

**Advancing Green Chemistry:
An Action Plan for Michigan Green Chemistry
Research, Development, and
Education**

September 2008



TABLE OF CONTENTS

Background	1
Action Plan	2
Phase One: <i>Building Awareness</i> (1-12 months)	2
Phase Two: <i>Building the Program</i> (6-36 months)	5
Phase Three: <i>Building the Future</i> (3-5 years)	8
Appendix A: Methodology	11
Appendix B: Economic Development Strategies for Building the Michigan Green Chemistry Program	12
Appendix C: Green Chemistry Education Strategies	13
Appendix D: Green Chemistry Directions and Opportunities within Education	15
Appendix E: Building on Michigan's Existing Capacity to Advance Long-Term Directions	16

BACKGROUND

In October 2006, Governor Jennifer M. Granholm issued Executive Directive No. 2006-6 (Directive), "Promotion of Green Chemistry for Sustainable Economic Development and Protection of Public Health." The Directive establishes state policy encouraging the use of safer, less toxic, or non-toxic chemical alternatives to hazardous substances and the research, development, and implementation of Green Chemistry in Michigan, which is the design of chemical products and processes that reduces or eliminates the use and generation of hazardous substances.

The responsibility for carrying-out the Directive is primarily the Department of Environmental Quality's (DEQ's) with assistance from other state agencies. The Directive calls for the DEQ to establish a Green Chemistry Support Program (hereinafter referred to as the Michigan Green Chemistry Program) to promote and coordinate state Green Chemistry research, development, demonstration, education, and technology transfer activities in Michigan.¹ The DEQ is also required to convene a Michigan Green Chemistry Support Roundtable (hereinafter referred to as the Michigan Green Chemistry Roundtable) that is representative of public health, industrial, environmental, local government, and general public perspectives. The Michigan Green Chemistry Roundtable is to advise the DEQ on how best to carryout the work of the Michigan Green Chemistry Program.

1. Providing encouragement for Green Chemistry research, development, demonstration, education, and technology transfer.
2. Examining methods by which state government can create incentives for consideration and use of Green Chemistry processes and products.
3. Facilitating the adoption of Green Chemistry innovations in Michigan.
4. Expanding education and training of undergraduate and graduate students, and professional chemists and chemical engineers in Michigan, including through partnerships with industry, in Green Chemistry science and engineering.
5. Collecting and disseminate information on Green Chemistry research, development, and technology transfer.
6. Providing venues for outreach and dissemination of Green Chemistry advances, such as symposia, forums, conferences, and written materials in collaboration with, as appropriate, industry, academia, scientific and professional societies, and other relevant groups.
7. Supporting economic, legal, and other appropriate social science research to identify barriers to commercialization and methods to advance commercialization of Green Chemistry.
8. Providing for public input and outreach to be integrated into the Michigan Green Chemistry Program by the convening of public discussions, through mechanisms, such as citizen panels, consensus conferences, and educational events.
9. Promoting voluntary, cooperative efforts with industrial sectors to develop Green Chemistry plans.
10. Making recommendations to the Governor on an annual basis for a Governor's Green Chemistry Award, promoting excellence, innovation, economic development, and public health risk reduction by businesses and institutions.
11. Maintaining a Web site to provide information about the Michigan Green Chemistry Program.

¹ The DEQ is adopting this name—as well as that of the Green Chemistry Roundtable—at the recommendation of stakeholders. It differs from the wording of Executive Directive No. 2006-6 by dropping the word "support". This clarifies that this effort creates a green chemistry program for the State of Michigan, rather than reinforce an established program, which is implied by the word "support."

To develop a framework for implementing the Directive, the DEQ working with the Lowell Center for Sustainable Production (LCSP), has created an action plan to advance Green Chemistry in Michigan. The methodology used in the action plan's development is described in Appendix A.

ADVANCING GREEN CHEMISTRY: AN ACTION PLAN FOR MICHIGAN GREEN CHEMISTRY RESEARCH, DEVELOPMENT, AND EDUCATION

This action plan recommends a course of action that the DEQ and its stakeholders should undertake over the next five years to construct an infrastructure for advancing and sustaining Green Chemistry in Michigan.

- Phase One (1-12 months) - *Building Awareness*;
- Phase Two (6-36 months) - *Building the Program*; and
- Phase Three (3-5 years) - *Building the Future*.

Under each of the three phases are a series of key action steps. The goal of these actions is to make Michigan a leader in Green Chemistry education, research and application.

All of these action items are crucial to the success of Green Chemistry in Michigan, but some will take longer to implement than others. Incorporating Green Chemistry into the educational curricula for example will take longer than developing a conference or a Green Chemistry Awards Program. However, developing a vibrant Green Chemistry educational network could take place sooner than actual integration in curricula. Many of the longer term action items will depend on interests and needs identified in the earlier years of the Program. It is essential that all actions be advanced from the beginning of the action plan to ensure they can be implemented within the five years of the plan. The overlapping of the timelines for Phases One and Two indicate the actions in each of these phases need implementation in the very early stages of the Michigan Green Chemistry Program's development.

While the DEQ ultimately has responsibility for implementing the Michigan Green Chemistry Program, it is important that the Michigan Green Chemistry Roundtable and its constituency take ownership in developing ideas, making recommendations, and supporting implementation of tasks identified in this action plan. Two critical aspects of this action plan are to create ownership and leadership within the Michigan Green Chemistry Program and Green Chemistry efforts within the state. Such ownership, particularly of the Michigan Green Chemistry Roundtable, is critical to the long-term success and viability of the Program.

Application of some elements in the action plan particularly those under years 3-5 will require an infusion of public and private funds; however, action should be taken as soon as possible to develop plans for implementing specific action items. Clearly, raising additional resources for the implementation of longer term action items is necessary and ensures the sustainability of the program. To the extent that pilot projects and smaller efforts can be initiated with existing funding, such actions should be undertaken.

Phase One (1-12 Months) - Building Awareness

Green Chemistry is not well known or understood, there is uncertainty as to what researchers and companies are working on or teaching in Green Chemistry, and there are no mechanisms to communicate Green Chemistry efforts to others. Therefore, it is important that the DEQ

articulate a clear and consistent description of Green Chemistry and its objectives. However, the success of this initiative is dependent upon the engagement of key constituency groups in the state to lend their support and resources to communicate the benefits of Green Chemistry for public health and welfare, the environment, and the economy.

Action 1: Define the Scope and Priorities of the Green Chemistry Program

Although the Directive states clearly “Green Chemistry means chemistry and chemical engineering to design chemical products and processes that reduce or eliminate the use or generation of hazardous substances while producing high quality products through safe and efficient manufacturing processes”, there is controversy and uncertainty regarding the boundaries of the Program.

It is the opinion of the DEQ and the Michigan Green Chemistry Roundtable that while product and process environmental impact reduction is essential, this directive specifically addresses reducing or eliminating the use or generation of hazardous substances in the design, manufacture, and application of chemical products. These principles, referenced in the Directive, were first published in the 1998 book “Green Chemistry: Theory & Practice,” by Paul T. Anastas and John C. Warner, as a means to make the concepts of green chemistry accessible to the scientific community.

Therefore, it is recommended that the Michigan Green Chemistry Roundtable establish a workgroup to define the parameters and priorities of the Green Chemistry Program, and propose metrics and means for measuring progress. This will establish clear and concise boundaries for the activities undertaken by the Michigan Green Chemistry Program. This will then guide research, development, application, and education efforts.

Action 2: Build a Resource Clearinghouse for Green Chemistry Activities in the State

Compiling and analyzing Michigan’s existing Green Chemistry resources has a two-fold goal. The first is to compile information on Michigan’s Green Chemistry efforts into a single portal, capturing the Green Chemistry research, development, application, and education efforts underway in Michigan, and the resulting success stories. This information will be gathered, characterized and compiled into a Green Chemistry resource clearinghouse that will be available within six months. The initial research categories for the clearinghouse should include, but not be limited to Green Chemistry research and development; applications; education; capital resources; funding; and efforts in professional organizations, trade associations, consulting firms, advocacy organizations and agencies.

Although the focus of the resource clearinghouse is to capture information specific to Michigan, it should also cover a national perspective. The resource clearinghouse should be publicly available and accessible; the success stories will illustrate Green Chemistry’s benefits to public health and welfare, the environment, and the economy.

The second goal is that the data collection process begins an outreach process, helping to establish a Green Chemistry practitioners’ network in Michigan. It will identify ***leaders and champions*** in Green Chemistry. These leaders will be crucial to the future implementation of the program. This outreach process will be the initial step towards a Green Chemistry Research and Education Conference within the first two years of the Program.

Therefore, the Michigan Green Chemistry Roundtable should establish a workgroup to develop a statement of work for establishing and operating a resource clearinghouse that will collect and disseminate information on Green Chemistry in the Great Lakes region.

Action 3: Build Support and Commitments from Key Stakeholders to Advance Green Chemistry in Michigan

Moving forward with the action plan requires cooperation and leadership, and support and commitment from key constituency groups. No one entity has the necessary resources for fully implementing these action items; success can only be achieved through strategic alliances and partnerships.

This is an ambitious plan that suggests a course of action that creates a Green Chemistry Program for sustainable Green Chemistry in Michigan. Whether this program resides in state government or is external is unimportant. What is important is the resolve demonstrated by industry, higher education, public interest groups, the healthcare and economic development sectors, and government. Therefore, it is necessary that the Michigan Green Chemistry Roundtable and the State of Michigan show leadership and willingness to involve all interest groups in the implementation of this action plan.

Members of the Michigan Green Chemistry Roundtable should communicate with their constituencies to discuss the Michigan Green Chemistry Roundtable's actions and build support for future endeavors. Given that the Michigan Green Chemistry Roundtable constitutes numerous interest groups, these discussions will generate ideas for effectively moving the program forward, infusing interest in Green Chemistry, and generating ownership in the Michigan Green Chemistry Roundtable's actions.

There must be a concerted effort to inform and educate the general public on the importance of Green Chemistry, connection to their everyday lives, and impacts on Michigan's economy and environment. Educational events should be a mechanism for public input and outreach. This will result in better informed consumers, behavioral change in the marketplace, and support for public policies that promote Green Chemistry.

Government promotion of voluntary, cooperative partnerships with industrial sectors is essential to garnering support for Green Chemistry. Engaging industry in committing to developing and implementing Green Chemistry plans will result in wise environmental decisions and safer products in the marketplace.

Therefore, it is critical that the DEQ and Michigan Green Chemistry Roundtable develop an outreach strategy as soon as possible to engage stakeholders in advancing Green Chemistry in Michigan. This engagement requires a demonstration of cooperation and leadership to garner support and commitment from key constituency groups for this action plan. This will help ensure the Green Chemistry Program's sustainability.

Action 4: Build Financial Resources for Long-Term Success

Building awareness of a Green Chemistry Program in Michigan must include efforts from the very beginning to establish financial resources for its ongoing implementation and sustainability, ensuring its long-term success. These resources should be multifaceted, but will include direct funding, and collaboration with existing state and other programs.

Making a clear link between Green Chemistry and economic development and competitiveness for the state will strengthen the position of the Program as both an economic and environmental health initiative. Outreach to financial sources such as the Michigan Economic Development Corporation's (MEDC) existing economic development funding programs should be initiated immediately, so that ways can be explored that integrate Green Chemistry into their existing economic development funding strategy.

The sustainability of the Green Chemistry Program and movement is dependent on securing the long-term financial resources. Therefore, a prospectus and initial conversations with potential financiers and hosts for this effort should be initiated at an early stage in order to lay the groundwork for the emergence of an entity to advance Green Chemistry.

We encourage Foundations to seek investment opportunities in research, development, demonstration, education and dissemination of emerging green and sustainable chemistry practices. Foundations can and should play a critical role in making Michigan a center for Green Chemistry. This will require education and outreach to Foundations on Green Chemistry and investment opportunities.

Therefore, the Michigan Green Chemistry Roundtable should establish a workgroup to determine the means for building financial resources to ensure a place for Green Chemistry in Michigan's future. This charge should include a marketing plan to engage Foundations and other investors in supporting the work of the Michigan Green Chemistry Program.

For guidance on building financial resources in Michigan to support the Michigan Green Chemistry Program, see Appendix B.

Phase Two (6-36 Months) - Building the Program

Phase Two should be built on the resource database and clearinghouse, networks and initial leadership created in Phase One to begin establishing Michigan as a leader in Green Chemistry. Starting with the success stories collected and the Green Chemistry champions and leaders that emerge, the focus of this phase should be to bring greater awareness and education regarding Green Chemistry to a wide audience, while celebrating Green Chemistry successes in the state.

Action 5: Convene a Green Chemistry Research and Education Conference

A multi-stakeholder conference would educate a wide audience about the benefits of Green Chemistry; establish a venue for sharing successes, barriers, and strategies; and developing a network to support the Michigan Green Chemistry Program. The conference should highlight success stories uncovered in the development of the Green Chemistry resource clearinghouse and create opportunities for networking and leadership. It should illustrate and promote research, development and application initiatives; understand barriers and opportunities; and demonstrate the health and environmental benefits of Green Chemistry. It must also demonstrate the economic benefits of Green Chemistry, illustrating how it is good for businesses bottom line and how it can grow their business. The conference should have clear objectives, outcomes and follow-up to build on the momentum the conference will generate. Those attending will need to know how they and their business/organization will benefit from attending. The conference will require significant outreach and marketing. Planning for such a conference should begin immediately as such events can take a significant time to organize.

Specifically, the conference will:

- ❑ Be an opportunity to introduce Green Chemistry and its societal benefits to a wide audience;
- ❑ Build, engage, and network Green Chemistry champions and leaders;
- ❑ Engage a range of businesses in learning about the economic benefits of Green Chemistry and how to overcome barriers;
- ❑ Showcase innovative Green Chemistry research within industry, academia, and the community; and
- ❑ Provide an opportunity for educators of different levels to engage in dialog about building capacity and curriculum in Green Chemistry education.

Therefore, the Michigan Green Chemistry Roundtable should form a workgroup to plan and prepare for a Green Chemistry Conference in the near future. The workgroup could consider dividing the conference into two sections: one focused on education, where teachers and students can present research and educational efforts; and one focused on research, development and application. Nonetheless, it is important to view this as an integrated conference.

The conference may become an annual event, or there may be smaller conferences targeting specific audiences e.g., demonstrations among an industry sector. At any other Green Chemistry conferences or initiatives both in Michigan and around the country, this subgroup should make sure Michigan's Green Chemistry efforts are represented.

Action 6: Create an Annual Green Chemistry Awards Program

The Directive calls for a Governor's Green Chemistry Award, promoting excellence, innovation, economic development, and public health risk reduction by businesses and institutions. The annual Presidential Green Chemistry Award Program is an excellent model for an award that generates interest and enthusiasm in Green Chemistry. Hundreds of companies and researchers now compete annually for recognition of their efforts in Green Chemistry and the database of applications has become an important source of information on Green Chemistry efforts and education. Formal acknowledgement of the Green Chemistry efforts in Michigan through an award program will serve the same purpose.

The Governor's Green Chemistry Award Program should endeavor to garner both wide participation and a wide audience within Michigan, so the initial awards ceremony should be held at the Green Chemistry Research and Education Conference. Creating interest, enthusiasm, and participation from this wide audience will require the award categories be broader than the Presidential Green Chemistry Award Program.

The suggested award categories are:

- ❑ Manufacturing/industrial applications that recognize individual efforts, team efforts, corporation efforts;
- ❑ Academic research and development efforts, including undergraduate, graduate and post-doctoral student work;
- ❑ Educational reform efforts e.g., recognizing Green Chemistry elements that have been added to a curriculum; Green Chemistry certifications, etc.; and
- ❑ Community reform that recognizes efforts from advocates, local government, service organizations, and the general public.

As a starting point for the first awards, past Michigan nominees to the Presidential Green Chemistry Awards should be invited to submit applications for awards. The award ceremony should be an important media event, held with state government leadership.

Therefore, the Michigan Green Chemistry Roundtable should establish a workgroup to develop criteria for awards and a consistent review process. These criteria will further help define the parameters of Green Chemistry efforts in the state. Companies and organizations can self-nominate for awards, and an objective review panel should review applications. All awards should be Michigan specific illustrating how they support Michigan's growth; how the innovation will be advanced; and how it benefits Michigan's economy, environment, and health.

Action 7: Establish a Green Chemistry Education Network and Opportunities

As discussed earlier, Green Chemistry is not well known or understood and environmental concerns are not an integral part of chemistry education at this point in time. There are a number of academics teaching and conducting research on Green Chemistry in Michigan, some who have received Presidential Green Chemistry Awards. Despite these disparate efforts, there has been limited coordinated academic leadership in the area of Green Chemistry. It is critical that Green Chemistry academic champions emerge and that efforts are made to ensure the training and mentoring of leaders in the future (see Appendix C for a list of potential directions in building academic coordination on Green Chemistry).

Once Green Chemistry academic champions emerge, Green Chemistry educational curricula and activities that are relevant for K-12, within universities, within industry and with the general public can be developed. A Green Chemistry education strategy and programs must take into account all of these levels of education (see Appendix D for examples of strategies to advance Green Chemistry at different levels of education).

Therefore, it is recommended that the Michigan Green Chemistry Roundtable establish a workgroup that will work with the Michigan Education Association and academic institutions to form a long-term education strategy and programs that ensure Green Chemistry is incorporated into science and chemistry education from K-12 through the university level. As part of this effort, as soon as possible, Michigan should establish a Green Chemistry education network to link teachers at different levels to share curriculum, training tools, and strategies.

Action 8: Build on Michigan's Existing Capacity to Advance Long-Term Green Chemistry Directions

Building on the Green Chemistry resource database, networking efforts, and the Green Chemistry Research and Education Conference a number of potential directions for Green Chemistry innovation will present themselves. Some opportunities already exist. Building on and consolidating existing capacity and opportunities within and outside the state will help in making decisions about these potential directions. The ultimate goal of this action is to establish capacity that will ensure the long-term viability of the Support Program and Green Chemistry successes in the state. The existing capacity identified that could be utilized in the action plan is government, and professional and business organization capacity. For details of this, see Appendix E.

Therefore, the Michigan Green Chemistry Roundtable should establish a workgroup to make recommendations on consolidating existing capacity within and outside the State that could be utilized within the action plan to ensure the long-term viability of the Michigan Green Chemistry Program.

Phase Three (3-5 Years) - Building the Future

Phase Three focuses on long-term projects that bring economic and intellectual wealth to Michigan as well as new jobs in sustainable industries. This phase will build directly from the resource database and clearinghouse; financial resources and opportunities; results of the Green Chemistry Research and Education Conference(s); the Annual Green Chemistry Awards programs; and from building on existing capacity within education, professional organizations and government. The specific long-term projects will be developed throughout the preceding years, but there are clear directions to aim for that will further solidify Green Chemistry efforts in Michigan.

Action 9: Facilitate Research and Commercialization of New Innovative Technology

This action will catalyze research and adoption of Green Chemistry innovations in Michigan, and spur investment in a variety of enterprises. Developing and implementing growth area investments in Green Chemistry technologies is key to establishing Green Chemistry's long-term success in Michigan. These will illustrate Green Chemistry's potential and be "showcase" projects. The Michigan Green Chemistry Roundtable should link these initiatives around green jobs and clean tech in Michigan to ensure job growth and economic development in the state is a major component of Green Chemistry.

Potential research opportunities in Michigan are:

- ❑ Biomass conversion;
- ❑ Synthetic fabric in office furniture industry; and
- ❑ Water based paints in the auto industry.

To facilitate research and commercialization of Green Chemistry technologies and practices, the Michigan Green Chemistry Roundtable and their constituencies should develop a strategy for implementing long-term projects that illustrate growth areas and provide economic benefit to Michigan.

Action 10: Establish the Michigan Green Chemistry Program as a Model for Green Chemistry Innovation

As a model for innovation, the Support Program would play a pivotal role in promoting, coordinating, and facilitating Green Chemistry in the Great Lakes region. Whether the Support Program exists in state government or externally is irrelevant, what is important is that the Support Program carry out the action items previously identified in a coordinated fashion. For long-term sustainability, the DEQ, Michigan Green Chemistry Roundtable, and stakeholders should craft a plan for securing financial resources for the duties of the Michigan Green Chemistry Program and ensure Michigan is a center for Green Chemistry innovation.

Therefore, the Michigan Green Chemistry Roundtable should form a workgroup to scope the feasibility of establishing a Green Chemistry Innovation Center to supplement or carryout the work of the Michigan Green Chemistry Program.

It is conceivable that an innovation center could:

- ❑ Be the focal points of all Green Chemistry activities in Michigan;
- ❑ Coordinate all Green Chemistry outreach activities and events;
- ❑ Coordinate educational resources, including Green Chemistry training;

- ❑ Conduct on-site educational training to the general public and school children. Green Chemistry students at universities will conduct these trainings;
- ❑ Support and catalyze research on Green Chemistry, including playing a brokering role to identify vendors for research and application needs;
- ❑ Support an industry to industry Green Chemistry group where companies can go to share information and questions on Green Chemistry challenges and solutions. Industry needs new ideas and this will provide an opportunity for those not in the immediate industry or sector to weigh in on solutions that may have cross sector appeal;
- ❑ Link the industry to industry Green Chemistry group with universities so universities understand industry needs;
- ❑ Support sector or cross-sector Green Chemistry initiatives in industry;
- ❑ Provide and coordinate technical support including research and development, application and conducting or facilitating product performance testing;
- ❑ Provide opportunities for technology demonstration and transfer of Green Chemistry innovations; and
- ❑ Provide guidance to working in a Green Chemistry career-education, training, and certification.

APPENDIX

APPENDIX A

Methodology

The document “Advancing Green Chemistry: An Action Plan for Michigan Green Chemistry Research, Development and Education” was created by the Lowell Center for Sustainable Production. It is a road map for implementing the Michigan Green Chemistry Program, and highlights key priorities and actions. Information in the action plan represents the thoughts and ideas gathered from the various stakeholder and supporter of Green Chemistry in the State of Michigan:

- A Green Chemistry Stakeholders meeting on December 12, 2007, hosted by the Department of Environmental Quality (DEQ). Over 40 stakeholders, representing environmental groups, industry, and educators, took part in this day long meeting. The group discussed program priorities, partnering opportunities, and formation of the Green Chemistry Roundtable.
- Interviews in January and February 2008 with leaders in the field of Green Chemistry.
- Interviews with 15 participants of the Green Chemistry Stakeholders meeting and other key stakeholders, during February and March 2008.
- Written comments on the draft action plan from stakeholders.
- Comments on the draft action plan provided by the Michigan Green Chemistry Michigan Green Chemistry Roundtable at its initial meeting on May 22, 2008, hosted by the DEQ.
- The Lowell Center for Sustainable Production’s fifteen years of experience working with government, businesses and communities in studying and promoting safer forms of production.

APPENDIX B

Economic Development Strategies for Building the Michigan Green Chemistry Program

There are several possible directions for building financial resources to establish and support the Michigan Green Chemistry Program such as:

- ❑ MEDC's 21st Century Jobs Fund which will invest more than \$2 billion in new technologies that will drive Michigan's economy into the future. Four key growth areas have been identified that have potential areas of collaboration and synergy with Green Chemistry efforts: life sciences, advanced manufacturing, alternative energy, and homeland security. Possible areas of collaboration are:
 - ❑ Criteria are added to the selection of 21st Century Jobs Fund grantees that would give priority to Green Chemistry innovation.
 - ❑ The 21st Century Jobs Fund Incentive packages are used as models to attract businesses for Green Chemistry research, development and application.
- ❑ The New Economy Initiative for Southeast Michigan which has recently been established by 10 foundations contributing \$1 million each. Grants will be given to support the efforts of nonprofit organizations and governing agencies to transform the economy of southeast Michigan and return prosperity to the region.
www.neweconomyinitiative.org/index.php?option=com_content&task=view&id=18&Itemid=32
- ❑ The capital resources of companies who have left the state could be Green Chemistry resources. Prime examples are Pfizer's facilities in Holland and Ann Arbor. One of Michigan's state universities has opportunities to utilize the Holland facility and Spark of Ann Arbor (an agency that seeks to advance the economic development of innovation-based businesses in the Ann Arbor area) is facilitating the utilization of the Ann Arbor facility. Collaboration with facilitators of these facilities could provide capital resource opportunities for Green Chemistry innovation research and technology.
- ❑ State and private universities that may be willing to provide capital, in-kind or matching grant support for implementation of aspects of the Michigan Green Chemistry Program. For example, there are numerous sustainability centers, some of which are endowed, at universities in the state.
- ❑ Michigan's renaissance zones, economic development zones, administered by the Michigan Economic Development Corporation, could provide tax incentives for companies locating within their borders. Such benefits could be used to establish Green Chemistry "eco-industrial parks" co-located with educational institutions such as community colleges.

As a first step, the Michigan Green Chemistry Program could commission a study on the economic development opportunities in Green Chemistry and bio-based materials and fuels, demonstrating economic growth potential and funding sources. It could outline a menu of possible incentives to advance Green Chemistry research, development, and adoption in the state. Such incentives could include tax incentives, access to low income loans or low cost space, preferential purchasing treatment, support in securing venture capital funds, supporting legislation, etc. Such incentives packages are already being developed in the renewable energy field.

APPENDIX C

Green Chemistry Education Strategies

There are several potential strategies for advancing Green Chemistry in education that can be implemented at each level of education including:

K-12

A new generation of leaders in Green Chemistry is essential to ensuring the long-term adoption and transition to safer chemistry. As such, educational efforts must begin with changes within existing curricula for K-12. Links can be made between chemistry and environmental science (including toxicity and human health). It is important for children to start to understand the benefits and potential health effects of chemistry and that chemistry must be considered in the context of health and environment. There is a need for modification of curricula and laboratories that can help educate students on the benefits of chemistry and the design of benign molecules.

- ❑ Some of this work has begun through the Green Chemistry Education Database. <http://greenchem.uoregon.edu/gems.html>.
- ❑ Curriculum and education resources for middle school and high school have been developed by Beyond Benign www.beyondbenign.org/.
- ❑ *Green Chemistry Options for the State of California's* May 2008 report indicates in Options One and Two the development of a program to train K-12 science education teachers in the concepts of Green Chemistry; and the expansion of California's science education materials programs to include training and laboratory materials for conveying concepts in Green Chemistry to K-12 classrooms suited to each grade level. www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/SAP_Report.pdf (pages 15 and 16).

Universities

As faculty in many universities and community colleges have expressed an interest in Green Chemistry, a first step towards building Green Chemistry into university education could be a meeting of major universities and community colleges to ask for their involvement in the Green Chemistry action plan. Faculty could also be engaged in discussing opportunities for building long-term Green Chemistry education program that benefits all institutions and reduces the funding competition between them. Projects that can be implemented within universities using a combination of private and public funds include:

- ❑ Granting one year Green Chemistry assistantships/fellowships to undergraduate students. The students would work within a company on a Green Chemistry application that will directly benefit Michigan. This creates a triple win: student, university, and company.
- ❑ Funding sabbatical semesters for faculty at Universities with established Green Chemistry programs e.g., Carnegie Mellon or University of Oregon.
- ❑ Fund faculty community colleges and universities to attend Green Chemistry trainings/conferences.
- ❑ Providing scholarships for students in Green Chemistry who can make a strong case for its application.
- ❑ As companies like to hire those who have been interns and have a track record with the company, developing strong university/industry links to ensure future employment opportunities for Green Chemistry students. Green Chemistry programs might grow if students know there are jobs available upon graduation.

- ❑ Creating two year programs for lab technicians, plant operators, managers etc., so companies can hire them and allow them to do further study in Green Chemistry.

Resources currently available for Green Chemistry development in universities include:

- ❑ Beyond Benign www.beyondbenign.org is able to interface with undergraduate, graduate and post-secondary institutions to encourage the implementation of Green Chemistry curriculum materials and to develop materials where needed.
- ❑ Green Chemistry Education Networks: The Green Chemistry Education Network (GCEdNet) www.gcednet.org; and The New England Association of Chemistry Teachers (NEACT) www.neact.org. Details for these two networks are in Appendix D.
- ❑ Green Chemistry in Education Workshops (GCEW) as modeled by the University of Oregon's Department of Chemistry <http://chemistry.gsu.edu/CWCS/green.php>. Details for these workshops can be found in Appendix D.
- ❑ *Green Chemistry Options for the State of California's* May 2008 report indicates in Options Three, Four, Five, Six, Seven and Eight the development of Green Chemistry interdisciplinary education courses into the general education curriculum for undergraduates in California colleges and universities; integration of Green Chemistry into higher education chemistry and chemical engineering curricula (at undergraduate and graduate levels); development of fellowships, and graduate and undergraduate internships in Green Chemistry; promotion of Green Chemistry in business school education; support of new faculty positions in Green Chemistry; and the introduction of Green Chemistry into vocational and workforce development training programs.
www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/SAP_Report.pdf (pages 17 - 21).

Industry

There are several important directions in Green Chemistry education that should be undertaken to ensure knowledge is developed and applied. These directions should consider that the most important education for industry is demonstration and application.

- ❑ Half day or full day symposiums demonstrating actual innovations/research could be set-up regularly to keep sectors abreast of innovations. These symposia would need to be organized in collaboration with groups conducting education within their own sectors e.g., sustainable manufacturing user groups, sustainable roundtables, trade associations, and professional associations.
- ❑ Continuing education/training courses for industry chemists/scientists could be developed to provide education on Green Chemistry research and development tools. Engaging the American Chemical Society's Green Chemistry Institute, which offers professional development for educators and scientists, is critical. Beyond Benign is also able to provide educational materials and workshops to industries seeking to train their workforce in Green Chemistry practices.
- ❑ A toolkit to support the transition to Green Chemistry and the design of safer processes and products should be developed. Such a toolkit, developed through partnership with the DEQ, academic institutions, and public interest groups, would include tools for product and chemical design as well as chemical assessment. Manufacturers, formulators and end-users of chemicals need established criteria and tools to assess/evaluate whether a chemical or product is "greener", "safer" etc. Good tools and objective criteria will form the foundation of a credible Green Chemistry Program.
- ❑ Industry sector and supply dialogs on Green Chemistry and safer alternatives could be initiated in conjunction with the Green Chemistry Program to stimulate information and technology, and experience sharing in particular sectors. For example, as a result of

requirements under the European Union's Restrictions on Hazardous Substances Directive, the Massachusetts Toxics Use Reduction Institute has established a wire and cable dialog to explore alternatives to lead, some flame retardants, and other chemicals of concern.

- The Michigan Green Chemistry Program could work with industry and academic stakeholders to host seminars for business leaders that include information on Green Chemistry as DEQ has done in the past.

Public

Educating the public would begin with the Michigan Green Chemistry identity, which would provide information on the benefits Green Chemistry provides. Specific suggestions to further educate the public include:

- Seminars and/or seminar series within universities or Museums of Science called "Green Chemistry Saturdays". Students of Green Chemistry within universities could be required to teach the public at conferences or Green Chemistry days with hands on activities.
- The Michigan Green Chemistry Program could work with community partners to develop trainings for advocates, communities and workers on Green Chemistry and tools for its application in practice.
- The Detroit Science Center (or other science museums in the state) could house an interactive Green Chemistry display.
- Existing environmental festivals, such as Earth Day fairs could be utilized to provide education on Green Chemistry.
- DEQ or other stakeholders could write op-eds or news articles in state newspapers or other media on Green Chemistry successes in the state.
- Beyond Benign www.beyondbenign.org/about/about.html could partner with local community groups to create educational materials through a variety of media.

APPENDIX D

Green Chemistry Directions and Opportunities within Education

There are a number of directions that could help establish Green Chemistry education networks and opportunities including:

- Green Chemistry Education Networks. As soon as possible, Michigan should establish a Green Chemistry education network to link teachers at different levels to share curriculum, training tools, and strategies. Two models for such a network are:
 - The Green Chemistry Education Network (GCEdNet) www.gcednet.org facilitated by the University of Oregon's Department of Chemistry. The GCEdNet have offered to help set up a node of the network in Michigan. A Google map of individuals interested in Green Chemistry <http://greenchem.uoregon.edu/Pages/MapDisplay.php> has been produced which could form the basis of a Michigan Green Chemistry Education Network.
 - The New England Association of Chemistry Teachers (NEACT) <http://www.neact.org/>.
- Green Chemistry in Education Workshops (GCEW). Michigan should establish summer training programs in Green Chemistry education. A goal of such trainings and any educational activity is to "train the trainer" so that impacts can be multiplied. As a model, the University of Oregon's Department of Chemistry holds Green Chemistry in Education Workshops (GCEW) <http://chemistry.gsu.edu/CWCS/green.php> over the summer for faculty. These enabling workshops train chemical educators who can implement Green Chemistry in the classroom. This has helped to produce educational materials that can be incorporated

into a Green Chemistry curriculum. This is known as the Green Chemistry Education Database <http://greenchem.uoregon.edu/gems.html>.

- ❑ Engage Beyond Benign, a nonprofit focused on creating a workforce and public that is well educated in Green Chemistry in order to create safer materials for a thriving society. Its focus is the dissemination of Green Chemistry information to academia, industry, non-governmental organizations, and the community www.beyondbenign.org.
- ❑ Engage the American Chemical Society's Green Chemistry Institute which offers professional development for educators and industry scientists.
- ❑ Engage academic institutions in Michigan that have strong Green Chemistry/Engineering, and sustainability programs.
- ❑ Engage leaders in community colleges to develop Green Chemistry training programs for students and professionals in the field.

APPENDIX E

Building on Michigan's Existing Capacity to Advance Long-Term Directions

Existing capacity within Michigan that could be utilized to ensure long-term viability of the Michigan Green Chemistry Program includes:

Michigan Green Chemistry Program Capacity Building

Michigan has an active pollution prevention outreach program in its Department of Environmental Quality. The resources and contacts established for this effort should be applied to advance Green Chemistry in Michigan. Further, Michigan should take leadership in Green Chemistry Promotion by incorporating Green Chemistry criteria into state procurement processes. There are numerous options for The Michigan Green Chemistry Program to build capacity and where resources are available, state government should be included in these:

- ❑ Build on the resource database and clearinghouse from Phase One, and add additional functions that would provide a mechanism for exchanging Green Chemistry challenges, resources, conferences, news, and other information specific to Michigan. This could include a blog, which would provide information and gather input from a wider audience. Through this clearinghouse for example, a forum could be established for manufactures to share information on Green Chemistry/substitution needs for particular chemicals or processes – in essence a problem solving forum. These functions could eventually be transferred to a Green Chemistry Innovation Center (see Phase Three).
- ❑ Building on the clearinghouse functions above, initiate industry sector and supply dialogs on Green Chemistry and safer alternatives, as noted in Appendix D. to stimulate information and technology, and experience sharing in particular sectors.
- ❑ Establish a demonstration sites program to highlight promising new Green Chemistry technologies with the potential for broad application.
- ❑ Develop fact sheets on Green Chemistry success stories as well as on substances of concern and Green Chemistry alternatives.
- ❑ Train state technical assistance professionals (manufacturing extension, pollution prevention technical support) in promising Green Chemistry/biomaterial innovations to diffuse to businesses.
- ❑ Consider including Green Chemistry innovations as part of Supplemental Environmental Projects (in response to violations) to encourage/fund education or implement Green Chemistry projects.
- ❑ Develop a Green Chemistry and bio-based materials and fuels procurement program to ensure these are prioritized in state purchasing.

Professional and Business Organization Capacity Building

Numerous active professional and business organizations exist both within and outside of Michigan with collaborative opportunities for the Michigan Green Chemistry Program. These organizations should be engaged in promoting the program; engaging in research and outreach (for example training of professional chemists on Green Chemistry tools); undertaking supply chain discussions on Green Chemistry application in conjunction with government authorities; hosting member conferences on Green Chemistry; etc. Some examples of these professional and business organizations include:

- ❑ The American Chemical Society's Green Chemistry Institute (GCI). The GCI and other international networks of Green Chemistry scientists, practitioners, and educators have expertise in grants, awards, industrial innovation, education, conferences, public resources, and most of the activities covered in this plan.
- ❑ The Responsible Care program implemented by chemical companies who are members of the American Chemistry Council spells out clear goals and objectives for success in very specific program areas.
- ❑ The four Sustainability Roundtables in the state, the most active of which is in West Michigan. These were founded by the Sustainable Research Group.
- ❑ Sustainable Manufacturing User groups, founded by the Sustainable Research Group.
- ❑ The Suppliers Partnership for the Environment, an innovative partnership between automobile original equipment manufacturers and their suppliers and the Environmental Protection Agency (EPA) www.supplierspartnership.org.
- ❑ The Green Suppliers Network, facilitated by the USEPA, with technical support from the Sustainable Research Group in West Michigan.
- ❑ The Michigan Manufacturing Association.
- ❑ Michigan American Chemical Society chapters.
- ❑ Regional Economic Development Councils.
- ❑ Manufacturing Extension Partnerships.