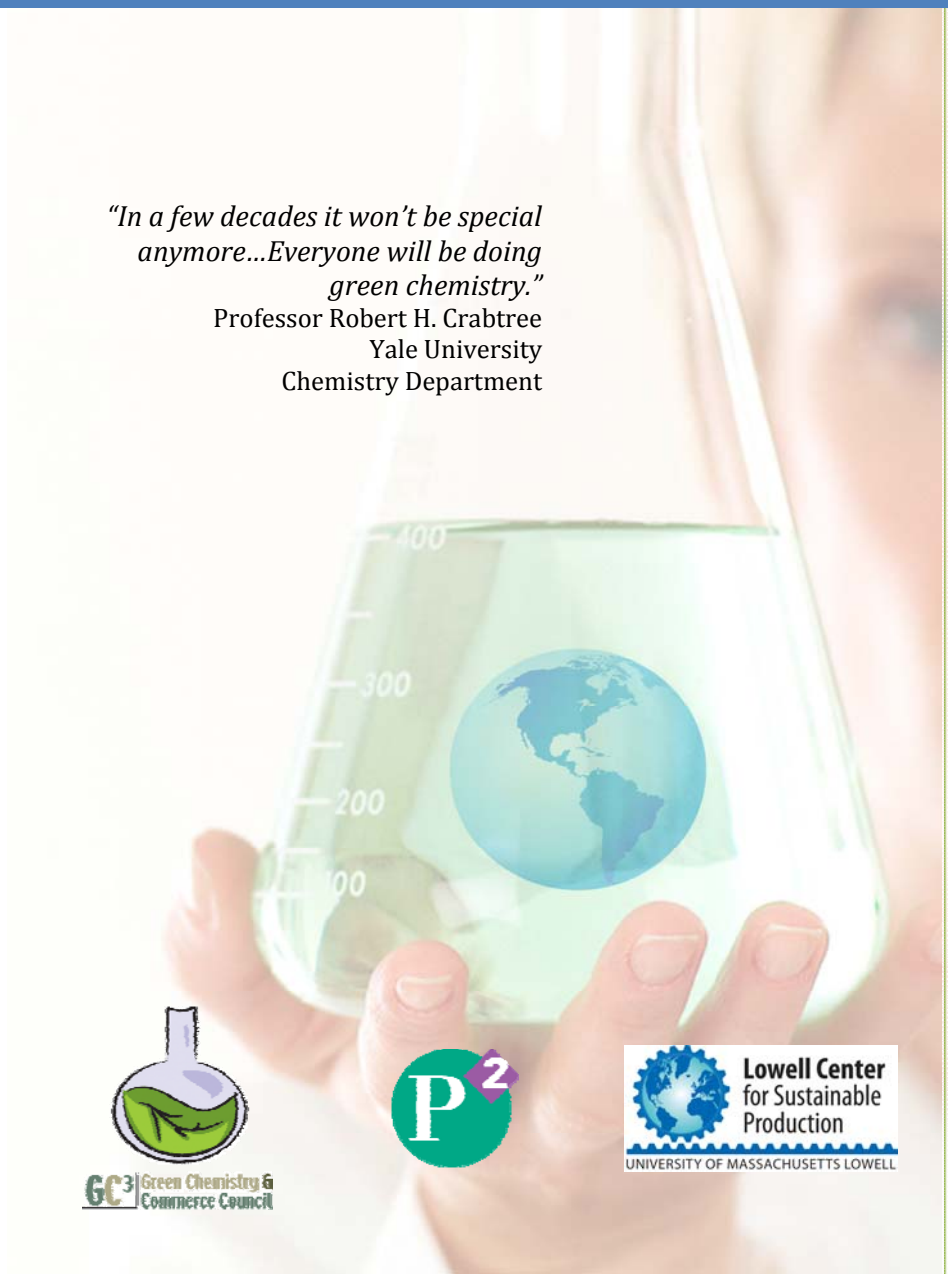
A Resource Guide for States and Higher Education

2009

Growing the Green Economy Through Green Chemistry and Design for the Environment

"In a few decades it won't be special anymore…Everyone will be doing green chemistry."
Professor Robert H. Crabtree
Yale University
Chemistry Department



GC3 Green Chemistry & Commerce Council

P2

Lowell Center for Sustainable Production
UNIVERSITY OF MASSACHUSETTS LOWELL

Contributors

Karen Thomas, environmental consultant, was the primary author in collaboration with Joel Tickner, Lowell Center for Sustainable Production and Ken Zarker, Washington State Department of Ecology.

Supporting Contributors include:

- Jeff Burke, National Pollution Prevention Roundtable
- Mellissa Coffin, Lowell Center for Sustainable Production at the University of Massachusetts Lowell
- Richard Cottrell, SYSCO Corporation
- Clive Davies, US EPA Office of Pollution Prevention and Toxics
- Lauren Heine, Clean Production Action & Lauren Heine Group LLC
- Roger McFadden, Staples, Inc.
- Paul Richard, Warner Babcock Institute for Green Chemistry
- Yve Torrie, Lowell Center for Sustainable Production at the University of Massachusetts Lowell

Collaboration Project Team members include:

- Nishkam Agarwal, US EPA Office of Pollution Prevention and Toxics
- Bill Balek, International Sanitary Supply Association
- Kyle Bartholomew, Minnesota Technical Assistance Program
- Archie Beaton, Chlorine Free Products Association
- Jack Daley, Daley International
- Michael DiGiore, New Jersey Department of Environmental Protection
- Pam Eliason, Toxics Use Reduction Institute at the University of Massachusetts Lowell
- Terri Goldberg, Northeast Waste Management Officials Association
- Paul Gosselin, California Department of Pesticide Regulation
- Jessica Hoffmann, National Pollution Prevention Roundtable
- Robert Jackson, Michigan Department of Environmental Quality
- Bob Kerr, Pure Strategies, Inc.
- Drummond Lawson, Method Home Products
- David Livengood, Oregon Department of Environmental Quality
- Kira Matus, Harvard University/ Joint Project with Yale University Doctorial Candidate
- Cindy McComas, Minnesota Technical Assistance Program
- Gary Miller, University of Illinois Institute of Natural Resource Sustainability
- Aisling O'Connor, Fitchburg State College
- Kathleen Schuler, MN Institute for Agriculture and Trade Policy
- John Vana, NY State Department of Environmental Conservation

Growing the Green Economy Through Green Chemistry and Design for the Environment

A Resource Guide for States and Higher Education

A joint report by
The Green Chemistry and Commerce Council

Lowell Center for Sustainable Production at the University of Massachusetts Lowell and
The National Pollution Prevention Roundtable

Publication support provided by the
Washington State Department of Ecology
Ecology Issued Publication Number 09-04-010

The Green Chemistry and Commerce Council (GC3) was formed in 2005 and provides an open forum for participants to discuss and share information and experiences relating to advancing green chemistry and design for the environment as it pertains to sustainable supply chain management.

The mission of the GC3 is to promote and support green chemistry and design for the environment approaches to research and practices nationally and internationally among companies and other governmental and non-governmental entities by:

- Implementing green chemistry, green engineering, and design for the environment throughout supply chains and sharing strategies to overcome barriers and reduce environmental footprints.
- Promoting education and information on safer chemicals and products that can increase demand by a broad range of consumers.
- Identifying existing and needed information on toxics hazards, risks, exposures, and safer alternatives to promote green chemistry as defined in the *12 Principles of Green Chemistry*.

The **National Pollution Prevention Roundtable** (NPPR), a 501(c)(3) non-profit organization, is the largest membership organization in the United States devoted solely to pollution prevention (P2). The mission of the Roundtable is to provide a national forum for promoting the development, implementation, and evaluation of efforts to avoid, eliminate, or reduce pollution at the source.

NPPR promotes the development, implementation, and evaluation of efforts to avoid, eliminate, or reduce waste generated to air, land, and water. The sustainable and efficient use of energy, materials, and resources is vital to the protection and enhancement of human health and the environment, and the conservation of natural resources. These efforts are integral to accelerate the shift towards sustainable consumption and production to promote environmentally responsible social and economic development.

The Lowell Center for Sustainable Production facilitates the Green Chemistry and Commerce Council. It uses rigorous science, collaborative research, and innovative strategies to promote communities, workplaces, and products that are healthy, humane, and respectful of natural systems. The Center is composed of faculty, staff, and graduate students at the University of Massachusetts Lowell who work collaboratively with citizen groups, workers, businesses, institutions, and government agencies to build healthy work environments, thriving communities, and viable businesses that support a more sustainable world.

The objectives of LCSP 's Chemicals Policy and Science Initiative are to:

- Significantly advance policy dialogue on reforming chemicals policy in the United States.
- Assist in the development of sustainable chemicals management outside the US.
- Encourage the development and use of safer alternatives by creating and promoting a comprehensive framework for alternatives assessment.
- Identify tools and appropriate ways of assisting green chemistry innovation and safer supply chain management of chemicals.

This guide is available on:

- The Green Chemistry and Commerce Council (GC3) website at www.greenchemistryandcommerce.org/publications.php
- The National Pollution Prevention Roundtable website at www.p2.org

For more information contact:

Green Chemistry & Commerce Council
c/o Melissa Coffin
Lowell Center for Sustainable Production
University of Massachusetts Lowell
1 University Avenue
Lowell, MA 01854
Phone: (978) 934-2997
Email: Melissa_coffin@uml.edu

National Pollution Prevention Roundtable
Ken Zarker, Co-chair
Pollution Prevention Policy and Integration Committee
11 Dupont Circle NW, Suite 201
Washington D.C. 20036
Phone: (202) 299-9701
Email: kzar461@ecy.wa.gov

Table of Contents

Introduction 1
Defining Green Chemistry and Design for the Environment 2
Green Chemistry 2
Design for the Environment 3
Examples of Green Chemistry and Design for the Environment Successes 5

Methods for States to Advance Green Chemistry and Design for the Environment 6
Information Development, Collection, and Dissemination 6
Economic Incentives 8
Recognition Programs 8
Regulation and Policy Tools 9

The Roles of Educational Institutions 10

GC and DfE Toolbox 12
Green Chemistry 12
Design for the Environment 12
A Sampling of a Few of the Tools in the Toolbox 13

Appendices

A: North American Eco-logo Certification and Recognition Protocols 15
B: US EPA Tools for Chemical Toxicity, Exposure Assessment, Hazard and Risk Assessment 17
C: References and Resources 19

Introduction

For more than fifteen years, green chemistry (GC) and design for the environment (DfE) have successfully been used to benefit the environment and the economy. The Green Chemistry and Commerce Council (GC3) and the National Pollution Prevention Roundtable (NPPR) developed this guide to further entrench these approaches as the bedrock of industry practices and government policies regarding chemical and materials selection. The guide outlines options for states to promote research, development, and use of GC and DfE to:

- Eliminate or reduce the use or generation of hazardous chemicals in manufacturing.
- Promote the development of the green economy.

Washington State describes "greening" the economy as developing new products, techniques, and services that promote a healthy environment and energy security. The global market for green economy technology has grown for seven straight years. The $8.4 billion invested in North America, Europe, China, and India in 2008 increased by 38 percent from 2007, according to The Cleantech Group LLC. The fastest growing sectors included:

- Energy efficiency
- Energy generation
- Energy storage
- Recycling and waste treatment
- Transportation

The current federal and many state's emphasis on green economic growth provides an opportunity for the GC3-NPPR partnership to assist in the advancement of GC and DfE approaches. Many of the federal and state efforts focus on "green collar job programs" for energy efficiency and renewable energy. In addition to the development of clean technology, GC and DfE approaches offer significant opportunities for:

- Safer chemicals and products to advance clean energy.
- Green building.
- Green transportation and environmental protection.
- Safer jobs.
- Safer consumer products.

The American Chemistry Council estimates that each job in chemistry generates 5.5 additional jobs elsewhere in the economy. When applied, many of the options outlined in this guide will:

- Create new "green jobs" (e.g., manufacturing positions, university researchers).

- Retain existing jobs by redefining job responsibilities (e.g., environmental agency staff).
- Assist companies to thrive by redefining themselves as green (e.g., business tax incentives).
- Stimulate the local economy (e.g., new enterprises, conferences).

This guide will help state governments promote green practices, create green economic opportunities, and move national policy forward by:

- Defining and presenting examples of GC and DfE.
- Presenting options for states to use, such as the development, collection, and dissemination of information, economic incentives, recognition programs, and regulations and policies.
- Presenting roles for education institutions, a vital partner in this effort.
- Identifying available resources and tools.

Defining Green Chemistry and Design for the Environment

As states consider promoting these approaches, clear and consistent definitions of GC and DfE are essential.

Green Chemistry

Green chemistry is an approach to chemistry that uses the 12 Principles of Green Chemistry. It reduces or eliminates the need for and generation of hazardous materials during the manufacture, design, and application of chemistry. The GC3 and NPPR are committed to applying the 12 Principles below in chemical process and product design:

1. Prevent waste: Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. Design safer chemicals and products: Design chemical products to be fully effective, yet have little or no toxicity.
3. Design less hazardous chemical syntheses: Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. Use renewable feedstocks: Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are made from agricultural products or the wastes of other processes. Depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined.
5. Use catalysts, not stoichiometric reagents: Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single

reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.

6. Avoid chemical derivatives: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
7. Maximize atom economy: Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. Use safer solvents and reaction conditions: Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.
9. Increase energy efficiency: Run chemical reactions at ambient temperature and pressure whenever possible.
10. Design chemicals and products to degrade after use: Design chemical products to break down to innocuous substances after use so they do not accumulate in the environment.
11. Analyze in real time to prevent pollution: Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. Minimize the potential for accidents: Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

According to the Michigan Green Chemistry Roundtable, the scope and boundaries of a Green Chemistry Program should:

- Consider all the stages of the life cycle of a chemical.
- Focus on "hazard reduction" as the primary impact category of interest in each life cycle stage with a focus on the design stage. Other life cycle impacts of innovation should also be considered.
- Reduce hazards to human and ecosystem health.

Design for the Environment

Co-pioneered by industry, the DfE concept encourages businesses to incorporate environmental and health considerations in the design and redesign of products and processes. It is the systematic assessment of human health and safety and environmental issues during the product development phase. Designing for the environment improves environmental and human health and increases product performance and market competitiveness. The focus is on finding sustainable solutions to identified materials of concern. In essence, DfE represents the application of green chemistry in practice.

The DfE program of the U.S. Environmental Protection Agency (EPA) works with a broad range of stakeholders to reduce human and environmental risks by preventing pollution. Industry representatives and environmental groups convene to develop goals and guide the work of the partnership. Partnerships evaluate the human health and environmental considerations, performance, and cost of traditional and alternative chemicals, materials, technologies, and processes.

EPA has formed numerous DfE partnerships with electronics, wire and cable, and furniture and automobile refinishing industries and focuses on such issues, such as lead-free solder, safer flame-retardants, and best business practices.

As an incentive for taking part, DfE offers technical tools, methods, and expertise. The DfE Program uses the unique chemical assessment tools and knowledge of EPA's Office of Pollution Prevention and Toxics to inform industries about substitution in processes and using green chemistry in products.

In certain sectors, EPA DfE partners can receive EPA recognition or use the DfE label on environmentally improved products. The DfE logo on a product signifies that the DfE scientific review team has screened each ingredient and has judged that the product's ingredients all pose the least concern among chemicals in their class.

In the Formulator Program, EPA's DfE Program joined manufacturers of chemically-blended products to improve their human health and environmental profile. Their work benefits the biodegradability of waste streams, aquatic life, and other elements of the environment, as well as human health and safety. This type of DfE partnership focuses on selecting the safest possible ingredients to create high-performing, cost-effective products. DfE can provide:

- Information on chemical characteristics.
- Toxicity of raw materials and additives.
- Safer substitutes for chemicals of concern.
- Innovative new chemistries.

Through the Safer Detergents Stewardship Initiative (SDSI), EPA's DfE Program recognizes environmental leaders who voluntarily commit to the use of safer surfactants. Safer surfactants break down quickly into non-polluting compounds and help protect aquatic life in both fresh and salt water.

Examples of Green Chemistry and Design for the Environment Successes

- A more effective fire extinguishing agent that eliminates halon and uses water in combination with an advanced surfactant.
- Removal of arsenic from wood preservatives used on lumber for decks and playground equipment.
- Higher performance automotive coatings that remove substantial lead content and replace it with the relatively benign element yttrium.
- From 1996-2008, projects that received the EPA Green Chemistry Presidential Awards:
  - Eliminated over 1.1 billion pounds of hazardous chemicals and solvents.
  - Reduced releases of nearly 400 million pounds of carbon dioxide to air.
  - Saved over 21 billion gallons of water.
- Use of the DfE label on about 1,000 products that have been reformulated to be environmentally safer, cost competitive, and effective represents a reduction of more than 270 million pounds of chemicals of concern.
- Recognition by EPA of 40 champions (highest level) and 22 partners who committed to using safer surfactants through the Safer Detergents Stewardship Initiative.
- Development of a database of safer cleaning-product ingredients called CleanGredients through an EPA partnership with the GreenBlue Institute. As of 2009, 27 chemical manufacturers paid to list 138 chemicals and more than 327 formulators paid to use the system.
- Assisted by EPA's DfE multi-stakeholder alternatives analyses, industries have moved to safer flame-retardants in furniture and reduced the use of lead in electronics. The analyses also provided information on personal protective equipment and management practices to minimize risks associated with chemical exposures at nail care facilities.

Methods for States to Advance Green Chemistry and Design for the Environment

State governments have a unique opportunity to promote safer chemical processes and products and the growth of the green economy by advancing green chemistry and design for the environment.

Each state's goals and capabilities will dictate which of the following methods is appropriate; it is not necessary to use all of them. Some options are more costly and more difficult than others depending on the nature of the method and a state's political climate and resources.

It is also important for states to consider existing federal and state GC and DfE programs when developing new initiatives to assure consistency, to the extent practicable. This will reduce confusion and cost and lead to the highest possible standards. Current programs include:

- The Michigan Green Chemistry Program.
- The California Green Chemistry Initiative.
- EPA's Design for the Environment and Green Chemistry Programs.

If a state wishes to develop a comprehensive program, the first step may be to establish a green chemistry initiative or program by executive directive or other appropriate legislative means. The initiative would then be used to coordinate the specific elements chosen. This is not a necessary step however, and adopting just a few or even one of the options below can yield large gains in promoting GC and DfE approaches.

■ Information Development, Collection, and Dissemination

- **Establish a green chemistry and design for the environment program, initiative, institute, or task force.** This could serve as the coordinating body to engage stakeholders and share knowledge, tools, and experience. An institute could provide technical research to identify and replace "chemicals of concern" with safer chemical or non-chemical alternatives. A task force could design an action plan for the state, set policies, and develop criteria for other components of the effort. A university, non-governmental organization, or a state environmental or health agency could house the program, institute, or task force. For example: Michigan's Green Chemistry Program is part of the Michigan Department of Environmental Protection and California's Green Chemistry Initiative and the Green Ribbon Science Panel are housed at the California Department of Toxic Substances Control.

- **Integrate green chemistry and design for the environment into active pollution prevention technical assistance programs.** Develop green chemistry and design for the environment expertise in existing pollution prevention and manufacturing technical assistance programs. This may involve hiring or training staff on characterizing hazards and risks and life-cycle analysis to reduce the use of and exposure to chemicals of concern. Once the expertise is developed, it should be integrated into existing services, such as on-site technical assistance, workshops, and guidance manuals. Disseminating case studies will provide ideas and motivational incentives. Example: The Massachusetts Office of Technical Assistance developed GC and DfE expertise and offers these services to Massachusetts businesses.

- **Convene a green chemistry and design for the environment conference.** A conference can provide a forum for sharing successes and strategies and can assist in creating a network to support the initiative. This can also be an opportunity to identify industry research needs to assist in a state's preparation of requests for proposals for funds. (See Research and Development Fund under Economic Incentives heading.) Example: California Green Chemistry Symposiums I, II, and III. Similarly, a state could add a GC or DfE session at an established conference on related topics. Example: Arizona's Green Summit.

- **Create a resource clearinghouse for green chemistry and design for the environment activities.** Compile research, development, use, and education information about GC and DfE efforts into a single location. The clearinghouse could host a listserve for timely sharing of ideas and successes and to further develop the network of state support for GC and DfE. Related example: The University of Oregon's Greener Education Materials for Chemists is a database of green chemistry education materials.

- **Promote chemical information and alternatives assessment.** Support the sharing of information and tools, such as chemical use, toxicity, hazards, exposure, and alternatives, as well as methods to reduce the use of and exposure to chemicals of concern and to design safer chemistries. Example: The Interstate Chemical Clearinghouse (IC2) is under development, established by a partnership of states to promote a clean environment, healthy communities, and a vital economy through the development and use of safer chemicals and products.

- **Issue public service announcements and information on the value of green chemicals and products.** Raise public awareness about the importance and availability of green products through radio, television, websites, or printed materials.

■ Economic Incentives

- **Create a green chemistry and design for the environment research and development fund.** Establish a state grant fund to promote green chemistry research. Select proposals in consultation with a higher education expert review panel. Other similar options include a green chemistry research challenge or public-private research partnerships. Example: The Green Chemistry Research Fund was identified as an option in "Green Chemistry Options for the State of California." States may also tailor existing programs to fund GC and DfE research. Example: New York Empire State Development offers funding for projects that produce measurable results in pollution prevention, reuse, and recycling.

- **Provide green chemistry and design for the environment tax incentives.** Support research and development efforts of companies attempting to develop and market safer, less toxic products through targeted tax breaks. Related example: The Washington Business and Occupation Tax Incentive for High Technology is an annual credit of up to $2 million for research and development in specific high technology categories, including environmental technology.

- **Provide investment tax credits, low-interest loans, loan guarantees, or subsidies for green chemistry manufacturing equipment or products.** Make financial capital available to companies at preferential terms through the means chosen to encourage GC and DfE. Examples: "Green Chemistry Options for the State of California" discusses this option. France offers reduced-interest loans to businesses investing in the production of green products.

- **Promote green chemistry and design for the environment through incentives tied to economic development projects.** Promote GC and DfE through existing economic development projects, such as industrial parks, brownfields, or low-impact development. Example: "The Modernizing Washington Manufacturers" program provides $2 million for modernizing existing manufacturing processes, retaining jobs, and transforming them to "green" jobs through the existing Washington Manufacturing Services Fund.

■ Recognition Programs

- **Implement green chemistry and design for the environment awards program.** Recognize excellence, innovation, economic development, and public health risk reduction by businesses and institutions through an awards program. Examples: EPA Presidential Green Chemistry Challenge Awards and the planned Michigan Green Chemistry Awards. Another

option is to add a GC or DfE category to an existing environmental awards program. Example: Texas Environmental Excellence Awards.

- **Recognize top poster displays at conferences.** Issue awards to the top GC and DfE poster displays at conferences to promote the concepts and to foster ideas and information sharing.

■ Regulation and Policy Tools

- **Require environmentally responsible state purchasing.** Require that state agencies buy the least toxic products available when performance and price are comparable, with a preference for products made locally. See Appendix A for descriptions of the three principal third-party programs for use by states to identify green products (EcoLogo, Green SealTM, EPA's DfE Formulator Program). Examples: Environmentally Preferable Purchasing Programs in Washington and New York states.

- **Apply fee or tax to substances of high concern.** Encourage green chemistry research and the use of less hazardous chemicals by increasing the cost of these substances of concern. Related example: Tax on cigarettes. The fees could fund technical assistance or research into safer alternatives. Example: Massachusetts Toxics Use Reduction Act.

- **Negotiate supplemental environmental projects focused on GC and DfE in enforcement settlements.** Ensure that projects are focused on developing or demonstrating new GC or DfE technology when incorporating supplemental environmental projects into enforcement settlements. Example: EPA has used this strategy for pollution prevention projects in enforcement settlements since 1989.

- **Prepare GC action plans for chemicals of high concern.** Outline alternatives and action steps to minimize use of chemicals identified. Action steps could include demonstration projects, state procurement programs, data collection on use, dialogs with industry suppliers, and mandatory requirements for substitution. Examples: The Mercury Chemical Action Plan and Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan of Washington State.

- **Require safer alternatives planning.** Through statute, require companies using certain chemicals at certain volumes to conduct a chemical use inventory and safer alternatives plan. Example: Massachusetts Toxics Use Reduction Act.

- **Restrict chemicals or products of concern.** Use existing or new legislation to restrict specific chemicals or product categories in ways that create markets for safer substitutes. Example: California, Maine, and Washington are among states that have passed laws phasing out the use of the flame-retardant polybrominated diphenyl ethers.

- **Prepare list of chemicals of concern.** List chemicals that should be avoided where possible. They signal potential regulatory actions that could encourage green chemistry research and shifts in chemical preferences. Example: California Prop 65 list. States can also require authorization to use these chemicals. Example: REACH Authorization Process.

- **Promote DfE by implementing policies that support producer responsibility and closed loop management of chemicals and materials.** This will reduce exposure and toxics use and encourage recycling. Example: Electronic waste take-back programs.

The Roles of Educational Institutions

Educational institutions are vital to furthering the GC and DfE approaches by:

- Educating the future workforce of the green economy.
- Discovering new green chemistry and product options.
- Supporting efforts to overcome application challenges.
- Analyzing policy options.
- Serving as the host for needed dialogues between researchers and businesses and communities.

States can partner with or pursue policies that support educational institutions in these endeavors:

- **Create a green chemistry education network.** Provide a link for teachers at different levels to share curriculum, training tools, and strategies. Examples: The Green Chemistry Education Network facilitated by the University of Oregon's Department of Chemistry is specific to the issue. The New England Association of Chemistry Teachers houses the network within the organization. Beyond Benign has developed curriculum and education resources for middle and high schools. The University of Oregon's Greener Education Materials for Chemists is a database of green chemistry education materials.

- **Offer GC and DfE college courses.** Higher education institutions can offer green chemistry, toxicology, and environmental science and policy courses as part of the chemistry curriculum. Examples: The New York Pollution Prevention Institute is developing a green chemistry higher education curriculum. Existing resources include the University of Oregon's Greener Education Materials for Chemists, a database of green chemistry education materials.

- **Provide GC and DfE scholarships, internships, and graduate student support.** This is an inexpensive method for encouraging students to become eager promoters of new approaches. Example: "Green Chemistry Options for the State of California" discusses this option.

- **Encourage K-12 education programs.** University courses with a focus on GC and DfE could require students and staff to conduct outreach to local high schools and primary schools teaching green chemistry. Example: The New York Department of Environmental Conservation is working with the New York Education Department and the New York Pollution Prevention Institute on developing a green chemistry lab manual for high schools. Existing resources include curriculum and education resources for middle and high schools developed by Beyond Benign.

- **Establish a consortia of state research universities to support green chemistry.** Higher education institutions can form strategic partnerships and alliances to educate, discover, develop, apply and promote GC and DfE. Use existing green chemistry faculty and research groups where they exist. Example: The New England Green Chemistry Consortium

- **Convene innovation-focused industry dialogues.** Higher education institutions can facilitate discussions with industry on GC and DfE topics. This will build the network and can be a forum for identifying GC and DfE research needs and sharing successes. Example: The Green Chemistry and Commerce Council established by the Lowell Center for Sustainable Production at the University of Massachusetts Lowell.

- **Host a symposium for industry.** This would allow the educational institution to showcase GC and DfE research and innovations to industry and increase networking opportunities. This would also link industry research needs to researcher expertise. Examples: The Northern Essex Community College Technology Center's Green Chemistry Business Summit and Gordon Research Conference – Green Chemistry at Bates College.

For additional information, see the Lowell Center for Sustainable Production's report *Options for State Chemicals Policy Reform: A Resource Guide, Module 5: Policy Options for Chemical Innovation and Green Chemistry*, at www.sustainableproduction.org/ (click on *Publications*, then *Chemicals Policy*).

CG and DfE Information Toolbox

Green Chemistry

A number of informational tools are available to assist businesses in applying green chemistry methods, such as:

- EPA's **Green Chemistry Expert System**, a computer program that can be used to select green chemicals and reactions. It includes the Synthetic Methodology Assessment for Reduction Techniques (SMART) module that quantifies and categorizes the hazardous substances used in or generated by a chemical reaction based on information provided by the user. Reactions can be modified and reevaluated to optimize their green nature. www.epa.gov/greenchemistry/pubs/gces.html

- Massachusetts Institute of Technology's **Green Chemistry Alternatives Wizard**, a web-based tool that allows the user to search from a select list of common solvents and the associated process. The Wizard identifies less hazardous and more environmentally benign chemicals or processes that may be substituted. http://web.mit.edu/environment/academic/purchasing.html

- **CleanGredients®**, a project of the nonprofit Green Blue Institute (GreenBlue®), is an online database of cleaning product ingredient chemicals that meet established requirements for superior environmental and human health performance. CleanGredients helps formulators identify ingredients that have potential environmental and human health benefits and pass the U.S. EPA's Design for the Environment Screens for Safer Chemical Ingredients. It also helps chemical manufacturers showcase their chemicals with superior environmental and human health profiles. www.cleangredients.org

Design for Environment

To apply design for the environment methods, states and businesses need to be able to quickly assess, categorize, prioritize, and act on chemicals using prevention measures. Information about chemical hazards, exposures, and risks is necessary before this action can occur. Many tools are available to assist states and businesses in this process.

Two recent reports present information about many such tools:

- A February 2008 report by the Lowell Center for Sustainable Production Options for State Chemicals Policy Reform: A Resource Guide, contains Module 3: Assessment and Prioritization of Chemicals: Policy Options for States and the Federal Government, which discusses how states can rapidly screen chemicals and rank them for hazards and risks. It also describes how governments can best decide where to focus their risk management efforts. This module includes examples of many tools for screening, assessing/ prioritizing, and decision-making about chemicals and processes. www.sustainableproduction.org/ (Click on Publications, then Chemicals Policy).
- A 2005 report by the Toxics Use Reduction Institute at the University of Massachusetts Lowell, Alternatives Assessment for Toxics Use Reduction: A Survey of Methods and Tools, focuses on nine tools for alternatives assessment of chemicals that have been developed by government and private organizations in the United States and Europe. This report also includes a summary of over 100 various methods and tools that were available as of 2004, ranging from full life cycle assessment to specific parameter assessment tools. www.turi.org/library/turi_publications/toxics_use_reduction_policy_analysis/alternatives_assessment_for_toxics_use_reduction_2005

EPA has developed an extensive array of tools to assist in chemical prioritization and assessment. Many of them are available on these EPA websites: www.epa.gov/oppt/tools/dsalpha.htm and www.epa.gov/epahome/Data.html/. See Appendix B for a listing and description of some of the EPA tools addressing chemical toxicity, exposure assessment, and hazard and risk assessment.

EPA's website (www.epa.gov/dfe/) Design for Environment section also provides numerous fact sheets, case studies, Cleaner Technology Substitute Assessments, and life cycle assessments demonstrating alternatives assessment methodologies for specific processes and/or specific chemicals.

A Sampling of a Few of the Tools in the Toolbox

Dutch QuickScan

The Dutch Ministry of Housing, Spatial Planning, and the Environment developed the Quick Scan method to prioritize the management and evaluation of about 100,000 substances. Using existing data, criteria, and decision-making rules to evaluate substances, the method assigns a substance one of five different categories of concern. Both "hard" (animal testing results) and "soft" (scientific literature, expert judgment, and structure-activity models) data are used in the evaluation.

The Quick Scan considers risks to workers, consumers, and the environment and is completed by industry for all substances produced, traded, or used in the Netherlands. www.vrom.nl/pagina.html?id=37626 (see Progress Report, 2001).

Kemi PRIO

The Swedish Chemicals Agency's PRIO is a web-based tool that facilitates the assessment of health and environmental risks of chemicals so that environmental managers, purchasers, and product developers can identify the need for risk reduction. PRIO also provides a guide for decision-making that can be used in setting risk-reduction priorities. The PRIO database contains chemicals identified as being of high concern by the government (phase-out or risk reduction). It allows users to search for substances, obtain information on properties, identify substances contained in product types, and obtain help in developing support for product development. www.kemi.se/templates/PRIOEngframes___4144.aspx

Green Screen

Clean Production Action's Green Screen for Safer Chemicals is a comparative hazard assessment method designed to inform decision-making by businesses, governments, and individuals concerned with the risks posed by chemicals and to advance the development of green chemistry. The Green Screen defines four benchmarks on the path to safer chemicals, with each benchmark defining a progressively safer chemical:

1. Avoid—chemical of high concern.
2. Use but search for safer substitutes.
3. Use but still opportunity for improvement.
4. Prefer—safer chemical.

Each benchmark includes a set of hazard criteria that a chemical, along with its known and predicted breakdown products and metabolites, must pass. All of the hazard and benchmark criteria developed for the Green Screen are based on government and other precedents for classification.
www.cleanproduction.org/Greenscreen.php

PBT Profiler

EPA's PBT Profiler, a web-based evaluation tool, estimates environmental persistence (P), bioconcentration potential (B), and aquatic toxicity (T) of discrete chemicals based on their molecular structure. The user enters a chemical using the Chemical Abstract Service Registry Number (CASRN). If the chemical is in the accompanying database of more than 100,000 chemicals, the structure is retrieved and entered into the model. A drawing program is also available so that the user can draw and enter the structure. The PBT Profiler may be valuable for those developing new chemicals or considering the use of new chemicals.
www.pbtprofiler.net/

Appendix A

North American Eco-logo Certification and Recognition Protocols

Three major certification and recognition programs exist in the North American market to allow for third-party certification and U.S. EPA recognition. These programs are available to manufacturers and suppliers who wish to differentiate their products as "green" in the marketplace.

EcoLogo

EcoLogo is a North American eco-labeling program initially launched by the Canadian federal government in 1988. The EcoLogo program helps identify environmentally preferable ("Green") goods and services. EcoLogo certification identifies environmental leadership, high quality products, and proven environmental claims. EcoLogo meets ISO 14024 requirements, and the logo itself is internationally recognized. Currently the EcoLogo program is managed by TerraChoice Environmental Marketing, Inc. Products meeting the criteria of the EcoLogo program will normally carry the EcoLogo symbol depicting three doves intertwined with three maple leaves. www.ecologo.org/en/

Green SealTM

Green Seal, founded in 1989, is an independent non-profit organization dedicated to safeguarding the environment and transforming the marketplace by promoting the manufacture, purchase, and use of environmentally responsible products and services. The Green Seal program embodies a number of environmental and performance standards for a diverse landscape of products. Well-known standards for institutional cleaning products include the GS-34 Standard for Degreasers, the GS-37 Standard for Industrial & Institutional Cleaners, and the GS-40 Standard for Industrial & Institutional Floor Care Products. Products certified as Green Seal usually carry the distinctive Green Seal checkmark logo. www.greenseal.org/

EPA's DfE Formulator Program

The DfE Formulator Program, situated in the U.S. EPA's Office of Pollution Prevention and Toxics (OPPT), is a rigorous, science-based program that encourages partners to reformulate products to be environmentally safer, cost competitive, and effective. Products meeting the DfE criteria are allowed to display the distinctive DfE globe logo on labels and literature. That DfE logo means that each ingredient in the product has been screened for potential human

health and environmental effects and that – based on current available information, predictive models, and expert judgment – the product contains only those ingredients that pose the least concern among chemicals in their class.

The DfE Formulator Program is distinct from other product recognition or ecolabeling programs because of two defining characteristics: its assessment methodology and its use of a technical review team with many years of experience in assessing chemical hazards, applying predictive tools, and identifying safer substitutes for chemicals of concern. The National Sanitation Foundation (NSF), located in Ann Arbor, Michigan, and ToxServices based in Washington, DC also assist the DfE Program as third-party reviewers of the toxicological aspects of products submitted for DfE recognition.

The DfE Screens for Safer Ingredients, have enhanced the transparency of the DfE Program. Developed in partnership with a broad group of stakeholders, the screens allow the program to evaluate each formulation ingredient within its functional class based on critical health and environmental endpoints. In this way, ingredients can be viewed as part of a continuum of improved or safer ingredient choices. In establishing thresholds for green ingredients, the screens delineate the safer or low-concern end of the spectrum, guiding and ensuring best-in-class ingredients for DfE-recognized products. (For more information on the DfE Screens see www.epa.gov/dfe/pubs/projects/gfcp/index.htm.)

The DfE Formulator Program partners with manufacturers of chemically blended products, helping them bring to market a wide range of safer products, from all-purpose cleaners and conversion coatings that do not use Chrome 6, to holding tank treatments and zinc-free floor finishes.

The Formulator Program has had especially strong participation from the cleaning product sector and counts among its partners many large, small, and medium-sized companies. Over the past year, interest has intensified in the consumer products area, driven by corporate sustainability efforts, including Home Depot's Eco Options program and Wal-Mart's on-going challenge to their suppliers to use safer ingredients in their products.
www.epa.gov/dfe/pubs/projects/formulat/index.htm

Appendix B

US EPA Tools for Chemical Toxicity, Exposure Assessment, Hazard and Risk Assessment

Chemical Toxicity Data

IRIS Database - IRIS is a database of human health effects that may result from exposure to various substances found in the environment. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on chemical substances for use in risk assessments, decision-making, and regulatory activities. www.epa.gov/iris/

OncoLogic is a desktop computer program that evaluates the likelihood that a chemical may cause cancer. www.epa.gov/oppt/newchems/tools/oncologic.htm

Scorecard - The Scorecard Database provides information on chemical releases, risk prioritization of substances, and other relevant information for chemicals and facilities. www.scorecard.org

Triage Database - Triage is a searchable database of scientific studies on the health and environmental effects of toxic chemicals related to Section 8(e) of the Toxic Substances Control Act (TSCA). www.epa.gov/8e_triag/

TSCATS - (Toxic Substances Control Act Test Submissions) is an online index to unpublished, non-confidential studies covering chemical testing results and adverse effects of chemicals on health and ecological systems. The studies are submitted by U.S. industry to EPA under several sections of TSCA. There are four types of documents in the database: Section 4 chemical testing results, Section 8(d) health and safety studies, Section 8(e) substantial risk of injury to health or the environment notices, and voluntary documents submitted to EPA known as a *For Your Information* (FYI) notice. www.rtknet.org/tsc/

Exposure Assessment Tools

The EPA Office of Pollution Prevention and Toxics (OPPT) has developed several exposure assessment methods, databases, and predictive models to help in evaluating:

- What happens to chemicals when they are used and released to the environment.
- How workers, the general public, consumers, and aquatic ecosystems may be exposed to chemicals.

See www.epa.gov/oppt/exposure/ for the list of tools and descriptions of them.

These tools may be helpful when appropriate monitoring data are not available or need to be supplemented, when considering potential exposure in the design and selection of products and processes, and when evaluating pollution prevention opportunities. The results of an exposure assessment are generally combined with a hazard assessment (potential for a chemical to cause adverse health or environmental effects).

Hazard and Risk Assessment Tools

ECOSAR (Ecological Structure Activity Relationships) is a personal computer software program used to estimate the toxicity of chemicals used in industry and discharged into water. The program predicts the toxicity of industrial chemicals to aquatic organisms such as fish, invertebrates, and algae by using Structure Activity Relationships (SARs). The program estimates a chemical's acute (short-term) toxicity and, when available, chronic (long-term or delayed) toxicity. www.epa.gov/oppt/newchems/tools/21ecosar.htm

The **High Production Volume Information System** (HPVIS) provides complete and easy access to technical health and environmental effect information on chemicals that are manufactured in exceptionally large amounts. Information in this database is submitted through EPA's High Production Volume (HPV) Challenge Program. HPVIS allows users to search for summary information, test plans, and new data on high production volume chemicals as they are developed. www.epa.gov/hpvis/index.html

PBT Profiler - an evaluation tool that estimates environmental persistence (P), bioconcentration potential (B), and aquatic toxicity (T) of discrete chemicals based on their molecular structure. The user enters a chemical using the Chemical Abstract Service Registry Number (CASRN). If the chemical is in the accompanying database of more than 100,000 chemicals, the structure is retrieved and entered into the model. A drawing program is also available so that the user can draw and enter the structure or the structure can be entered as a line notation using the Simplified Molecular Input Line Entry System (SMILES). The PBT Profiler is a web-based evaluation tool that may be valuable for those developing new chemicals or considering the use of new chemicals. www.pbtprofiler.net/

RSEI (Risk-Screening Environmental Indicators) is a computer-based screening tool developed by EPA that analyzes risk factors to put Toxics Release Inventory (TRI) release data into a chronic health context. www.epa.gov/oppt/rsei/

Appendix C

References and Resources

General Green Chemistry and Design for Environment Resources

- **American Chemical Society's Green Chemistry Institute** www.acs.org (includes information on the annual GC and Engineering Conferences and on the Pharmaceutical Roundtable www.acs.org/gcipharmaroundtable).

- **Green Chemistry and Commerce Council** www.greenchemistryandcommerce.org/home.php

- **Green Chemistry Resource Exchange** www.greenchemex.org/

- **Lowell Center for Sustainable Production** www.sustainableproduction.org/
  - Chemicals Policy Initiative www.chemicalspolicy.org/ (includes link to *Options for State Chemicals Policy Reform: A Resource Guide*)

- **U.S. Environmental Protection Agency** www.epa.gov/greenchemistry (includes link to Presidential GC Challenge Awards) and www.epa.gov/dfe/.

- **Warner Babcock Institute for Green Chemistry** www.warnerbabcock.com/

State Green Chemistry and Design for Environment Resources

- **California Green Chemistry Initiative** www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/index.cfm

- **California Department of Toxic Substances Control**, *Green Chemistry Options for the State of California* - includes extensive list of resources www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/SAP_Report.pdf

- **California, Maine, and Washington laws** on the use of flame retardant polybrominated diphenyl ethers– search the State Legislation database at www.chemicalspolicy.org/

- **Michigan Green Chemistry Program** - www.michigan.gov/deq/0,1607,7-135-3585_49005---,00.html

- **Michigan Green Chemistry Action Plan** – Michigan Department of Environmental Quality and the Lowell Center for Sustainable Development, *Advancing Green Chemistry: An Action Plan for Michigan Green Chemistry Research, Development and Education* www.michigan.gov/documents/deq/deq-ess-p2-chemistry-actionplan_236382_7.pdf

- **New York Environmentally Preferable Purchasing Guide** - www.nyc.gov/html/nycwasteless/downloads/pdf/eppmanual.pdf
- **New York Empire Development Fund** - www.empire.state.ny.us/Manufacturing_&_Environment/Environment/pollution_prevention.asp

- **New York Pollution Prevention Institute** - www.nysp2i.rit.edu/

- **Washington Environmentally Preferable Purchasing Program** - www.ga.wa.gov/PCA/SL/ManualsGuidelines/Manuals/EPP-Manual.pdf#Page=7

- **Washington Polybrominated Diphenyl Ether Chemical Action Plan** - www.ecy.wa.gov/biblio/0507048.html

- **Washington Mercury Chemical Action Plan** - www.ecy.wa.gov/biblio/0303001.html

- **Washington State Green Economy Framework** - www.ecy.wa.gov/climatechange/greeneconomy_framework.htm

Educational Institution Green Chemistry and Design for Environment Resources

- **Beyond Benign** – www.beyondbenign.org

- **Carnegie Mellon Institute for Green Chemistry** - www.chem.cmu.edu/groups/collins

- **EPA Green Engineering** - www.epa.gov/opptintr/greenengineering/

- **Gordon Research Conference** – Green Chemistry at Bates College www.grc.org/programs.aspx?year=2008&program=green

- **Green Chemistry Education Network** (University of Oregon) - www.gcednet.org/

- **Green Chemistry at the University of Oregon** - www.uoregon.edu/~hutchlab/greenchem/

- **New England Green Chemistry Consortium** - http://chemistry.umeche.maine.edu/Green.html

- **Northern Essex Community College Technology Center's Green Chemistry Business Summit** www.rsc.org/chemsoc/gcn/pdf/GCBSSummaryNotes.pdf

- **University of Oregon's Greener Educational Materials for Chemists** - http://greenchem.uoregon.edu/gems.html
- **Yale Center for Green Chemistry and Green Engineering** - www.greenchemistry.yale.edu/

Additional Green Chemistry and Design for Environment Resources

- **Canadian Domestic Substances List Categorization** - www.ec.gc.ca/ceparegistry/subs_list/dsl/s1.cfm

- **EPA Environmentally Preferable Purchasing** - www.epa.gov/opptintr/epp/

- **France reduced-interest loans** http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/205&format