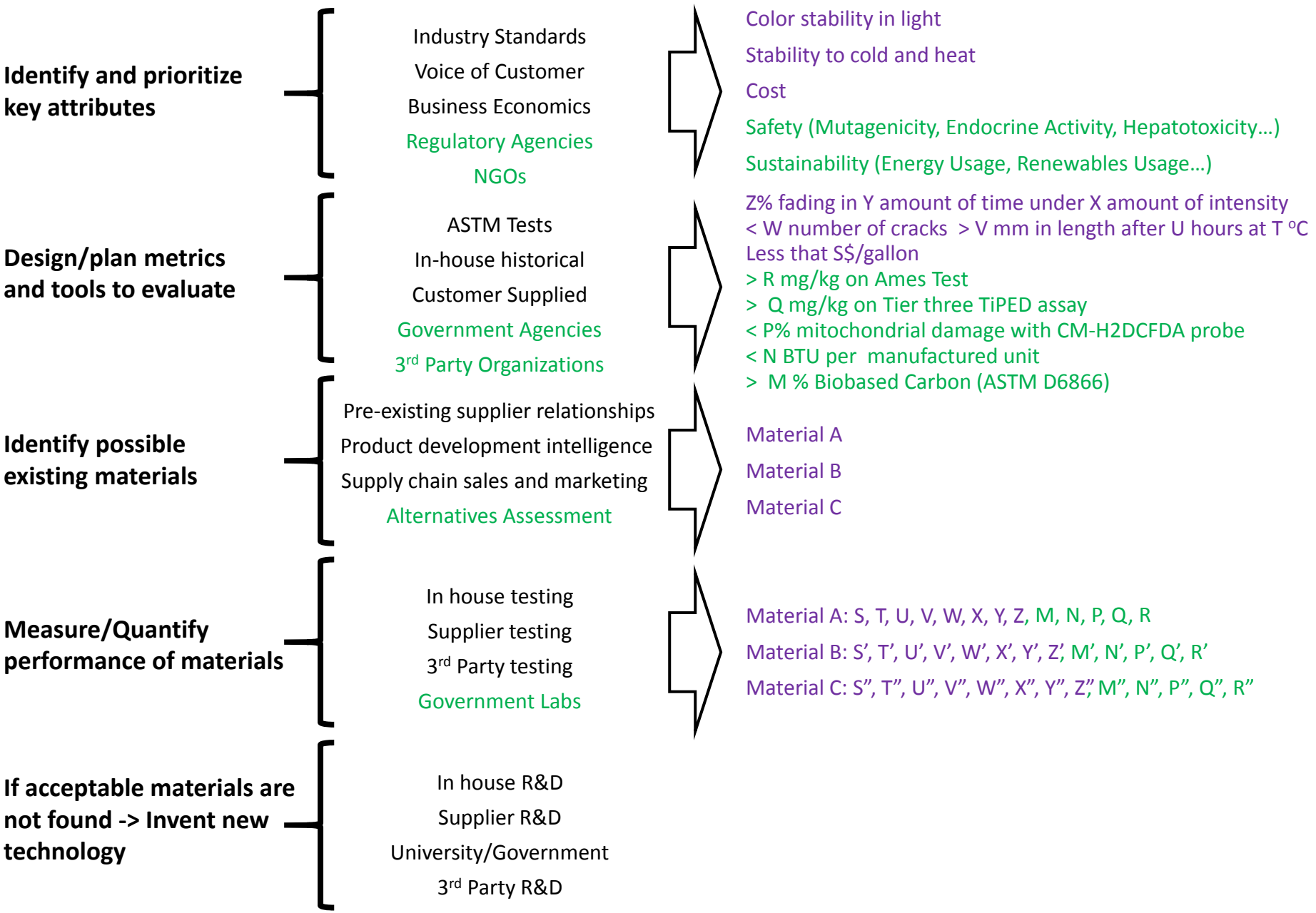


This will happen less than 25% of the time.

Performance and Cost



Performance, Cost, Safety and Sustainability



A deliverable attribute must be:

Quantifiable

Color doesn't fade.

Achievable

Color NEVER fades (IS NOT achievable)
Color only fades a little over a certain period of time (IS achievable)

Measurable

Optical density decreases by less than 10% after
48 hours with 20000 lumens solar simulator.

Today's Talk:

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Lets talk about nothing:

There are two issues with the use of “free” and “zero”:

(1) What does “chemical free” mean?

“BPA Free”:

(2) Can we ever have an “anything” free product?

● Handling receipts with care

Surprise: The thermal paper receipts from many ATMs and cash registers are coated with high levels of BPA, which can be absorbed through the skin or transferred from fingers to food, reveals research by John C. Warner, Ph.D., author of *Green Chemistry: Theory and Practice.*

BPA in cash register receipts….

No BPA added in the coating…

Unavoidable trace amounts of BPA in the paper!!!!

So what does “BPA-Free” mean?

Is it achievable?

“Nothing” and Big Numbers:

55 Gal Drum water

6.97×10^{27} Molecules of water

6 9 7 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Teaspoon of sugar

7.93×10^{21} Molecules of sugar 1.14 ppm

7 9 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Grain of sugar

5.22×10^{17} Molecules of sugar 50.6 ppt

3 5 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Nanogram of sugar

1.76×10^{12} Molecules of sugar

176 Billion molecules of sugar

1 7 6 0 0 0 0 0 0 0 0 0

Amedeo Avogadro

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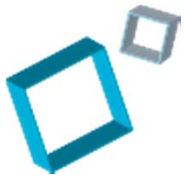
The ability to invent & design solutions to a problem is directly proportional to the quality of the description of success.

Quantifiable
Achievable
Measurable



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TiPED

Tiered Protocol for Endocrine Disruption

Green Chemistry

Cite this: DOI: 10.1039/c2gc35055f

www.rsc.org/greenchem

PAPER

Designing endocrine disruption out of the next generation of chemicals†

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DOI: 10.1039/c2gc35055f

A central goal of green chemistry is to avoid hazard in the design of new chemicals. This objective is best achieved when information about a chemical's potential hazardous effects is obtained as early in the design process as feasible. Endocrine disruption is a type of hazard that to date has been inadequately addressed by both industrial and regulatory science. To aid chemists in avoiding this hazard, we propose an endocrine disruption testing protocol for use by chemists in the design of new chemicals. The Tiered Protocol for Endocrine Disruption (TiPED) has been created under the oversight of a scientific advisory committee composed of leading representatives from both green chemistry and the environmental health sciences. TiPED is conceived as a tool for new chemical design, thus it starts with a chemist theoretically at "the drawing board." It consists of five testing tiers ranging from broad *in silico* evaluation up through specific cell- and whole organism-based assays. To be effective at detecting endocrine disruption, a testing protocol must be able to measure potential hormone-like or hormone-inhibiting effects of chemicals, as well as the many possible interactions and signaling sequellae such chemicals may have with cell-based receptors. Accordingly, we have designed this protocol to broadly interrogate the endocrine system. The proposed protocol will not detect all possible mechanisms of endocrine disruption, because scientific understanding of these phenomena is advancing rapidly. To ensure that the protocol remains current, we have established a plan for incorporating new assays into the protocol as the science advances. In this paper we present the principles that should guide the science of testing new chemicals for endocrine disruption, as well as principles by which to evaluate individual assays for applicability, and laboratories for reliability. In a 'proof-of-principle' test, we ran 6 endocrine disrupting chemicals (EDCs) that act *via* different endocrinological mechanisms through the protocol using published literature. Each was identified as endocrine active by one or more tiers. We believe that this voluntary testing protocol will be a dynamic tool to facilitate efficient and early identification of potentially problematic chemicals, while ultimately reducing the risks to public health.

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USA
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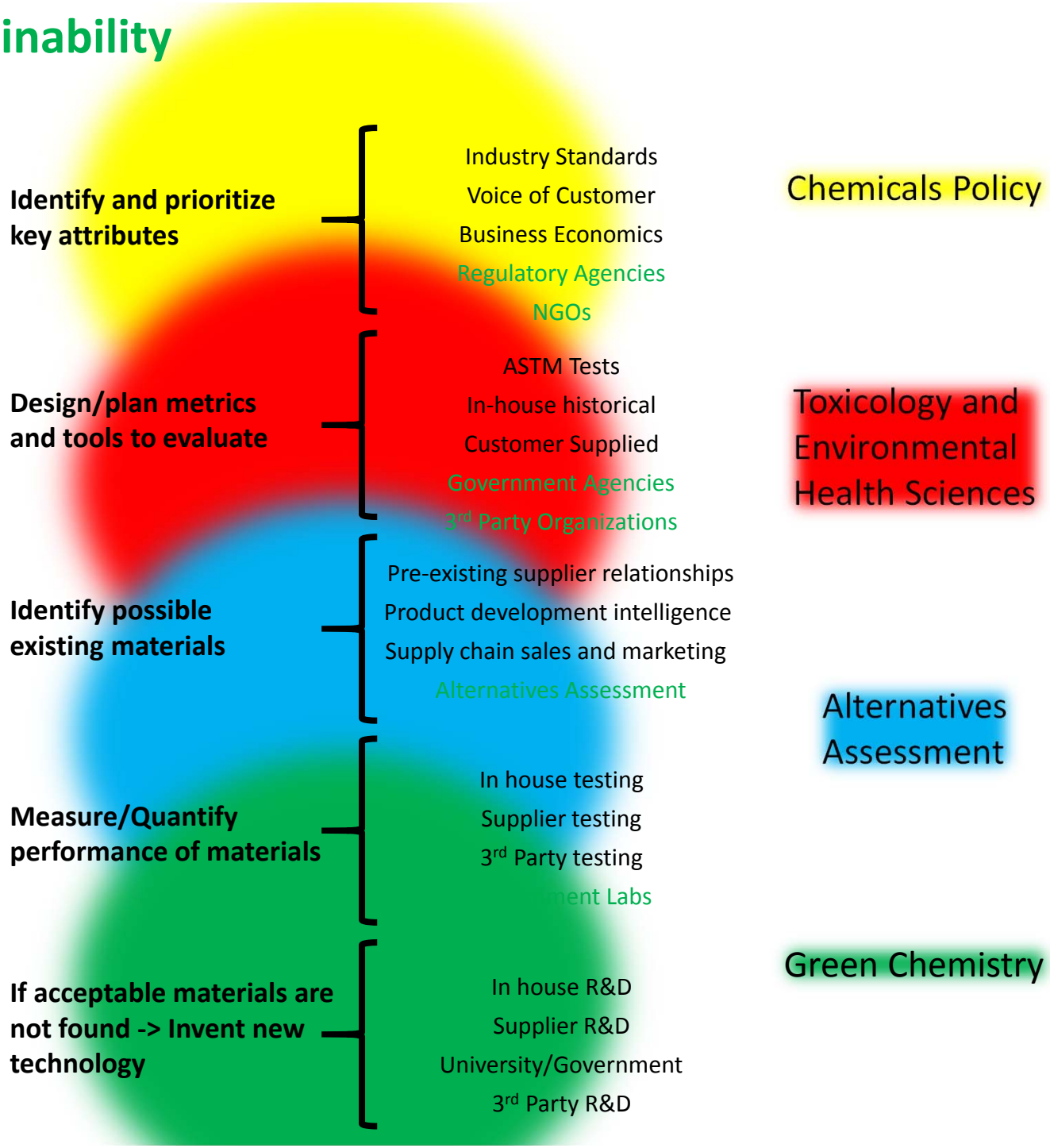
Richmond, VA, USA

[l]*Centre for Green Chemistry and Catalysis, Department of Chemistry, McGill University, Montréal, QC, Canada*
[m]*Department of Biology, North Carolina State University, Raleigh, ...*
USA
[n]*Department of Environmental and Molecular ...*
University, Corvallis, OR. Current ...
Toxicology Division, Nat...
Research Lab...

Safety and Sustainability



We can’t sit on our hands waiting for all the criteria to be sorted out.

While zero may not be achievable from a regulatory perspective…

From an innovation and design perspective, it will always point us in the right direction.

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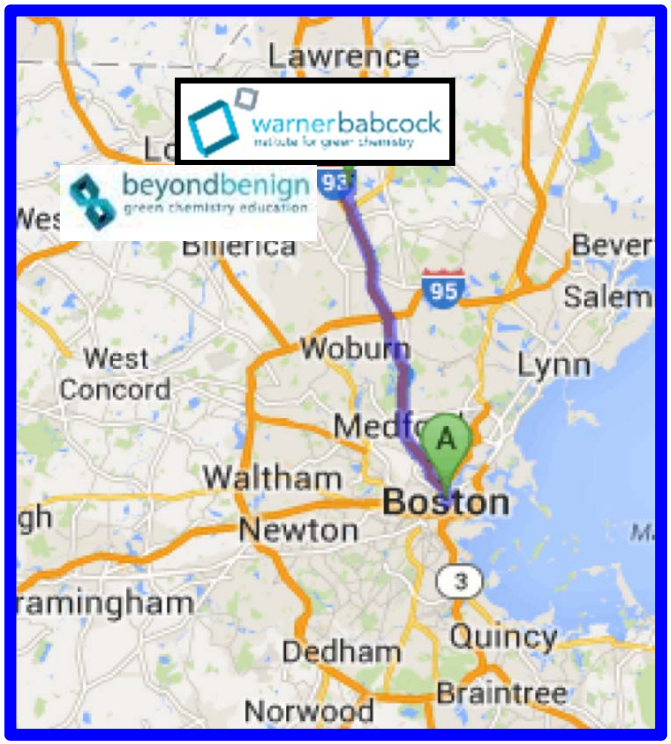
John Warner **Amy Cannon** **Jim Babcock** **Joe Pont, CEO**



100 Research Drive
Wilmington, MA 01887

Science

Business

Explore

Observe and define structure and dynamics.

Basic Research

Understand

Identify and characterize impact of changes of structure on dynamics and dynamics on structure.

Parameterize

Design alterations in structure and/or dynamics to purposefully control response.

Technology Greenhouse

Market Analysis

Explore

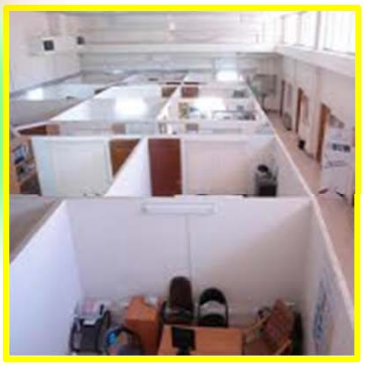
Observe and define a product and market.

Understand

Identify and characterize market history and likely future trends

Parameterize

Design potential products and assess potential markets and parameters for success.



Technology Incubator

Create

Create a potentially useful prototype.

Develop

Develop a potentially successful product.

Commercialize

Commercialize a successful product.




Hairprint: Hair Color Restoration

Increased Recycled Asphalt
And Lower Temperature Process

COLLABORATIVE AGGREGATES LLC

Alberta Innovates Technology Futures

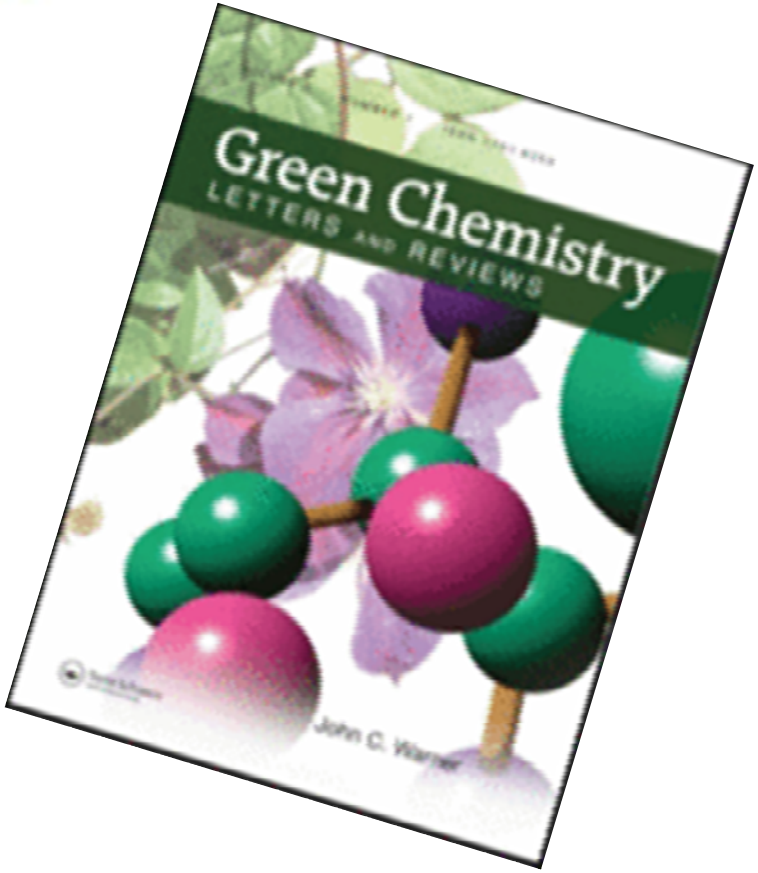
COLLABORATIVE AGGREGATES LLC

Formaldehyde Free
Wood Composite Adhesives

Reuse of Ocean Plastics

warnerbabcock
institute for green chemistry

beyondbenign
a warner babcock foundation



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Thanks for joining us!

For more information about the GC3:
www.greenchemistryandcommerce.org

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Business Mainstreaming Green Chemistry