2015 Michigan Green Chemistry & Engineering 101 Workshop

# New Product Development and Green Chemistry

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University of Michigan, Ann Arbor, Michigan USA

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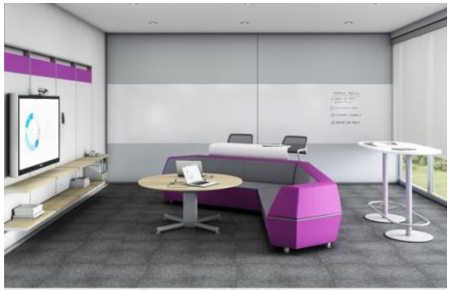

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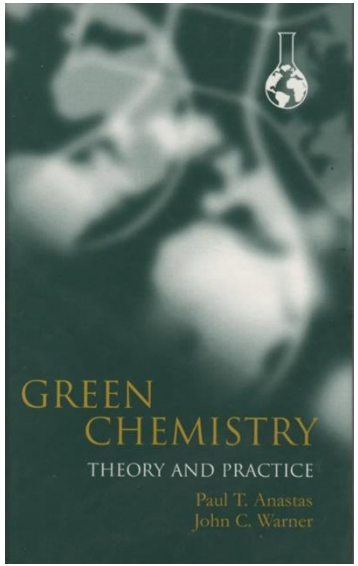
# ❑ What is Green Chemistry?

Green Chemistry is the utilization of a set of **principles** that reduces or eliminates the use or generation of **hazardous substances** in the **design**, **manufacture** and **applications** of **chemical products**.[1]

**Principles of Green Chemistry[1]**

1. Prevent waste
2. Design safer chemicals and products
3. Design less hazardous chemical syntheses
4. Use renewable feedstocks
5. Use catalysts, not stoichiometric reagents
6. Avoid chemical derivatives
7. Maximize atom economy
8. Use safer solvents and reaction conditions
9. Increase energy efficiency
10. Design chemicals and products to degrade after use
11. Analyze in real time to prevent pollution
12. Minimize the potential for accidents




1: Anastas, Paul T., and Warner, John C. Green Chemistry Theory and Practice, Oxford University Press, New York, 1998.

## Green Chemistry Pocket Guide

**The 12 Principles of Green Chemistry**

Provides a framework for learning about green chemistry and designing or improving materials, products, processes and systems.

1. Prevent waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

**www.acs.org/greenchemistry**

ACS Chemistry for Life™ | ACS Green Chemistry Institute™

## The Chemistry of Nature

Green Chemistry Definition: *The design, development and implementation of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.*

Green Chemistry is doing chemistry the way nature does chemistry – using renewable, biodegradable materials which do not persist in the environment.

Green Chemistry is using catalysis and biocatalysis to improve efficiency and conduct reactions at low or ambient temperatures.

Green Chemistry is a proven systems approach.

Green Chemistry reduces negative human health and environmental impacts.

Green Chemistry offers a strategic path way to build a sustainable future.

*To catalyze and enable the implementation of green chemistry and engineering throughout the global chemical enterprise*

**Contact us: gci@acs.org**

## A *New* Kind of Chemistry!

**Green Chemistry — Sustainable Chemistry in Sync With Nature**

The design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.

- Smarter
- Safer
- More Efficient
- Saves Money
- Conserves Energy
- Prevents Pollution
- Designed for Reuse or Recycle
- Enhances Chem's Public Image

*"The best way to predict the future is to create it."*
- Peter Drucker

Green chemistry can create a better future.

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## The Chemistry of Nature

- Green Chemistry emulates nature by using renewable materials that biodegrade easily in the environment.
- Green Chemistry uses materials more efficiently with less energy.
- Green Chemistry respects the environment, preventing pollution before it can happen.
- Green Chemistry helps build a sustainable future.
- Green Chemistry fosters innovation, creates jobs and inspires the next generation of chemists.

*To catalyze and enable the implementation of green chemistry and engineering throughout the global chemical enterprise*

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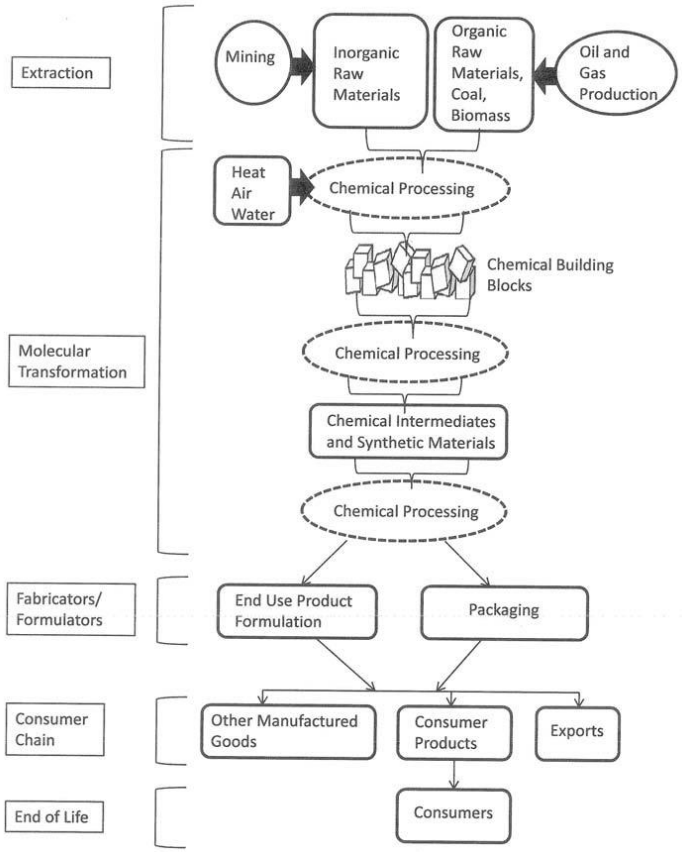
# Scope of the Chemical Enterprise




## Molecular Transformers

Bulk, Fine & Specialty Chemicals

- Chemical manufacturers
- Pharmaceutical industry

## Formulators

Physical mixing/blending of chemicals

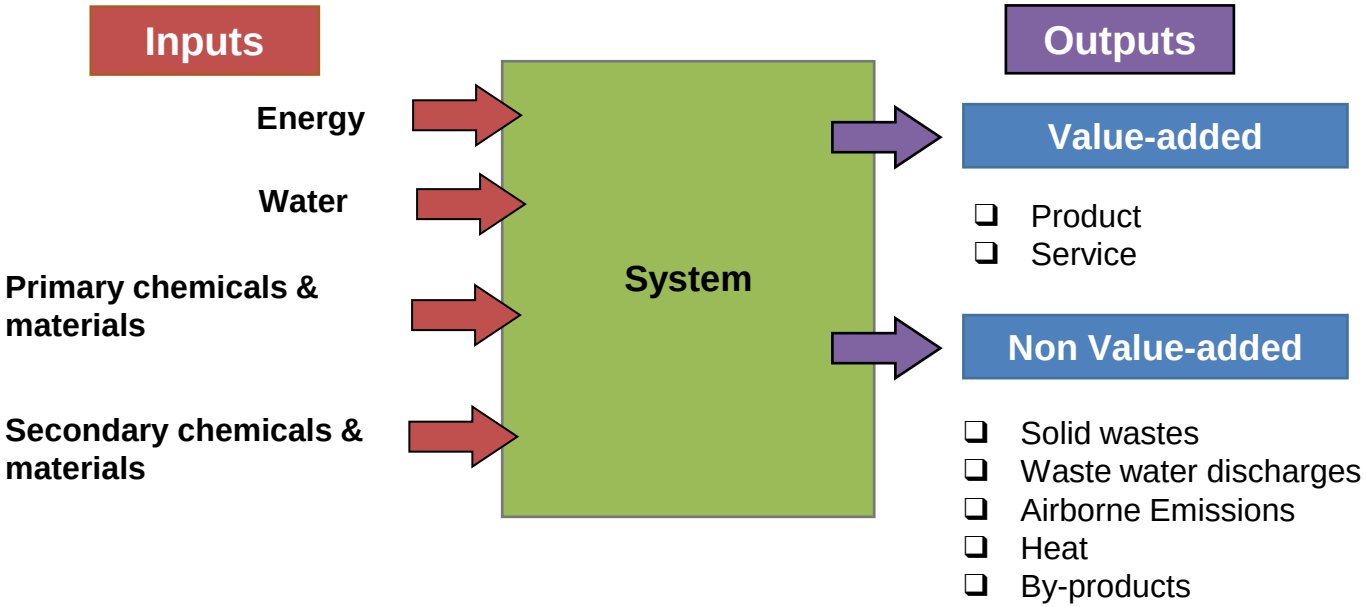
## Fabricators

Manufacturers of consumer goods:

- Component manufacturers (tier suppliers)
- Final product manufacturers (Original Equipment manufacturers (OEMs)

Source: NSF/GCI/ANSI 355 – 2011: *Greener Chemicals and Processes Information* Standard

# Green "*insert name*"



As a relative measure, green(er) encompasses:

- ❑ Amount
- ❑ Type (kind)

# Chemical Dimension of a System

## Chemical Management

- Acquisition
- Inventory & Tracking
- Storage
- Use
- Disposal & Treatment
- Transfer, Transport & Shipment

## Chemical Assessment

- Risk Assessment
- Hazard Assessment
- Alternative Assessment

## Chemical Substitution / Reduction

- Waste Minimization
- Pollution Prevention

- Green Chemistry

# What is Design for Environment?

***Integration of environmental considerations into the <u>product design</u> and development process to reduce environmental impact of product over <u>entire life-cycle</u>***

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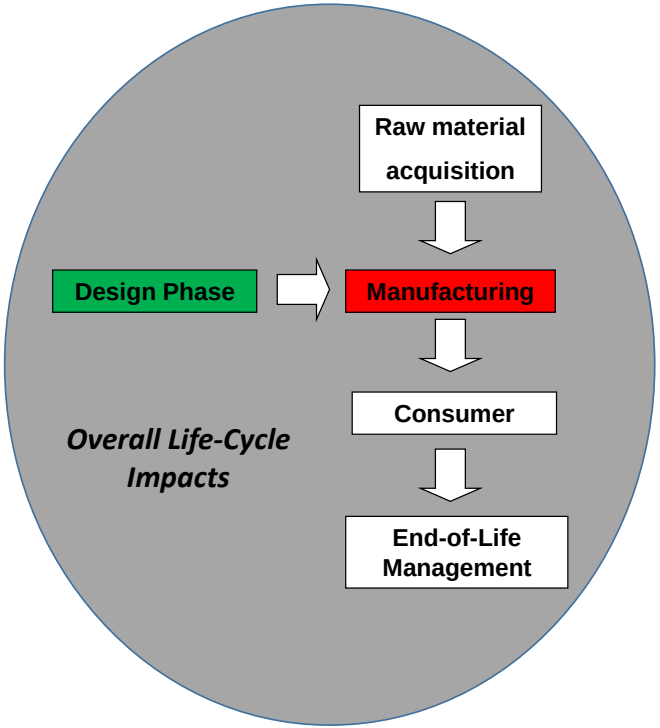



More than 75% of the environmental impact of a product during its lifecycle is determined and "locked-in" at the **DESIGN STAGE**

*Green chemistry can be viewed as the application of the concepts and strategies of **Design for Environment** at the **molecular level***

Make chemicals, materials, products less hazardous throughout the entire life cycle by **applying the Principles** at the design stage of product development

- **Hazard is a "design flaw"**
- **"Benign by Design"**

## Influencers

Regulations

Customer Needs

Cost

## Disclosures

Labels

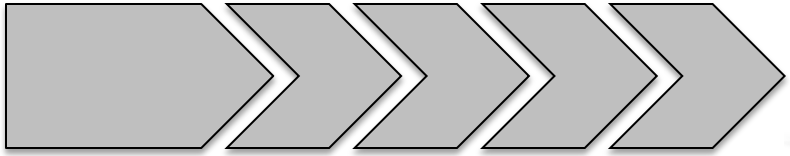
Product Environmental Profiles

Certifications

LCA

EPD

## Product Development



## Toolbox

Performance

Supply Chain

Design for Environment

Life Cycle Assessment

Material Chemistry

End of Life Management

Supplier Engagement

Green Chemistry

Materials Innovation & Exploration

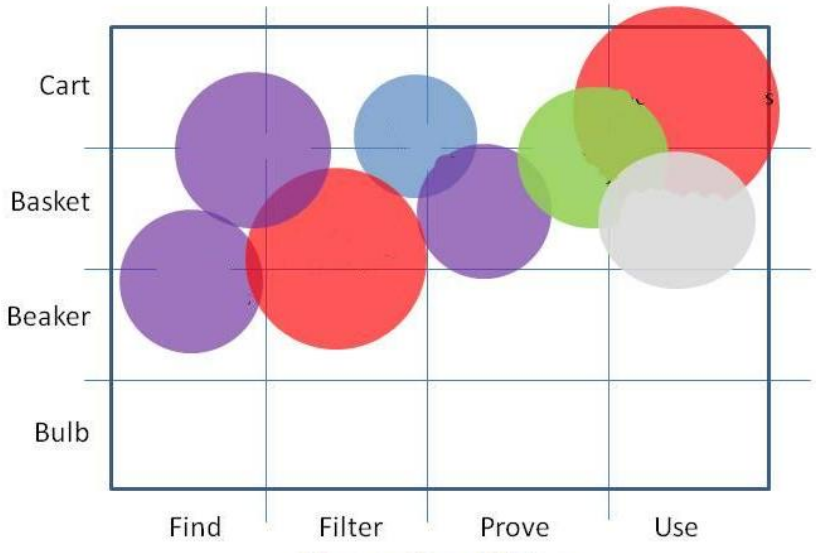
materiality & process

**Material chemistry** and **material process** are components of a **material experience** and in the design process these **cannot be separated from the consideration of material choice**.

# materiality *ethos*

preserve & compel

**Humanizing**… **preserving** the **planet** and **protecting** the **human experience**. We seek material and process decisions that **benefit** the planet rather than simply reduce harm done. We seek material and process solutions that are **compelling** and create **lasting emotional connection**




**New Design Concepts**

**New Materials**

**New Processes**

**Form and Function – "Physical" solutions**

**New Green Chemicals / Materials**



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# Structural Color

Photo credit: Clinton S. Boyd

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Image source: http://transmaterial.net/morphotex/

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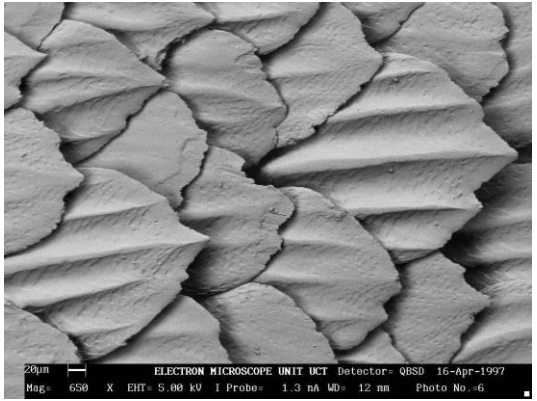


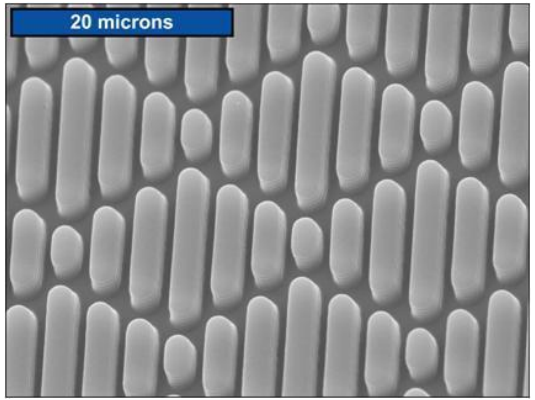


Source: http://sharklet.com/

Source: https://vimeo.com/112761863

Source: MIT Self-Assembly Lab

CLIP Technology:
Continuous Liquid Interface Production

Source: http://carbon3d.com/

# Thank you.

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