The Green Chemistry Landscape in Minneapolis Saint Paul

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for the BlueGreen Alliance
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BLUEGREEN ALLIANCE

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Background

How big is the chemicals industry?

Global chemical production, particularly of commodity chemicals, is a mature industry. In 1930 1 million tons of chemicals were produced worldwide, in 2005, 400 million tons were produced[1]. Chemical production is the thirteenth largest industry in the world. The United States alon produces or imports over 42 billion pounds of chemicals daily[2]. Over 100,000 different chemicals are produced each year, and over 3000 high volume chemicals, those on a magnitude of over 1 million pounds per year, are produced or imported for use in the United States each year[3]. In 2001, global trade was valued at $1.6 trillion, and the chemistry industry continues to expand at a rate of 3-5percent[4] per year, doubling every 25 years[5]. In the United States the chemistry industry accounts for one to two percent of GDP and employs approximately one million people.[6]

At the same time, there is a reduction in key areas of green chemistry, namely the pesticides industry, due to advances in biotechnology. Citigroup estimates a $2 billion reduction in pesticide demand since 1995.[7]

What is the opportunity for greener chemistry?

There are many opportunities to increase green chemical production and use. Chemistry permeates our lives, whether we think about it or not. From the cleaning products we use to the drugs we take, from our hand lotion to our choice of outdoor furniture, our pool cleaners, the fuel we use and the way we build and remodel our homes, chemistry plays a huge role. Chemicals are used throughout industry, beyond the manufacture of chemical products themselves; chemistry plays a role in all manufacturing through the use of solvents, adhesives, fuels, coatings, dyes and cleaners. In building and maintaining our schools and hospitals, in the buildings where we work and play, in our homes and in the care of our bodies, chemistry plays a major role. Though we may not be aware of it, greener options exist for many of the products we use every day.

The ecological and health impacts of the chemistry industry are significant. From the 77,000 existing hazardous waste sites expected to grow at a rate of 600 per year[8], to the bioaccumulation of chemicals such as dioxin, PFOS and other endocrine disruptors. There is a need for clean, green chemistry.

While opportunities exist across all products and processes, the main *product areas* where green chemistry has been growing most rapidly are:

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[1] Innovest Chemicals Industry Overview, March 2007.
[2] California brief
[3] EPA High Volume Chemicals paper
[4] In "The State of Green Business 2009: Greener Design Comes Out of the Lab," Joel Makeover states a rate of 3percent (February 9, 2009 GreenBiz.com); The Metabolix website quotes a rate of 4-5percent; Frank Ackerman sites figures from 2001 on the global value of chemistry in his paper for Health and Environment Funders Network, " Green Chemistry: Strategic Opportunities" (November 2007).
[5] Wilson, et. al, 2006.
[6] Ackerman, 2007. Original source: Marianne Lines, “Addressing Sustainability in the Chemical Industry,” in Transforming Sustainability Strategy into Action, (eds.) Beth Beloff, Marianne Lines, and Dicksen Tanzil, Wiley 2005
[7] Parzen, 2007; Innovest, 2007.
[8] Wilson, et. al. 2006.

- Industrial and residential cleaning products
- Personal and home care products
- Paints, finishes and adhesives
- Plastics
- Fuels and solvents

Additionally, across all chemical (and non-chemical) processes, there is a growing demand within chemicals manufacturing to:

- Reduce wastes
- Replace non-renewable feedstocks with renewable, bio-based materials
- Reduce use of hazardous or toxic materials in production as well as reduce toxicity of the final product.

The Green Chemistry Market

The field of green chemistry is expanding. In the past few years there have been advances in around the use of renewable feed stocks. Leaders from academia, industry, government and the non-profit sector are now coming together in innovative ways to advance the next generation chemicals industry[9].

As publicity grows about the impact of chemicals on our health and the environment, consumers are looking for greener products for their homes and personal use. The explosive growth of the green building products industry shows that new markets can be defined based on environmental and ecological ideals[10].

Greener options exist for many chemicals, and both the expertise and the variety of green chemicals are expanding rapidly. More and more, consumers have the opportunity to make better choices for themselves and the environment, and a growing number of people are doing this, despite the economic downturn.[11] As an example, greener chemical options exist in many areas, including:

- Plastics manufacturing - ultimately our cars, toys, clothing, furnishings
- Cleaning products, both commercial and residential
- Lawncare, fertilizers and pesticides
- Swimming pools
- Fuels including biofuels
- Healthcare products and pharmaceuticals
- Personal care products including health and beauty
- Paints, adhesives and building products

Driven by pure scientific innovation, a response to the growing public awareness, and a desire to improve the triple bottom line, many of these areas are experiencing rapid market expansion and advances in technology. Large amounts of venture capital, foundation and government funds have recently become available for expansion and commercialization of some of these cutting edge technologies, particularly renewable materials. Minneapolis Saint Paul metro area based renewable materials companies alone have recently secured over $60 million in private funding for technology expansion and commercialization.[12]

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[9] Julia Parzen. Integrating Green Chemistry and Safer Materials into Regional Economics and Workforce Development Strategies. For the Health and Environmental Funders Network. August, 2007; David Wallinga, personal conversation, April 2009

[10] Ackerman, 2007

[11] EnviroMedia report for GreenSeal on consumer choices.

[12] Tom Webb, "What's Developing: Bioscience Players in Minnesota," 3/27/2009.

Green chemistry makes good business sense. Major U.S. companies like S.C. Johnson and 3M have been improving their bottom line by greening their production for years.[13] Green chemistry makes sense for business for a wide variety of reasons including cost savings through waste reduction, response to the customer's demands for healthier products and reducing future liability by engaging a precautionary approach to chemicals use.

Prevent wastes
Renewable materials
Omit derivatization steps
Degradable chemical products
Use safe synthetic methods
Catalytic reagents
Temperature, pressure ambient
In-process monitoring
Very few auxiliary substances
E-factor, maximize feed in product
Low toxicity of chemical products
Yes, it is safe.

Figure 1: The twelve principles of green chemistry

But What Is Green Chemistry?

Green chemistry is an emerging field. In part due to the growing number of concerns about toxics in consumer products[14], desire to reduce energy consumption and greenhouse gases and impending resource shortages, green chemistry seeks to find new solutions that reduce waste, eliminate toxic chemicals, use renewable feed stocks, and improve energy efficiency in chemical production.

Definitions of green chemistry are fairly consistent across industry, academia and the public sector. The United States Environmental Protection Agency and the Europe-based Organization for Economic Cooperation and Development (OECD) definitions are nearly the same. For the purposes of this report I will use the OECD definition:

> *The OECD defines green chemistry as: "the design, manufacture, and use of environmentally benign chemical products and processes that prevent pollution, produce less hazardous waste and reduce environmental and human health risks."*[15]

Green chemistry is still an emerging field. Despite the clarity of the OECD's definition, green chemistry is a broad concept that has implications across almost every area of life.

12 Principles of Green Chemistry

Developed by Paul Anastas and John Wagner in 1998, these twelve principles form the base of much of the green chemicals thinking (see Figure 1 for a simplified version[16], the complete version is in Appendix A). While it is often impractical to achieve all of these goals at once, these principles lead to safer manufacturing practices, products that have minimal harmful effects on people or the environment, reduced waste, less pollution, decreased reliance on oil and other non-renewable feed stocks and reduced carbon emissions.

The E-factor measures the ratio of the mass of waste produced versus the mass of the product. A low e-factor indicates efficient production and minimized waste. Use of catalytic reagents also minimizes waste as they can be re-used multiple times. Auxiliary substances refers to things like solvents and reagents, chemicals that are not part of the chemical reaction. Minimizing these also minimizes waste.

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[13] Joel Makeover, 2009; Tom DePasqualie (3M), personal conversation, May 2009.
[14] Joel Makeover, 2009.
[15] Ackerman, 2007.
[16] Figure taken from S.L.Y Tang, R.L. Smith and M. Poliakoff. Green Chem. y, 761-762; 2005; Source: Poliakoff & Licence, ibid.

Precautionary Principle

The precautionary principle as applied to chemical manufacturing puts the burden of proof that a chemical is harmless on the side of the producer, versus the current regulatory approach that puts the burden of proof that a chemical is harmful on the public. This is the underlying principle of the European Union's REACH approach to chemicals regulation:

> *"The aim of REACH is to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances."*[17]

It is also the principle behind the Life Cycle Analysis and Total Impact approaches that many area manufacturers use.

Continuous Improvement

Green chemistry is not about declaring an end product that is "green" (though there certainly are some), but generally refers to designing processes that are continually improving the performance of chemicals, reducing waste, and that ask important questions at every stage of manufacturing and use about the impact of products and the manufacturing process on human health.

Green chemistry is complex; it is not black and white but rather exists on a continuum. Many industry leaders consider green chemistry a process of continuous improvement rather than a series of identified green products[18]. Because total impact must be considered from resource extraction to disposal, there are few chemical products that are easily defined as green. Lack of information, lack of alternatives and complex decisions about tradeoffs plague this industry. The complexity of decisions regarding whether a product or company is green opens the door for spurious claims by product manufacturers and increases the challenge in educating consumers.

Measuring Green Chemistry

As with any industry within the emerging green economy, the employment and firm data available from the Bureau of Labor Statistics is of little use in measuring green chemistry. There are no distinctions between green and traditional jobs within the NAICS classification system and, of all the "green" sectors, green chemistry seems the hardest to separate and quantify. Chemical production is complex and chemistry permeates the production and maintenance of nearly everything we use. While there are some products that can be certified as green, and undoubtedly, there are some jobs that are directly related to these products, it is very difficult, if not impossible, to measure the employment and economic contribution of green chemistry in isolation. The majority of the positive impact of using the principles of green chemistry is imbedded in the use and production of chemicals across a wide range of industries, most of which are not considered to be "green." The economic impact is in the cost savings captured in waste reduction, reduction in workplace injuries and improved worker health and productivity.

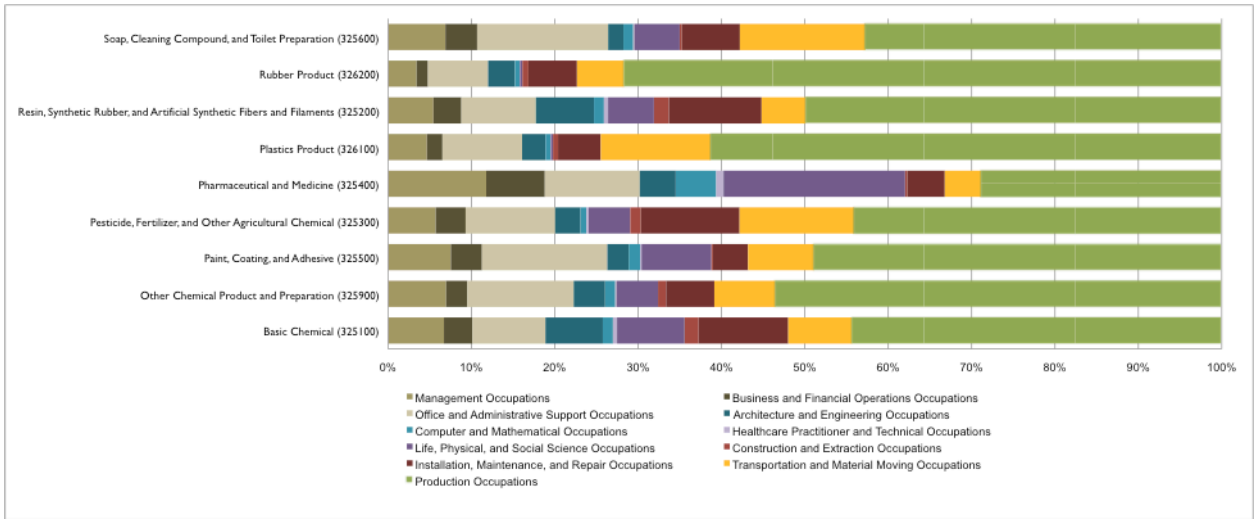
Chemical production requires similar skills whether green or not. Since green chemistry is emerging, a majority of the technology specific jobs are in research and development occupations[19].

Across chemicals manufacturing just over half of the workforce is in production occupations, with the greatest opportunities for production jobs in rubber products manufacturing (71.7

[17] REACH website: http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm
[18] David Wallinga, personal conversation; Lynne Olson, personal conversation; Pam Helms, personal conversation
[19] Mitchell, et. al., Green Cities, Green Jobs, 2008

percent of the workforce) and plastic products manufacturing (61.3 percent of the workforce). Lower percentages of manufacturing employment in well established industries such as basic chemicals (44.3percent), pharmaceuticals (28.8percent), agricultural chemicals (44.1percent) and soap, cleaning compound and toilet preparation products (42.7percent) could reflect a growing global trend to locate manufacturing facilities in developing countries where production costs are lower, and less transportation is required between raw materials, manufacturing and markets. (See Figure 2, data source: Bureau of Labor Statistics, 2007, larger version in Appendix C)

Figure 2



While there are no tools to accurately measure employment in the green sector, there are some tools that can determine the economic and environmental impact of a particular production process, though usually not on a local or very specific level. The Environmental Input-Output Life Cycle Assessment provides national level data on the economic and environmental impact of a particular process. For assessment at other scales, the Environmental Protection Agency's Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) could be useful, however, it has a limited number of preset models, and is geared toward broad scale change, such as opening or closing a plant, versus incremental change, like switching from the use of a material known to have adverse environmental and health impacts. For example, it could not assess the impact of switching from PVC to a more benign option such as non-chlorinated plastic, or switching from a process using a reagent to a catalytic process.[20]

The nature of green chemistry means that a large share of its environmental and health impacts are embedded in the production of regular (“non-green" products. The case of Ibuprofen is one classic example. The original patented formula involved 6 steps, and had an overall atom efficiency of only 40percent. In 1984 the process was redesigned. The new process uses catalysts, eliminates 20,000 metric tons of waste per year and reduces the need for non-renewable inputs (aluminum trichloride). Ibuprofen is now produced in just three steps, and has an over all atom efficiency of 77percent[21]. Considering the scale of production, greening the production of chemicals that are produced for a wide (non-"green") market can have a great impact.

[20] Ackerman, 2007. For a more robust explanation of the issues involved with the economic modeling available using the TRACI and EIO tools see Ackerman, 2007.
[21] Poliakoff, Martyn and Pete Licence. "Green chemistry"

While a niche green product company might be able to make a truly green product, the true challenge is waste and hazard reduction at scale. Producing high quality green products on a small scale is important but in comparison to greening the process of a major traditional company that produces a non-green formula at hundreds of times the scale, it has little overall impact. There are many large companies who have focused research and development on improving performance, reducing waste and toxicity, applying as many of the green principles as economically feasible. Many of these companies, such as 3M, Cargill and Ecolab, lead the way in research and development, As these companies strive to improve performance and reduce environmental and health impacts, they push the technology forward, creating innovations that are applicable across a wide variety of businesses.

Where Is the Market Going?

Policy Trends

One of the growing movements in green chemistry is toward more effective regulation. While products and processes are becoming more and more green for business and market reasons, the need for improved chemistry regulation is clear. In the absence of effective federal level policy, states are creating their own green chemistry policies and the European Union's REACH (**R**egistration, **E**valuation, **A**uthorization and Restriction of **Ch**emical Substances) policy is redefining high level comprehensive chemicals policies that encourage innovation and competiveness while providing greater protection for people and the environment. Current federal level regulation through the Toxic Substances and Control Act (TSCA) is widely criticized by chemists and environmental advocates.

There are over 80,000 chemicals in the U.S. Environmental Protection Agency's (EPA) chemicals database. Very little information exists about the effects and properties of the vast majority of these[22] Of the 3000 high production volume chemicals only 7 percent have a complete set of data about basic toxicity, and 43 percent have absolutely no publicly available data on possible acute and chronic health effects, reproductive effects, environmental fate, ecotoxicity ormutagenicity.[23] Approximately 1000 chemicals are added each year, and global chemical production is expected to double every 25 years, further compounding the data gap[24].

The TSCA takes a substance-by-substance approach and puts the burden of proof regarding chemical toxicity on the public rather than on industry[25]. This system requires enormous resources properly understand and monitor chemicals production. Testing the effects of chemicals is cost and resource prohibitive, it is very hard to prove negative effects of a particular chemical. Therefore, approximately 25 percent of the chemicals in the database are considered hazardous based on known properties, but in the entire history of the TSCA only 5 chemicals have been banned outright[26]. The lack of information about the effects of chemicals already in production and use make the system, and manufacturers, vulnerable to liabilities.

In 2008, California became the first state to pass a comprehensive green chemicals policy, setting up a framework for dealing with "chemicals of concern"; in 2006, Michigan's Governor Granholm signed Executive Directive No. 2006-6 for the Promotion of Green Chemistry for Sustainable Economic Development and Protection of Public Health. The Michigan Directive

[22] EPA, Chemical Hazard Data Availability Study, 1998; Parzen, 2007
[23] According to the EPA study, a high volume chemical is produced or imported in the United States at more than 1,000,000 pounds per year.
[24] Green Chemistry: Cornerstone to a Sustainable California, brief prepared for the Green Chemistry Initiative, 2008.
[25] Catherine Zimmer, personal conversation, March 2009
[26] Catherine Zimmer, personal conversation, March 2009

and the California Green Chemistry Initiative are considered models for how states can lead the way toward comprehensive chemicals regulation.

On a global level, the European Union's REACH directive has facilitated a major shift in chemicals production for the European market. The new policy requires extensive testing of the approximately 30,000 chemicals sold in quantities greater than 1 ton per year in the EU[27]. Critics of the REACH policy state the expense of this testing, several billion dollars, and compliance requirements could negatively affect the profitability of chemicals producers. The REACH legislation will save local governments more than the cost of testing by reducing the need for wastewater treatment alone, and the reduction in cancers and other illnesses saves the healthcare industry in both the short and long term. Initial fears that this policy would put a halt to innovation have been unfounded. The REACH legislation is targeted at large scale, legacy producers of potentially hazardous chemicals; it lowers regulation on low-volume chemical production, opening up the field for innovation by smaller companies.[28]

There is a high level of interest locally in changing chemicals regulation. Currently the Healthy Legacy Campaign seeks to ban the use of a number of known toxic substances, such as bisphenol-A (BPA)[29]. This proposed legislation, and bills of this kind, are stop gap measures to further regulate these hazardous substances until more comprehensive chemicals policy can be passed in the state.

In Minnesota, leaders across industry, academia and advocacy have started convening around the idea of a comprehensive chemicals policy for the state. Steve Kelley at the University of Minnesota's Center for Science, Technology and Public Policy has been the host and facilitator of these conversations, providing a forum for idea exchange and exploration of a wide range of topics in green chemistry. Many key people across academia and industry support a green chemicals policy for Minnesota similar to those in Michigan and California.

Industry Trends

Businesses across the spectrum are engaging the principles of green chemistry because they make good sense. The first step toward green chemistry is the use of biomass as a renewable source of carbon. Renewable materials such as non-food crops and waste materials from bio refining show great promise. The second major trend is in waste reduction, which takes on many forms including use of catalytic agents to reduce byproducts and inputs in chemical production, to creating concentrated and dry chemical products that reduce packaging waste. The last major trend is probably the most contentious and involves reducing the toxicity of chemical products and processes. Industry efforts are currently focused on three general realms of green chemistry:

- Reducing waste and improving process efficiency
- Reducing toxicity and pollution prevention
- Switching to renewable, bio based carbon sources

Many chemical manufacturers use the principles of green chemistry because they positively affect their bottom line. Designing and engineering chemical processes using these principles reduces energy consumption, decreases the amount of waste firms have to dispose of, can

[27] Ackerman, 2007
[28] Ackerman, 2007
[29] A recent study by the University of Rochester showed that 93percent of Americans tested had detectable levels of BPA, a bioaccumulative compound that has been linked to cancer. BPA is banned in Canada and across Europe, and 14 states are considering legislation to ban products with BPA (from: Susanne Rust. "Study: Chemical used to make plastic lingers in body" Milwaukee Journal Sentinal, printed in the Pioneer Press on 1/28/2009).

reduce the amount of inputs required, and overall improve production efficiency[30]. In many cases firms find that switching to green chemistry is good business[31].

Waste Reduction & Process Efficiency

Waste reduction refers to a wide range of green strategies, from waste reduction in chemical formulation and production by using continuous processes and maximizing atom efficiency, to reduction in packaging and distribution. Waste reduction greatly impacts the profitability of a product and many companies pursue waste reduction strategies because it is good business, the environmental benefit is sometimes a secondary consideration.

There are many inspiring examples of waste reduction strategies within industry. Three distinct examples show the range of solutions available when new thinking is applied to existing issues. Ecolab's mid 1980s switch to solid products which reduced packaging, transportation costs, and storage space, thereby reducing carbon emissions and energy use. The reformulation of Ibuprofen after the patent expired in 1984 eliminated 20,000 tonnes of waste per year, and an innovative business arrangement between Dupont and Ford Motors Canada dramatically reduced the product needed and waste created in painting cars.

> *Reducing the amount of inputs into a reaction whenever possible will reduce the amount of product and waste. This simple technique for waste prevention may seem at odds with the goals of industry - whose profits are generally based on quantity of product produced and sold - yet it has already been employed in certain cases. One interesting case involves DuPont and Ford. Rather than buying actual paint for its cars, Ford has contracted with DuPont for a car painting service. So instead of getting paid more to produce more paint, DuPont is gets paid more to produce more painted cars. In this arrangement, DuPont can save money by reducing – not increasing – the amount of paint it makes and uses! Scale reduction is especially well suited to University teaching laboratories, where the technique and experience gained is paramount, and obtaining large quantities of product is insignificant.*[32]

Waste reduction can also refer to using formulations that create the most effective product possible so as to minimize the amount of inputs needed and reduce the by-products of manufacturing, as well as reduce the total amount of product needed to achieve the desired result. For example, a dilute material that has good biodegradability but requires twice as much product as a more concentrated material may not be the best environmental choice. Less effective but "green" products, while they claim to be biodegradable or natural, are not necessarily the best choice when the total impact is considered.

Reducing Hazardous Materials

While it is high on the agenda of many companies, reducing hazardous materials can be difficult, primarily because so little is known about the vast majority of chemicals. Companies like 3M cannot get information from upstream suppliers.

Replacement of Petrochemicals / Use of Renewable Feed Stocks

The need for renewable feedstocks is clear. Replacing the petrochemical supply chain is a key concern of the chemical industry. Instability in the price and supply of oil, gas and coal are driving chemicals companies to find alternate sources for the carbon needed for today's

[30] Martyn Poliakoff and Pete Licence. Green Chemistry. Nature. Vol 450: December 6, 2007

[31] Joel Makeover. Green Design Comes Out of the Lab. GreenBiz.com, January 2009; Interview with Aveda CEO, Dominique Conseil, for GreenBiz.com, May 12, 2009, http://www.greenbiz.com/podcast/2009/05/12/aveda-paradigm-shift-cosmetics

[32] Marc Steyer, MIT student paper, from an unknown source; Lynne Olson, Ecolab, personal conversation, May 2009.

chemistry industry[33]. The vast majority of the chemicals sold today are carbon-based. The industry relies on limited resources of oil, coal and natural gas for the supply of carbon necessary to meet the demands of the market[34]. Over 90percent of the chemicals used today rely on non-renewable petrochemical feedstocks. Though renewable feedstocks have become a primary focus of the market there remain many challenges about their broad scale use, not least of which is competition with the global food supply. In addition to the market the political pressure developing in this area is growing, as oil resources become more scarce and the cost of oil increases.

The Sustainable Biomaterials Collaborative advocates for the sustainable production of biomaterials, including use of sustainable farming techniques, elimination of GMO crops in the production of polymers, use of organic feedstocks, use of non-food crops, and better restrictions on the land that is used.

Extracting carbon from biomass is one of the many challenges in this realm, as bio materials have a different composition than oil (more oxygen) and require new reactions[35].

Consumer Trends

The consumer market for green chemistry is growing. A recent study by Clorox found that a majority of consumers are planning to buy eco-friendly products and many of these consumers will pay a premium of up to 25percent for a more benign product. [36] While only 2percent of people think using green personal care products will most benefit the environment, 31percent of people surveyed did use green personal care products. The numbers are even higher for green cleaning products where only 4percent of people think switching to green cleaning products will have a significant effect on the environment, but 58percent of those surveyed purchased green cleaning products[37].

Through media coverage of issues such as lead found in children's toys, the effects of bioaccumulative chemicals such as PFOS and dioxin, the concern over air quality and VOCs and the link between chemicals and cancer, there is a growing awareness about the toxic impact of substances we use on a daily basis. Driven by this new awareness and an overall desire to "go green" many people are choosing greener products. Considering that chemistry is all-pervasive, affecting almost all areas of our lives, there are many opportunities for green chemistry products for the consumer market. Primary areas of opportunity for this market are:

- home cleaning and personal care products
- building materials
- plastics.

Industrial and commercial consumers have the power to affect significant change. Market-driven efforts by major commercial consumers include:

- Healthcare Industry: from cleaning to medical plastics to pharmaceuticals, the industry is one of the largest chemicals consumers;
- Building products: producing low waste, low VOC paints and adhesives that meet LEED standards;

[33] Tom Webb, "Starter Culture" Pioneer Press, 3/27/3009; Steve Davies, NatureWorks, personal conversation April 2009.
[34] Ackerman, 2007; Poliakoff and Licence, 2007.
[35] Nature article
[36] Elevance website: www.elevance.com; NY Times article, "Can Burt's Bees Turn Clorox Green?"
[37] EnviroMedia study for Green Seal

- Janitorial Industry: cleaning our schools, offices and the places we play, this industry is impacted primarily through Environmentally Preferable Purchasing programs especially educational initiatives like Green Schools;
- Hospitality industry: driven by environmentally savvy marketing and a desire to reduce costs, waste reduction, toxics elimination and improved performance are key for this experience based industry;
- Product manufacturing: from cars to medical devices manufacturers are looking to reduce waste and impact through non-toxic and environmentally benign solutions.

Barriers to Growth Led By Consumers:

The primary barrier to consumer-led growth in green chemistry is lack of information. Recent studies show that consumers are optimistic about green efforts, such as recycling, but have little or no clear information about the products they use on a regular basis[38]. For example, 72 percent of Americans do not know that most plastic is made out of oil, 40 percent think plastics will biodegrade (in home composters, marine environments, underground and in landfills), and those surveyed believe that 38 percent of plastic is recycled in the U.S., when in reality, according to the E.P.A., it is only six percent.[39]

The lack of available information affects industrial consumers as well. One of the greatest gaps in the chemicals industry is knowledge about the specific effects of the vast majority of chemicals in use today[40]. Without complete knowledge of the chemical inputs they are using, it is impossible to do true life cycle or total impact assessment.

For the consumer this lack of information leads to a level of distrust, not knowing how to distinguish between "greenwashing" and what is a valid green claim. Many companies are actively providing information on green chemistry to their consumers. Seventh Generation has an online, searchable database of typical ingredients in cleaning and personal care products including both "traditional" toxic chemicals and natural ingredients. Method is a founding partner in the B-Corporation initiative, which is a new sustainable business certification standard. While B-Corporation labeling is not limited to green chemistry, another key company in the green chemistry industry, Green Harvest Technologies, is also a founding partner. But approximately 33 percent of consumers don't know how to verify these green claims. While some companies, like 3M, are very careful about product claims regarding environmental impact[41], others create their own green labels and make broad and general claims, which often further confuse consumers[42].

In the area of green chemistry, people are making choices to consume green products even though they don't necessarily think it will have a large impact on the environment[43]. A recent study by EnviroMedia for Green Seal, shows that despite the economic slowdown, people are still making the choice to buy green chemistry products (cleaners and personal care products). This reflects both the change in perception that green means more expensive, and a balancing by consumers of a small price increase against choices that support personal and environmental health.

[38] Studies by EnviroMedia for GreenSeal, by Clorox; and, by InsightExpress for Metabolix
[39] InsightExpress for Metabolix
[40] US EPA report on lack of information about high production volume chemicals
[41] Tom DePasquale, personal conversation
[42] Pam Helms, Caldrea
[43] The GreenSeal study was directed specifically at environmental impact, it didn't ask about impact of going green on personal health - people could be making choices to use green chemistry out of both their environmental commitment and a desire for a healthy life.

Green Chemistry Certification Is Needed

Eco-labelling.org asks the question, "who's deciding what's green?" on their website dedicated to discussing issues around ecolabelling. Their global ecolabels database currently has 298 different labels each with different standards and levels of verification and certification. Given this sea of information it is no wonder consumers are confused.

In the consumer related industries, the major barrier to growth is consumer education and lack of one consistent certification system. There are dozens of certification and eco-labeling systems, some specific to an industry, some specific to particular types of products. Each labeling system presents difficulties for both producers and consumers. Overall there is a lack of clarity around product labeling and issues in green chemistry are too complex for simple checklists. For example, cleaning products companies must balance effectiveness of the product (minimizing waste in production and use) with cost and use of less preferable materials

Consumers often base purchasing on brand reputation, but also rely on eco-labeling and personal research on what is green[44]. While a savvy consumer is good, sometimes consumers make decisions based on faulty or misleading information. As one example, while Sodium Laureth Sulfate (SLS) is often cited as a chemical to be avoided by advocates for safer personal care products, sometimes the use of some SLS can make a product more effective, decreasing the need for other harmful chemicals in the end products or in the manufacturing process. The choices in green chemistry are not always clear cut.

Since the answers are unclear, third party certification could provide consumer confidence, particularly if one certification system became the established leader. Consumers need better information about the broad impact that chemicals and chemical production has on our environment and our health. While there is growing awareness that chemicals may have a health impact, there is less understanding about how switching green chemistry can have a significant positive effect on the environment and other issues of great importance for our times. For example, in many cases switching to bio-based plastics can impact our dependence on oil and carbon emissions.

What Does Green Chemistry Manufacturing Look Like in Minneapolis Saint Paul?

Industry Cluster

This is a strong industry cluster even though jobs in chemical manufacturing are underrepresented in the metro area (see Table 1). Basic chemicals manufacturing has a location quotient as low as 0.12 which means we have only 10 percent of the expected employment in this industry compared to the nation as a whole[45]. Employment data does not reflect the entire picture of the presence, importance and impact of chemicals manufacturing on the local economy. Many companies are headquartered in the metro area and maintain research and development facilities in Minneapolis Saint Paul, but manufacture products in neighboring states and other countries, closer to both the source of their feedstock and their buyers. While it doesn't make business sense for large scale manufacturing facilities to be located in the city, the presence of these large companies with research and development facilities creates an atmosphere of innovation, critical for new business creation and retention of top talent.

[44] EcoMedia for Greenseal, ibid.
[45] Generally industries with competitive advantage have a location quotient of 1.2 or higher, showing a concentration of employment greater than that required to satisfy the demands of the local market.

As of the 2002 economic census[46] there were 435 firms and just over 21,000 jobs in the chemicals manufacturing industry in metro area. Given the recent expansion of the bio-based materials industry, and growth of companies like Restore and Caldrea, the total employment is likely to be higher. When complete data is available next summer, a shift-share analysis of the chemicals industry would likely be instructive. The metro area had a slight concentration of employment in the bio polymers industry, but this industry has had significant growth since 2001.

The Minneapolis Saint Paul area is strongest in plastics manufacturing, with an LQ of 1.11 and nearly a third of all chemicals manufacturing employment in the area (14,105 employees as of the 2002 census). Growing the plastics manufacturing industry would have the greatest impact on employment and the greatest opportunity to increase manufacturing jobs, even though most of the manufacturing in plastics is done outside of the metro area.

Companies with diverse product lines, like 3M and Tennant, are not necessarily included in the chemicals manufacturing employment data, and some companies, like Caldrea, are not classified as chemicals manufacturers, though their activities and growth certainly impact the chemicals manufacturing market.

Four Areas of Leadership in the Minneapolis Saint Paul Metro Area:

The Minneapolis Saint Paul metro area benefits from a historically strong base of knowledge in chemical formulation and production. There are a number of key firms with deep roots in the metro area including Cargill, 3M, Ecolab and Aveda. Over time these firms have demanded specialized services and have created many spin-offs, growing the number of supportive and related industries in the area. These four key firms in particular are known for their strong

Table 1
Chemical manufacturing in the Minneapolis Saint Paul MSA, 2002

NAICS	Description	LQ	Firms	Employees
3251	Basic chemicals	0.12	15	345
3252	Resins, synthetic rubbers, artificial synthetic fibers and filaments	0.27	9	428
3254	Pharmaceuticals and medicines	0.37	28	1,494
3255	Paints, coatings and adhesives	0.54	21	565
3256	Soaps, cleaning compounds, and toilet preparations	0.82	51	1,484
3259	Other chemical products and preparations	1.05	40	1,778
3261	Plastics products	1.11	239	14,105
3262	Rubber products	0.29	32	854
Total			435	21,053

Source: U.S. Economic Census, 2002

research in basic sciences and development of innovative solutions. They have been a resource for chemical production locally and globally. Over time, the growth of these key companies has contributed to an ideal business environment for smaller companies and startups in the realm of green chemistry.

Green chemistry requires "innovative scientific solutions to real world problems"[47], historically an area that the metro area excels at.

[46] Data from the 2007 economic census at the MSA level is not yet available
[47] The Michigan Directive

Our main export in the field of chemicals manufacturing is knowledge. We are the headquarters and research and development home to many major chemicals manufacturers, though they choose to build their plants closer to both markets and feedstocks. As a mature economy, it may be time for Minneapolis Saint Paul to focus on the service and experience sectors in this key industry. For example, the city of Portland Oregon focuses some of their economic development effort on exporting and promoting their expertise in green building. Efforts to develop this important local cluster could focus on supporting start-up companies and growing and exporting our unique and cutting edge chemicals manufacturing knowledge.

Four major realms of green chemistry are at play in the metro area. We are strong in health and beauty products manufacturing, renewable materials development, cleaning products manufacturing and commercial coatings (paints, adhesives) manufacturing. There are also a handful of firms working within the realm of green chemistry that are not in one of these four key areas.

Industry Details

Cleaning Products, Industrial and Residential

The industrial cleaning industry contributes over $150 billion to the US economy and uses over 5 billion pounds of chemistry each year[48]. A high percentage of these chemicals are considered to be toxic, contributing to a high level of workplace injuries among janitorial staff each year.[49] Beyond worker and workplace health, cleaning products impact our waterways. Persistent detergent metabolites were found in over 69 percent of streams tested in a 2002 U.S. Geological Survey nationwide study[50]. In a state that prides itself on the beauty and cleanliness of our natural waterways, thisan issue of great importance.

The growth of Environmentally Preferable Purchasing (EPP) and green cleaning programs in local and regional government, educational institutions, hospitality, health care facilities and across private business has created demand for cleaning solutions that are benign for the environment and people. EPP policies seek to improve workplace health and reduce pollution while increasing worker productivity and overall effectiveness. Local innovation in this industry ranges from changes in product delivery and cleaning equipment, to reducing waste in manufacturing and distribution and developing formulations from bio-based materials.

With three major companies in industrial cleaning technology located in the metro area, we are leaders in innovation within this field. Ecolab, 3M and Tennant all invest heavily in product development and basic research in the industrial cleaning industry.

What makes a green cleaner? Identifying the formulation that best produces the desired effect while minimizing health and environmental impacts is one of the major challenges in the cleaning products industry. There are over 298 different eco-labels, all of which require varying levels of certification[51]. In green cleaning product formulation there has to be balance effectiveness against environmental and health concerns. Many so-called green products merely dilute the cleaning solution to achieve high biodegradability, but this leaves the product less effective, often requiring use of additional chemicals to produce the desired effect. Concentrated chemicals have a considerably lower biodegradability, but reduce waste in

[48] RPN guide to green cleaners.
[49] RPN guide to green cleaners
[50] National Geographic “Green Guide Products Report” 2006, source: RPN guide to green cleaners
[51] Eco-labelling website: http://ecolabelling.org/

production, shipping and use.[52] Very few people take into account this balance of efficiency and effectiveness in green chemistry. The total impact is important, but also harder to measure.[53]

While consumer customers may still be willing to pay a premium for greener cleaners, commercial customers will not spend more money on green products. Environmentally benign and non-toxic cleaners have become the industry norm. More and more customers are demanding green solutions. Concentrated chemistry may be part of that solution. Customers will spend more for something that works twice as well, so they can use half as much[54].

Economic development strategies in this realm should focus on consumer education and market creation through the promotion of EPP programs with strong recommendations for local product use.

Major challenges for this industry:

- Eco-labeling
- Consumer/citizen education

What is needed in Minneapolis and Saint Paul:

- Consumer education promoting EPP and the city's leadership in this area.
- Large companies, such as 3M needs help with their image, particularly in the face of recent scandals and bad publicity.

Industrial/Commercial Cleaning Products Manufacturers in Minneapolis Saint Paul:

- Ecolab
- 3M
- Tennant
- Restore Products (also produces household cleaners)
- Cool Clean Technologies
- BioForce/EnviroRite

Ecolab

Ecolab is a global leader in chemistry for the industrial cleaning industry; in particular, they lead the industry in solid chemical products development, manufacturing and distribution. Ecolab finds that in some cases they push the market, such as their move to dry products in the 1980s, while other times the market demands change. For example, recent pressure from the hospitality industry to improve green standards and performance has Ecolab searching for even more sustainable solutions and certifying products for use in EPP and green certification systems.

It made better business sense to pack, ship and store dry products versus shipping liquids, which are heavy, messy and require more storage space. This move dramatically reduced packaging; product that previously required a 60 gallon drum could be packaged in a 9 pound capsule. Shipping dry product reduces greenhouse gas emissions (more product can be shipped per truckload) and the smaller packaging requires less storage space, reducing energy consumption for warehousing and storage. Launching this innovation in the 1980s, for both environmental and business reasons, customers who were initially skeptical, now like both the convenience and savings aspects of this dry product. This is one example of where Ecolab pushed the market.

[52] Lynne Olson, Ecolab, personal conversation, May 2009
[53] Todd Lafrenz, Metro State University, personal conversation, April 2009
[54] Lynne Olson, Ecolab, personal conversation, May 2009

Customers like the dry products for their sustainability aspect, but also because it is easier to handle.

Ecolab's sustainability team considers sustainability like health; it is a process of continuous improvement. They have a multifaceted, total impact/systems approach to sustainability, considering factors such as the effectiveness and appropriateness of the chemistry used and produced, waste and energy reduction, and safety in manufacturing and in product use.

3M[55]

As a global leader in product development, 3M has adopted a full life cycle management approach to manufacturing since the 1970s. Despite recent negative publicity over PFOS, 3M has a deep commitment to the health of the environment and people. Each division has their own product steward who assesses the impact of products at each stage of development and manufacturing, from raw material extraction to disposal. Manufacturing, research and development at 3M is a process of continuous improvement where they constantly strive to find better inputs and solutions that ultimately reduce the overall environmental impact.

In an effort to consistently communicate sustainability, in1990 they put in place an environmental claims marketing policy. All products that make environmental claims have to be carefully vetted by a committee to ensure compliance. While a vast majority of 3M's products could be considered environmentally benign, having no more than minimal impact at each production stage, of the more than 60,000 products manufactured only a small portion have identified claims of sustainability. Internal efforts to identify green products started with the products where there is strong market demand for green certification: the green building industry. 3M currently does not produce specifically for the green market, rather vetted products from across the company are presented in an environmental solutions catalog.

As with other large companies, in some product lines 3M is pushing green chemistry, in others the market is requiring products with the highest environmental standards possible. In the case of janitorial products, for example, 3M has made advances in the delivery technology moving away from single-use scrubbing pads to a multi-use system that reduces waste. However, when they approached their customers about reformulating their cleaning chemistry, which is already a relatively low toxicity formulation, their customers primary concern is maintaining effectiveness.

As with other companies in this industry, the main challenge is consumer education. Customers do not fully understand life cycle management and continuous improvement. There is greater understanding of total impact in the renewable energy market, and slowly people are beginning to seek out information to weigh the costs and benefits of the products they use. Internally 3M is educating their employees on how to implement the company's sustainability principles developed in 2008 throughout their work and life in a monthly sustainability speaker series.

Tennant[56]

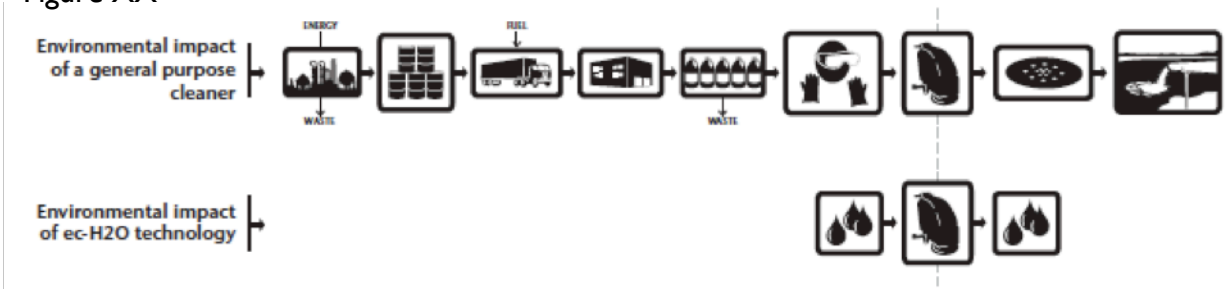
Minneapolis based Tennant Company is a world leader in developing innovative, sustainable solutions for industrial cleaning. While they do manufacture a number of

[55] Keith Miller, 3M, personal conversation, April, 2009; Linda Eichinger, 3M, personal conversation, March 2009; Tom DiPasquale, 3M, personal conversation, April 2009.
[56] Information on Tennant is from the Tennant website: http://www.tennant.com; and from press releases.

GreenSeal certified cleaners, their focus is on designing cleaning equipment to reduce or eliminate the need for chemicals altogether. They sell products in over 80 countries worldwide and have manufacturing facilities in 6 locations worldwide, including Minneapolis.

They recently won their fourth CleanNZ Innovation Award for their new chemical free ec-H2O cleaning solution (previous awards were for their FaST™, M20 technologies). In 2007, Tennant Company was awarded the Minnesota Governor's Award for Excellence[57] for their pollution prevention and waste reduction efforts. The award recognizes their

Figure XX



proven commitment to pollution prevention including reduction of:

- *hazardous raw materials usage by 2,200 pounds;*
- *water usage by 3.7 million gallons;*
- *hazardous waste by 2,200 pounds;*
- *solid waste by 49,316 pounds;*
- *water pollutants by 35,860 pounds.*[58]

The ec-H2O completely eliminates the need for chemistry, using only water to clean. Highly oxygenated microbubbles restructure water which is then electrified to produce highly charged particlesthat bond to the dirt molecules and are then sucked back into the machine. After 45 seconds the charged water returns to it's natural state. Clean tap water goes in, dirty tap water comes out.[59] As a major chemicals consumer, this chemical free technology could revolutionize the cleaning industry.

Their FaST Foam-activated Scrubbing Technology is a floor scrubber that uses up to 70percent less water and 90percent less chemicals than other available technologies. The FaST neutral and heavy duty chemicals are GreenSeal certified and the cartridge technology nearly eliminates contact with chemicals.

Cool Clean Technologies, Inc.

Eagan-based Cool Clean Technologies, Inc. develops solutions using Carbon Dioxide for industrial cleaning applications. Solvents are a top priority for green chemistry. Not only are most solvents highly volatile, flammable or toxic, they are the bulk of the waste from chemical production. Innovations in solvent technology will improve workplace air quality and reduce pollution. One of the major opportunities for green chemistry is in

[57] The Minnesota Governor's Award " honors superior environmental achievement by Minnesota businesses that have developed innovative practices that prevent pollution and waste, improve resource efficiency, and lead to sustainability".
[58] Tennant Company press release, 3/9/2007
[59] Figure XX source: Tennant Company

finding alternatives to petroleum based solvents.[60] Cool Clean Technologies does just that.

A small but growing company, they have 25 employees in a 10,000 square foot manufacturing facility. Estimated sales are $1.9 million.[61] The company benefits from the historically rich innovation culture in the metro area. The management team comes out of the area's precision device and chemical engineering industries, having contributed to innovative solutions at BMC, Chart Industries and 3M.

Cool Clean Technologies have already developed a number of solutions to traditional solvents using liquid CO2, including solutions in plastics recycling, and oil removal from vitamins, as well as technology that replaces the highly toxic solvents used in dry cleaning with liquid CO2. They manufacture their own brand of garment care equipment, the CO2 Machine Cool Clean and are the sole manufacturer of the SolvAir garment care solution.

Cool Clean Technologies continue to seek out and commercialize new applications of their CO2 technology. In many cases they find that CO2 provides a more economical alternative to water and chemical cleaners. They have developed and manufactured equipment and products that deliver their innovative CO2 based technology, replacing resource intensive and wasteful oil-based cleaners and lubricants in industrial applications.

Solvents are used widely across many industries. Cool Clean Technologies are exploring expansion opportunities in a number of applications including:

- Sterilization or disinfection of specialized textiles or other substrates
- Removal of oils for various applications, including industrial parts
- Cleaning or extraction of medical devices
- Extraction of polymers

BioForce[62]

Minneapolis based BioForce manufactures and sells products in two distinct markets. For the consumer market they produce the EnviroRite line of perfume, dye and allergen free cleaning products. EnviroRite products are sold locally in some of the coops and nationally through specialty asthma catalogs. Their key product, however, is manufactured for the commercial market. BioForce developed an innovative technology to turn food waste, used grease from the restaurant industry, into a low VOC ester based solvent that can be re-covered one more time after use to make biofuel. This new solvent replaces highly toxic petroleum based solvents in wide use in the printing industry. They currently have 6 employees and sales of $1-$2.5 million[63].

BioForce's main limitation is on the supply side. They could produce 6000 gallons of this chemistry per month in their facility in Northeast Minneapolis, and the printing industry would readily purchase whatever is available. The Star Tribune alone purchases 1000 gallons per month, mixing this bio based solvent with their petroleum based one at a 15percent solution; they would like to increase both the concentration and the volume of the bio based chemistry for both environmental and business reasons. California's

[60] Martyn Poliakoff and Pete Licence, 2007
[61] Dunn & Bradstreet Million Dollar Database.
[62] Glen Nelson, personal conversation, April 2009
[63] ReferenceUSA

stricter environmental regulations require the use of low VOC solvents and a minimum of 92 percent of the product must be remanufactured. For printers with West Coast markets, this product is crucial. BioForce has interest from a number of other large newspapers and publishing companies.

As with many innovations in chemistry, this product was discovered when working to develop something else. Recognizing the unique properties, the chemists at BioForce sought out a customer market and found it in the printing industry. While there was readily available demand for this product, the innovation and product development happened on the supply side.

BioForce faces two constraints. The first is their ability to source feedstock, and the second is lack of ability to measure and market how their green technology reduces carbon footprint. Currently they buy about 95 percent of their inputs from restaurants in the metro area, but they need greater access to this food waste. Virgin feed stocks do not work as well for their process and many of the ideal food service providers have contracts with multinational waste management companies. BioForce needs help developing their supply chain for greater and more consistent access to inputs. Their market is ready for expansion and they have the space to expand their manufacturing if they had access to consistent inputs.

"In 1998, Restore Cleaning Products proved the caliber of its products in a test run by the state of Minnesota. Going up against 23 companies, including giants such as Ecolab and 3M, the tiny company ranked No. 1 for safety, performance and environmental attributes." [Upsize Magazine, October 2005]

Residential Cleaning Products Companies in Minneapolis Saint Paul:

- Restore Products
- Caldrea

Restore Products

Founded in 2001, Restore Products manufactures 14 different cleaning products and owns 24 different formulas based on natural ingredients such as corn, soy, coconut and orange. Primarily geared toward the residential market, Restore Products are sold at stores catering to an environmentally conscientious consumer, such as Whole Foods and the Wedge. They recently brokered a deal with United Natural Foods, Inc. (UNFI) which expands their distribution network from regional to national.[64]

Key to Restore Products future is innovative, patented technology that dispenses their liquid product after reading the bar code on the bottom of the bottle. Created by Brown with the help of a local mechanical engineer, the refilling station reads a barcode on the bottom of the product, mixes and dispenses the appropriate product, then gives the customer a $1 off coupon as an incentive for reusing the bottle. This technology could have wide application across the chemicals industry. As of June 2008 there were 25 Restore filling stations in six states. As a private company, sales are not disclosed but Brown reported that the company's sales were less than $2 million in 2004, while the company's sales projections have grown from $147,000 in 2001 to over $33 million for 2009.[65] Brown expects to continue expanding the refilling stations with a total of 35 refilling stations by the end of the year.

[64] Information on Restore Products comes from three sources: Neil Orman "Practical Visionary" Upsize Magazine, October 2005 (accessed online May 2009); Sarah Brouillard "Real Life: Three local business owners share tales and tips" Upsize Magazine, June 2008 (accessed online May 2009); Restore Products website: http://restoreproducts.com/

[65] Current data from ReferenceUSA shows sales of $1-$2.5 million.

Restore Products is an example of homegrown innovation. In the 1990s, founder Laurie Brown opened one of the first environmentally focused retail stores in the U.S. Among the many lessons learned from that experience, it allowed her to fine tune Restore's product formulations through years of customer feedback.

Tapping in to the local individuals with chemical and mechanical engineering talent, and specialized legal knowledge, allowed Brown to "fly under the radar" while creating her products. Major competitors in the area are represented by local law firms, and supported by engineering and product development firms. As a small company she could not have competed against the multinationals in product development.

Their main barrier to growth has been raising funds. As a company on the leading edge of consumer's environmental awareness, finding investors who can help bring the company to scale has been challenging. Lack of venture funding has slowed growth of the company. According to Brown, “I’ve had investors look at me, and just shake their heads. Then I go back to them three years later, and they’re like, ‘Wow, you’ve made a lot of progress. I thought you were crazy.’”[66]

Caldrea

Caldrea grew out of the strong local presence of marketing and advertising talent. Though recently acquired by SC Johnson, Caldrea is still managed and directed by women. Founder Monica Nassif has a marketing and public relations background. Before starting Caldrea she worked for local retail giant Target Corporation and had her own public relations and marketing firm. She started Caldrea out of her own desire to create a line of beautiful and creative products for the home. Staying in Minneapolis made sense. She tapped in to the metro area's highly skilled advertising and marketing industry, as well as the base of contract chemical manufacturers in the area who could produce high-quality bio-based personal and home care products.[67]

Caldrea produces fourteen different types of products between the personal care and home cleaning markets. Known for unique and high quality scents, Caldrea uses bio-derived ingredients where possible and their products are highly biodegradable. They make smart raw material choices based on safety for consumers and the ultimate environmental impact.

As a company, Caldrea believes that being green means continuous improvement. An internal sustainability team encourages practices across the company with the motto, "better than yesterday,” reinforcing the idea that sustainability is not an end goal, but rather a process.

Instead of being burdened by the large capital expense of a manufacturing facility, they chose to focus their efforts on product and business development. They own their formulas, their ideas and their brand, but they use a number of local contract manufacturers, mostly in the personal care products industry, to make their products. While they do use two manufacturers in Wisconsin, the majority of their products are manufactured in the Minneapolis Saint Paul metro area. They have a strong commitment to staying local and tapping into the well-established local base of knowledge about personal care product manufacturing. Growing their market share would have an impact

[66] Orman, 2005
[67] Information on Caldrea came from conversations with Pam Helms and the company website: http://www.caldrea.com

on the revenues brought into the city as well as some job growth in contract manufacturing.

One of their main challenges to growth is consumer knowledge. Eco-labeling is both critical and problematic in this industry. The GreenSeal system works by product type, and GreenSeal certification has only been developed for 6 of their 14 product types. The company is considering EPA's Design for the Environment (DfE) certification, though one barrier there is brand identity. The DfE system does not have a readily recognizable or widely known brand. For widespread adoption of this standard, the EPA would need to create a solid brand identity and consumer awareness through marketing. Caldrea's main competitors, California-based Method and Seventh Generation, have recently launched major initiatives to educate consumers on being green. Method is a founding member of the B-Corporation movement, and Seventh Generation hosts an online database of chemicals in use in the personal care industry including information for consumers on known and suspected health effects.

Health and Beauty Products Manufacturing

The health and beauty products market represents significant growth opportunity, particularly for natural products and green chemistry. Global revenues for health and beauty products are valued at over $150 billion per year and the overall market is growing at an estimate 5percent per year[68]. There is a growing awareness of the health and environmental effects of the products we use on our bodies and in our homes. This trend is reflected in the recent move by Clorox to purchase one of the fastest growing natural health and beauty product lines, Burt's Bees, for close to $1 billion in 2008. Within the global market, natural beauty products are increasing in share; sales for these products are growing at a rate of 15percent per year, three times faster than the overall market. As an example of this rapid growth, sales of Burt's Bees increased from $23 million in 2000 to $164 million in 2007.

Minneapolis and Saint Paul has a concentration of health and beauty products manufacturers, particularly in the hair and skin care industry, which represents 50percent of the overall marketplace[69].

In part due to the growth of the cooperatives and our strong advocacy organizations in health, environment and agriculture, Minneapolis-Saint Paul consumers are savvy about the products we use on our bodies and in our homes. Our consumer base is interested in organic and local produce, promoting a healthy lifestyle, alternative health practices, and engaged in the outdoors and environmental advocacy. This makes Minneapolis Saint Paul the ideal test market for niche consumer products companies.

"We found that most of the designers and chemists who had worked with such great companies as Estée Lauder, Aveda, and Thymes were in or around Minnesota. We fell in love with Minneapolis. It's a green town, but very hip, and people here are so creative and well educated." Luke Vukmer, co-founder of Organic Body Brands [MSP Magazine, September 2008]

These niche consumer products companies, like Aveda, Organic Grooming, Thymes and Caldrea, require the smart, cutting edge product design and marketing that has made Minneapolis a leader in the advertising industry. We compete with major consumer markets in our advertising talent; the Minneapolis-Saint Paul metro area has a high concentration of advertising professionals, historically the concentrated talent in this industry helped grow the metro area's giants in food, retail,

financial services, agriculture, and technology. Other factors that could influence the location decisions of companies in the consumer products market are close ties to major retail markets through Target, and to local niche markets through stores like Kowalski's, who both have commitments to promoting local and trendy specialty products.

The metro area is a nexus of critical services and conditions for this industry to garner a competitive advantage. Not only do we have the necessary research and development facilities and knowledge in non-toxic and bio based chemistry, but also services in specialized printing such as the flexographic printing used for the dairy industry, a well developed and talented consumer-market based advertising industry that grew out of supporting retail giants Target and Best Buy and Super Valu, as well as other Fortune 100 Companies.

Minnesota has a heritage in natural hair care and many of the personal care products chemists have worked at Aveda. It is a tight knit community and they share knowledge and experience through an active local chapter of the National Society of Cosmetic Chemists. Many of the 100 or so chemists in this group have worked at more than one of the consumer products companies located in the metro area and there are a considerable number of both formal and informal networking opportunities through this organization. The group is mainly comprised of chemists from the personal care products industry, though people from 3M and Ecolab also attend meetings. As a global leader in personal care products, there is a large contingent of people from Aveda in the chapter.

Economic development strategy in this area should be focused on market expansion and strengthening industry collaboration. The metro area's unique blend of marketing, product development and chemistry talent mixed with an educated and environmentally savvy consumer base are an asset that could be packaged for companies worldwide, following the example of Cleveland's Design District.

Metro Area Natural Health and Beauty Products Companies:

- Aveda
- Caldrea & Mrs. Meyers Clean Day (also residential cleaning products)
- Thymes (also residential cleaning products)
- Aurora Naturally
- Act by Nature
- Organic Grooming, including Herban Cowboy
- Elevance (also in the bio-based chemicals realm).

Related companies:

- Rocco Altobelli/Greenway Labs
- Regis
- Chem/Serv, Inc.
- 3M

Supporting industries with strong local presence:

- Chemistry R&D in health and beauty products
- Agriculture and food science, particularly organics cultivation
- Advertising and marketing
- Specialty retail including natural food co-ops, novelty and niche house wares stores (Patina, Bibelot, etc.), and high-end grocers (Kowalski's).
- Access to major retail markets through Target

Aveda

Since1978, Minnesota-based Aveda has been the global leader in the natural health and beauty products industry with their line of ayurvedic, organic and natural products. Within chemicals manufacturing they are leaders in their comprehensive, life cycle approach to manufacturing and R&D. As early adopters of life cycle analysis for all of their products, they take corporate responsibility seriously.

They have consistently set the bar in environmental leadership within the health and beauty industry, and beyond. In 1989, they were the first company to adopt the CERES Principles for corporate environmental performance and they continue to advance the practices of corporate environmental responsibility. They are ISO 14000 certified, and are the largest corporate purchaser of wind power in the state, buying enough wind power to completely offset the energy needs of their Blaine facilities. Going beyond environmental leadership, Aveda is revolutionizing the model for doing business with indigenous communities across the globe. They partner with numerous communities around the world to source sustainable natural ingredients.

Their cradle-to-cradle approach makes them leaders within chemical manufacturing. They are the first beauty company in the world to have Cradle-to-Cradle endorsement by McDonogh Braungert for some of their products[70]. They define sustainable practices for research and development, and set the benchmark for full life cycle analysis and integration of the precautionary principle in product stewardship[71]. Though they are now owned by Estee Lauder, the research and development remains in Minneapolis, likely due in part to the deep knowledge base and chemical engineers specializing in green and plant derived chemistry.

Elevance

Elevance's primary technology turns soybean oil into a naturally derived emollient that replaces the petroleum-based products currently available to the personal care products industry. This new product is designed to meet the demands of the beauty products industry and their consumer's growing desire to use more natural products. Founded in 2005 by Cargill, Elevance is now using their partnership with Dow Corning Corporation to commercialize their technology, and using Dow's position as a leading ingredient supplier in the Personal Care industry to connect with the global marketplace.[72] Elevance acts at the intersection of two major realms of green chemistry, the consumer driven health and beauty products industry and the producer driven field of renewable materials. Anticipating enormous market potential for their new technology, they are ready to scale up operations and recently received $40 million in private funding for expansion[73].

Organic Grooming

In 2008, Pittsburg based Organic Grooming (also known as Organic Body Brands), creators of the Herban Cowboy line of organic men's body and skin car products, relocated to the Minneapolis Saint Paul area because of the "eco-alt" consumer base. The Wedge was one of their first buyers and in Minneapolis they found supportive services and industry knowledge to develop, design, and market high quality organic personal care products. The company plans to add two new product lines in 2009-2010.

[70] Marc Gunther. " Aveda, Cradle to Cradle, and a Paradigm Shift in Cosmetics" GreenBiz.com, May 12, 2009
[71] Linda Eichinger, 3M, Personal conversation, April 2009
[72] Elevance website: www.elevance.com; Tom Webb, 2009.
[73] Tom Webb, 2009.

Caldrea

Caldrea mainly produces consumer home cleaning products but their line does include a few personal care products. Caldrea is growing, becoming a larger player nationally and within the local personal and home care products manufacturing industry. Their chemists are active within the Twin Cities Society of Cosmetics Chemists and they are engaged in the pursuit of high quality bio-based, highly functioning formulas that are a pleasure to use.

Rocco Altobelli/Greenway Labs

While Rocco Altobelli products do not have a high profile in the natural beauty products market, the company does produce some "naturally derived" products. Their subsidiary chemicals research, development and contract manufacturing facility, Greenway Labs, are key players in the metro area personal care products industry. Their current Director of Research and Development is the chair of the Twin Cities Society of Cosmetics Chemists.

BioBased Polymers and BioRefining – Using Renewable Feedstocks

Within the $2 billion per year chemicals industry there are only a handful of firms working in the realm of renewable feedstocks,[74] even though there is significant activity and growth potential in this area. Four issues drive the renewable materials industry: supply and price fluctuations in petro chemicals market; health concerns with conventionally produced plastics; attention to carbon footprint; and, recent breakthroughs in biochemistry.

Currently oil, coal and natural gas supply the carbon needed for 90 percent of the chemicals manufactured, the remaining 10 percent come from other non-renewable minerals. The oil supply chain is highly unpredictable, plagued by supply shortages and wild price fluctuations. Additionally, there are higher and higher costs associated with raw minerals extraction. Despite the economic downturn the market is still growing[75].

To date much of the energy in biobased chemistry has been in biofuels, but this has limited opportunities for expanding competitive advantage. In biofuels production there is potential for invention in new technology development, but not in product development, which is where there is real revenue potential. The end product of biofuels production is ethanol, not a patentable, proprietary molecule. In bio materials production both the process technology and end product can be patented, opening up more opportunities for wealth creation[76]. While biofuels research and development is necessary, ultimately there may be more value in bio materials innovation.

While renewable material is probably the area of the greatest growth within chemistry, it is also an area of significant challenges. Environmental advocates question the degree to which biobased polymers and biorefining are green[77]. The promise of biorefining is the replacement of non-renewable, oil feedstocks with plant-based materials, however there are significant challenges to overcome, not least of which is competition for food production[78]. Currently many of these bio-based plastics are made from high starch food feedstocks such as corn, potatoes, sugar cane and cassava.

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[74] Comments from Jim Stoppert, CEO of Segetis, in Tom Webb's article "Starter Culture", Piioneer Press 3/272009
[75] Steve Davies, NatureWorks, personal conversation, April 2009
[76] Webb, "Starter Culture", 2009.
[77] Many concerns with the biobased material production are raised by Jim Thomas in "Plastic Plants" for the New Internationalist, issue 415, September 2008
[78] Thomas, 2008

Concerns over genetic modification, use of chemical fertilizers and pesticides in crop production and end product biodegradability begin to temper the fervor with which biobased materials are promoted. Many of these crops are genetically modified to maximize starch production and minimize other inputs[79]. GMO crops are still highly controversial, particularly for the environmentally savvy consumer. Furthermore, not all of these biobased products are biodegradable in natural settings, raising specific concerns over marine degradation, and biodegradability in dominant waste management strategies such as landfilling[80].

Additionally, there are many barriers to the expansion of bio materials such as PLA and PHA. These biobased polymers are still niche products competing against a proven commodity, petrochemicals, which has a well-developed supply and distribution chain. If they cannot insert their polymer seamlessly into existing networks there is a significantly higher barrier to entering the market. On the other end, there are limited recycling and end of life management options for these products, which decreases their overall environmental performance.[81]

While these products have only a small portion of the plastics market, there is growing competition in the field. In 2007 the U.S. Department of Commerce National Institute of Standards and Technology awarded Metabolix $2,000,000 to further develop and commercialize their innovative bioplastics technology. Unlike Ingeo, produced by Minnetonka based NatureWorks (Cargill), the Metabolix technology developed at MIT used in Mirel brand plastics (Telles /ADM), and Dupont's Sorona processes use synthetic microbe technology to create plastics. Metabolix bioplastics replace four carbon petro-chemicals widely used in producing fibers (such as Spandex), polyurethanes, engineering resins, and personal care products[82].

Economic development strategy in this area should be focused on retention. While this is an emerging business, there is a lot of federal and private funding available in the renewable materials realm. Companies in the metro area may need help tapping into government resources for product development. World class research and development facilities tied to an academic institution would be a major benefit to these companies, not only for new product development, but to grow the next generation of scientists and skilled employees.

Metro Area Renewable Materials Companies:

- Cargill
- Elevance
- Gevo
- Segetis
- Draths
- NatureWorks

Supporting industries and services with strong local presence:

- University of Minnesota lab in bio polymer and bio catalyst research
- Biofuels
- Agriculture

[79] Thomas, 2008
[80] Thomas, 2008
[81] David Wallinga, IATP, personal conversation, April 2009.
[82] Metabolix website, www.metabolix.com

Cargill

Cargill remains one of the key drivers of new knowledge in the biobased and renewable feedstocks field. They have historically strong research and development in basic chemicals and materials science and have expertise in the commercialization of this knowledge[83].

As one of the key companies within chemicals research and development, Cargill has been a leader in developing bio-based polymer, renewable materials and expanding materials science. Their presence creates the ideal business environment for start-ups in the realm of bio materials. A number of chemists from Cargill have formed specialized companies in the bio materials realm. These spinoffs benefit from the pool of talent in the metro area created through the historical presence of firms strong in chemicals research and development and new technology commercialization such as 3M, Honeywell, H.B. Fuller, Ecolab, Tennant, and Medtronic, among others.

Cargill manufacturing and biorefining facilities generate an enormous amount of materials and by-products. Many of these can be used in the creation of new plant-based materials that can replace petrochemical based products used across a number of industries including biofuels, personal care products, plastics, paints and adhesives.

While many divisions of Cargill are working to expand the markets and technologies for biobased materials, two product divisions within Cargill have developed commercial renewable materials solutions:

BiOH[84]
The BiOH technology uses soybean oil as the feedstock to make a biobased flexible foam for use in the furniture and upholstery industry. Currently BiOH cannot produce enough, and has not been proven long term, to completely replace conventionally produced foams. For their customers, they currently replace 5-20 percent of the content of upholstered furniture, bedding, carpet backing, and automobile seats with their biobased product. Founded in 2004, BiOH has been rapidly expanding. Cargill recently opened the first full scale production facility (Chicago); in August 2007, just two years ago, they opened their Plymouth-based research and development facility.

Industrial Oils and Lubricants[85]
Founded in 1998, this division turns agricultural feed stocks, sunflower, flaxseed and soybean oils into industrial oil products such as paints, inks and lubricants. Their primary product, Agri-Pure™, is a line of bioderived lubricants for industrial applications. These bioderived, renewable products are formulated for a variety of industrial applications and have numerous environmental benefits including low volatility, biodegradability, and low toxicity. This division is based in Minnetonka, with three offices worldwide. They operate 51 oilseed manufacturing facilities worldwide, with the largest plant in Illinois.

NatureWorks[86]

Minnetonka based NatureWorks grew out of research and development from within Cargill. The product was commercialized through a partnership with Dow and Teijin companies, where Dow supplied the expertise on chemical plant manufacturing and Teijin provided distribution expertise.

[83] Pam Helms, Caldrea, personal conversation, May 2009.
[84] Webb, 2009; BiOH webstie, http://www.bioh.com/
[85] Webb, 2009; Cargill website, http://www.techoils.cargill.com/index.htm
[86] Steve Davies, NatureWorks, personal conversation, April 2009

NatureWorks are the inventors and producers of the Ingeo resin, which is a compostable plastic made from a renewable feedstock, specifically dextrose, the byproduct of an existing biorefining process.

Ingeo production started in 2002, with the opening of their plant in Nebraska, collocated on one of Cargill's largest corn wet milling facilities. In five years their production has grown to 150 million pounds per year, at their world-class facility, where they just started up a second line, which will double production capacity.

Their first plant supplies the domestic need but approximately 30 percent of their product is currently shipped to Asia for use in product manufacturing for the American market. One of the value propositions of the product is that it can replace existing petroleum based plastics, providing a lower carbon footprint. Shipping the product to Asia is an interim step that does not make business sense in the long run, and goes against the principle of carbon reduction. Future expansion will require a plant located closer to the market.

As with many new technologies, initially the market for Ingeo was entirely driven by NatureWorks. But the balance between push and pull has switched recently, and the market demand has been growing rapidly. In early 2006, Walmart switched all of their clear plastic packaging to PLA based plastics using the Ingeo resin. And on Earth Day of this year Frito Lay Sun Chips upgraded their packaging. They are now using 30 percent Ingeo based flexible film packaging. This innovation was 2-3 years in development, and Frito Lay is paying a premium for the packaging, but it positions them ahead of all other producers in a tight market. Today they can claim a reduced carbon footprint, and by 2010 they will be able to claim biodegradability as well when they switch to 100percent biobased packaging.

There are two main challenges for NatureWorks, breaking into the petro-chemicals supply chain and tapping into federal level policy and opportunities. While their product easily replaces petro chemically based resin, there are 6 steps in the supply chain between the plastic manufacturing and the finished product and the supply and distribution chain was built for the petrochemical industry. This poses problems for product differentiation and for small producers.

While some private venture capital exists for new product development, there are growing opportunities through federal level grants and programs aimed at stimulating the green economy. NatureWorks needs help translating federal level policy and opportunities to a 150 person company based in Minnetonka.

Segetis[87]

Segetis works in basic chemicals production, creating building blocks for other manufacturers to create end products in the emerging industrial bioproducts realm such as bio-plastics, surfactants, plasticizers, adhesives, solvents and other compounds. Segetis produces binary monomers from non-food agricultural and forestry feedstocks, such as corn stover and waste from wood products manufacturing. Unlike many of the bio-based chemical producers, their process does not require fermentation, allowing them to set up a manufacturing facility with less capital expense.

[87] Segetis website: www.segetis.com; Parzen, 2008; Webb, 2009.

In February 2009 Segetis opened a demonstration manufacturing facility in Golden Valley capable of producing up to 250,000 pounds of chemicals per year. While they currently have 37 employees, they are expanding, in particular adding expertise to their product commercialization team. In 2008 they secured $15 million in funding from Khosla Ventures.

Their proprietary process produces a new class of chemicals. This is a potential barrier to growth if it their monomers cannot fit into existing, well-established distribution networks for petro-based chemicals.

Draths Corporation[88]

Founded in 2005 in Okemos, Michigan, Draths moved their headquarters to Minnesota to scale up production and recently built a 12,500 square foot product and process development facility in Plymouth. Draths received angel funding and recently secured $5 million in funding from Khosla Ventures for "strategic and technical development."[89]

Draths Corporation turns corn sugars into nylon fiber and other materials. Operating along the entire benzene value chain, the Draths technology enables renewable alternatives that are identical to petro-chemicals. Their biobased materials are used in the manufacture of everyday products such as nylons, paint, plastics and resins that are now made with petro chemicals.

Benzene is the highest production material in the aromatics industry. Each year over15,050 million pounds of benzene are produced in the US alone[90]. While Draths currently has limited production facilities, the potential for expansion is huge.

While the founders did not come out of the metro area talent pool, the CEO was part of Cargill's industrial bioproducts division.

Paints and Adhesives

While technically part of the chemicals industry, paints and adhesives tend to be considered under the green building products designation. The market and trends within the building products industry are best discussed in that context, as the growth in green building has been a particularly strong driver. However, two major companies in this industry have contributed to the metro area's talent pool in chemical innovation and continue to house basic chemicals research and development. Additionally, there are issues with the manufacture and disposal of paint that can be discussed within the realm of green chemistry.

Paint production depends on the use of solvents and other highly volatile petro chemically derived chemicals. Efforts to green the chemistry in the paints and finishes industry have mostly focused on lowering the VOC (Volatile Organic Compound) content, and transitioning from oil based formulas to water based[91]. While there are some programs to recycle leftover paint, not enough is being done to reduce the wastes from this industry. To date this issue has fallen on local governments as part of their hazardous waste management strategy and industry has not taken an active role in total impact assessment or life cycle management at the end of use.

[88] Draths Cororation website: http://drathscorporation.com/; Webb, "What's Developing?", 2009
[89] Webb, "What's Developing?", 2009
[90] American Chemistry Council, source: Innovest, 2008
[91] " Environmentally preferable water-based paints have increased in market share to over 80percent (PSI, 2004; EPA, n.d.b)." Source: RPN Green Purchasing Guide.

The volume of waste produced by the paints industry is considerable. In the US alone there are between 16 and 35 million gallons of leftover paint each year just in the consumer market, and less than half of that paint is properly handled (managed or recycled). One metro area based company, Amazon Environmental, is taking this issue on, recycling leftover paint into new Green Seal certified paints and latex additives for cement.

Metro Area Paints, Coatings and Adhesives Companies:

- HB Fuller
- Valspar
- Cortec Corporation
- Amazon Environmental, Inc.
- American Chemical Company

HB Fuller[92]

HB Fuller is a St. Paul based global leader in adhesive, sealant, paint and other chemical products. They employ over 3,000 people worldwide and had revenues of $1.4 billion in 2008. Though they have facilities in 36 countries, they house their research and development in a 225,000 square-foot facility in St. Paul.

For more than two decades, HB Fuller has had a commitment to improving workplace and environmental health. They have both compliance and prevention programs in environment, health and safety (EHS), and use a continuous improvement philosophy to drive development of new solutions that decrease the impact of their products on people and the environment.

Valspar

Since 1806 Valspar has been a leader in residential and industrial coatings manufacturing. The produce products for residential and architectural markets, packaging and automotive industries, and commercial and industrial coatings for a broad range of applications. Their research and development facilities are located in downtown Minneapolis, with manufacturing facilities worldwide.

Valspar is committed to continuously improving their products and processes for environmental and human health. Between 2003 and 2007 they reduced their total VOC emissions by 35 percent (284 tons). In the same time period they reduced the emissions of Hazardous Air Pollutants by 59 percent (212 tons), and Toxic Release Inventory (TRI) chemicals releases to air, land, and water by 39 percent (153 tons). Internally they are working to reduce waste and improve energy efficiency across all operations. In an eco-industrial partnership, a portion of Valspar's production waste is used by another company as fuel.

Amazon Environmental, Inc.[93]

Fridley based Amazon Environmental remanufactures leftover paint into their Amazon Select paint. With the paint they can't remanufacture into a new finish, approximately 50 percent of the volume they receive, they produce a latex cement additive, Process Latex Pigment (PLP), through their patented process.

[92] HB Fuller website: http://www.hbfuller.com
[93] Amazon Environmental website: http://www.amazonpaint.com/

American Chemical Company

Dennis Warneke, founder of American Chemical, believes that industry should have access to low VOC, water based and minimally packaged adhesives for use across a wide variety of applications. He sells adhesives from a number of manufacturers under his website, "Glue it Green" (www.glueitgreen.com). One of the main innovations that he would like to see in wide use throughout U.S. industry is "sausage pack" adhesives and caulk application. Widely used in Europe, these are the same adhesives that are packed in heavy plastic tubes used extensively in the building and construction industries. The advantage of this alternative delivery system is that it produces minimal packaging waste. Once used, the tube can be flattened and recycled through the aluminum recycling stream. However, without more stringent waste reduction requirements for LEED and other building certification, contractors are reluctant to change over to this alternative delivery technology[94].

Other Innovations:

Starch Tech

Founded in 1996, StarchTech now occupies a 50,000 square foot combined manufacturing and office space in Golden Valley, Minnesota. Edward Boehmer founded the company out of his vision to develop and commercialize products using starch-based solutions.

Reducing waste in packaging is one of the main ways companies green their practices. While not generally considered in the chemistry realm, packaging materials are often made of plastics (foams and films). Additionally, this proprietary, patented process and technology allows the packing materials to be shipped in a compressed pellet form, saving costs and reducing environmental impact of transportation and storage. For example, what would take a whole trailer to ship using conventional petro-chemically based peanuts can be shipped in one bag of the starch pellets.

> *"This simple, affordable and innovative solution, which provides you with starch pellets and the machine to transform them into ready-made, on-demand, biodegradable packing peanuts, allows users to produce a high quality, eco-friendly packing peanuts in a cost-effective manner.[95]"*

Blue Water Ponds

The Blue Water Ponds technology replaces the need for chemically based herbicides with a bio-based technology to clean ponds. While this solution doesn't fall into the category of green chemistry, it effectively eliminates the use of harmful chemicals, helping to protect the environment that Minnesotans enjoy. A homegrown company, recently launched by two environmental scientists, Blue Water Ponds is still a small company, but as the only company in the Midwest to supply this technology, there is significant growth potential. Their main challenge now is to grow their customer base, particularly in the large commercial market, such as golf courses and industrial parks.[96]

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[94] There is an initial costs to switching over from caulk tubes to sausage packs as the tool used with the packs is different than the caulking gun in wide use in the U.S..

[95] Starch Tech website: http://www.starchtech.com

[96] "Open for Business: Blue Water Ponds" Pioneer Press 4/3/2009; Blue Water Ponds website: http://www.bluewaterpond.com

Opportunities:

Green buildings

LEED standards are not aggressive enough at reducing the use of toxics in building construction. Building construction accounts for 75percent of all PVC used[97], as well as significant portions of paints, finishes and adhesives. Alternatives need to be created and incentivized where PVC is used. This may include revising building codes and training building inspectors on the use of alternative materials.

Healthcare Industry

The health care industry is a major opportunity to increase the green chemicals market. The healthcare sector is a one of the largest purchasers of chemical products, accounting for 37percent of all chemical product purchases in the US in 2002.[98] Health care is one of the largest industries and is a major consumer of toxic chemicals. The healthcare industry is rapidly growing and is a major component of both metro area employment and the US GNP, representing 15percent of the annual GNP.

Allina Hospitals is one of the co-founders of the Global Health and Safety Initiative, working toward patient, workplace and environmental safety and sustainability within the healthcare industry.[99] This initiative recognizes the power of the healthcare industry to effect change and improve health through purchasing choices. Over 80percent of the industry's more than $70 billion purchasing power is concentrated in just seven GPOs (Group Purchasing Organizations). The initiative advocates for these GPOs to adopt policies for environmentally preferable product purchasing (EPP). Encouraging a switch to safer and renewable chemicals and materials (green chemistry and bio-based products), clean and renewable energy that support the initiative's goals for a safer and sustainable health care industry. The Global Health and Safety Initiative is committed to open sharing of information about healthy buildings, environmentally preferable purchasing (providing the resource for Safe and Sustainable Purchasing), and clean energy use.

What Can Be Done to Grow Green Chemistry?

There are many ways to grow green chemistry. Researcher and green chemistry advocate Michael Wilson identified three gaps to green chemistry policy adoption: the Data gap (information), the Safety gap (accountability) and the Technology gap (capacity)[100]. Policies aimed at addressing these three gaps will have a greater chance of success in the long run.

Work to Adopt a Comprehensive Green Chemicals Policy at State Level:

A comprehensive green chemicals policy at the state level would help the area's green chemistry businesses, and ultimately would benefit the cities through pollution reduction and improvements in public health.

[97] Parzen, 2008
[98] Parzen, 2008
[99] Global Health and Safety Initiative
[100] Wilson, et. al., 2006; and Wilson, et. al., 2008.

What is already being done:

- Steve Kelley at the Humphrey Institute's Center for Science, Technology and Public Policy, along with partners across academia and industry, has started the conversation about adopting a comprehensive green chemistry policy in Minnesota.

Recommendations:

- Actively engage in these conversations across city departments.
- Help strengthen the network by using city contacts with industry and advocacy organizations.

Adopt and Promote Environmentally Preferable Purchasing Policies and Programs:

Adopt strong Environmentally Preferable Purchasing programs with local purchasing preferences. Encourage the use of established EPP guidelines throughout local government (public schools, healthcare providers). Incentivize adoption of EPP policies in economic and business development.

Local governments are one of the largest purchasers of chemical products, particularly janitorial supplies but also pool chemistry, landscaping and grounds maintenance, and other areas. Whether though the school district, health care network, municipal offices, the cities own and maintain a lot of real estate.

What is already being done:

- The state of Minnesota and Hennepin County have model EPP programs. Last fall the city of Minneapolis adopted a comprehensive EPP policy. Product availability and knowledge continue to expand. EPP policies need to be updated on a regular basis.
- The Minneapolis School District piloted a green cleaning program in four of its schools. Making results public through parent communication, media, public service could start to shift thinking. Adding a research and evaluation component on worker and student health and productivity to this pilot could expand knowledge across the field.

Recommendations:

- Revise Ramsey County and City of Saint Paul EPP guidelines.
- Adopt green cleaning programs across all public schools
- Establish a technical advisory office or website to direct citizens and businesses to information about green products and solutions.
- Work with other partners such as University of Minnesota Extension, the Solid Waste Management Coordinating Board, and the Minnesota Pollution Control Agency to increase consumer awareness.
- Establish an information booth about green cleaning at the farmer's markets.
- Promote local green cleaning companies on the city websites.
- Promote city EPP policies, make policies easily accessible on city website as a guideline for local businesses. Advertise and make available the city's EPP guide (or collaborate with the state and the SWM club to make theirs more widely known). Talk widely about the city's EPP leadership.
- Help local businesses connect with resources already available through the Minnesota Pollution Control Agency's small business pollution prevention consulting services.

Foster Information Exchange and Learning Networks

Access to information is key to expanding and growing a strong cluster in the green chemicals industry. Learning networks, whether they take the form of business-to-business events, internal company seminars, public information exchanges, or collaborations like those hosted by Steve Kelley at CSTPP, increase the knowledge base and competitive advantage of industry in a given region.

The region has incredible resources. For example, Cargill, 3M, Aveda and Ecolab continue to be a resource of materials science. Smaller companies draw on the basic research power of these companies to expand innovation.

What is already being done:

- The City of Saint Paul and 3M Corporation both have a speaker series on sustainability. These programs not only increase worker knowledge as it applies to their job, but at 3M employees are encouraged to think about how the topics apply to their life outside of work as well.
- City of Minneapolis B2B eco expo at Mill City Museum on Earth Day 2009 brought together 58 exhibitors and over 200 people.
- The Minneapolis Area Green Business Network has over 100 members.
- Organizations such as the Twin Cities Society of Cosmetics Chemists allow for information exchange within their industry.

Recommendations:

- Connect and collaborate on initiatives such as sustainability speakers. Share resources, information and speakers across academia, private business and the public.
- Leverage connections across jurisdictions and agencies to open up discussion about green chemistry.

Decrease the Barrier to Innovation

The introduction and adoption of green chemistry has been slow. While many companies have adopted green chemistry principles as a means of cost savings, there is less incentive for expensive R&D that may, or may not, lead to better business practices.

Businesses lack the resources, financial and services, to commercialize new products[101]. In Minneapolis this can be seen in the struggle that BioForce is having in securing a consistent and sufficient supply of their renewable feedstock. While they could go to a virgin feedstock, the chemical process they have developed works best with used cooking oils, which means reusing something that otherwise is considered a waste product. They need help connecting to and brokering agreements with potential suppliers.

> "Process innovation is often risky, expensive and difficult, giving the chemical industry one of the longest new product technology cycles (10-20 years) and new process technology cycles (40-50 years) in all of manufacturing."[102]

Recommendations:

- Work with private sector and academic partners to build a strong research and development facilities and partnerships for green chemistry.

[101] Wilson, 2006
[102] According to green chemistry experts Ken Geiser and Alexander McPherson, source: Frank Ackerman, 2007

- Continue to build networking opportunities, such as the B2B Eco Expo created by the City of Minneapolis and the City of Lakes Chamber of Commerce for businesses to connect with potential academic and private sector partners.
- Help area businesses connect with funding sources and internationally recognized sustainability awards such as the Presidential Green Chemistry Challenge[103]

Marketing and Public Service Message

Working with local business leaders and the region's strong advertising and marketing industry to educate the broader public about switching to green chemistry can create both economic and health benefits. Spreading the word about how Minnesota companies are switching to green chemistry could be a strategy that not only promotes our leadership in sustainability but also could help drive local industry through increased demand. Minnesotans are proud of their environment and people across a broad spectrum take interest in practices that affect out rivers, lakes and streams. One of the main barriers to broad scale adoption of green chemistry is lack of consumer knowledge about the economic and health effects of chemical production and use.

Switching to greener chemistry can have additional economic benefits for local government. Green chemistry reduces the burden on waste water treatment plants, decreasing overall cost of operation and increasing quality of the discharge. Encouraging the metro area population to shift their chemistry use to greener options could help reduce waste water treatment and environmental cleanup costs.

Recommendation:

- Work with local advertising and marketing expertise to communicate both continuous improvement and green products to the market.

[103] •"The Presidential Green Chemistry Challenge Awards Program is an opportunity for individuals, groups, and organizations to compete for annual awards in recognition of innovations in cleaner, cheaper, smarter chemistry. The Presidential Green Chemistry Challenge Awards Program provides national recognition of outstanding chemical technologies that incorporate the principles of green chemistry into chemical design, manufacture, and use, and that have been or can be utilized by industry in achieving their pollution prevention goals." from the EPA's Green Chemistry website: http://www.epa.gov/gcc/

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- Peter Stravinsky, Institute for Agriculture and Trade Policy
- Todd Lafrenz, Professor, Metro State University
- Pam Helms, Caldrea
- Dennis Warneke, American Chemicals, Inc.
- Glen Nelson, BioForce
- Lynne Olson, Ecolab
- Brian Davis, Ecolab
- Tom DePasquale, 3M
- Linda Eichinger, 3M
- Keith Miller, 3M
- Steve Davies, NatureWorks, LLC
- Catherine Zimmer, HEARRT
- Julia Parzen
- Johanna Kertesz, MPCA
- Angie Bourdagh, MPCA
- Garth Hickle, MPCA
- Jeremy Lenz, BioBusiness Alliance
- Steve Kelley, Center for Science, Technology and Public Policy, Humphrey Institute of Public Affairs

Appendix A: The 12 Principles of Green Chemistry

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 often made from agricultural products or are 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 that 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.

Paul Anastas and John Warner in *Green Chemistry: Theory and Practice* (Oxford University Press: New York, 1998).

Source: EPA Green Chemistry (accessed May 2009).

Appendix B: The Michigan Directive

The Michigan Directive is a model for a statewide comprehensive green chemistry policy and implementation guide. Established in 2006, it was the first comprehensive state level policy directive for green chemistry.

The Michigan Directive defines "green chemistry" as:

> *...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*. (Michigan Directive).

This definition of "green chemistry" is based upon the 12 principles developed by John Wagner and Paul Anastis in 1998, generally considered to be the most comprehensive directive on green chemistry (see Appendix)

The Michigan directive not only defines green chemistry but directs how the policy can be applied to economic development in the state through 1) research and development, 2) promoting the use of green chemistry, 3) creating coordination of state agencies around green chemistry.

It also defines a green chemistry support program facilitated through the Department of Environmental Quality. This program is directed to provide:

- encouragement and support the research and development of innovative chemical solutions
- look at ways to incentivize green chemistry processes and products in the state
- expand the education and training of students at all levels in chemistry and chemical engineering
- facilitate partnerships between industry and academia
- be a resource for information on green chemistry research and reach out to disseminate this information allowing for technology transfer
- reach out to the green chemistry community and broader public via collaborations with academia, the scientific community and industry and hold symposiums, forums and conferences on green chemistry
- provide a venue for public input and outreach on green chemistry
- promote private sector development of green chemistry
- make recommendations to the Governor outstanding work and new developments in green chemistry
- maintain avenues of communication about the Green Chemistry Program.

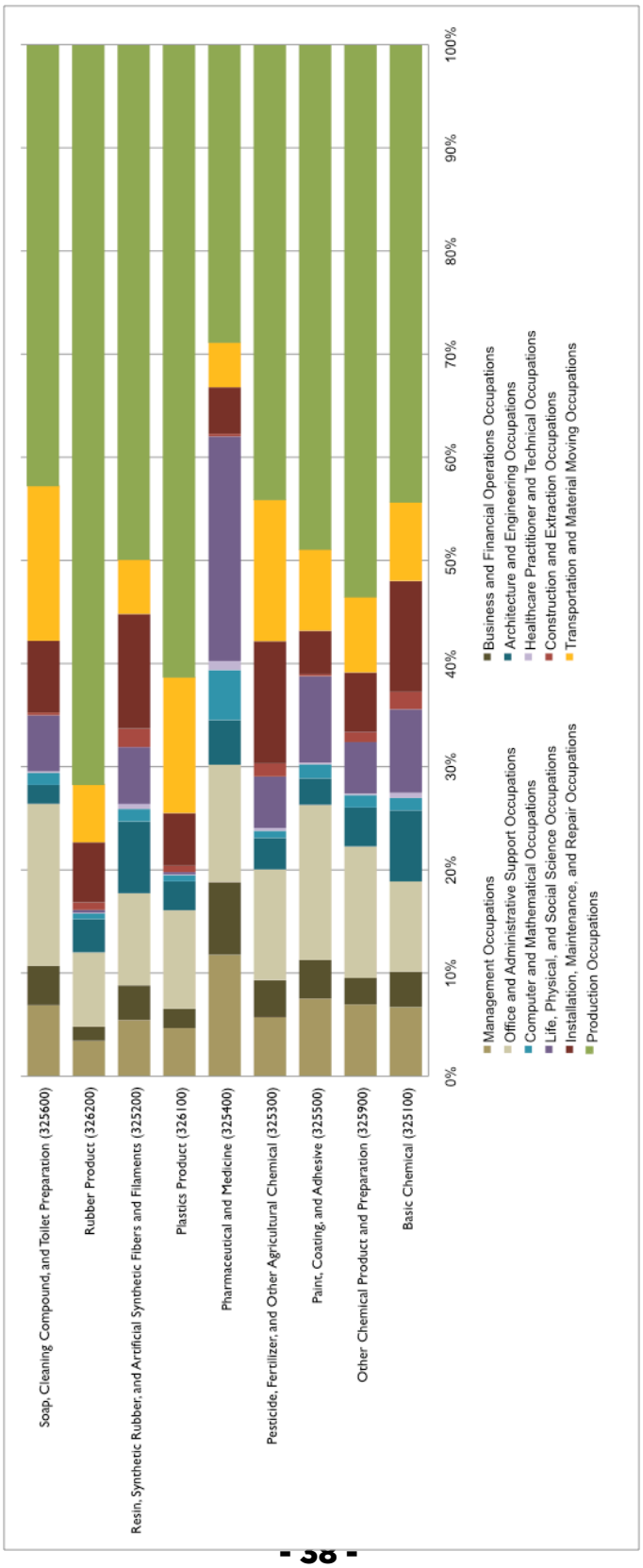
The Directive also establishes a roundtable of advisors across academia, industry, public health, all levels of government, and the general public.

Appendix C: Occupational Structure of the Chemistry Industry

Appendix D: Green Chemistry Resources

Green Chemistry in General

- Advancing Green Chemistry



http://www.advancinggreenchemistry.org

- EPA Green Chemistry
  http://www.epa.gov/gcc/

- American Chemistry Society Green Chemistry Institute
  http://www.acs.org/greenchemistry

- Beyond Benign
  Promoting the principles of green chemistry to a broad audience through K-12 education, community outreach and workforce development.
  http://www.beyondbenign.org/index.html

- CleanGredients
  US EPA/GreenBlue partnership for innovative formulations
  http://www.cleangredients.org

Bioplastics and Renewable Feedstocks

Advocacy organizations:

- Business NGO Workgroup
  http://www.busngoworkgroup.org/

- Sutainable BioMaterials Collaborative
  http://www.sustainablebiomaterials.org/

Major Companies in other locations (competitors):

- Metabolix (MIT technology development. Metabolix uses an engineered microorganism to make plastic)
  http://www.metabolix.com

- Mirel (Metabolix and Archer Daniels Midland Company (ADM) are commercializing Mirel through a joint venture called Telles)
  http://www.mirelplastics.com/

- Green Harvest Technologies ("Green Harvest Technologies (GHT) is a green product development and marketing company that is developing sustainably-produced, biobased consumer products.")
  http://greenharvesttechnology.com/

Personal and Home Care Industry:

- Twin Cities Chapter of the Society of Cosmetics Chemists
  http://www.tccscc.org

Advocacy organizations:

- Safe Cosmetics Campaign
  http://www.safecosmetics.org/

Major Companies in other locations (competitors):

- Burt's Bees
  http://www.burtsbees.com

- Seventh Generation
  http://www.seventhgeneration.com/

- Method
  http://www.methodhome.com/

Environmentally Preferable Purchasing

- Responsible Purchasing Network
  www.rpn.org

- Minnesota Pollution Control Agency EPP Guide
  http://www.rethinkrecycling.com/government/eppg/why-buy-intro-eppg/introduction

Health and Healthcare

- Global Health and Safety Initiative
  http://www.globalhealthsafety.org/

- Practice Green Health
  http://www.practicegreenhealth.org/

- Health Care Without Harm
  http://www.noharm.org/

- Prevent Harm Minnesota
  http://www.preventharm.org

- Healthy Legacy
  http://www.healthylegacy.org/

- Clean Production Action
  http://www.cleanproduction.org

Green and Eco-labeling

- Design for the Environment
  http://www.epa.gov/dfe/pubs/projects/formulat/label.htm

- Ecolabelling
  http://ecolabelling.org/

- Green Seal
  http://www.greenseal.org/

Green Chemistry Education

- Lowell Center for Sustainable Production, University of Massachusetts Lowell
  http://www.greenchemistry.uml.edu/

- Center for Green Chemistry & Green Engineering at Yale
  http://www.greenchemistry.yale.edu/

- University of Oregon, Greener Education Materials for Chemists
  http://greenchem.uoregon.edu/gems.html

- Center for Sustainable Systems at the University of Michigan
  http://css.snre.umich.edu/