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Environmental & Public Health Consulting

Introduction to Green Chemistry

May 30, 2017

Manila

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Environmental & Public Health Consulting

- **Education:**
  - Daughter of two social scientists who worked for UN ESCAP
  - Ph.D. Molecular genetics and neural development
- **California EPA Department of Toxic Substances Control**
  - Hazardous waste inspector; pollution prevention coordinator;
  - Local government liaison
- **Independent consultant;** clients include:
  - **Non-profit coalitions:**
    - IPEN, Blue Green Alliance, Electronics Take Back Coalition, Safe Cosmetics Campaign
  - **Government:** California, Hawaii, San Francisco, Seattle, Santa Monica, Palo Alto
  - **Academia:** UC Berkeley Extension, UCLA Sustainable Technology and Policy Program, U of Washington
  - **Business:** Large retailers (Wal-Mart, Disney); companies with innovative solutions (CleanWell, New Gen Surgical)
  - **Tools:** GoodGuide, ChemHAT, BizNGO Plastics Scorecard; Green Chemistry Metrics

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

SF Environment
Our home. Our city. Our planet.
A Department of the City and County of San Francisco

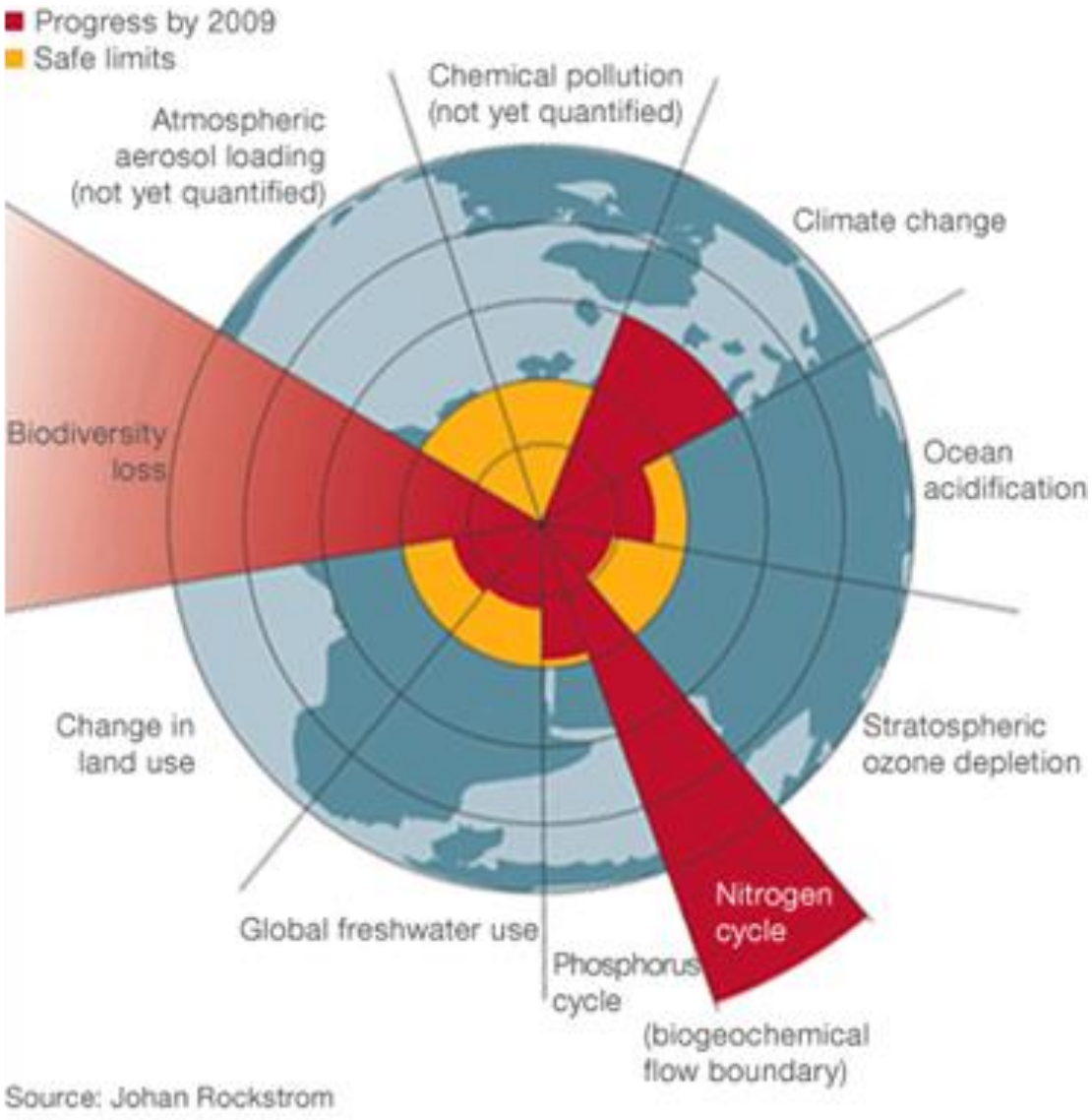
IPEN
a toxics-free future

Introduction to Green Chemistry

- Why green chemistry?
- What is green chemistry?
  - Definition and principles
- Implementing Green Chemistry
  - Designing and selecting safer alternatives
  - Drivers and frameworks
- Green Chemistry in Practice: Examples
- Mainstreaming Green Chemistry
  - Green Chemistry & Commerce Council (GC3)
- Green Chemistry and Climate Resilience
- Green Chemistry & the UN SDGs

Why green chemistry?

- Because we've spent decades mitigating the downstream toxic impacts of petroleum-based industrial chemistry on communities, individuals, and the environment
- Moving back from the end of the pipe:
  - We've called it: waste reduction, industrial ecology, cleaner production, pollution prevention…..
- Green chemistry is "benign by design"


Progress by 2009
Safe limits
Chemical pollution
(not yet quantified)
Atmospheric
aerosol loading
(not yet quantified)
Climate change
Biodiversity
loss
Ocean
acidification
Change in
land use
Stratospheric
ozone depletion
Nitrogen
cycle
Global freshwater use
Phosphorus
cycle
(biogeochemical
flow boundary)
Source: Johan Rockstrom

Global Chemical Production Increasing

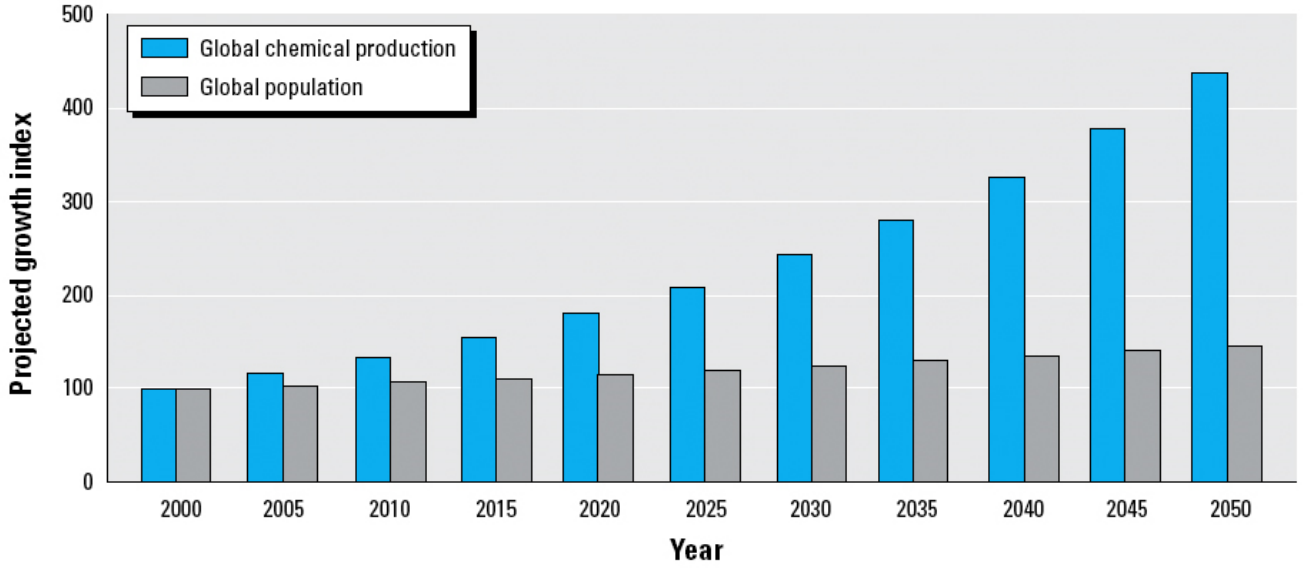
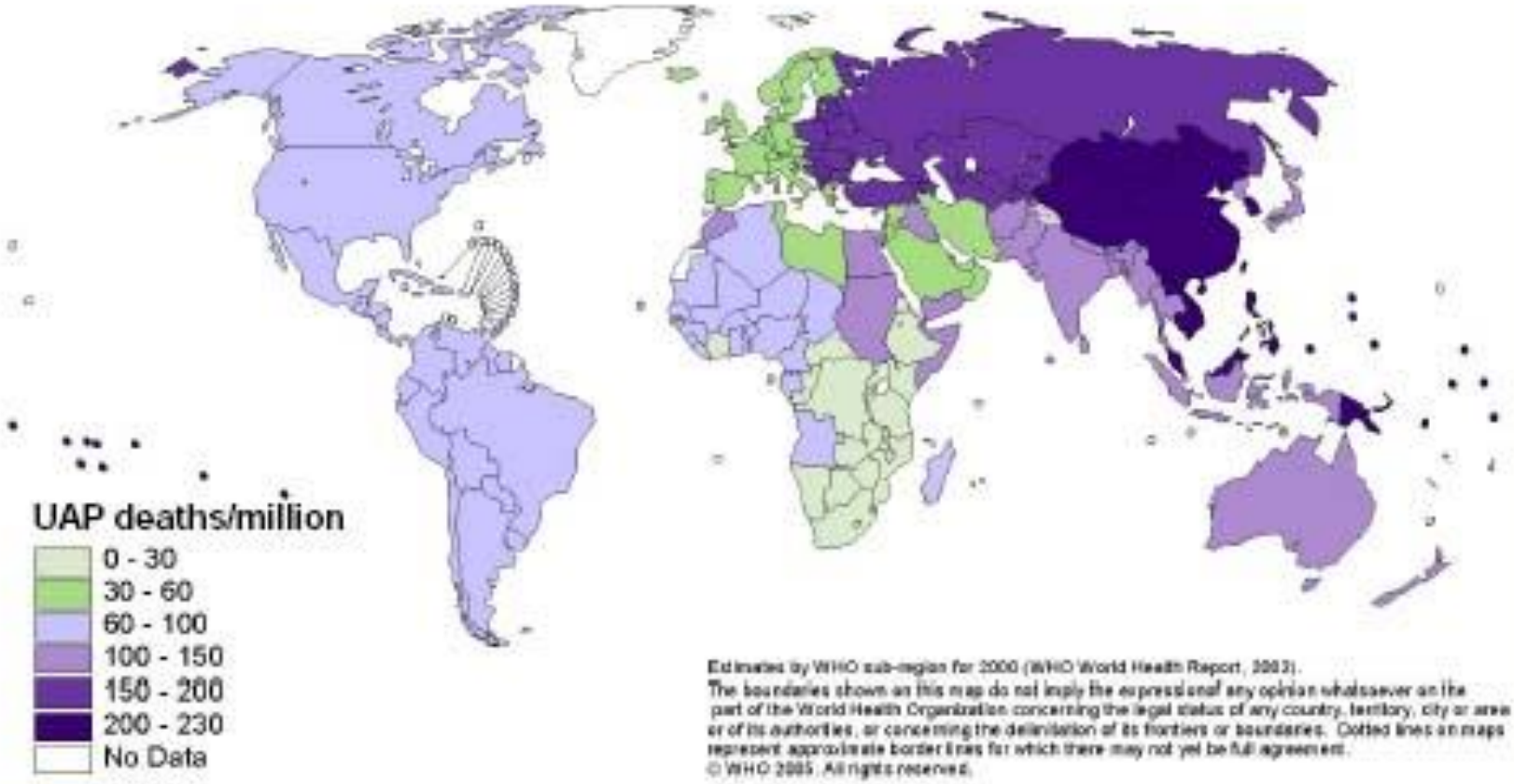


Figure 2. Global chemical production is projected to grow at a rate of 3% per year, rapidly outpacing the rate of global population growth, estimated at 0.77% per year. On this trajectory, chemical production will double by 2024, indexed to 2000 (American Chemistry Council 2003; OECD 2001; United Nations 2004).

Environmental exposures linked to major public health issues

- Air pollution and cardio-vascular disease
- Reproductive/ developmental exposures with lifetime impacts
- Cancers: some direct links, some indirect
- Neurological diseases, autoimmune diseases
- Pediatric asthma
- Obesity, type II diabetes

Deaths from urban air pollution



What is Green Chemistry?

- Green chemistry is the **design** of chemical products and processes that reduce or eliminate the use and generation of ***hazardous*** substances"
  - Anastas, P. T.; Warner, J. C. Green Chemistry: Theory and Practice, Oxford University Press: New York, 1998
  - Paul Anastas and John Warner: the "fathers of green chemistry"

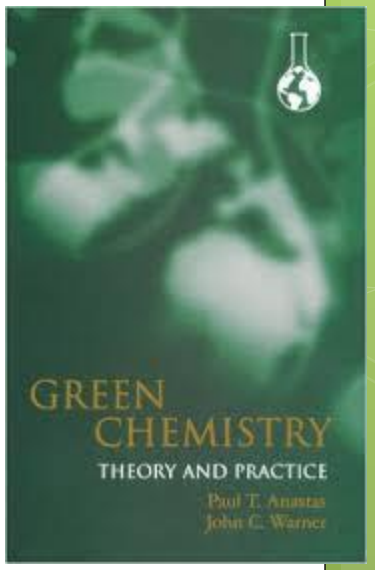


Figure 3. Principles of Green Chemistry.

Implementing Green Chemistry: Safer Alternatives

- A safer alternative ***represents an option that is less hazardous to humans and the environment than the existing chemical or chemical process.***
- *A safer alternative to a chemical of concern* ***may include a chemical substitute or a change in materials or design that eliminates the need for a chemical alternative.***
- ***US National Academy of Sciences* National Research Council, *A Framework to Guide Selection of Chemical Alternatives* (2014), National Academies Press**

Drivers to Safer Alternatives

- Comprehensive Chemicals Policy Reform
  - European Union REACH legislation (2006)
  - US: National and state chemicals policy efforts
    - California Safer Consumer Products Regulations (2013)
- Supply Chain Demands
  - Proactive OEMs, manufacturers, retailers
- Increased Consumer Awareness and Demand for Safer Products
  - Online guides for safer products
- Increasing Access to Information on Hazards
- Investors
  - Shareholder activism
  - Investment advisors differentiating industries on chemical use

Safer Alternatives: Framing Questions

- Is it necessary?
- Is there another way to achieve the desired functional use?
  - Alternative chemistries
  - Product/ material redesign
  - System change examples:
    - Moving from BPA thermal receipts to electronic processing
    - Changing the "dry clean only" label on garments
- Beyond the zero-sum game
  - Realistic assessment of trade-offs
  - Avoiding regrettable substitutions
  - Market incentives for alternative options

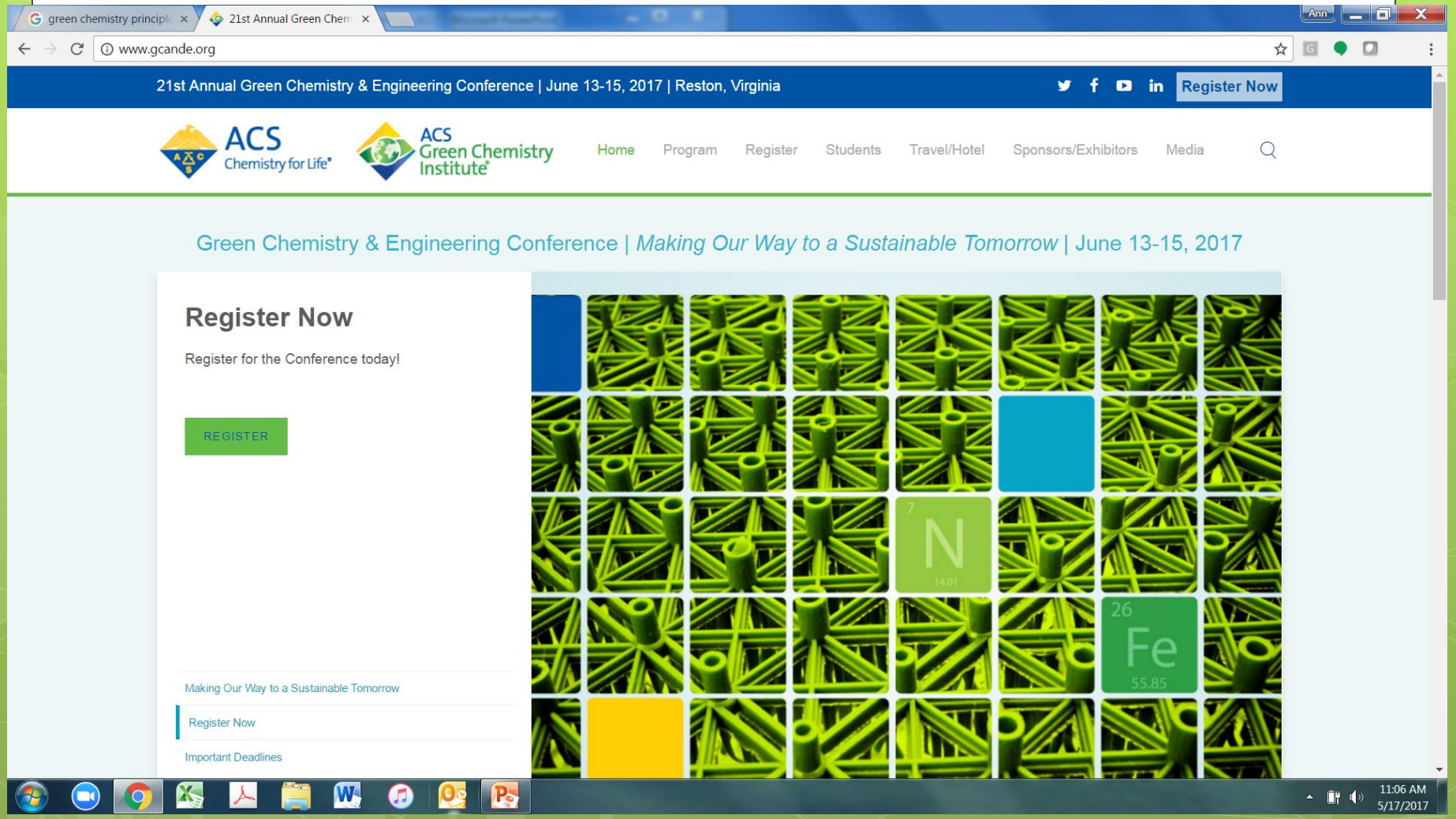
Assessing Alternatives: Challenges

- Shift to evaluating **hazard** portion of risk
  - If Risk = hazard + exposure
- How to achieve **functional use** without toxic effects to humans or the ecosystem?
  - Green Chemistry Education
    - Chemists are not currently taught toxicology, *although this is changing*
- Articulating and assessing **trade-offs**

Additional Educational Resources for Green Chemistry

- More information and the list of winners of the Presidential Green Chemistry Challenge Awards at US EPA's website (for now…)
- Free online course on green chemistry, Carnegie Mellon University
- Comprehensive collection of global green chemistry education efforts at the University Oregon
- University of Washington online certificate program in Green Chemistry & Chemical Stewardship

Annual Green Chemistry & Engineering Conference



Green Chemistry in Practice

Plywood Glue Designed by Mussels

- Traditional plywood is made with urea-formaldehyde adhesive
- Formaldehyde:
  - Known human carcinogen
  - Global market exceeds 52 million tonnes annually
  - Biggest use: building and construction, particularly plywood and MDF (medium-density fiberboard)
- Columbia Forest Products PureBond Plywood
  - Made with soy-based adhesive modeled on the glue from mussels
    - Biomimicry: Nature-inspired design to solve human problems.
  - Better than the original: great adhesion AND exceptional water resistance
- Company's tag line: **"PureBond: proving that enhanced environmental quality and increased product performance can go hand in hand."**

Mango Materials:
turning waste methane into biodegradable plastic

Connora Technologies: Recycling thermoplastics

Innovative Partnerships

- Patagonia's "Enjoy" Bodysurfing Hand Plane
- Ecovative's Mushroom core body-surfing hand plane
- Covered in Connora Technologies dissolvable resin
- (North Shore, Oahu, Hawaii)

Green Chemistry & Bio-based Start Up Network

Grow BioPlastics:

biodegradable agricultural plastics from wood waste

Poly 6:

bioplastic from citrus waste for 3-D printing, flexible electronics, medical implants and more…

California's Safer Consumer Product Regulations

- Requiring the selection of safer alternatives and incentivizing green chemistry
- Going beyond REACH
  - REACH required an assessment of alternatives if your product was a Substance of Very High Concern (SVHC); (~175 chemicals)
  - California has laid out an alternatives assessment process
    - Candidate Chemical list (2,300 chemicals)
- Priority Product Workplan
  - Highlights product and chemical categories of potential concern

Why Not Green Chemistry?

- Ninety percent of manufactured goods are in some way linked to the chemical industry.
  - However, green chemistry is still not mainstream
- Green Chemistry & Commerce Council report on Market Barriers and Incentives (2015)
- Ongoing work on exploring strategies to overcome these barriers

Making the Business Case for Green Chemistry

- April 2015 GC3 report, authored by the consulting firm Trucost
- Evaluates the potential business and economic value of safer chemistry.
- This includes reducing the use and generation of hazardous substances, reducing the human health and environmental impacts of processes and products, and creating safer products.

Mainstreaming Green Chemistry: Strategies

- **Enhance Market Dynamics** by continuing to build a comprehensive, ongoing understanding of green chemistry enablers, market drivers, and obstacles.
- **Support Smart Policies** by designing and advocating for innovative state and federal policies that increase the supply of and demand for green chemistry solutions.
- **Foster Collaboration** by facilitating the flow of information about green chemistry solutions among suppliers and product makers, and assembling partnerships to tackle priority challenges.
- **Inform the Marketplace** by disseminating information about green chemistry business, economic, and health benefits, as well as opportunities and funding.
- **Track Progress** by improving green chemistry metrics and periodically gathering and reporting data on progress.

Green Chemistry & the Bio-Economy

- Estimated 1 trillion Euro value for the top 5 European economies (Germany, France, Italy, Spain, UK) (2017)
- US Department of Agriculture estimate of 2013 contribution of US bio-economy:
  - $369 billion, 4 million jobs, 2.64 job multiplier
  - US GDP USD $18 trillion; agriculture 5.5% of GDP
- McKinsey & Company estimated "worldwide production of biobased products is projected to grow from approximately $203.3 billion in 2015 to $400 billion by 2020 and $487 billion by 2024.
- ASEAN potential?
  - Bioethanol (Vietnam); bioplastics (Thailand); palm oil biomass (Indonesia); biomedical (Singapore);
  - Bio-industrial hub (Malaysia): goal of USD 1 billion by 2020

Bio-based Chemical Platforms

- 1,4 succinic, fumaric and malic acids
- 2,5 furan dicarboxylic acid
- 3 hydroxy propionic acid
- aspartic acid
- glucaric acid
- glutamic acid
- itaconic acid
- levulinic acid
- 3-hydroxybutyrolactone
- glycerol
- sorbitol
- xylitol/arabinitol

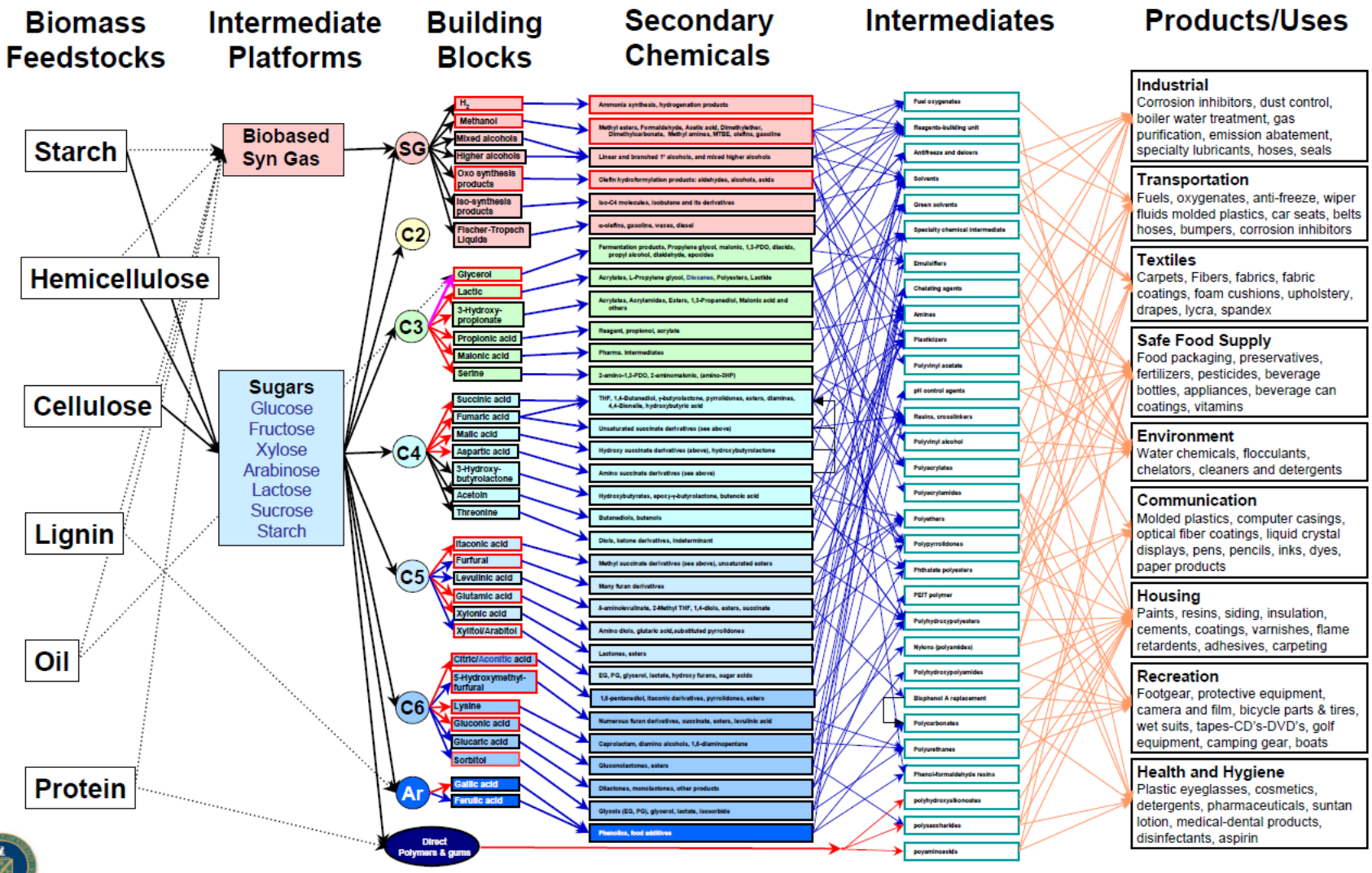


Figure 1 – Analogous Model of a Biobased Product Flow-chart for Biomass Feedstocks


SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

Green Chemistry and the UN SDGs: Opportunities

- Reverse externalized costs of chemical use on human health and the environment, such as:
  - US$90 billion for health-related pesticide costs in Sub-Saharan Africa from 2005 – 2020.
  - €157 billion as a median annual health cost for diseases associated with endocrine disrupting chemicals in the European Union.
  - US$236 billion annual costs for pollution associated with the production and use of volatile organic compounds.
  - US$977 billion annual costs related to childhood lead exposure in low- and middle-income countries. This figure represents 1.20% of global GDP in 2011. The authors note that the largest burden of lead exposure is now borne by low- and middle-income countries.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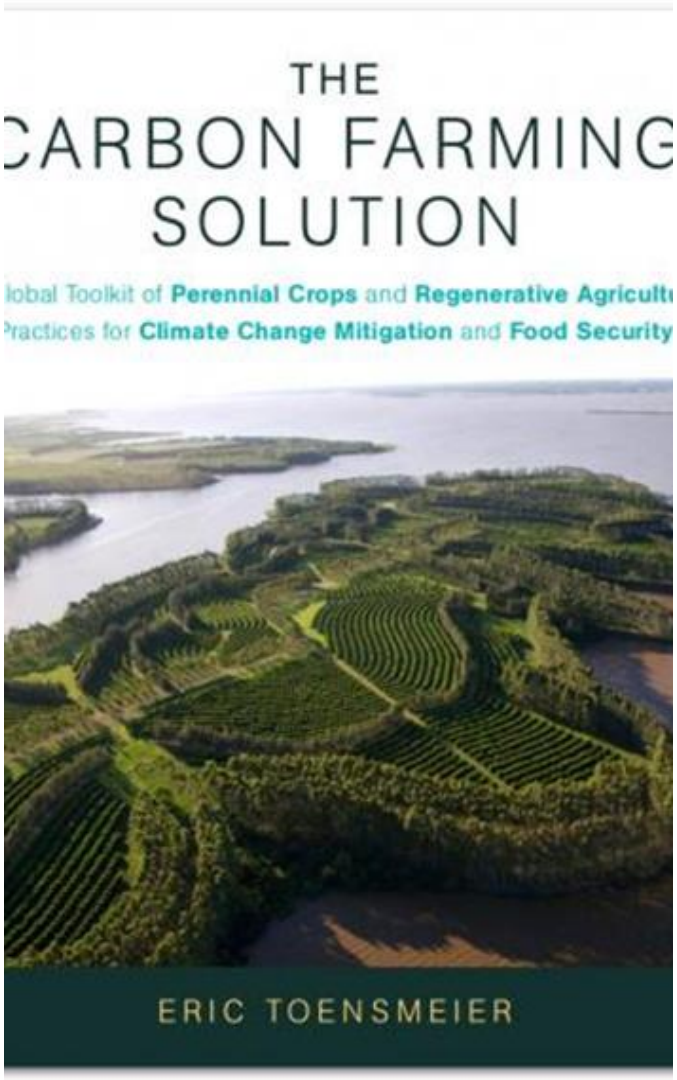
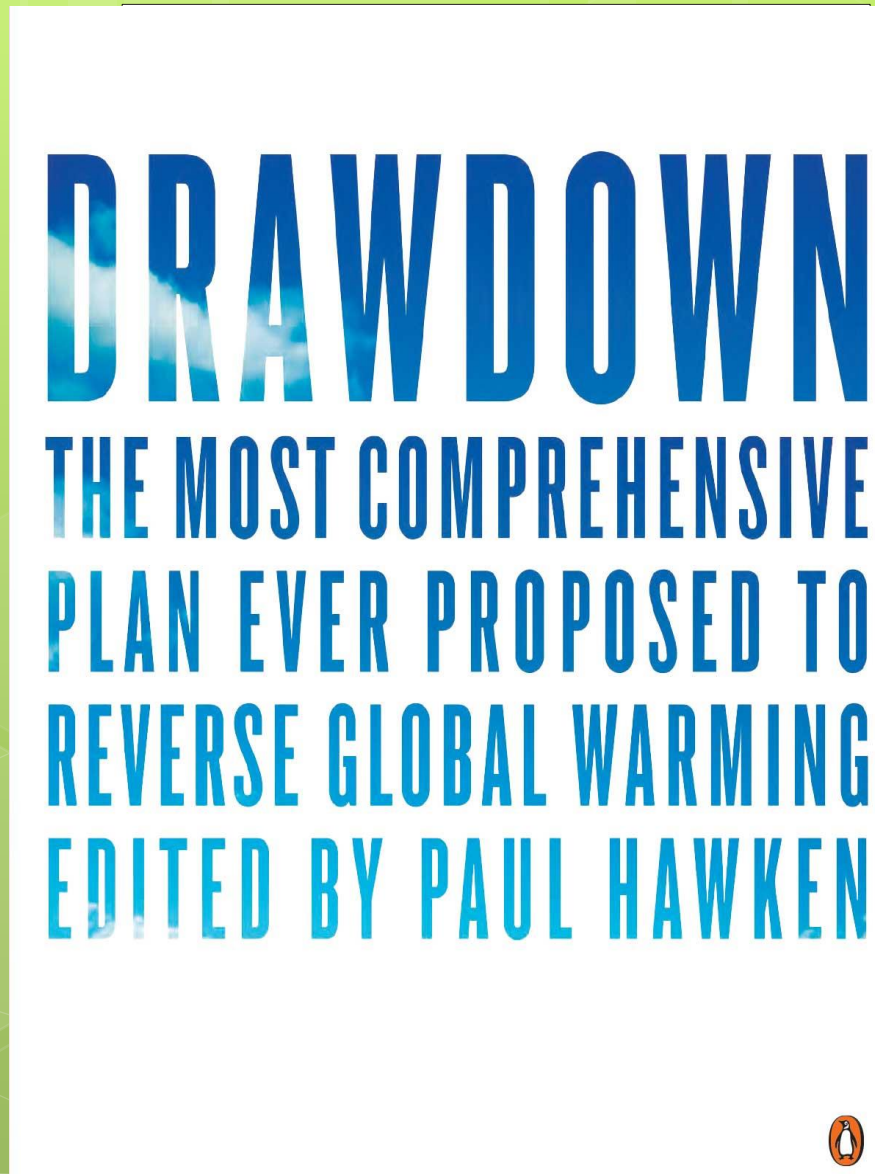
Green Chemistry & Climate Resilience

- Principle #7: Use of renewable feedstocks
- What if we made these ***regenerative*** feedstocks?
  - Sequester carbon from the atmosphere
  - Restore soil, increase water retention (drought resilience)
  - Stimulate local agricultural and industrial economies
  - Replace petroleum feedstocks and downstream toxicity



Perennial Industrial Feedstocks

The Carbon Farming Solution (2016) includes a global survey of potential feedstocks



Project Drawdown

www.drawdown.org

- *"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."*
  - *Buckminster Fuller*

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B the Change