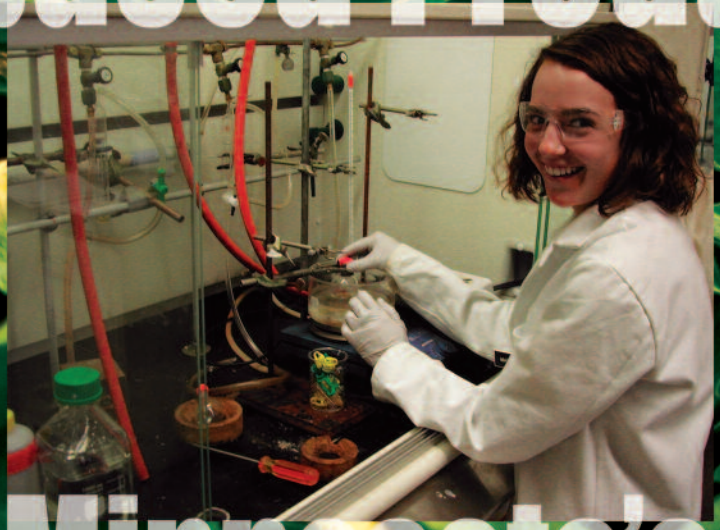
VOLUME ONE

Biobased Products



Minnesota's Opportunity & Challenge

A Focus on BioPlastics

Agricultural Utilization Research Institute

Biobased Products

Minnesota's Opportunity and Challenge

A Focus on BioPlastics

Agricultural Utilization Research Institute

Minnesota-based organizations have been at the forefront of early development of biobased products and biobased plastics. The Agricultural Utilization Research Institute (AURI), the Minnesota Soybean Growers Association and the Minnesota Soybean Research and Promotion Council (MSRPC) believe that this industry is an emerging opportunity for Minnesota businesses to capitalize on consumer demand. For this reason, our organizations partnered to bring forward a comprehensive report exploring the opportunities and challenges facing the industry.

While the biobased products industry is extensive, this report focuses on bioplastics. The report emanated from the West Central Minnesota Renewable Materials Coalition's interest in developing renewable materials cluster. The Coalition has already begun to work with local manufacturers with an interest and capabilities to manufacture products using bioplastics that meet targeted client company specifications. Due to the significant potential statewide impact, this report was expanded to address the assets and opportunities across Minnesota.

During the past several months, AURI has worked with Russell Herder, a Minnesota-based market research firm, to systematically garner the insights of key players in the bioplastics industry. In addition, the Student Marketing Advisory Center at Southwest Minnesota State University conducted a survey of manufacturers. The survey gauged perceptions and awareness of biobased alternatives. Using this information, the project team developed a comprehensive review of opportunities and recommendations.

This report is only the first step. Development of innovative solutions requires communication among multiple stakeholders across a wide spectrum of interests; collaboration is necessary to advance mutual interests. This growing network will require extensive and deliberate planning. AURI, with the help and support of partners like the Minnesota Soybean Growers, will convene and develop a network centered on innovation in the biobased materials sector that generates economic impact across the state.

AURI and the Minnesota Soybean Growers look forward to continuing to partner with agriculture, academia, government and the state's processing industry to grow the biobased products industry in the state and nation. We hope that you will join us in this exciting work.

Sincerely,

Al Christopherson
Chairman of the Board
Agricultural Utilization Research Institute

Gene Stoel
Chairman of the Board
Minnesota Soybean Research and Promotion Council

AURI AG INNOVATIONS

Minnesota Soybean Research & Promotion Council

Biobased Products

CONTENTS:

Note from the Authors:

While specific companies and products are mentioned within this study, this document is not intended to provide an exhaustive or comprehensive review of the entire bioplastics industry and all who are involved in it in Minnesota, the United States or around the world. This study is not intended to show preference to any specific companies, products or technologies. Rather, information included in this report is a snapshot in time. We have included examples of companies and products mentioned to provide an overall framework for discussion and to underscore significant points. We deeply appreciate the cooperation of those who graciously gave of their time and expertise in the preparation of this report, and invite others with an interest or experience in this area to contact AURI for possible inclusion in future updates.

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Executive Summary

The Process to Successful Adoption of Bioproducts

Progress toward sustainability has moved from emerging trend to mainstream commerce.

Without question, progress toward sustainability has moved from emerging trend to mainstream commerce. Management in corporate America has embraced sustainability as a rich strategy in an intensely competitive global economy – so much so, that 93 percent of CEOs see such initiatives as important to their company's future.[1] Though markets have tightened in the past couple of years, even the recession appears not to have derailed continued development of next-gen green products and the infrastructure needed to manufacture them.

Minnesota is likewise feeling the impact – and market potential – of such innovative thinking. One dimension of this is in bioplastics, a family of products that can vary considerably in form and function, yet offer strong potential for growth.

As a market category, plastics typically play an important role in almost every aspect of our lives – from the cars we drive to the beverage containers, household items and furniture we encounter everyday. While most are found in containers and packaging, durable and nondurable goods are also ubiquitous. The worldwide market for packaging, alone, is valued at $429 billion, with a growth forecast of $500 billion in sales within the next few years.[2]

But, despite broad use of plastics, there are significant issues in their production and disposal. In 2008, alone, the United States generated approximately 13 million tons of plastics in the municipal solid waste (MSW) stream. Consumers have taken notice and are applying pressure to entities such as food companies to make packaging more environmentally friendly. In response, sustainable packaging is projected to represent 32 percent of the total global packaging market by 2014. Plastic-based packaging, which represents 35 percent of all materials used, will be the fastest-growing sector within the sustainable packaging market over the next few years.[2]

A number of factors, such as a desire to reduce dependence on oil, environmental concerns related to pollution and landfills, and human health issues are driving market interest about bioplastics around the world – well beyond just packaging.

Minnesota manufacturers understand the potential in this trend. Eighty-one percent say that it is important, at least to some degree, for their business to produce environmentally sustainable products.[3]

While interest in bioplastics exists, awareness is lacking. Thirty-nine percent of Minnesota

plastics manufacturers say they feel uninformed about the uses and opportunities for biobased material. Yet, two-thirds of Minnesota plastics manufacturers anticipate increasing their use of biobased material throughout a range of industry subsectors – most predominantly, within bioplastics and biopolymers.

To ultimately be successful, industry experts say there are issues within bioplastics that must be addressed, such as the financial equation. Friedrich Srienc, Professor at the BioTechnology Institute, University of Minnesota, agrees. "The bottom line is basically economics. People are not really willing to pay more for things because they are biodegradable or sustainable," he says.[4]

Also, while manufacturers express a desire to use biobased materials from both an environmental and marketing perspective, they have concerns about the ability of these materials to meet the specifications and standards of their customers. Other issues complicating the growth of biobased materials – at least for now – lie in the complex regulatory sector. For a manufacturer distributing internationally, these concerns can extend far beyond Minnesota's borders.

With the projected growth in incorporating bioplastics into the production and supply chain, there are steps that could be taken to increase adoption. Education could ease the process: 80 percent of Minnesota manufacturers indicate an interest in learning more about utilizing biobased material in their operation. But, while increasing the knowledge base is critical to the innovation process, a lack of information may be impeding industry growth.

Also, resolving issues related to the waste stream could be advantageous. While the initial push in bioplastics was toward compostability, the fact is that the infrastructure needed to ensure biodegradable performance under optimum conditions simply does not exist. As well, securing funding for biobased material research is another challenge that needs addressing.

Bioplastics offers the opportunity to not only help drive employment and the economy, but to positively impact Minnesota's rural communities. The state appears to be well positioned to become a leader in the bioplastics industry, in part because it already has clusters of renewable-materials companies that are converting agricultural products into biofuels, chemicals and bioplastics. In fact, more than 75 Minnesota academic, private and public organizations are now involved in biomass catalysis and synthesis; more than 80 Minnesota organizations work in materials science; and at least a dozen Minnesota companies – large and small – produce renewable bioplastics and biopolymers.[5] According to experts, the state has what is needed: the intellectual capital, the innovative spirit, the environmental mindset, rich agricultural resources, a receptive manufacturing community and a proven track record in fostering biocatalysis.

So, where are the greatest opportunities? The proverbial "low-hanging fruit" is most frequently said to be in pressure-sensitive adhesives, foam, hardened plastics, packaging and certain types of non-load-bearing or non-critical-performance molded products. There is also indication that there may be opportunity in vertical integration: owning several stages of the value stream – from manufacturing to distribu-

Interest in bioplastics exists... but awareness is lacking.

While increasing the knowledge base is critical to the innovation process, a lack of information sharing may be impeding industry growth.

The state has what is needed: the intellectual capital, the innovative spirit, the environmental mindset, rich agricultural resources, a receptive manufacturing community and a proven track record in fostering biocatalysis.

"There is need for more connecting of the dots. It will take a little bit of capital and a little bit of risk tolerance before that kind of thing can come together. But it will never happen if people don't start talking about it."
- Doug Cameron, Alberti Advisors

tion – either directly or through partnerships and agreements.

Perhaps Doug Cameron, of Alberti Advisors, said it best: "There is need for more connecting of the dots. It will take a little bit of capital and a little bit of risk tolerance before that kind of thing can come together. But it will never happen if people don't start talking about it."[6]

Recommendations

What needs to take place for bioplastics production to grow in Minnesota? The following steps are recommended:

Educate

- *Proactively shape awareness, attitudes and understanding* of the economic, health and environmental benefits of biobased products among consumers, retailers, manufacturers, and the financial and agricultural communities.
- *Support Minnesota educational institutions* in shaping the skills and mindsets necessary for sustainable development.
- *Provide education to manufacturers* to help ease transition of using biobased material in their operation.
- *Conduct a "connect the dots" conference* which brings resin/polyol providers together with university researchers, start-ups, manufacturers and venture capital to discuss what is happening, who is doing what and to begin networking Minnesota ideas, research and businesses that can help each other succeed.
- *Evolve group into a community of innovation* to help nurture potential of biobased manufacturing in Minnesota.
- *Aggressively raise the media profile* of what is happening in Minnesota related to biobased plastics, green chemicals and bioproducts.

Collaborate and Support

- *Nurture an investment environment* more favorable to stimulating innovation and market development.
- *Create an innovation ecosystem* involving academic institutions, nonprofits and the private sector that encourages knowledge sharing and joint ventures.
- *More robust technology transfer.* A guide or website that incorporates services available to increase biobased opportunities.
- *Encourage a strategic approach* toward developing and manufacturing biobased products, supported by comprehensive and coordinated legislative actions in such areas as agricultural, environmental and industrial policy.
- *Find ways to leverage Minnesota's strong biofuels foundation* in the next-generation green chemicals marketplace.
- *Support financing of demonstration projects and onsite assistance* to manufacturers to further encourage adoption and up-scaling of biobased production and innovations.
- *Investigate the possibility of using ethanol plants as the centerpiece for a biorefinery "campus,"* including incubators for start-up green chemical companies, biomaterials research and development, and manufacturing using biobased materials, including the use of distillers grains as plastics strengtheners and the emerging research on using waste glycerol from biodiesel production to produce bioplastics.
- *Consider a biobased plastics manufacturing pilot plant facility* in which manufacturers, bioplastics resin/polyols suppliers and product developers could test processes and products before scaling up to full production.

Remove Barriers

- *Create a clearer and more positive regulatory environment* for sustainability.
- *Support the development of closed system collection, recycling and composting of biobased plastics* in large companies, athletic facilities, etc. (e.g., University of Minnesota, Cargill, Target Field).
- *Conduct a pilot educational study* of a community-based composting infrastructure whereby residents could bring compostable materials – including bioplastics – to a single neighborhood composting location.

Sustainability

Reshaping Corporate Strategy

"It appears that skepticism over sustainability reigns. Problem is . . . business leaders didn't get the memo."
- *StarTribune*, January 2011

There is little doubt that progress toward sustainability is alive and well. From cleantech to energy efficiency, biodegradable products to recycling, the topic is demanding global attention. "It appears that skepticism over sustainability reigns. Problem is–for the skeptics – business leaders didn't get the memo. Business isn't waiting for politicians to act. Sustainability has moved from the tributaries of society into the mainstream of commerce," Chris Farrell wrote in the *Minneapolis StarTribune* earlier this year.[7]

CEOs "have a number of stakeholders that are pushing them in this direction – customers, investors, employees, even banks and insurance companies," Farrell quotes B. Andrew Brown of Dorsey & Whitney as saying.[7]

"Management is learning that an embrace of sustainability is a rich strategy in an intensely competitive global economy," according to Farrell, who cites that from 2007 through 2009, assets in sustainable and socially responsible investing rose by more than 13 percent – up from $2.71 trillion to $3.07 trillion. That compares with a one-percent gain by the broader universe of professionally managed funds over the same time period, according to Social Investment Forum, an industry trade group.[7]

"Sustainability now has to be on everyone's agenda, and that represents a fundamental change."
- Klaus Kleinfeld, Alcoa

A UN Global Compact-Accenture study published last year reported that corporate commitment to the principles of sustainability remains strong throughout the world. "In the face of rising global competition, technological change and the most serious economic downturn in nearly a century ... 93 percent of CEOs see sustainability as important to their company's future success," the report stated.[1]

Within the manufacturing sector, next-gen green products and the infrastructure needed to support them continue to emerge relatively unabated despite the recession, researchers reported in the annual State of Green Business 2010, therefore expanding opportunities for companies seeking to be part of the growing green economy.[8]

Investments in green product development continue to show growth, especially in large companies. When asked to identify their top environmental initiative, increasing investments in green product development (27%) narrowly overtook energy-efficiency investments (26%) for the first time since the annual State of Green Business study began. When asked about investment in green product development, 86 percent said it would be equal to or greater in 2010 than the previous year.[8]

"Demonstrating a visible and authentic commitment to sustainability is especially important to CEOs because it is part of an urgent need to regain and build trust from the public and other key stakeholders, such as consumers and governments – trust that was shaken by the recent global financial crisis. Strengthening brand, trust and reputation is the strongest motivator for taking action on sustainability issues," the study observed, based on research interviews with nearly 1,000 CEOs, business leaders and academic experts.[1]

Consider these findings[1]:

- Eighty-one percent of CEOs – compared to just 50 percent in 2007 – stated that sustainability issues are now fully embedded into the strategy and operations of their company.
- Fifty-four percent of management surveyed feel that this tipping point is only a decade away – and 80 percent believe it will occur within 15 years – an optimistic view unthinkable in 2007 and testament to the sea-change taking place.

Most corporate executives, according to the *Harvard Business Review*, acknowledge that how they respond to the challenge of sustainability will profoundly affect the competitiveness of their organizations.

Yet, in "The Sustainability Imperative," David Lubin and Daniel Esty wrote, "... most are flailing around, launching a hodgepodge of initiatives without any overarching vision or plan."[9]

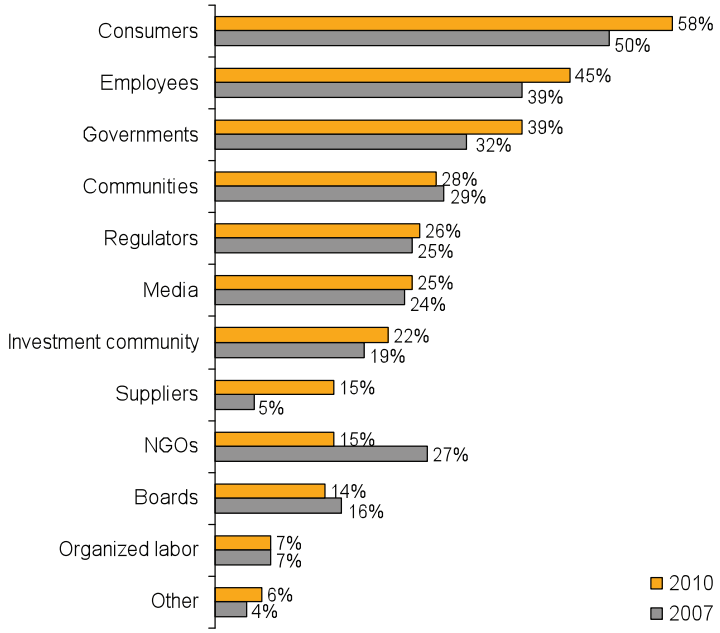
Lubin and Esty maintain that sustainability has risen to emerging "megatrend" status that requires businesses to "adapt and innovate or be swept aside."

"Getting advantage in a megatrend is not just about vision – it's also about execution in five critical areas: leadership, methods, strategy,

Consumers Increasingly Driving Businesses' Approach to Sustainability.

Over the next five years, which stakeholder groups do you believe will have the greatest impact on the way you manage societal expectations?

Respondents identifying each factor in their top three choices:



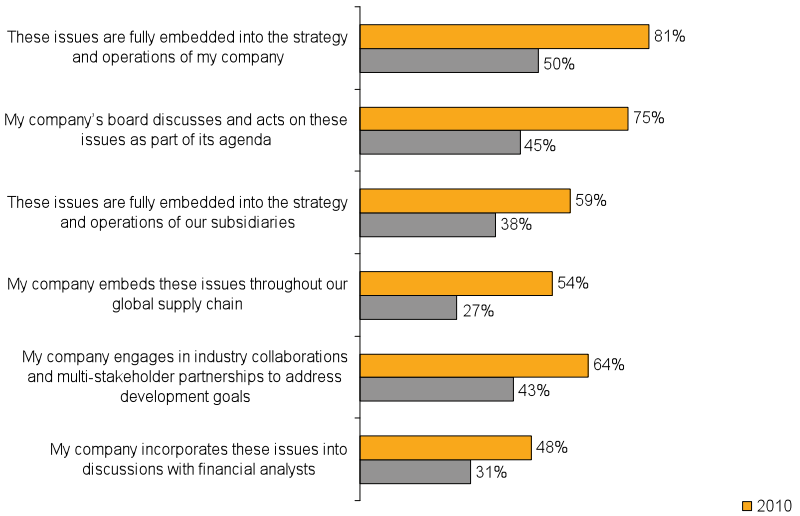
Source: United Nations Global Compact CEO Survey 2010; 2007 data from McKinsey UN Global Compact Survey

"Getting advantage in a megatrend is not just about vision – it's also about execution."
- David A. Lubin and Daniel C. Esty

Consumers–as well as business and government customers–are increasingly central to company sustainability strategies.

CEOs Report that Sustainability is Fully-Embedded Strategy

Respondents answering "Agree" or "Strongly Agree"

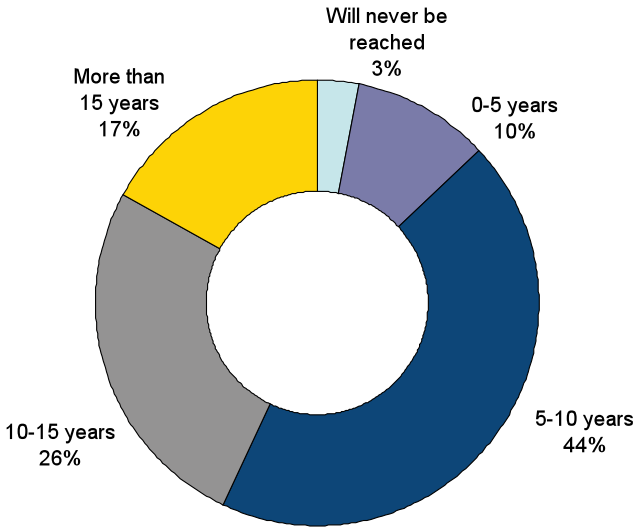


Source: United Nations Global Compact CEO Survey 2010, 2007 data from McKinsey UN Global Compact Survey

Management feels that the tipping point is only a decade away–80% believe it will occurr within 15 years.

Consumers – as well as business and government customers – are increasingly central to company sustainability strategies.

Projected Time Before Sustainability is Core Business Strategy for Majority of Global Companies



Source: United Nations Global Compact CEO Survey 2010

management and reporting. In each area, companies must transition from tactical, ad hoc and siloed approaches to strategic, systematic and integrated ones."[9]

This direction represents a shift, according to the UN Global Compact-Accenture study – and one that is being driven by three key factors[1]:

- Consumers – as well as business and government customers – are increasingly central to company sustainability strategies.
- Innovative, leading-edge technologies are advancing the sustainability agenda and increasing transparency through social media platforms.
- Partnerships and collaboration (e.g., with suppliers, non-governmental organizations, government agencies) are now a critical element in addressing sustainability issues. Seventy-eight percent of CEOs believe that companies should engage in industry collaborations and multi-stakeholder partnerships to accomplish development goals.

people
planet
profit
principles

The Plastics Landscape

A Snapshot of the Plastics Industry

Our Plastic Planet

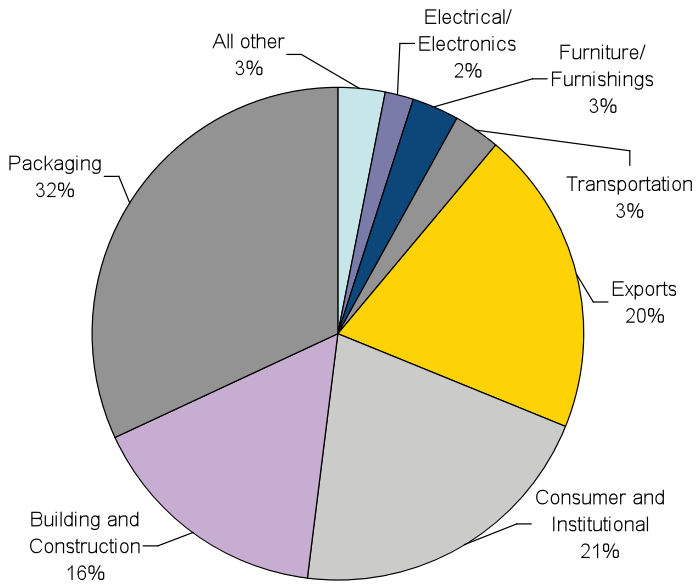
Minnesota is feeling the impact – and market potential of such innovative thinking. One dimension of this is in bioplastics, a family of products that can vary considerably in form and function, yet offers strong potential for growth.

Plastics play an important role in almost every aspect of our lives, from the cars we drive to the beverage containers, household items and furniture we encounter every day. The largest category of plastics is found in containers and packaging (e.g., soft drink bottles, lids, shampoo bottles), but the material is also prevalent in durable (e.g., appliances, furniture) and nondurable goods (e.g., diapers, trash bags, cups and utensils, medical devices).

Pike Research estimates that the worldwide market for all

The widespread use of plastics is expected to grow, as are governmental and consumer demands for more ecologically friendly manufacturing and end-of-life processing.

Percentage Distribution of Thermoplastic Resins
2009 Sales & Captive Use by Major Markets



Resins Comprising Market Distribution:

Low-Density Polyethylene (LDPE)
High-Density Polyethylene (HDPE)
Polypropylene (PP)
Polystyrene (PS)
Styrene Butadiene Latexes (SBL)
Polyvinyl Chloride (PVC)

Source: ACC Plastics Industry Producers' Statistics Group, as compiled by Veris Consulting, Inc.

types of packaging is currently valued at $429 billion, an annual growth rate exceeding the total global increase in GDP. "We forecast the market to surpass $500 billion in sales within five years," 2009 findings indicated.[2]

The demands on packaging have continued to increase as the global population grows, challenging industries to react to issues that were rarely considered in the past. The energy required to manufacture packaging, and the pollution created during the process, were not high priorities in years past. Now these factors – along with what to do with bags, containers, etc. once they have fulfilled their function – have grown in concern.

Whether for packaging or other purposes, the widespread use of plastics is expected to grow, as are governmental and consumer demands for more ecologically friendly manufacturing and end-of-life processing. In particular, disposal of plastic products has been an increasing issue. According to 2000 Environmental Protection Agency (EPA) statistics, Americans discard more than 3.3 million tons of low- and high-density polyethylene bags, sacks and wraps alone.[10]

Consider these facts[10]:

• In 2008, the United States generated approximately 13 million tons of plastics in the municipal solid waste (MSW) stream as containers and packaging, almost 7 million tons as nondurable goods and nearly 11 million tons as durable goods.

• Over 380 billion plastic bags, sacks and wraps are consumed in the U.S. each year.

• The total amount of plastics in the MSW stream – about 30 million tons – represented 12 percent of total MSW generation in 2008 – a twelve-fold increase since 1960.

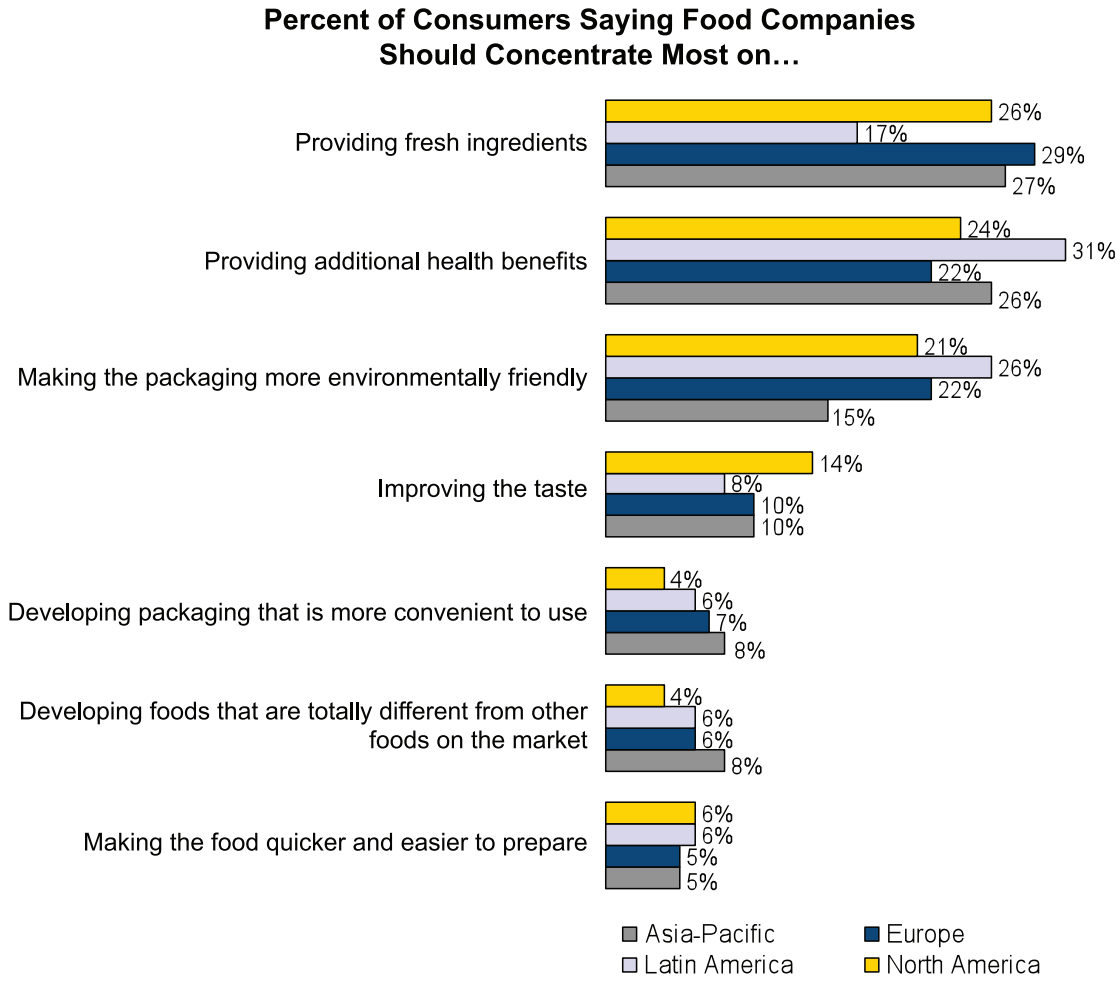
Plastics are recycled for both economic and environmental reasons, though overall recovery of the material for recycling is still relatively small – just over two million tons, or 6.8 percent of plastics generation in 2008. Recycling of some containers such as soft drink bottles reached levels as high as 37 percent, however.[10]

Consumer Concern

For years, environmentalists have promoted degradable plastics along with recycling as the answer to escalating municipal solid waste disposal and litter problems. While recycling has risen in popularity, the use of degradable bioplastics has lagged far behind due to cost, performance and other considerations.

Consumers, however, continue to apply pressure. In a 2009 study by Ipsos Marketing, 21 percent of North American consumers surveyed said food companies should concentrate on making packaging more environmentally friendly, compared to 14 percent who said the focus should be on improving how food tastes. Support for green packaging from other global regions was similarly strong: Latin America, 26 percent; Europe, 22 percent; and Asia-Pacific, 15 percent.[11]

Though consumer support for more environmentally friendly products is significant, there are critical issues affecting broad market acceptance of bioplastics. Confusion about materials and terminology, product labeling, and product end-of-life alternatives are just a few of the questions needing to be addressed.[12]



Source: Ipsos Marketing

Bioplastics Defined

Biobased plastics have experienced a renaissance.

Biobased polymers have been used in furniture and clothing for thousands of years, with the first artificial thermoplastic polymer (celluloid) invented in the 1860s. Since then, numerous compounds derived from renewable resources have been developed, but were overshadowed with the large-scale industrial use of crude oil in synthetic polymer production during the 1950s.[13]

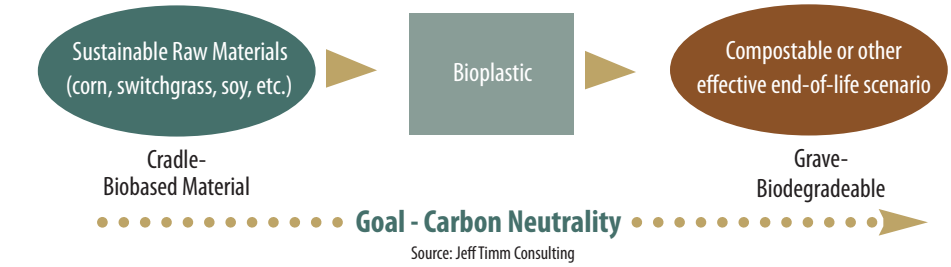
In recent years, however, biobased plastics have experienced a renaissance. Many new polymers from renewable feedstocks have been developed. According to the University of Hannover, there are now more than 300 types of bioplastics made – at least in part – from such materials as corn, sugar cane and starch.[14]

Technically, bioplastics are not a single class of polymers, but a family of products that can vary considerably. European Bioplastics, among other sources, regards such material as having two differentiated classes:

- Plastics based on renewable resources; and
- Biodegradable polymers that meet scientifically recognized norms for biodegradability

and compostability of plastics and plastic products.

Bioplastics Value Proposition



Source: Jeff Timm Consulting

While most bioplastics are biodegradable, this is not always the case. Biodegradability is defined by the chemical structure rather than the origin of the raw materials. As a result, there are synthetic polymers that are considered biodegradable. As well, traditional petroleum-based plastics can be biodegradable.

There are differences between biodegradable and compostable plastics. A claim that a product or package is degradable, biodegradable or photodegradable signifies that the entire product or package will completely decompose into elements found in nature within a reasonably short period of time after customary disposal. A compostable product indicates that the product or package will become usable compost (e.g., soil-conditioning material, mulch) in a safe and timely manner through an appropriate composting facility or in a home compost pile.[15]

Market Interest

Momentum is Building

Big Brands Adopt Bioplastics

In an effort to drive sales, attract new customers and – companies claim – do what is environmentally responsible, more and more companies across the United States are looking for ways to package their products using recycled or renewable materials.

In 2011, Nestle Purina® PetCare's Purina One® beyOnd™ reportedly will use a cornstarch-based polylactic acid lining in its bags as a replacement for petroleum-based material. As Purina explains on its website, "Our commitment requires that we produce high-quality, nutritious pet foods in a caring and responsible way. That's where environmental sustainability comes in. We're working with stakeholders inside and outside the company, up and down the supply chain, to find solutions that are good for the environment and good for our business."[16]

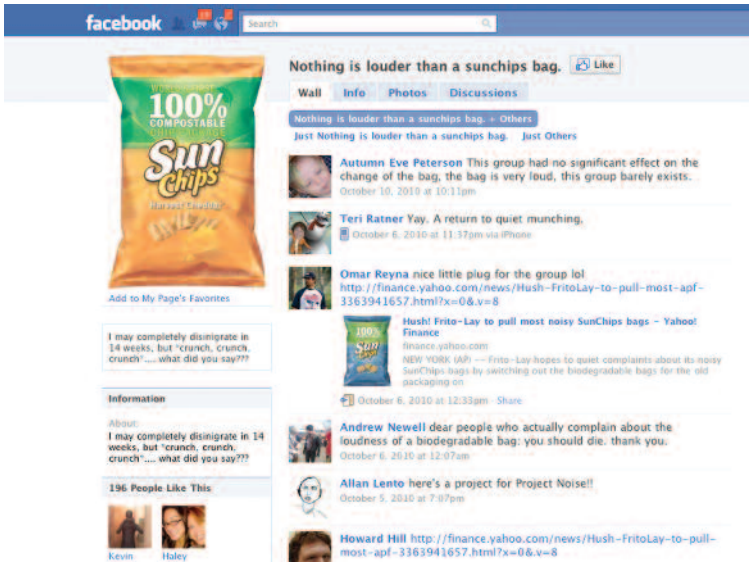
"Consumers are really looking to associate themselves with brands that have a cause beyond the product itself," said Nestle Purina® Brand Manager, Heather Scott, in an article published on STLToday.com.[17]

One of the challenges, the article noted, is for companies to find ways to tap consumer demand for greener packaging without raising prices. "Our research says customers won't pay more for it," James Glenn, President and CEO of Household Essentials, a Missouri company that makes laundry and storage products, was quoted as saying.[17]

There are other issues along the corporate journey toward using biobased packaging materials.

Dallas-based Frito-Lay®, which is owned by PepsiCo, introduced a biodegradable PLA bag in 2009 for all six of its SunChips® flavors. Months later, the company reverted most of the line back to its standard packaging because consumers said the starch-based compostable bags were too noisy.

The initial launch promoted the fact that the bags were compostable because they were made from plants versus plastic. But the technology Frito-Lay® used to make the packaging resulted in a bag that was stiffer than the plastic packaging – and louder. Customers complained, even creating groups on Facebook with names such as "I wanted SunChips but my roommate was sleeping..." and, "Nothing is louder than a SunChips' bag." Online videos reported that the bag was "louder than the cockpit of a jet," backed up by decibel level tests.[18]



Rather than being seen as insurmountable obstacles, however, such challenges are often considered part of the trial and error process involved in innovation. In Frito-Lay®'s case, rather than abandoning the new concept, the controversial biodegradable bags are still being used for packaging the original flavor while the company continues to work on a second-generation compostable version.

"We here at SunChips® are committed to developing sustainable packaging solutions that meet the demands of our snacks and our consumers," Frito-Lay® writes on its website. "We have several new compostable package options in the works that look promising and look for-

ward to introducing the next generation compostable bag to consumers in the near future."[19]

An industry success story that has been applauded by the Sustainable Biomaterials Collaborative (SBC), a network that has developed sustainability guidelines for biobased plastics along their entire lifecycle, is that of Stonyfield Farm. In October of 2010, Stonyfield, the world's leading organic yogurt company, announced the introduction of corn-based plastic for its multi-pack yogurt containers in conjunction with being the first major buyer of Working Landscape Certificates, a purchasable offset program that promotes sustainable corn production practices.

"Stonyfield Farm knows that how corn or other biomass used in plant-based plastics is grown is a major factor in whether or not the plastic is good for the planet," Brenda Platt, SBC, commented in a press announcement.[20]

Support for sustainability within the retail and manufacturing also isn't new. Years ago, Henry Ford used up to 60 pounds of soybeans in paints, enamels and molded plastic parts in his Model T. Plant-based plastic parts included steering wheels, dashboards and gearshift knobs. But lower-priced, petroleum-based products displaced these early bioplastics and have continued to command the marketplace for decades.[21]

Today, Ford is using soy-based polyurethane foams in select models. Toyota plans to replace 20 percent of the plastics used in its automobiles with bioplastics by 2015. The 2010 Lexus HS250h contains plant-based bioplastics to interior components including luggage-trim upholstery, cowl-side trim, seat cushions, door scuff plates and tool box areas. Mazda has developed a bioplastic console and seat fabric – and other automakers are adopting the use of bioplastics and biofoams in their designs at an increasing rate.[21]

According to SBC sustainability guidelines, to be considered green, biobased plastics must be derived from sustainably grown and harvested feedstocks, be manufactured without hazardous inputs and impacts, and be reused, recycled or composted at the end of their intended use. Working Landscape Certificates (WLCs) are a tool for bioplastic buyers to support complying farming systems.[20]

Minnesota-based Jim Kleinschmit, who directs the Institute for Agriculture and Trade Policy's (IATP) Rural Communities program and is a member of the Sustainable Biomaterials Collaborative (SBC), agrees.

"I think [the impetus behind biobased material adoption] is market demand, which is driven partly by consumers. Companies want to be part of change, especially one that's making a positive difference. But, I think it can also be driven by regulatory concerns. Some of these materials are better from the perspective of the end-of-life, since they can be composted and not landfilled. I think people are seeing the writing on the wall. If you look at Minnesota and the new requirements around using compostable bags for leaves and yard waste, it is only the beginning," says Kleinschmit.[22]

"Most Minnesotans have a strong interest in buying and using products that are biodegradable and environmentally friendly. The problem has been their inability to source products with those qualities for their homes and businesses," observes Dennis Timmerman, Senior Project Development Director at the Agricultural Utilization Research Institute (AURI).[23]

Kleinschmit says this interest could translate into positive economic impact. "At IATP, we believe bioplastics could be a real opportunity for Minnesota and the country's farmers, ranchers and foresters, as well as for rural communities looking at new manufacturing opportunities."[22]

In particular, Kleinschmit believes food service holds a particular market opportunity. "We are currently working on creating purchasing guidelines for institutions – such as schools and hospitals – that want to use disposable, single-use, compostable food ware (e.g., cutlery, plates). That type of product is not recyclable right now and, considering it is mixed with food, it actually has the ability to pull more organic material out of the waste stream if it is compostable. You can put it all in one spot - food and foodware - which makes everyone's life

"Bioplastics could be a real opportunity for Minnesota . . . as well as for rural communities looking at new manufacturing opportunities."
- Jim Kleinschmit, IATP

easier. As an institution and as 'eaters,' we don't have to confusedly try to sort everything out, so people are more likely to comply," he comments.[22]

According to Kleinschmit, the specifications, called "BioSpecs for Food Service Ware," should be available in 2011. He explains they are the product of a successful collaboration of leading researchers in bioplastics, plus organizations such as the Sustainable Biomaterials Collaborative and Business-NGO Working Group.[22] The specifications take into consideration the feedstock, toxicity and end-of-life requirements for products.[24]

"["BioSpecs"] is really for companies that want a quick scorecard to see who is actually meeting the claims that they are making," Kleinschmit continues. "They range from the basic, 'Is it compostable and biobased?' to 'Is the base material more sustainable or not from a feedstock perspective?' and 'Are there other materials in the product that impede its ability to degrade or safely compost?' These criteria are primarily for institutions, but could be for anyone who wants an assessment for a specific line of products."[22]

Retailers are also taking forward-thinking positions on the issue of sustainability. Mass merchandiser Target Corporation actively promotes its "green" commitment, writing on the company website: "...we are continually 'rethinking' our merchandise assortment to lessen impacts on our communities, our environment and our bottom line. Many of our categories include products made from recycled materials, non-toxic chemicals or all-natural ingredients ... We are also specifying more environmentally friendly packaging applications for our private-label brands. We will continue to evaluate and expand our eco-friendly products based on market availability and guest preference."[25]

Target is a member of the Sustainable Packaging Coalition, in part to gain an understanding of how the company's packaging needs can meet sustainability requirements.

In 2006, Target dedicated a packaging team to help make recommendations on more sustainable choices for Target-brand material and/or reduce packaging where feasible. The company indicates that it continues to look for opportunities to source packaging materials that are recyclable, made with recycled content, biodegradable or biocompostable, made with renewable resources, manufactured using renewable energy or using less nonrenewable energy, or sourced from companies practicing responsible harvesting.[25]

Relative to bioplastics, Target indicated that, "We have introduced six PLA packages in the bakery and deli areas in our SuperTarget stores and will look at expanding the use of PLA ... as additional supply becomes available."[25]

Target also introduced a corn-based gift card in December 2005, using resins made from renewable resources.[25]

In October 2010, Canon Inc. and Toray Industries, Inc. announced the development of the computer printer industry's largest exterior part using biobased plastic. The newly developed part is approximately 11 times larger and 6.5 times heavier than the previously realized largest biobased plastic part that achieved the same level of flame-retardance – a significant achievement that, until now, had not been possible in parts of this size due to challenges with moldability and flow characteristics.[26]

John Deere introduced bioplastics in selected

exterior panels some 10 years ago. Soy-based foam cushioning is expected to be in equipment beginning in 2011. According to Jay Olson, Global Materials Engineering Manager for John Deere, polyethylene for sprayer and seeding tanks will likely be the next component to go biobased.[27]

"Sustainability is the new buzzword for everything that pertains to design for the environment, recyclability, biodegradability, energy, lifecycle analysis, energy balance. Everything comes under the umbrella now of sustainability," says Olson.[27]

"At Deere, sustainability is a new and strategic initiative to support our business customers in their products to increase their productivity and their impact on the environment," Olson says. "If we can, through our products, provide solutions for our customers to reduce the impact on the environment for total sustainability, both environment and energy, that's where the future is in all of our products. One piece of that is the materials that we use to manufacture in our vehicles."[27]

Olson says that the company's strategic plan is aligning with the signature color of its equipment – driven in large part by the fact that Deere serves an agricultural marketplace whose products are used in biobased materials. "It is part of our strategy to support sustainability, a business strategy, so it's one of the metrics that we will be measuring, but it's a long journey. Even though we've been literally a 'green' company for a long time, now it is part of our strategic business plan...and it will be part of our decision analysis for everything that we do – not just material selection, but manufacturing operations and product design. We'll make decisions on how to make the largest impact for our customers on the use of their products."[27]

According to Olson, there are two primary reasons that a company might want to consider using biobased materials. "First, do you want to take a leadership role now at the infancy? And do you want to do the right thing for the world, for your customers, or do you just want to ap-

Photo courtesy of John Deere

John Deere introduced bioplastics in selected exterior panels some 10 years ago. Soy-based foam cushioning is expected to be in equipment beginning in 2011.

"Do you want to do the right thing for the world, for your customers, or do you just want to approach it as just another material substitution?"
- Jay Olson, John Deere

Larger-ticket items also allow for the introduction of bioplastics at a scale that does not necessarily result in a higher price to the end customer.

proach it as just another material substitution?"[27]

He says that a manufacturer can explore biobased materials as a simple materials substitution – or as a broader strategy for the company. Olson adds, "You have your design, test and build cycle that you go through to put a product into production, so you've got two positions to take. Look at it as just another material that adds value based on cost alone...or do you want to create a policy that makes sustainability part of your overall business strategy?"[27]

Larger-ticket items also allow for the introduction of bioplastics at a scale that does not necessarily result in a higher price to the end customer. "On a $10 item in a $300,000 tractor, you can't tell the difference. But, in spray foam for a house, the foam represents a significant portion of the cost. So, it's not necessarily the fact that there is a soy-based product being used, it's also related to the application," says Sam Ziegler, Senior Director of Field Services for the Minnesota Soybean Board.[28]

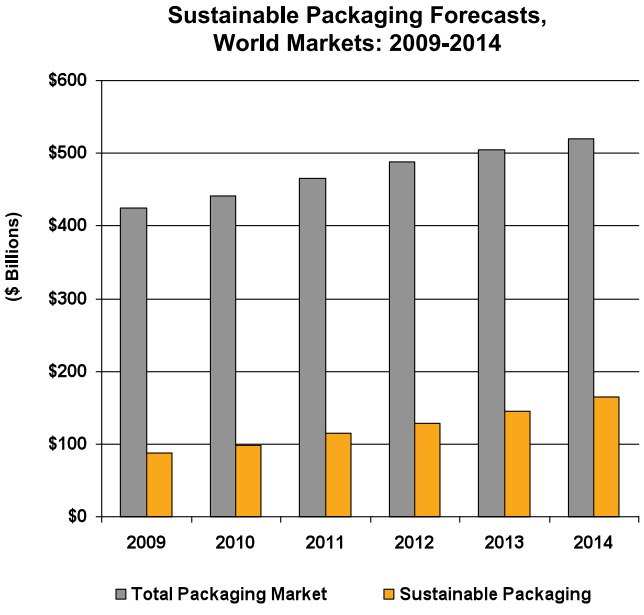
Sustainable Packaging Gets Traction

According to a recent study by Pike Research, sustainable packaging is projected to grow to 32 percent of the total global packaging market by 2014, up from just 21 percent in 2009. Plastic-based packaging, which represents 35 percent of all materials used, will be the fastest-growing sector within the sustainable packaging market over the next five years, the report indicated. Metal-based packaging, one of the easiest materials to recycle, will continue to be the sector with the highest percentage of sustainability, however, with more than 63 percent projected to be environmentally friendly by 2014.[2]

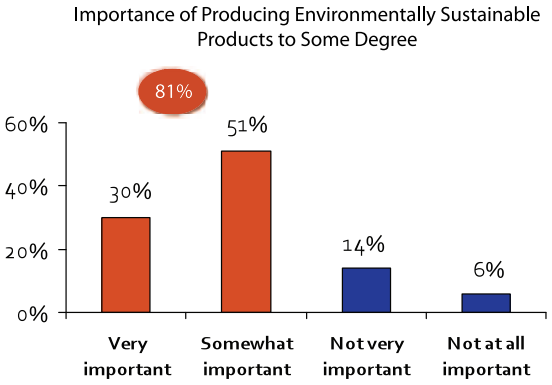
When it comes to the issue of developing more environmentally-friendly packaging, some companies focus on weight reduction, believing it provides a reasonable proxy for sustainability through lower raw material inputs, reduced transport, less waste and lower CO2 emissions. But an emphasis on weight alone can have negative consequences, including greater waste if the packaging becomes too fragile.[29] Simply switching to lighter packaging is not a silver bullet, according to the Sustainable Packaging Coalition (SPC), that urges manufacturers to think smart about packaging rather than simply thinking light.[8]

Other companies use life cycle analysis to help measure sustainability, a strategy that can be hindered if there are not commonly agreed upon measurements. To support an effective industry response, experts say, there is a need for common metrics and definitions on how companies measure the sustainability of their packaging.[29]

"... the move toward sustainable packaging represents a broad-based effort by manufacturers, retailers, industry groups, and governments to promote the design of minimal packaging that can be easily reclaimed. A tremendous amount of innovation is going into reducing en-



Source: Pike Research



Source: Russell Herder Renewable Materials Survey, 2010

ergy requirements to manufacture packaging and also to using more recyclable and compostable materials, but there is still a long way to go," said Pike Research President Clint Wheelock.[2]

Jim Lunt, Managing Director of Jim Lunt & Associates, LLC, agrees that more and more people are indicating a desire for renewable plastics. "They do not want oil-based, depleting, toxic materials. They don't completely understand what sustainability really means, but they believe it means something good – and they want that."[30]

Minnesota plastics manufacturers are clearly getting that message. In a November 2010 survey, just over half said consumer interest in environmentally friendly packaging and products will impact their operation – and that it is consumer demand that makes them more receptive to using such materials. Further, 81 percent said that it is important, at least to some degree, for their business to produce environmentally sustainable products.[3]

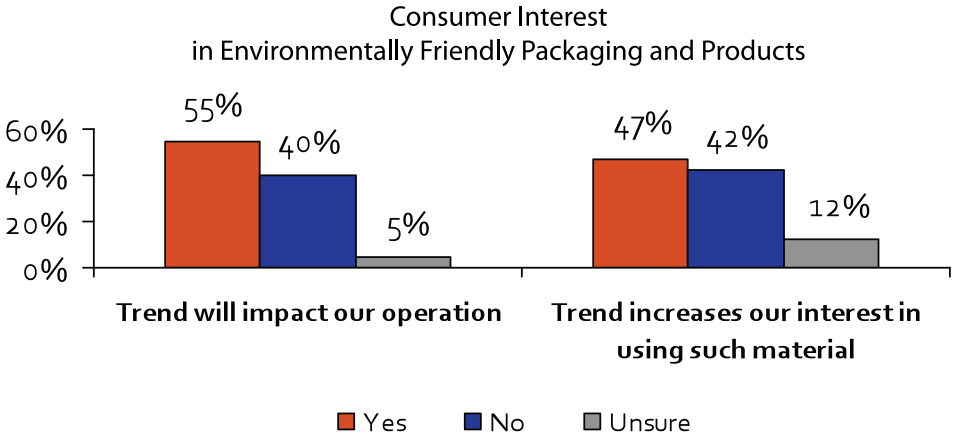
Growth Forecasts

U.S. biobased plastics capacity was 260,000 tons in 2007 with 80 percent of it biodegradable, reported Deloitte Consulting and the BioBusiness Alliance of Minnesota in "Destination 2025: Focus on the Future of the Renewable Materials Industry." This was expected to grow to 1,460,000 tons in 2011.[31]

Growth in bioplastics is being driven by a number of factors: an interest in reducing dependence on foreign oil supplies, environmental concerns related to pollution and landfills, global warming and human health issues related to toxic chemicals emitted by petro-based plastics. These factors are driving legislation around the world, which is creating markets for bioplastics through mandates, public policy and waste reduction initiatives.

"They don't completely understand what sustainability really means, but they believe it means something good – and they want that."

- Jim Lunt, Jim Lunt & Associates



Source: Russell Herder Renewable Materials Survey, 2010

For example, the Japanese government has set a goal that 20 percent of all plastics consumed in that nation will be renewably sourced by 2020. The federal farm bill in the United States requires that each federal agency design a plan to purchase as many biobased products as practically possible – and that federal procurement will be based on biobased content, price and performance.

According to Jim Lunt, global demand for bioplastics is projected to grow more than four-fold to 900,000 metric tons by 2013 – and global production will increase six-fold to 1.5 million metric tons by 2011 (up from 262,000 metric tons in 2007). More importantly, global production capacity is projected to increase from 360,000 metric tons in 2007 to about 2.3 million metric tons in 2013. In spite of this growth, bioplastics still represent only about one percent of the approximate 230 million tons of plastics in use today.[32]

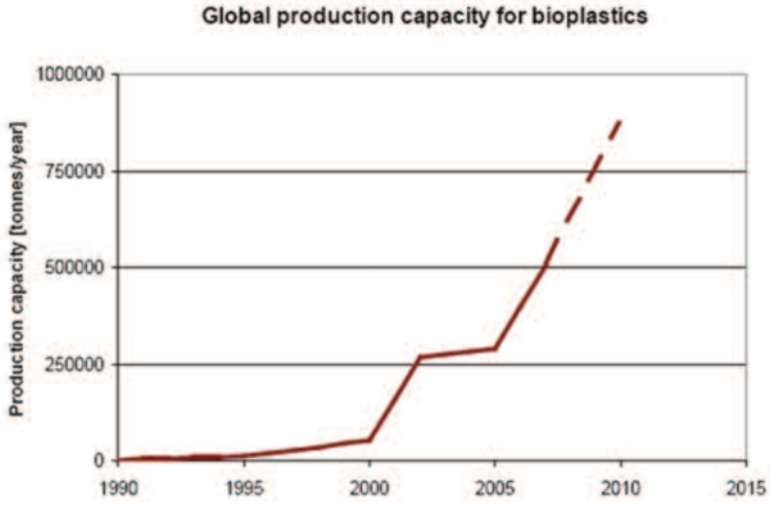
Expense and lack of sufficient quantity have limited sector growth. A study by The Freedonia Group, however, has forecast annual increases of 11 percent for degradable plastics through 2014. Although representing less than one-half of one percent of all thermoplastic resin demand in 2009, substantial growth opportunities appear to be on the horizon.[33]

According to the Freedonia Group, degradable plastic advances will be fostered by their increased cost competitiveness with petroleum-based materials, as well as their sustainability and friendlier environmental profile. "Degradable plastics demand is being broadened by enhanced performance properties brought about by more sophisticated polymerization and blending techniques. Testing and certification standards have also been established for many types of biodegradable plastics, with growing pressures to limit packaging waste and expand the composting infrastructure," the report summary noted.[33]

The Freedonia Group indicated "polylactic acid (PLA) will grow at the fastest pace through 2014, driven by a more competitive price structure and greater availability. Starch-based plastics will have a good outlook as a result of improved resin blends and applications in such areas as compostable yard and kitchen bags, and food service items such as plates, bowls and cutlery."[33]

Demand for polyhydroxyalkanoates (PHAs) plastics and products are projected to also increase, in such areas as films and molded containers.[33]

According to "Disposable Bioplastics," a market opportunity study issued by the United Soy-



Source: BioPlastics24.com, "Bioplastic Market – An Overview"

MARKET DEMAND FOR BIO-BASED PLASTICS

	2005[2]	2007[3]	2011[3]	'07-'11 CAGR[3]
Films /Bags	117	200	359	15.8
Ring Carriers[1]	40	42	51	4
Loose fill/Foam	16	17	20	4
Food service	7	17	31	16
Molded	28	46	123	28
Fiber	5	11	50	46
Total	213	333	634	17.5

1) Currently ring carriers are made from a photodegradable polyethylene, it is assumed that this product will switch to a bioplastic that is degradable by 2011.
2) Freedonia Group, Degradable Plastics Demand to 2010
3) Omni Tech estimates, based on industry communications

(Source: United Soybean Board, "Disposable Bioplastics Consumer Disposables Agricultural Films: A Market Opportunity Study," Phil Sarnacke and Stephen Wildes, April 2008)

Growth of bioplastics in the United States is estimated to be 19 percent per year through 2011.

bean Board (USB), the growth of bioplastics in the United States is estimated to be 19 percent per year through 2011, reaching a projected consumption of over 600 million pounds. This increase is being driven by several factors, the USB study observed, including large retailers, such as Walmart and Target, requesting that their suppliers adopt bioplastics for packaging products they stock; consumer concern over the depletion of petroleum-based raw materials; desire of manufacturers to develop more sustainable raw material sources; improvement in properties of bioplastics; governmental support for biobased products; and the cost savings bioplastics represents over petroleum-based product.[34]

"Among the bioplastic applications, four uses have standout growth opportunities in the immediate future: biodegradable bags/films; biodegradable plastic foam cushioning blocks; bioplastic fibers, degradable and non-degradable; and bioplastic molded products, degradable and non-degradable," the USB report forecasted.[34]

In Minnesota, two-thirds of plastics manufacturers surveyed in a recent industry study said they believe the use of biobased material will become more prevalent in the next three years. Forty-one percent said that doing such could also make their processes safer for employees and the community.[3]

To ultimately be successful, industry experts say bioplastics will need to meet the cost and performance requirements of petroleum based products, meaning such potential issues as heat deflection and brittleness must be addressed.[34]

While the future looks promising for bioplastics, experts agree that there are issues. Bioplastics can be inefficient to create, possibly using almost as much energy as plastics made with fossil fuels. At the same time, such products can release less carbon dioxide into the atmosphere.

Some experts, such as Helmut Kaiser in "Bioplastics Market Worldwide 2007-2025," predict bioplastics has the potential to reduce petroleum consumption for plastic by 15 to 20 percent by 2025. "Improved technical properties and innovations will open new markets and applications with higher profit potentials in automotive, medicine and electronics," the report

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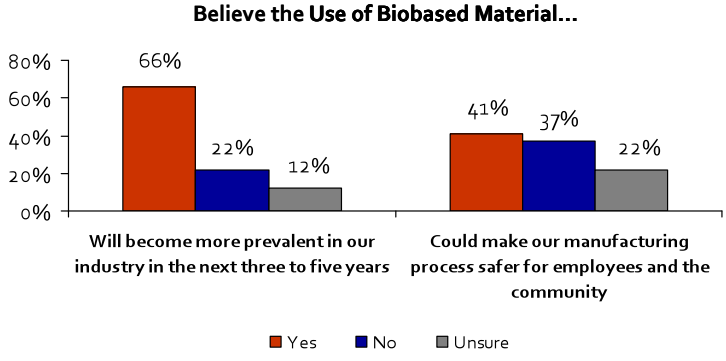
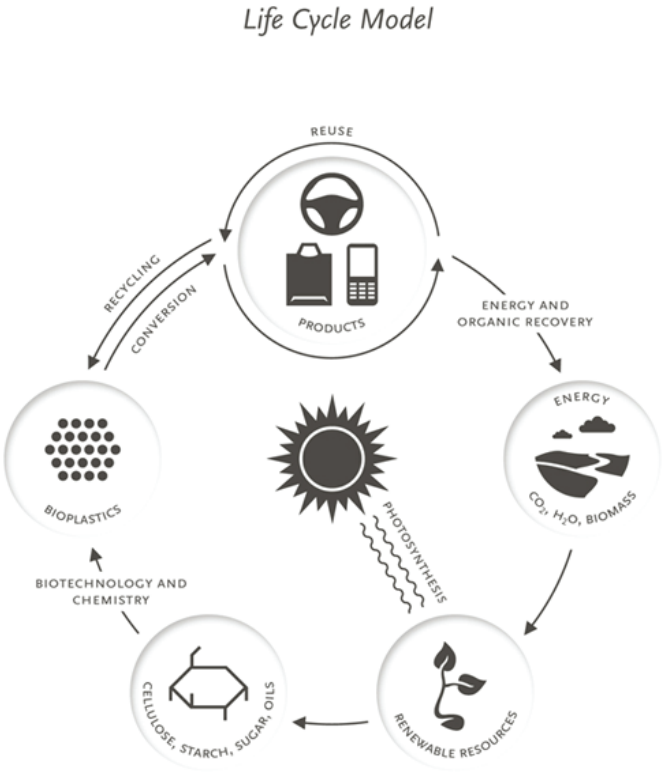


Source: Russell Herder Renewable Materials Survey, 2010



(Source: European Bioplastics, "Bioplastics at a Glance")

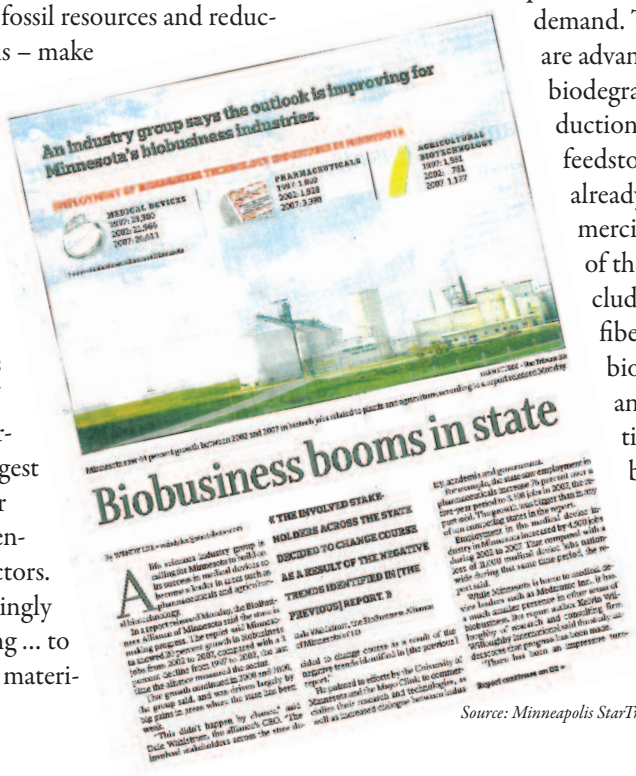
Meeting demand will require industry adoption and capacity building.

stated.[35]

European Bioplastics agrees, going on record saying, "The crucial point is the utilization of renewable resources. Bioplastics' great advantage – the conservation of fossil resources and reduction in CO2 emissions – make them one of the most important innovations for sustainable development. Plastics, with their current global consumption of more than 250 million tons and annual growth of approximately five percent, represent the largest field of application for crude oil outside the energy and transport sectors. It is becoming increasingly important and pressing ... to utilize alternative raw materials."[36]

"Petroleum-derived plastics have become ubiquitous in human society; however, their production from nonrenewable sources, contribution to greenhouse gas emissions and permanent presence in the environment after discard demand an alternative solution that is both environmentally friendly and sustainable," wrote John Barrett and Friedrich Srienc, both from the Department of Chemical Engineering and Materials Science at the University of Minnesota.[37]

"Both PHAs and polylactide show significant potential for meeting this demand. These materials are advantageous for their biodegradability and production from renewable feedstocks, and both are already available commercially. Applications of these materials include packaging, fibers for textiles, biomedical materials and protein-functionalized biobeads."[37] It is important to note that soy-based polyols are also being used to replace petroleum-based


An industry group says the outlook is improving for Minnesota's biobusiness industries.

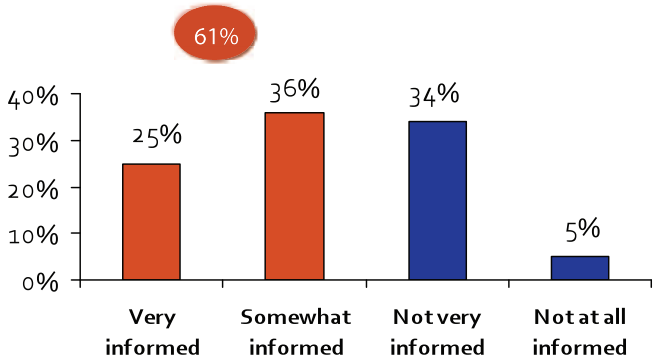
Biobusiness booms in state

Source: Minneapolis StarTribune

sources in foams, lubricants, inks, paints, construction materials and other applications.

Meeting demand, however, will require industry adoption and capacity building. What is clearly lacking now is sufficient industry awareness. Thirty-nine percent of Minnesota plastics manufacturers say they feel uninformed about the uses and opportunities for biobased material. Eight in 10, however, say they are interested in learning more.[3]

How Informed Are You about Biobased Material Use and Opportunities in Your Industry?



Source: Russell Herder Renewable Materials Survey, 2010

Market Drivers

It's About Oil . . . and Much More

Replacing Petroleum

Numerous factors appear to be driving growth within bioplastics. The most significant, according to Doug Cameron with Alberti Advisors, is the cost of oil. "I think a lot of it is an expectation that petroleum prices will continue to rise, and petroleum will be very unstable in price and will be challenging to economics," he says. "I think the biggest driver for the chemical industry is the uncertainty in petroleum price and the feeling that the biomass or sugar prices will stabilize and maybe be lower in the long-term."[6]

Cameron notes that market pull from juggernaut retailers, such as Target and Walmart, is also influencing the amount of biobased content in plastics. On the other hand, he does not believe that biodegradability is a significant market driver. "I think biodegradability is a niche opportunity, but I think it's more about the ability to lower costs and finding better feedstock supply situations."[6]

According to a December 2008 document on their corporate website, Walmart noted that select produce packaged in corn-based NatureWorks PLA can be found in all Walmart stores and Sam's Club locations, including vegetable and fruit trays and bags. Walmart also hosts an annual Sustainable Packaging Exposition that brings together product suppliers and packaging suppliers to discuss sustainable packaging innovations and options.

Numerous factors appear to be driving growth within bioplastics . . . the most significant being the cost of oil.

Foam trays from Dyne-a-Pack *(Photo courtesy of NatureWorks, LLC.)*

"I think the markets drive what happens. People look at the price tag of the object they are going to buy – and that decision whether or not to buy, feeds its way back up through the value chain – and that will influence whether it comes from a plant source or a petroleum source, based on the price of that source," says Paul Rothweiler, Vice President of Sales and Marketing of Aspen Research.[38]

Headquartered in St. Paul, Aspen Research/Aspen Materials is a hybrid of research and development, consulting and product development. Aspen works with companies to develop new products and materials, processes and technologies – and to improve efficiencies and profitability.

According to Rothweiler, Aspen is not totally focused on biobased materials, however. "We continue to modify PLA for a number of clients – some large and some small."[38]

In 1997, Aspen was purchased by Andersen Windows, which had done research and development business with Aspen to create ways to channel waste streams of plastic and wood from their core operations in value-added products. The resulting material technology, called Fibrex™, resulted in a superior window product in terms of performance that become the Renewal by Andersen™ line of windows. At the time of the interview, Aspen was in the process of being acquired by one of its clients – a company that makes PLA-composite biodegradable pots for plants that allow consumers to plant "pot and all" without disturbing the root system. Andersen will continue to be a client of Aspen.

The company has drawn on the talent that exists in the metropolitan area with a history of innovation on a national and global scale. "Most of the employees here worked 15 to 20 years in a Fortune 500 company before they discovered Aspen and came here to work," Rothweiler says.[38]

"Purchasing agents are going to have an interesting role going forward, because it no longer is going to be just comparing one petroleum-based source to another petroleum-based source. They are going to have a very large palette of materials to choose from when determining what they need to purchase for making the products consumers want to buy," Rothweiler adds.[38]

Biobased/agricultural sources are not the only avenue being explored in an effort to replace petroleum-based plastics. Boston-based Novomer – a spin-off of Cornell University – is a chemical company using carbon dioxide and carbon monoxide to make plastics, which are very competitive to bioplastics in terms of environmental impact. Novomer claims its proprietary catalyst technology can be used to manufacture polypropylene carbonate (PPC), which is used to make plastic packaging and coatings – and that its process uses 50 percent less energy than traditional plastics manufacturing. The company also has shown it can leverage existing manufacturing infrastructure.[39]

Biobased plastics, derived from starches and sugars in traditional Minnesota crops, are going to find tough competition from products derived from sugar cane. In May 2009, The Coca-Cola Company unveiled a new plastic bottle made partially from plants. The PlantBottle™ is made of 30 percent plant-based material, derived from sugar cane and molasses and turned into a key component for PET plastic.[40]

According to a company press release, the bottle can be processed through existing manufacturing and recycling facilities without contaminating traditional PET.[40]

Coca-Cola critics, however, say that adding too much bioplastic into plastic recycling streams could contaminate recyclables and frustrate recycling efforts.[41]

"I doubt Minnesota ethanol producers are going to want to get into making ethylene glycol for the Coke bottle because the price is a lot cheaper in Brazil," says Doug Cameron of Alberti Advisors.[6]

Human Health Concerns

Studies have demonstrated that polycarbonate bottles – the hard, clear-plastic type – can leach biphenyl A (BPA), a chemical that turns on estrogen receptors in the body. But, a 2009 study by M. Wagner and J. Oehlmann entitled

Biobased plastics, derived from starches and sugars in traditional Minnesota crops, are going to find tough competition from products derived from sugar cane.

"If it has the same performance, better cost and better environmental footprint, then it becomes an easier decision to switch."
- Ben Wallace, Marvin Windows and Doors

"Endocrine Disruptors in Bottle Mineral Water: Total Estrogenic Burden and Migration from Plastic Bottles" indicates that bottles made from polyethylene terephthalate (PTE) may also affect estrogen levels with its "hormone-mimicking" activity. The implications on reproductive health, embryo development and the overall human endocrine system are profound.[42]

John Souter of Accent Signage Systems, Inc. notes that there are a number of studies on indoor air quality and children's health at school. "Indoor air quality, as you know, is a function of what particles are in the air, such as molds and spores that come from either internal or external sources. But, what is not so often understood is, there are also emissions from materials such as formaldehydes, etc., which is a big deal," Souter says. "Several case studies published recently indicate that controlling indoor air quality has increased children's ability to learn, primarily because they have fewer sick days. I honestly think that is going to be something of a driving factor, especially with the National Green School movement, as well as promotions by USGBC." Souter adds.[43]

Completed ADA compliant signage made entirely of NatureWorks Grafica™ materials. (Photo courtesy of Accent Signage)

Virtually all of the current four billion square foot decorative laminate market in the United States (i.e., high pressure laminates, thermofoils) are derived from hazardous and toxic formaldehyde or PVC materials. Formaldehyde is a known cancer-causing agent, and regulations are tightening on any formaldehyde-emitting products. These current products are in wide use in homes, offices and commercial locations.

Biobased material technologies can be positioned to create higher value by displacing current "nonrenewable and hazardous" petrochemical products with an authentically green and renewable solution.

Biovation is a Minnesota-based company focused on new generations of laminates and decorative, digital technologies and structural composites to replace high-pressure laminate products derived from formaldehyde resins. "We're talking to one large company that says formaldehyde is the next asbestos," says Mike Riebel, President of Biovation. "To come up with a green, zero-formaldehyde solution, the BioSurf™ technology we have developed is the best solution."[44]

Manufacturer Acceptance

While interest in biobased products – and the technology to produce them – clearly exists, industry purchasing demand has been cautious within some sectors. Marvin Windows & Doors, a Minnesota-based company with a stated commitment to improving resource productivity while lowering environmental costs, sees both opportunities and challenges in using such products.

"We are trying to use more sustainable materials and processes. On the material side, petroleum-based polymers are not typically going to be the most sustainable option, but sometimes their durability makes them the more sustainable option. There are some materials that are going to be hard to replace because they are very robust and have a fairly good environmental footprint, even if they are petroleum-based. But there are other applications where biobased materials may be the best choice. If it has the same performance, better cost and better environmental footprint, then it becomes an easier decision to switch," says Ben Wallace, Wood Scientist at Marvin Windows and Doors.[45]

Wallace adds, "Our primary material is wood, the original biobased material. Wood has been

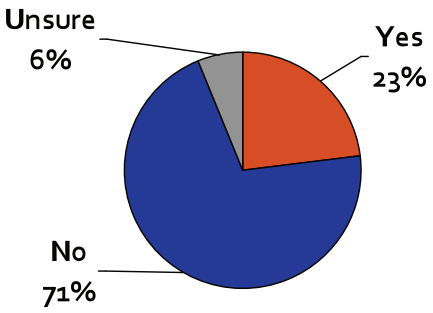
around forever and often remains the best performance choice. Biobased materials using resources such as corn or wheat are typically meant for interior applications; they do not have good moisture resistance. That is changing; they are getting better. We will continue to look at them, but currently we are not using anything that has not been an existing biobase for years."[45]

According to Wallace, there are some in Marvin's industry sector that are using wood-plastic composites, largely still incorporating petroleum-based plastics, however. "As far as agriculture-based, there is not much out there. My guess is that it is going to come into adhesives first. As of yet, they really do not have that long-term moisture durability for exterior exposure down," he says.[45]

The landscape does, indeed, appear to still be developing. Seven in 10 Minnesota plastics manufacturers say they are not aware of anyone in their industry incorporating biobased material into their operation to a significant degree – hence, why end users may not be seeing a proliferation of options at this point.[3]

Researchers such as Marvin's Ben Wallace maintain a deep interest in reviewing new technologies and materials, trying to determine if – and when – to integrate them into production.

Awareness of Industry Manufacturers That Have Incorporated Biobased Material to a Significant Degree



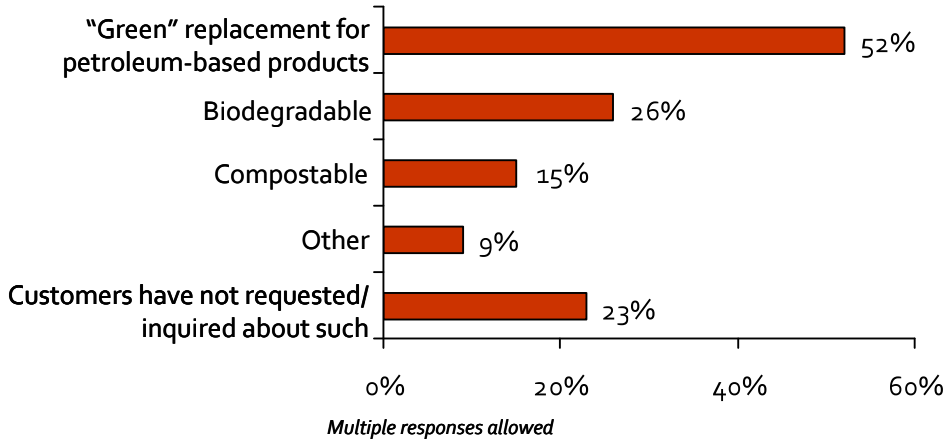
Source: Russell Herder Renewable Materials Survey, 2010

"For instance, a sealant injection mold is a very small component of our window. The part has to work, it has to work well and it has to last. The second is going to be what it is made out of and the cost. Those will have to balance. If it is an equal cost, it is pretty easy to choose the better, more sustainable biobased material assuming the performances are equal," Wallace says.[45]

Wallace adds, "Typically it is going to be a trade down, however, which is not going to work to have a long-term, durable product. Long-term durability affects our sustainability

Minnesota plastics manufacturers who could potentially supply companies such as Marvin have been getting inquiries – typically from end users that are seeking a "green" replacement for petroleum-based products.

Interest Areas of Customers Who Have Requested or Inquired about Products Made with Biobased Material



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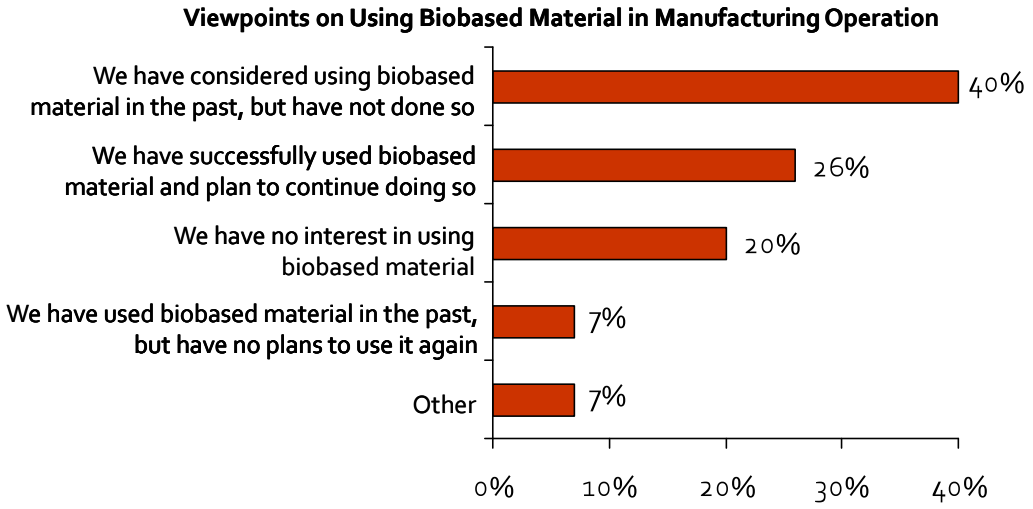
Source: Russell Herder Renewable Materials Survey, 2010

Nearly two-thirds of Minnesota plastics manufacturers anticipate increasing their use of biobased material.



Source: Russell Herder Renewable Materials Survey, 2010

more than the materials we use. If we are having to produce that part two or three times in a life cycle of a window to replace it, that is not going to be viable."[45]

Interestingly, the reverse is also true. Minnesota plastics manufacturers who could potentially supply companies such as Marvin have been getting inquiries themselves – typically from end users that are seeking a "green" replacement for petroleum-based products.[3]

The issues facing plastics manufacturers are in many ways similar to their customers; they want to be sure performance and economics are sound. While 40 percent of manufacturers say they have considered using biobased material in their operation, only 26 percent say they have successfully done so and plan to continue.[3]

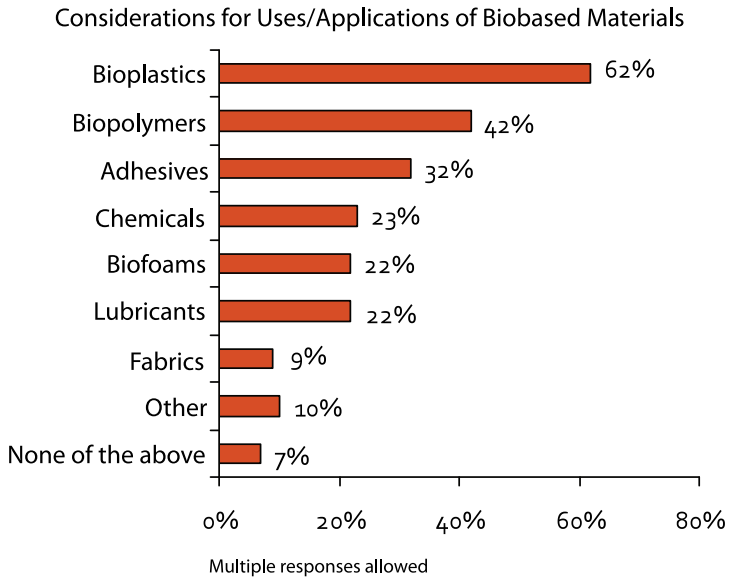
According to Jeremy Dworshak, Material Engineer at manufacturer Steinwall, Inc., the decision-making about whether to use biobased materials "is not in the processor's arena. The drivers of that decision are going to be the OEMs. That is why we are trying to get them on board and get buy-in with it. There are still unknowns with exactly how well they will perform in all aspects and applications that they could be used in."[46]

Looking ahead, however, nearly two-thirds of Minnesota plastics manufacturers anticipate increasing their use of biobased material throughout a range of industry subsectors – most predominantly, within bioplastics and biopolymers.[3]

According to Dennis Timmerman, Senior Project Development Director with AURI, that shouldn't be a surprise. "Minnesota's manufacturing and materials sector has always sought to employ innovative approaches to problem solving and identification of new opportunities," he comments.[23]

"The stars appear to be correctly aligned in respect to developing a biomaterials industry in Minnesota," Timmerman continues. "Our state's leading stakeholders are beginning to implement strategies to incorporate biobased materials in their product mix. AURI and its partnering organizations are seeing interest from a wide spectrum of the manufacturing sector to build biobased components to address environmental considerations of their customers. To successfully achieve growth in this arena will require a willingness to engage a strategy of trial and error within their respective industries."[23]

Jim Albrecht, President of ComDel Innovation in Wahpeton and Fargo, ND, says that the key to bringing biobased products to market is to "find an avenue to get there and do so economically."[47]



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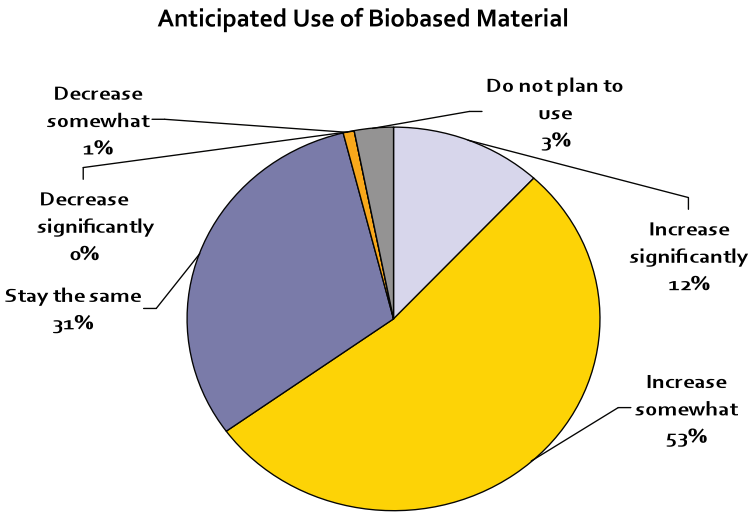
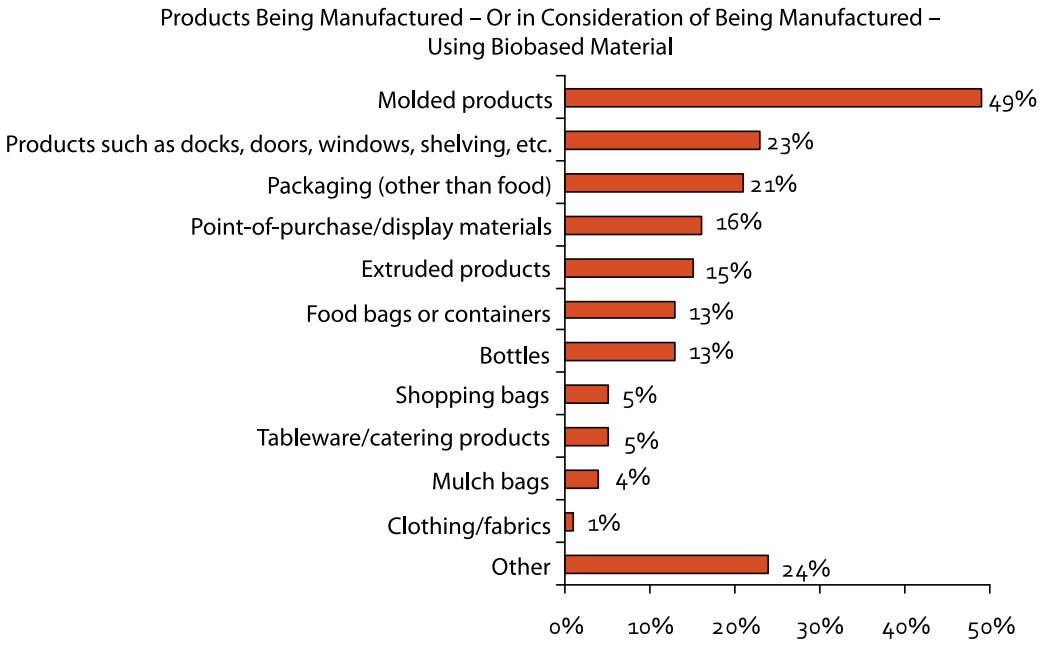


Source: Russell Herder Renewable Materials Survey, 2010

"In our business, we need to know where next generation technologies are coming from."
- Jim Albrecht, ComDel Innovation



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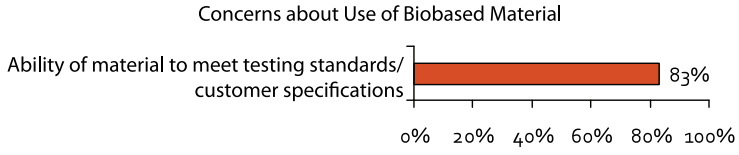

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Source: Russell Herder Renewable Materials Survey, 2010

"There will be interest [in bioplastics] as long as the performance is there."
- Ben Wallace, Marvin Windows and Doors

"In our business, we need to know where next generation technologies are coming from, which includes understanding where biomaterials are at and how we can turn these things into product. It really is just starting. It's evolutionary," Albrecht says.[47]

Biobased products that are currently being manufactured in Minnesota – or are in consideration to be – cover a broad spectrum, most predominantly within molded products.[3]

Given the need to appease technical and economic concerns of purchasers, companies promoting use of bioplastics to customers can face an uphill communication effort. Marketing, research and development are typically the primary entry points – each having equally critical consideration sets.

"There will be interest [in bioplastics] as long as the performance is there," Ben Wallace, Marvin Windows, concludes. "If performance is not in place, the manufacturers that build the products that go to market are simply not going to sacrifice performance to be biobased."[45]

From the plastics manufacturers' perspective, that viewpoint appears to be well understood. Most (83%) say that their primary concern in

producing bioplastics is the ability of material to meet testing standards and/or customer specifications.[3]

USDA BioPreferred Program

The federal government offers a significant market for companies offering biobased plastics and other biobased products. The BioPreferred program was created by the Farm Security and Rural Investment Act of 2002 (2002 Farm Bill), and expanded by the Food, Conservation and Energy Act of 2008 (2008 Farm Bill). The purpose is to increase the purchase and use of biobased products among federal agencies. The United States Department of Agriculture (USDA) manages the program.[48]

Under a cooperative agreement with the USDA, the Center for Industrial Research and Service at Iowa State University manages the database of biobased products for the BioPreferred program. According to Iowa State's Jessica Riedl, "We assist companies with submitting their product information to the program and help them get into the catalog of biobased products." That catalog is used by Federal agencies in their procurement process. Under the procurement program, BioPreferred designates categories of biobased products that are required for purchase by Federal agencies and their contractors. "It's up to each agency to some degree how much flexibility they'll give to a biobased product," Riedl adds.[49]

Riedl continues, "They are supposed to give preference to biobased products in 50 designated categories, and they are supposed to give preference to products with higher biobased content." The online catalog is also available to consumers or manufacturers who want to identify companies making biobased products and, according to Riedl, has some 1,800 product listings and is growing rapidly.[49]

Listing one's product in the BioPreferred program is free – and requires only "self-certification" that the product meets the biobased standards. Federal agencies may ask the manufacturer for additional information related to ASTM testing for biobased content, environmental and health effects analysis, life cycle costs and product performance against industry-recognized standards.

According to the USDA BioPreferred Program, there are more than 2,200 companies in the United States that either manufacture or distribute biobased products. The Minnesota map shows companies that have products already designated for preferred Federal procurement via USDA's BioPreferred Program (green dots). Companies with products that are expected to be given future designation are indicated with red dots. (Source: USDA)

The criteria for certification becomes more defined for those seeking official USDA certification that was recently announced. In January 2011, the USDA launched a new labeling initiative to identify biobased products, which are commercial or industrial products whose main ingredients are renewable plant or animal materials. Approved products will be able to use the USDA Certified Biobased Product label, but they will undergo a certification review in the process. Under this voluntary labeling program, biobased product manufacturers and distributors will be able to affix a USDA Certified Biobased Product label on qualifying products. The label indicates the product meets or exceeds

the amount of biobased content required for product certification. This content varies according to the type of biobased product certified. Food, fuel and feed products are ineligible.[48] A search of the catalog listed 43 Minnesota companies offering biobased products.

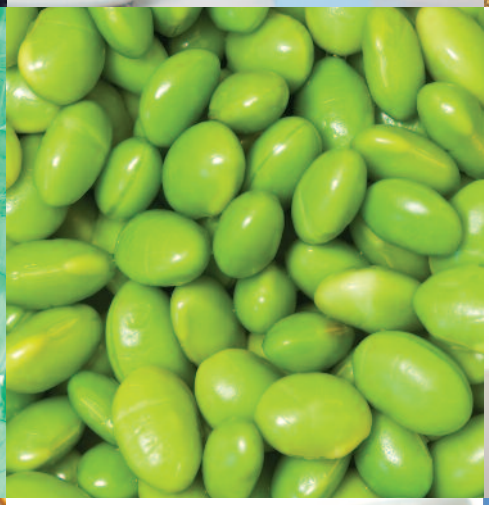
Labeling applications were accepted beginning February 21, 2011. Products must be biobased to receive product certification. Biobased products already identified within existing product categories under the Federal procurement preference portion of the BioPreferred program must meet the minimum biobased content of the category. Products that do not fall within a pre-identified category must

be 25 percent biobased unless the applicant applies for and receives an alternative minimum biobased content allowance. Mature market products, which are excluded from the Federal procurement preference program, are also excluded from product certification and labeling.[48]

Mike Riebel, of Minnesota-based Biovation, would like to take this idea one step further. "We'd like to see certification that something is a Minnesota-grown, Minnesota-manufactured product that is biobased, petrochemical-free and formaldehyde-free; maybe even a Minnesota stamp that would better support Minnesota bioproducts," he suggests. "Or, perhaps creating new regulations, similar to federal biopreferred programs developed by the USDA, so that Minnesota state offices use more of these products."[44]









Market Challenges

Overcoming a Century of Petroleum Dominance

Price is the standard by which many manufacturers measure the viability of incorporating biobased plastics into their operations, especially in a difficult economy.

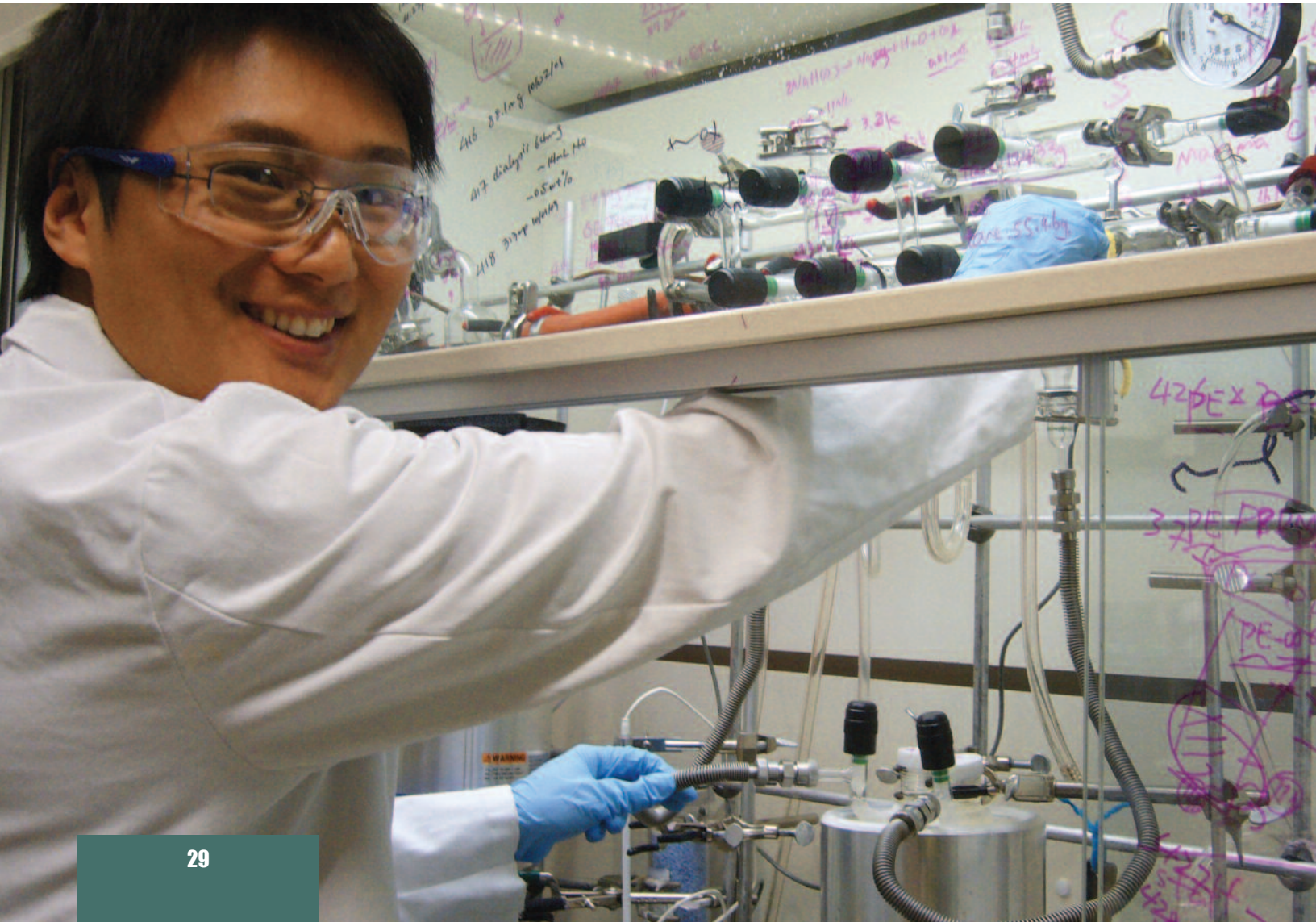
Economics

The economics of the biobased equation is an area that needs further exploration.

According to Steve Kelley, Humphrey Institute, "If the catalyst or additive material that you are looking at that would give a biobased plastic a new property costs $6 a pound versus 65 cents a pound, that's an important question when it comes to product design. We clearly ought to try to support more of the scientific research on the product development side as well as how to connect that to the economics. More wide-spread support from different sectors in Minnesota could help get these additional research resources," he suggests.[50]

John Barrett and Friedrich Srienc, researchers from the Department of Chemical Engineering and Materials Science at the University of Minnesota, agree that economics are an issue. "Despite their environmental benefits, the most significant obstacle to the proliferation of PHAs and polylactide is their cost, which is approximately three- to five-times higher than the cost of petroleum-derived plastics. Much of this price disparity should decrease in the future as the cost of oil will surely rise with diminishing supplies. Other factors affecting the price of these bioplastics are raw materials cost and energy needed for sterilization of feedstocks."[37]

Price is the standard by which many manufacturers measure the viability of incorporating biobased plastics into their operations, especially in a difficult economy. While more and more consumers – and the companies who market to them – are demanding environmentally responsible products, the fact is that the indus-



Elevance employee prepares specialty chemical samples for the company's development partners. (Photo courtesy of Elevance Renewable Sciences, Inc.)

try is accustomed to the price of petroleum-based plastics and that is the benchmark used to determine the value of bioproducts. As oil prices rise, the price gap between biobased products and traditional petro-based plastics closes, making the switch to bioproducts easier to justify.

"The science of polymer production from natural materials is not new, but the cost of plastic produced from cheap oil has been a major obstacle to its widespread use. Biobased materials are going through the same evolution faced by many other industries and as the science and processes evolve, the market will be there. It already exists for the right products," says Dennis Timmerman, Senior Project Development Director at the Agricultural Utilization Research Institute (AURI). "We at AURI are convinced that given the correct balance of resources, the biofuels and biobased industries offer a tremendous opportunity to grow the state's overall economy, create jobs and deliver environmental benefits to Minnesota."[23]

Darin Grinsteinner, with CPI Binani, says customers are not interested in compromising cost efficiencies or product performance. "Either the properties have to get better or the price has to get lower – one of the two," he comments. Yet, he continues to investigate bioplastics because "customers keep asking for it."[51]

"The economic potential of biorenewable polymers is based on two criteria they will have to meet to be competitive," says Marc Hillmyer, Director of the Center for Sustainable Polymers at the University of Minnesota. "First, they need to catch up in terms of their property profile – and they are doing that through copolymers, additives, processing changes and different polymerization schemes."[52]

"The second is price," Hillmyer continues. "The efficiencies of the petrochemical industry have been improved over many decades. The biorenewable industry is getting more efficient with fermentation process and other biotechnology efforts. It's all relative to petroleum. When oil was more than $120 a barrel, PLA and other biorenewable materials were doing quite well."[52]

The University of Minnesota has a long history of excellence in materials and polymer research – and that leadership continues today. Polyols are used to make polyurethanes, which are used in a variety of products including foams for seat cushions and furniture. Most polyols are petroleum-based, but researchers in the Center for Sustainable Polymers are exploring new ways to prepare and apply new biorenewable polyols, primarily those derived from soybean oil.

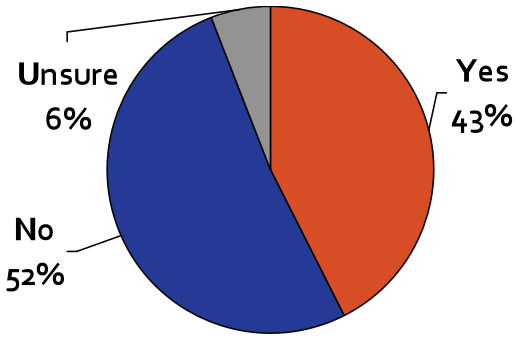
A 2009 report developed by Informa Economics for the Agricultural Utilization Research Institute noted that the United Soybean Board estimates the annual North American product demand for polyols represents 3.4 billion pounds, with a conservative estimate of the market potential for soy-oil-based polyols at about 600 to 800 million pounds (2006 estimates).[53]

Hillmyer says the Center is currently focused on three main topics. "The first is in polyurethane foam and biorenewable polyols, for both rigid and flexible applications. The second is pressure-sensitive adhesives, like a biorenewable version of sticky notes. And, the third is biorenewable durable goods that would be competitive with high-impact polystyrene, polycarbonate or ABS, for example."[52]

Half of recently surveyed Minnesota plastics manufacturers say that they do not expect biobased material to cost the same as their typical material source. In fact, 43 percent expressed concern that such material might be prohibitively expensive for them to use. When asked how much they would be willing to pay for biobased raw material, the average was nine percent more than they do now.[3]

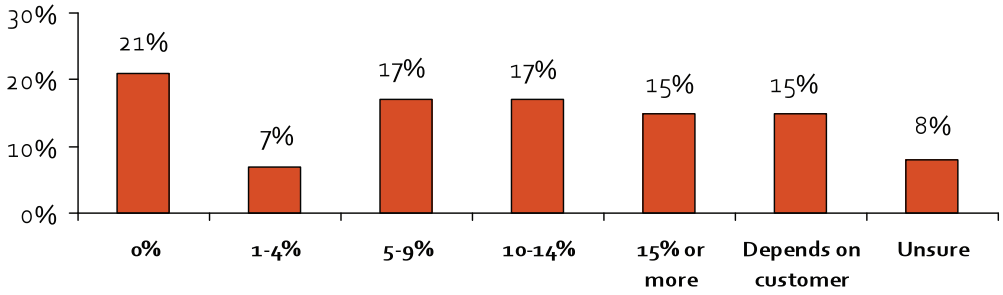
NatureWorks was the first to market and is the world's largest volume supplier of biobased plastic. Ingeo resins from NatureWorks are typically within 10 to 20 percent price parity with petrochemical resins. "Price is, and always will be, a prime consideration for some companies and, until recently, that has been a hurdle for some," says Steve Davies, Director of Marketing and Public Affairs for NatureWorks.[54]

Expect Biobased Material to Cost the Same as Our Typical Material Source



Source: Russell Herder Renewable Materials Survey, 2010

What Percentage More Would You Be Willing to Pay for Biobased Raw Material?



Source: Russell Herder Renewable Materials Survey, 2010

"With recent volatility in oil pricing – and, of course, all the conventional plastics derived from it – that dynamic is changing. Ingeo is actually at, or very close to, pricing parity with some resins, such as polystyrene. Increasingly, manufacturers are attracted to the relatively stable pricing that Ingeo offers, compared to the roller coaster of oil-based resin pricing," according to Davies. "There are companies positioning themselves now with Ingeo bioresin, because they know prices for petrochemicals will go up. Other companies and their customers place a high value on a low carbon footprint and this value overcomes the price differential."[54]

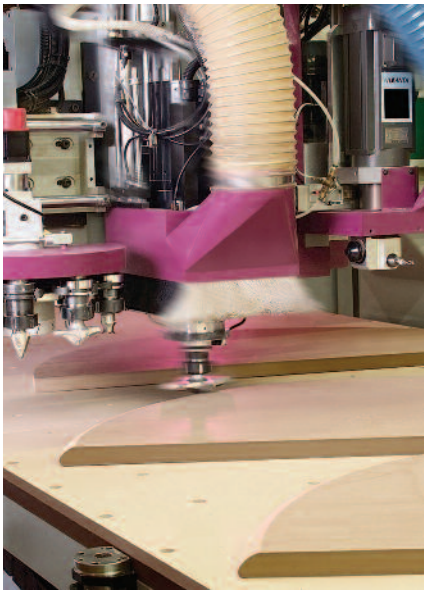
NatureWorks' 140,000-metric-ton production facility is located in eastern Nebraska, with another plant being planned outside the United States in an as-yet-undisclosed location.

Today, seven of the top eight thermoformers in the United States are using Ingeo®. "Our core business of fresh food packaging and food service products continues to grow at a healthy clip," says Davies. "Newer segments such as semi-durables and nonwovens are now picking up sales momentum."[54]

Ingeo® is used in a wide range of products from clothing to packaging to disposable dinnerware. When Ingeo® was introduced, many customers were primarily interested in the compostability characteristics it offered. Composta-

bility is still a key feature, especially for disposable dinnerware products. Now, however, many customers are interested in cradle-to-cradle recycling, which Ingeo® enables. NatureWorks is regularly introducing new Ingeo® grades. According to Davies, "These new Ingeo grades are tailored to specific end uses and manufacturing processes including a new injection molding grade and a new 'meltblown' nonwovens grade."[54]

Mike Rone, with Northern Contours, notes, "We're hearing from our salespeople and cus-



(Photos courtesy of Northern Contours)

The GroVia™ BioDiaper™, made of Ingeo™ fibers, is Oeko-Tex Standard 100 Certified. The lining, core and waterproof outer are free of harmful chemicals and made from sustainable resources. Unlike most disposable diapers, BioDiapers™ are free of fragrance, dyes, plastics and chlorine.
(Photo courtesy of NatureWorks, LLC.)

Bioserie iPhone covers
(Photo courtesy of NatureWorks, LLC.)

"How do you find a customer willing to pay a premium for such product? Or do we sacrifice part of our profit margin to get it introduced?"
- Jim Albrecht, ComDel Innovation

tomers that there is not a lot of pressure for green materials at this point in time. Economic conditions in general have put companies in survival mode – and they are not particularly interested in the increased costs involved with paying for something 'green.' Nobody is going to pay a 20 percent premium for these products. They may pay three to five percent more, but right now people are looking for ways to save five to 10 percent, not pay more." He continues, "Having said that, there is an underlying move towards greener products and, as the economy recovers, we anticipate increased demand for these products."[55]

Agreeing that it is critical that the economics "pan out," Jim Albrecht with ComDel Innovation asks, "How do you find a customer willing to pay a premium for such product? Or do we sacrifice part of our profit margin to get it introduced?"[47]

While the price of producing biobased material can still be more cost intensive, Gary Noble of Bio-Plastic Solutions tells other manufacturers, "If enough of us start buying it, that price may come down. Now we can sell it. And the more the volume goes up, the more that is going to come into alignment."[56]

Jeff Ackerson with Vinylite Windows says that current conditions in the building contractor marketplace are not conducive to selling a product that is even just five percent more expensive, especially in new home construction. "In a replacement market, you might eventually be able to get 10 or 15 percent more, especially if you had a customer who was interested in eco-friendly products," he adds. "There are a number of marketing messages you'd have to think through to position the product properly to convey that value."[57]

"If biobased materials become a mandate for government or military projects to be greener, then all the conversations about price go out the window."
- Mike Rone, Northern Contours

Harold Stanislawski, with the Fergus Falls Economic Improvement Commission, suggests an economic modeling matrix that illustrates what the price of biomaterials needs to be in order to be economically viable compared with petro-based materials. "A similar matrix exists for corn and ethanol prices," he says.[58]

"If biobased materials become a mandate for government or military projects to be greener, then all the conversations about price go out the window," says Northern Contours' Mike Rone. "But when you're talking real people and real markets, right now it's on the back burner."[55]

Economics are also a factor within the agricultural community. Past opportunities that offered market potential and the promise of incentives haven't always panned out, according to industry experts, leaving a certain amount of cynicism in their wake.

"I think there can be a high degree of skepticism (about new efforts such as bioplastics), but that does not mean that farmers are not willing to try it. If there were value-added products that could help stabilize the market for farmers, they would have interest," observes Tim Gerlach, Minnesota Corn Growers Association.[59]

Reliable Supply

When it comes to expense and inefficiency in a manufacturing plant, stopping and starting the process are at the top of the list. Profitability depends on keeping the manufacturing lines running at optimum levels – and any interruption in the supply or quality of raw materials or components can be a profit-killer. The manufacturers interviewed expressed concern about the current state of supply in the bioproducts industry.

"The price and availability fluctuations are a real hindrance," says RPI's Clair Angland. "I had a potential customer with whom I'd talked about price, and by the time we got ready to take the next step, the price had doubled and I couldn't get the quantity I needed. So, all of a sudden, I was having to start over."[60]

Thirty-four percent of Minnesota plastics manufacturers say the ability to find a consistent source/supplier for biobased material is an issue.[3]

"When it comes to manufacturers utilizing biobased or sustainable plastics, [manufacturers] have a concern about accessing a consistent and ample supply of raw material. While this is a valid issue, the opportunity that a new market like this could provide is significant," says Bruce

Stockman, Project Development Director at AURI.[61]

Nine in 10 Minnesota manufacturers express a preference to do business with local companies, but that would not be a deciding factor.[3]

"It would be nice if we had a local supplier, but it's not necessary," says Phil Johnson of Paydac. "It's more important that we can access a continuous, reliable supply - wherever the supplier is located. Once we get a material that works, we need to be able to keep getting that material."[62]

"I would definitely like to see these materials come from domestic U.S. sources, because it would defeat the intended purpose if we were replacing dollars spent on foreign oil with dollars spent overseas to access these materials," Johnson adds.[62]

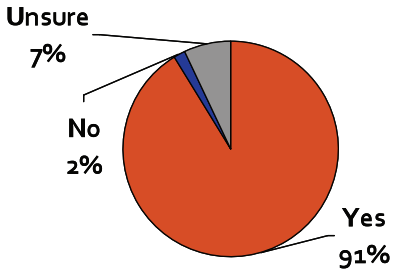
Vinylite's Jeff Ackerson agrees. "I'd love to buy local in Minnesota, but the total cost of the product, including delivery, has to be competitive," he says.[57]

But even traditional materials can be a problem in terms of delivery. Paydac's Phil Johnson notes that one supplier of petro-based materials recently changed lead times from two weeks to 12 weeks.

"That's a real issue for us," Johnson says. "It's almost impossible for us to predict what orders will be like 12 weeks from now, so we have to estimate long so we don't run out. Because running out is simply not an option. And with limited storage capacity for materials, that's a real problem."[62]

"Within Minnesota itself, there are very few companies who are buying biobased, biodegradable, compostable or compounded biomaterials and converting them into finished products," Jim Lunt, of Jim Lunt & Associates, says. "But there are a lot of people buying those products who are based in Minnesota and therefore can influence the supply chain."[30]

Would Prefer Local or Minnesota Supplier



Source: Russell Herder Renewable Materials Survey, 2010

Specifications and Standards

Petroleum-based plastics have been used in manufacturing for decades and have been improved, refined and proven over that time in a number of manufacturing processes and in a wide variety of industrial and consumer applications. While manufacturers (and their customers) express interest in using biobased materials from both an environmental and marketing perspective, they also express concern about the ability of these materials to meet the specifications and standards of their customers.

For example, Paydac Plastics of Elizabeth, MN, is a contract manufacturer of detailed molded plastic products – and their business is based entirely on the demands of one large customer who orders some 300 different products/SKUs. Making a change in materials or specifications – regardless of magnitude – could have serious consequences if they affect performance in any way. And that's a risk that a contract manufacturer such as Paydac is typically not willing to take.

The testing and approval process is another consideration.

"Even if biobased materials were the same cost, many of our customer's products have gone through an expensive approval process," says Phil Johnson of Paydac. "Several times we have come across material that is less expensive, but the customer has elected not to use it because the cost of the approval process would exceed the savings of the lower-priced material."[62]

Paydac has obtained a sample of PLA 2002D, and the company is interested in giving it a try to "get our feet wet," according to Johnson. Doing so, however, will require running the ma-

Nine in 10 Minnesota manufacturers express a preference to do business with local companies.

terial using a mold that is owned by their sole customer. "We haven't gone through the process of getting their permission yet," he notes.[62]

John Deere's Jay Olson, Global Materials Engineering Manager, notes that regulatory compliance and other considerations can affect the amount of time available to explore new materials in the manufacturing process. "If we switch from one material to another, we still have to run our internal testing of the seeds. Unfortunately, that takes time and money. Test time is a limited resource, so to make something that's not part of the strategic plan, like new products that have to hit the market because of emissions, but things that we want to do, like this, it takes second priority; it's just that simple," he adds.[27]

Debra Darby, of Telles, notes that her company recently announced several new customers, and continues to conduct trials with customers. The overall development process can take nine to 15 months, on average. "We're working with the customers' existing molds and tools – and we're finding really good results with injection molding, in particular," she says. "Some of our early injection molding trials have indicated faster cycle times and reduced energy consumption since the process can run at a lower temperature."[63]

Polyhydroxyalkanoates – or PHAs – naturally occur within certain organisms, including microbes. These microbes use PHA to store energy, consuming it for food when needed – a characteristic that gives a product called Mirel® its biodegradability. Mirel® is a PHA bioplastic material, a family of bioplastics which are biobased and biodegradable alternatives to many petroleum-based plastics. They are being commercialized through Telles, a joint venture between Metabolix and Archer Daniels Midland Company (ADM). Production began in

Photo courtesy of Mirel®

Photo courtesy of Mirel®

2010 in Clinton, Iowa. Eight grades of Mirel® bioplastics compounded products are commercially available for use in injection molding, film extrusion, sheet extrusion and thermoforming.

Mirel® has physical properties comparable to petroleum-based resin, yet is biobased and biodegradable in natural soil and water environments, home composting systems and industrial composting facilities where such facilities are available. The rate and extent of Mirel's biodegradability will depend on the size and shape of the articles made from it, as well as the specific end-of-life environment. Like nearly all bioplastics and organic matter, however, Mirel® is not designed to biodegrade in conventional landfills. "Mirel offers a wide range of alternative disposal methods, so we are really able to help divert plastic waste from landfills," Darby adds.[63]

Mirel® is made from the microbial fermentation of sugar – corn sugar, initially – through the joint venture with ADM.

Mirel® is essentially a natural polyester that performs like conventional plastic in a wide range of applications. "It also converts on existing equipment and in the regular plastics infrastructure that exists today, even though it is biobased," she says.[63]

One example of the opportunities enabled by Mirel® is an agricultural mulch film used to control weeds in fields. After harvest, farmers can simply till the biodegradable mulch into the ground where it is broken down by the microbes in the soil and disappears. Another company is using Mirel® to replace conventional plastic plant pots with a bottomless soil wrap intended to be planted directly into the ground, and will biodegrade in the soil after a growing season.

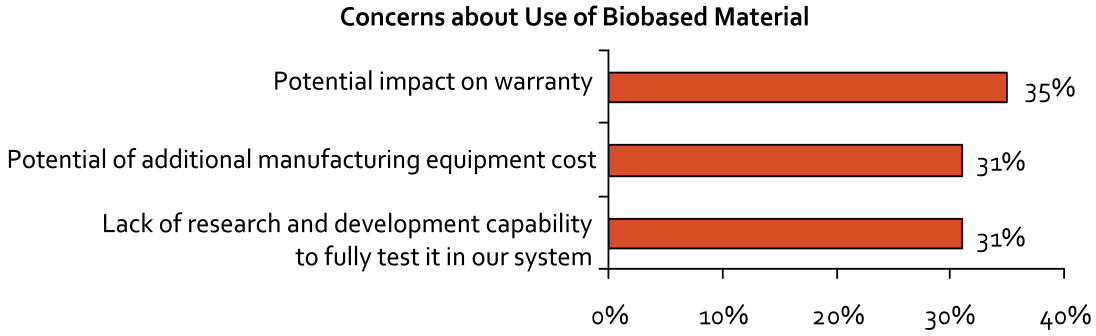
"Currently our commercial products are in use for horticultural applications, marine use and compostable bags. But, we are also working on materials for agriculture, and short-term use such as general packaging, single-serve food packaging and, eventually, durable products such as business equipment and consumer appliances," Darby adds.[63]

Though they continue to have strong interest in using biomaterial, Minnesota plastics manufacturers cite such issues as potential warranty impact, equipment costs and lack of sufficient internal research and development capability to fully test their systems before making the transition.[3]

"Any time we make a change of substance in the structure of the product, such as a stiffener or a profile, we need to run it through the testing process," says Jeff Ackerson of Vinylite, a Fergus Falls-based manufacturer of vinyl windows and doors. Vinylite products must meet the testing standards of the American Architectural Manufacturers Association, ASTM and other approving organizations.[57]

"Before we spend $2,000 on putting the product in a test wall, we'd want to model it on the computer first to see if it has a good chance of passing the test," adds Ackerson.[57]

In the northern tier of states, performance under extreme cold conditions is critical – not only when the product is in use, but also when it



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Source: Russell Herder Renewable Materials Survey, 2010

"This harmonization could really benefit the bioplastics industry and drive policy that enables the infrastructure rather than causing roadblocks."
- Debra Darby, Telles

is being shipped, stored or distributed to other manufacturers or end users. "There are a lot of liability, warranty and personal liability issues with component changes, so to invest in that is really expensive – and the return is pretty far out because of the investment of time and money in testing under various conditions," says Don Hurley of ShoreMaster, a manufacturer of boat docks and other marine equipment.[64]

RPI (Reprocessed Plastics) of Garfield, MN, processes post-industrial plastic by regrinding it and extruding it into sheets that are either sold as is or cut in-house into products sold by RPI. Occasionally, RPI simply sells the raw regrind if the market opportunity presents itself. RPI manufactures products such as baker's trays, cutting boards and stencils for highway department pavement painting (e.g., "STOP AHEAD" messages). "The tricky part is knowing whether these bioplastics are going to behave like polyethylene," says RPI's Clair Angland.[60]

"We have some of the longest warranties in the industry, so product performance is a big deal for us," says Rob Katzenmeyer of ShoreMaster. "Our suppliers submit spec sheets and they have conducted UV testing, fade testing and so forth. But time is the ultimate test."[65]

Debra Darby, of Telles, notes that some standards are becoming outdated as technology changes, citing the ASTM standard of D6400 for compostable plastics in an industrial composting environment as an example. "We are also seeing changes in legislation affecting the marketplace. California is discussing green washing and defining what is compostable and biodegradable. Minnesota has legislation in place for use of compostable yard waste bags," she says. "This harmonization could really benefit the bioplastics industry and drive policy that enables the infrastructure rather than causing roadblocks."[63]

Shifting from single-use disposable to durable plastics made from renewable resources helps reduce the need to build a composting collection and processing infrastructure. "Because people want durable, they are not as concerned about compostability," says Jim Lunt, of Jim Lunt & Associates. "But they are concerned about the origin of the carbon."[30]

"We think the real application is in engineered durable goods because the end of life is positive – and because of their ability to replace current hazardous petrochemical products in these markets," says Mike Riebel of Biovation. "The durable goods can be biocomposted just like bags, and they're easier to reclaim or recycle if the technology and the processes are correct ... It's a shame to see [biobased plastic] used as low-end packaging when it has the ability to be in so many other higher-valued products."[44]

Accent Signage Systems of Minneapolis uses Ingeo® for selected products within its Intaglio™ Signage System. Fully ADA compliant, this system features tactile letters, graphics and Braille – and was developed specifically for LEED® green-building applications. These signage sys-

Photo above illustrates completed ADA compliant signage made entirely of NatureWorks Grafica™ materials.

Photo courtesy of Accent Signage

tems have also earned the GREENGUARD certification for Children and Schools and the GREENGUARD certification for indoor air quality.

There is a movement toward incorporating a certain percentage of biobased materials in plastics – in effect, creating a "blend" of petrochemical and renewable plastics. This approach is similar to that used by the paper industry when it entered the "recycled source" market; paper stocks were labeled as having a certain percentage of "post-consumer waste." The incorporation of biobased plastics in this way can improve the perceived "greenness" of plastics and build demand for renewable sources. This is especially applicable in the durable plastics market, in which the recyclable/compostable attributes are less critical than with disposable items, such as plastic flatware or packaging.

To a company such as RPI, however, blends present a bit of a problem.

"If you blend it, you have a combination of biodegradable material and non-biodegradable material," says RPI's Clair Angland. Once that gets into the waste stream, there is no easy way to segregate the sources or types of plastic. "If it has some PLA in it, that portion may degrade over time, but you cannot call the product 'biodegradable' because of all the polyethylene that's in it."[60]

Manufacturing Challenges

Manufacturers with significant investments in equipment, testing, processing and research may be reluctant to risk changing to a new raw material or a component with different specifications. "There are many different grades of plastic, with wildly varying properties – and different plastics are suitable for different applications," says Steve Davies of NatureWorks. "The same goes for bioplastics."[54]

Standards and specifications are one concern, and are addressed in another section of this report. But the effect on machines and processes is a practical consideration that has some manufacturers asking questions that could mean the difference between keeping their production lines working – or shutting them down.

Clair Angland of RPI sums it up by saying, "I think I can make a sheet out of biobased plastics, but I don't know what it's going to do to my extrusion line. Is it going to plug things up? Will it purge out? Will I have little bits of PLA in everything from now until the end of time?"[60]

At RPI, melt index (flow rate) and end density are key characteristics. "It has to stay flexible through the cooling process to a certain temperature or it's simply going to break as it goes around the rollers – and then at a certain point, it has to be hard enough to cut with a saw," Angland says. "It has to follow the rules of what we're used to – either that or we'd really have to change our process."[60]

RPI needs to be able to create sheets that are one-eighth inch to three-quarter inch thick. The cutting process is also a concern for RPI. "I know that cutting the stuff is not easy ... it smears and gets taffy-like when you start cutting it," Angland says. "We're not going to be able to slit it with a razor blade like we currently do, so we're probably looking at circular saws – and maybe fluid to keep it cool during cutting, which means yet another piece of machinery."[60]

While RPI is intrigued by bioplastics, they are not willing to go out on a limb to give them a try. Angland says he would need a potential customer to help pay for the test. "If someone came in and said they'd pay for the trial and

"My advice to other manufacturers is don't be afraid of the material – try it."
- Gary Noble, Bio-Plastic Solutions, LLC

"They are not going to pay more for it. That's good, in my opinion because it drives industry to be more creative."
- Chad Ulven, North Dakota State University

then become an ongoing customer if it worked, we'd be willing to give it a go," adds Angland.[60]

Darin Grinsteinner is Engineering Manager for CPI Binani, Inc., a thermoplastic direct molding company in Winona, Minnesota. He has been experimenting with bioplastic resins with additives such as distillers grains or fibers in order to increase the performance characteristics. He says that customers are asking for current information on bioplastics. "They don't want a data sheet that's over a year old. They want current stuff," he comments. "So every year I'm going to do some natural fiber, biocontent plastics work – mainly on my own nickel. However, most of the suppliers that are in the supply chain are good at sharing costs."[51]

Harold Stanislawski, with the Fergus Falls Economic Improvement Commission, says, "Ideally, companies could dedicate machines to handling biobased products, which would eliminate the need to purge between bio/non-bio runs. There are reports of a lot of machines for sale in today's economy, which might offer an opportunity for an aggressive, biofocused visionary manufacturer to pick up the equipment needed for a dedicated bioline."[58]

Chad Ulven, Assistant Professor in Mechanical Engineering at North Dakota State University (NDSU), believes that industry will see a rapid acceleration of biobased material adoption within the next decade. Ulven's research at NDSU focuses on integrating natural fibers into synthetic resins to make "biocomposites," as well as looking at resins that are made from vegetable oil, starches and proteins, and incorporating synthetic fibers with an ultimate goal of creating a 100 percent biobased composite.[66]

"With composite materials, you really design the material to suit the application, not the other way around. You design the material to put strength and stiffness in the areas you need it. Now that we have enough knowledge base on these biobased composites, we can start doing those sorts of things – and we have been," Ulven comments.[66]

But as promising as Ulven says the market is, his work with manufacturers has shown there are challenges as well. "OEMs that I have encountered often are interested in utilizing renewable materials in their products because they feel it is the right thing to do – that it's responsible for the environment. At the same time, they are not going to pay more for it. That's good, in my opinion, because it drives industry to be more creative, to step up to the challenge and say, 'we can produce some of these biobased materials at an affordable cost to those of the petroleum-based,'" he explains.[66]

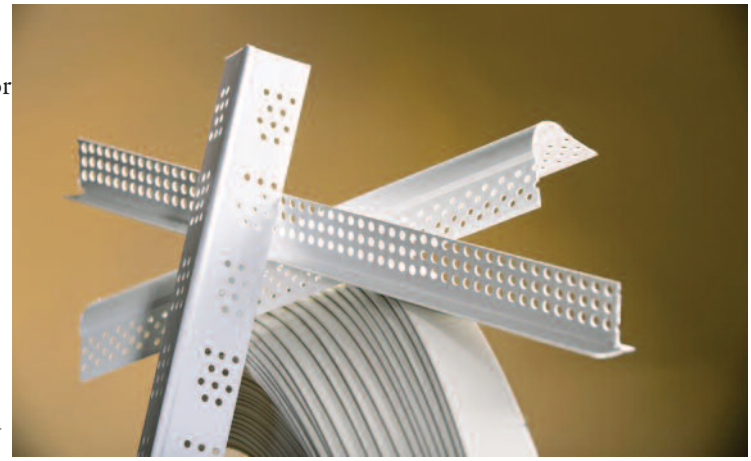
Ulven says, "We often are on the ground helping the molding process because these materials mold differently than your traditional petroleum-based plastic. That is why an educational component is so important with these materials. Just making sure people understand that their flow behavior is different, their melting temperatures are different and how you handle them is just a different methodology when you are working with them."[66]

Tim Welle, BioBusiness Alliance of Minnesota, agrees that it is often difficult for a plastics manufacturer to get to the scale they need to be successful. "You have to build a mold to do it; you need to have the machines tuned up and get up to a certain level. It is difficult – and difficult to get there right away. If I am a manufacturer producing a line of covers for that and I am running at 90 percent capacity, I cannot shut down, try something out and then come back," Welle says.[67]

Manufacturers such as Gary Noble of Bio-Plastic Solutions say, for the market to develop, some risks have to be taken. "My advice to other manufacturers is don't be afraid of the material – try it. If you have a job that you are finishing up, run it. Learn from it. Take an hour or two, purge your machine, throw it in, get as much information from the supplier of the resin and just run it in your machine," he says.[56]

Part of the issue lies in understanding the capabilities of specific biobased material and employing them correctly, according to Olga Selifonova of Reluceo. "People try to use things for non-intended purposes," she observes. "From my perspective, they need to look at the proper-

ties of every new offering comprised of biobased material, and use them precisely for what they can and should be used."[68]



Bioplastic construction pieces, such as sheetrock corners used during construction, or corner protectors. *(Photo by Rolf Hagberg Photography)*

Selifonova is Chief Executive Officer of Reluceo, a privately held green chemical company located in Minneapolis. The company is targeting novel functional polymers for replacing major consumer products that carry detrimental environmental impact and biodegradable plastics that can be responsibly manufactured with use of non-food biomass sources, such as crop and wood residues. Prior to founding Reluceo, Selifonova co-founded Segetis, Inc.

Gauging market potential is important and, according to Tim Welle of BioBusiness Alliance, requires evaluating the opportunity of biobased material in new ways. "It is a different way of thinking. How can this innovation help us grow the top line, not just cut the bottom line? How can this be a revenue generator? It probably will not be a cost cutter. And will this enable you to get into a new market?"[67]

Bio-Plastic Solutions, a Minnesota firm that has produced traditional extruded plastic parts for doors, windows, office furniture and medical devices for a decade did just that. They assessed the opportunity and are now attempting to capitalize on the biobased movement. The company, which manufactures durable furniture parts and building components from corn-based plastic, is one of the first in the nation to use renewable polymers in plastic profile extrusion, a process for making continuous plastic shapes. "We don't know of anybody else doing this for profile extrusion," Gary Noble, Bio-Plastic Solutions founder and CEO, commented in a 2010 published interview.[69]

Last year, the company introduced three new products for the building industry made from BioBest® Bio-Co-Polymer, its patent-pending renewable plastic material. The furniture edge trim, drywall corner bead, and interior wall guards are made from a blend of corn-starch-derived polylactic acid (PLA) and high-quality, petro-based polymers. The new products contain more than 80 percent renewable biobased carbon and are recyclable.

Bio-Plastic Solutions is also developing extrudable PLA polymers that incorporate crop fibers for use in building interiors.

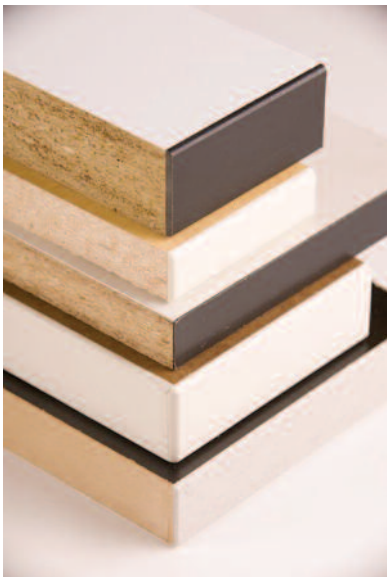
"I see a tremendous opportunity to add value to Minnesota agriculture as we focus on growing the biobased industry. Crop fibers, along with other specific biomass fibers, could provide the potential for expanding utilization of agricultural fibers, as well as job creation in rural Minnesota through production and processing," says Alan Doering, Senior Associate Scientist – Co-Products, with the Agricultural Utilization Research Institute.[70]

Research Doering conducts at AURI is supporting biobased companies looking at the physical and chemical composition of agricultural fibers along with particle size distribution after processing. This research will help identify which fibers work best in current molding equipment while adding strength and heat tolerance to the end product.[70]

"One of the obstacles processors face is that every ag-based fiber has unique characteristics. Lignin, hemi-cellulose, and cellulose content in

fibers can affect how it performs in the molding processes or its impact on adding strength or reducing deflection in building materials. These are only a few of the characteristics being investigated," Doering explains.[70]

The point of developing such products, according to Gary Noble, is one of market differentiation. "We asked ourselves how can we give ourselves an opportunity for better margins, be less oriented toward just price and more oriented toward product value," he says.[56]



Bioplastic edging that can be used on furniture. *(Photo by Rolf Hagberg Photography)*

In addition, Noble was seeing growing market demand for non-hazardous, non-carcinogen based products to serve as an alternative to petroleum or even wood-based options. While exterior building materials have some promise, the extensive testing required to mimic factors such as temperature changes and fading were time and cost intensive. Interior products, however, offered fewer hurdles but were not without its necessary growing pains.[56]

"Typical of most development, you go into it eyes wide shut," Noble says. "You think you have the right direction and you've gathered information, but what you learn as you are going along can be very disruptive to that success."[56]

Samples of colors that can be used in bioplastic materials. *(Photo by Rolf Hagberg Photography)*

Though the economic downturn has proven challenging for Bio-Plastic Solutions – and likely other innovators – Noble believes demand for durable bioplastics will be robust, as long as price and performance are on par with petroleum-based plastics. In particular, the health care facility and baby furniture markets look promising. BioBest® products contain no PVC plastic, no formaldehyde or hazardous chemicals, and emit no harmful VOCs – thus making them more attractive than the alternatives.

Targeting the green building and construction market makes sense – both public and private. John Souter of Accent Signage notes that federal policy and procurement is a positive driving force. "If you go to the United States State Department website, you'll see their green initiative – that is to have all of their federal buildings certified at least to a LEED Silver level by 2014," he says.[43]

Souter adds, "Fortunately, the State Department has taken the time and applied the resources to make this happen. I think you are going to see this more and more in the private sector as well. When people become more cognizant of green technologies, and once they find the money trail, things will go pretty quickly."[43]

Product Misperceptions

Another factor that must be dealt with to spur biobased market growth, says Chad Ulven of NDSU, are misperceptions on the part of both buyer and manufacturer.[66]

"When people think biobased, they think cheap. They think, 'This is going to fall apart in service, the degradation rate is very high and it is not going to survive the type of environmental conditions I need.' But what we have shown is that if you incorporate things properly and if you protect those natural-based constituents

within a robust plastic, the degradation and weathering do not change much at all if you do it properly," says Ulven.[66]

"People don't yet fully understand the unique properties of some of these biobased materials," says Biovation's Mike Riebel. "Everyone has this preconceived notion that, if it's a biomaterial, it's some biodegradable, disposable low-end packaging. That preconceived notion is one of the biggest barriers. These are more like engineered plastics if you know what you're doing with them."[44]

Biobased products can perform differently. As manufacturer Gary Noble with Bio-Plastic Solutions points out, "Buyers want to know if the product that you are trying to manufacture is going to work and act in the same way as the products they have been receiving to date." If not, he says, few are willing to take a chance – particularly in the current economic environment.[56]

Part of the issue lies in understanding the material itself. "You have to be able to design with a little more variability in your product. With steel, aluminum and materials of that nature, you know what your standard deviation is on properties. You know what your tolerances are when you are designing a structure out of those traditional materials. When designing using natural or biobased materials, you have to be able to accommodate for a larger variation in physical performance; that comes down to the design engineers being a little bit more savvy," explains Ulven.[66]

Critical to this, Ulven believes, is documentation. "What that takes is a larger database of material properties that one can go spec and learn from. That is not present right now. On the web, you have large databases for physical properties of synthetic plastics, metals – you name it, you can find it. With these biobased materials, it is very hard to come across spec sheets and mechanical property information to allow designers to play with it. Somebody has to take the initiative to either add to existing databases or start creating their own database that is widely available online."[66]

"Once they find the money trail, things will go pretty quickly."
- John Souter, Accent Signage

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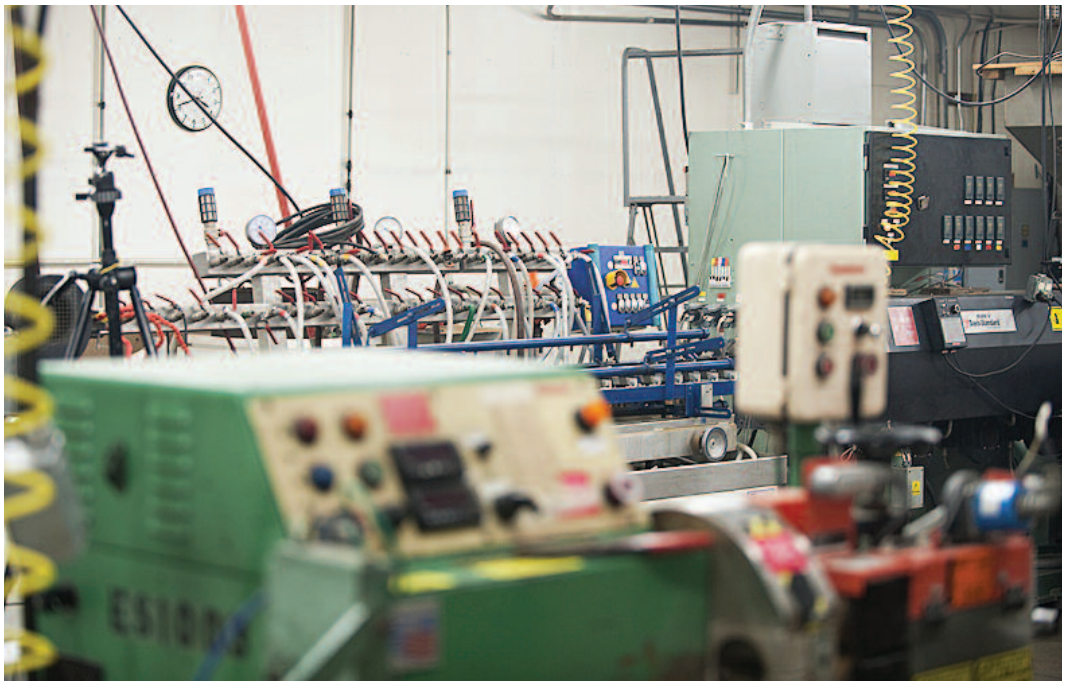


Photo of bioplastics company in southern Minnesota. *(Photo by Rolf Hagberg Photography)*

"We started getting phone calls . . . All of a sudden the enthusiasm became no longer just talk."
- Gary Noble, Bio-Plastic Solutions

For some manufacturers on the forefront of introducing biobased materials to the market, one of the most significant issues has been the recent economy. If their own survival is number one on a buyer's agenda, they may be less likely to invest in developing and marketing new products. As Gary Noble of Bio-Plastic Solutions comments, "For many months, nobody was willing to do much. They were extremely focused and intent on building what they had, holding on to their employees and keeping them busy."[56]

But then things started to change. "The latter half of 2010, we started getting phone calls. And it wasn't just small players, it was larger players. People were willing to try it. All of a sudden, the enthusiasm became no longer just talk. There is a willingness to at least approach the question (of using a biobased material) with their customers," Noble adds.[56]

Mike Riebel, of Biovation, has a unique perspective on bioplastics. "I get a lot of heck for this but, in my opinion, bioplastic is not a plastic. You have to think of it, technically, more like a food product," he says. "If you take a bioplastic and give it to a normal plastic guy, he's going to treat it like polyethylene, polypropylene or whatever. You give it to a food guy who extrudes spaghetti, he's going to look at it completely different in its ability to be processed, changed and modified – completely different than a plastics guy. The best way we've found is to get both of those disciplines to argue together to come up with the correct marketing solution."[44]

Perhaps contributing to a lack of manufacturer adoption is confusion. "What does it mean to be a bioproduct? How does that interplay with biodegradability? If those definitions are not firm, I think that might potentially slow the introduction and overall acceptance of them, because there might not be a hard and fast definition of what everybody is working toward," observes Jeremy Dworshak, Material Engineer at Steinwall, Inc.[46]

Steinwall, unlike some other Minnesota plastics manufacturers, has been actively pursuing use of biobased resin in production. As process engineers, Steinwall works closely with North Dakota State University (NDSU) and OEMs to refine the process and applications for ultimately producing bioplastic products. Partnering with an organization, such as NDSU, is an effective way to develop industry channels, Dworshak says.[46]

Regulatory Issues

Other issues complicating the growth of biobased materials – at least for now – lie in the regulatory sector. As Steve Kelley of the Humphrey Institute explains, these concerns can extend far beyond Minnesota's borders for a manufacturer. "I think that the changing international context on chemicals of concern is going to continue to push manufacturers in the direction of safer chemicals. One area of uncertainty is the U.S. Toxic Chemicals Act, which is up for revision. As long as that remains uncertain, it creates an environment where manufacturers are not sure what is going to happen or how it will fit into the international market," says Kelley.[50]

Kelley adds, "When you think about 3M and the European Reach Initiative, 3M is not going to ignore a market the size of Europe. So, one of the issues will be the extent to which these different markets have different expectations. The U.S. is such a big market, one would hope that there would be some consistency; whether that is politically possible between here and Europe is an interesting question."[50]

"I think manufacturers plus government plus the nonprofits and other observers are going to have to work together to become more clear about what we mean by sustainability," Steve Kelley says.[50]

But, the obvious question is, work together how?

"That is a good and hard question. One overall issue in chemical regulation: we need to figure out the difference between a risk-based approach to harmful chemicals and a hazard-based approach. From the environmental perspective, if the chemical is hazardous you want

to get rid of it. From the manufacturer side, the real question is not if the chemical is hazardous, but does it pose an actual risk to human health or is it the environment? I see a divide over that question that hasn't been bridged and requires a combination of science and politics to bring people together and balance these two different views," Kelley adds.[50]

The Minnesota Environmental Initiative (MEI) has convened a stakeholder group to consider the question of chemical regulation in Minnesota, where this discussion has been a part of the conversations. According to Kelley, "MEI completed phase one, which was to look at the feasibility of Minnesota developing its own approach to this. They are now trying to raise the money to do phase two of this stakeholder process that includes business, government and nonprofits. That is one example of a process that we could use to try to resolve some of these differences to get to greater certainty."[50]

The Need for Education

With the projected growth in incorporating bioplastics into the production and supply chain, some believe education could be beneficial to ease the process. In a survey conducted with Minnesota manufacturers in late 2010, 80 percent indicated an interest in learning more about utilizing biobased material in their operation.[3]

When asked how they would prefer to access information, most opted for doing so online, through a supplier or by reading a trade magazine.[3]

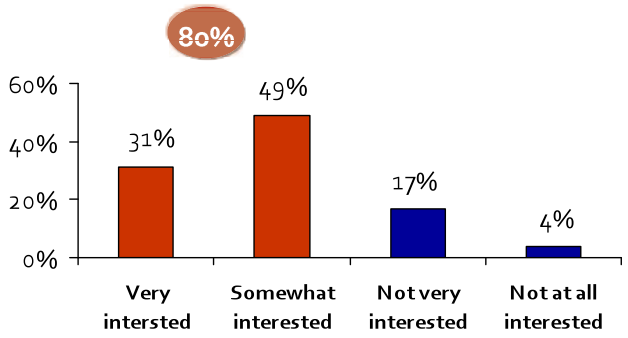
Chad Ulven, NDSU, believes such education could be delivered via conferences, symposiums or online – besides providing one-to-one guidance on the manufacturing floor. Such insight, he says, could ease receptivity to trying something new.[66]

"Just like with any new material a molder gets, they do trials. They usually get in 500 pounds and try to optimize the process before they actually produce the final product. You are going to do the same thing with this material, however, it makes a huge difference on your perception if you start very close to your optimal versus very far away from your optimal," Ulven comments.[66]

According to recent research conducted with Minnesota plastics manufacturers, a third felt

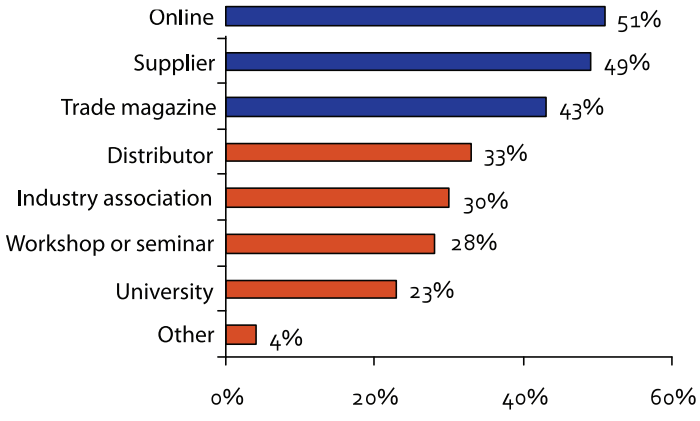
80% of Minnesota manufacturers have interest in learning more about utilizing biobased material in their operation.

Interest in Learning More about Biobased Material



Source: Russell Herder Renewable Materials Survey, 2010

Preferences for Learning about Biobased Material



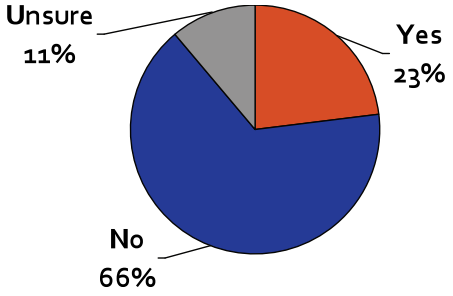
Multiple responses allowed

Source: Russell Herder Renewable Materials Survey, 2010

training is needed in the use of biobased material.[3]

"It is a new paradigm. Training – along with research and development on how to get there – is definitely a need. Hennepin Technical College, as an example, is well set up to provide that if they can get some funding. We have the players here for Minnesota to be the state that really understands how to use with this [biobased] material and get quality products out of it," says Tim Welle of the BioBusiness Alliance.[67]

Staffing or Training Needed for the Use of Biobased Material



Source: Russell Herder Renewable Materials Survey, 2010

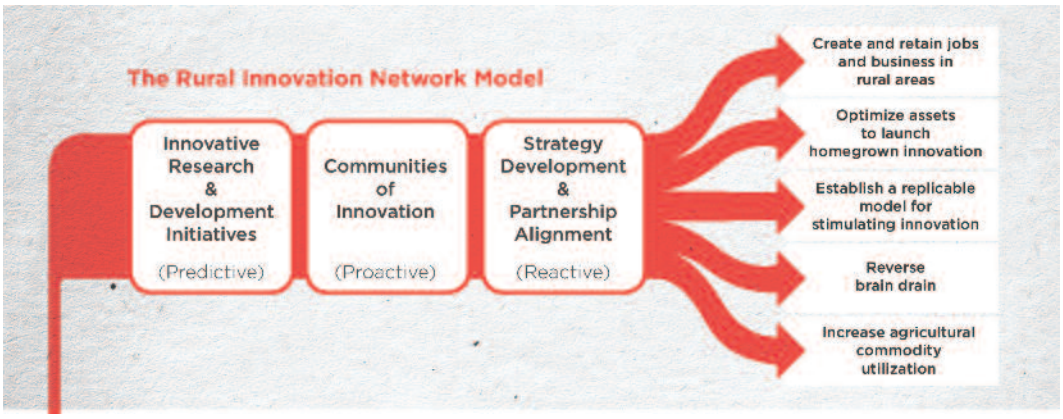
For some manufacturers, like Steinwall Inc., continued learning is already a major initiative. "Education and education sponsorship is a priority here, not only just with the academic institutions, but also internally. We have a very sophisticated training orientation that we developed," explains Jeremy Dworshak, Material Engineer. "Another thing that Steinwall does is publish a bi-monthly newsletter. We write technical articles and articles about injection molding. These go out not only to our customers, but also to our competitors, so we can help educate the industry as a whole – so we can all get better."[46]

Education may be useful within the agricultural industry as well, according to Tim Gerlach, Minnesota Corn Growers Association. Content, however, would be critical. "If you just have a one-on-one workshop or something, you might get a few attendees. But if it is not based in some substance and real-world product examples that work, it may not go anywhere," Gerlach comments.[59]

Confidentiality Versus Collaboration

Continued, successful innovation does not occur spontaneously. To bring innovation through to commercialization, according to the Agricultural Utilization Research Institute (AURI), requires planning, strategy development and a strong network of support. In its Rural Innovation Network Model, AURI advocates a systems approach that integrates technical and scientific assistance, market development, market research, business planning and targeted network outreach.[71]

"AURI's Innovation Launching Pad process is designed to explore the value chain and invite players to the table. The purpose is to move ideas to the implementation stage. Within AURI, we have a motto that innovation equals ideas plus implementation," observes Jennifer Wagner-Lahr, Senior Project Development Director at the Agricultural Utilization Research Institute.[72]



She adds, "It has been interesting to watch entrepreneurs, operators and service providers problem solve collaboratively. You would think that there would be motivation to remain closed lipped, but in our experience, we have witnessed a lot of sharing of information and willingness to make suggestions to others within the industry. It is just a matter of bringing people together in an environment that supports trust and communication."[72]

A willingness to share information is fundamental, but something that can be a challenge during the innovation process. As Joel Makower reported on www.greenbiz.com, "Genuine progress remains elusive as scientists, innovators and companies often travel down parallel paths, each reinventing the same metaphoric wheel."[73]

In an attempt to address this challenge on a broad scale basis, a small group of companies – including Nike and Best Buy – partnered with nonprofit Creative Commons to create GreenXchange, an open innovation platform that promotes the creation and adoption of technologies that have the potential to solve important global or industry-wide challenges. Knowledge is shared across many companies, individuals, suppliers, distributors, academia and others to solve common problems and to assist internal innovation.

The goal is to encourage patent holders to make their portfolio available for licensing on reasonable terms, while retaining the defensive benefits of patents. "Many patent holders have patented inventions that could have broad or new applications in areas that they did not anticipate, but they may not have a strategy to actively license them or offer them for such uses. By making public license offers on reasonable terms, patent holders can encourage others to seek out novel uses, which can have important economic or environmental benefits," developers explained.[74]

The project, which now boasts 463 "assets," was initiated at Nike, which has been developing materials and processes to reduce the environmental impacts of its own products. "In order to get to a green economy ... we're going to have to start collaborating in a much more open innovation way," Kelly Lauber, Global Director, Sustainable Ventures at Nike, was quoted in an article on www.greenbiz.com. "Because the issues in front of us ... they're all too big for any one company."[73]

(Photo courtesy of Elevance Renewable Sciences, Inc.)

Within the biobased material industry, collaboratives and industry association efforts do exist, but information sharing is not pervasive – particularly among retailers, OEMs and product developers. In preparation of this report, in fact, a number of entities clearly working within this space declined to share their progress.

Chad Ulven, NDSU, says such reluctance threatens to slow the development process. "One thing that really bothers me about trying to get these materials up and going in the industry is that everybody is so paranoid and secretive about what they are doing. That, to me, is just a hindrance."[66]

"People always ask, 'What if somebody else starts doing what you are doing? How is that going to impact how you move forward?' I welcome that. I welcome a couple dozen more peo-

A willingness to share information is fundamental.

"We need a bigger ecosystem for innovation."
- Robert Elde, University of Minnesota

"Sometimes when you are small, you have to look at it and understand that you can't protect everything. Sometimes you just have to get it out there."
- Manufacturer

ple trying to do what I am doing. We are such a small fraction of materials production in this country and materials usage that it is going to take a larger critical mass of people to make a business out of this to get it going. It is backwards to me," Ulven explains.[66]

Alan Doering, AURI, has seen first hand what successful collaboration can accomplish. "One of the biggest impacts on successfully developing biobased products that I have been involved with came from networking between companies that complement each other. For example, one company may have an idea and the materials to produce their biobased product while another company can provide or may already have processing technology to produce the final product," he says.[70]

NDSU's Chad Ulven comments, "Nobody is going to throw their hat in the ring and say, 'I am going to put a production facility on the ground here to produce these materials because all of these different people are going to use them.' No one is going to do that if no one lets anybody else know that they are trialing them and they are behind the scenes. A lot of people don't want to come out and say, 'We are trialing some of these materials; if somebody came out with a production facility, we would be up for orders in the future,'" he observes.[66]

"It is important to the University, and to society, for innovations to be moved into the marketplace."
- Eric Kaler, University of Minnesota

From the manufacturing perspective, broadly sharing information can threaten protection of intellectual property. As one manufacturer observes, "Why would I open my mouth? [By sharing information] you can accelerate the development cycle, but you kind of go, 'Wait a minute. If we do, we are going to have a problem.' But sometimes when you are small, you have to look at it and understand that you can't protect everything. Sometimes you just have to get it out there."

Jeremy Dworshak, of Steinwall Inc., agrees. "If you keep it as a black magic, people will be unsure. I think it is important to communicate it."[46]

The need for collaboration isn't relegated to the private sector. Some believe academia should further rethink their willingness to work with the manufacturing community. "Colleges need to recognize that they should be training students, not creating IP," one manufacturer says.

Dean Robert Elde, University of Minnesota, says interest in collaboration does exist from the University's standpoint, but agrees, "we need a bigger ecosystem for innovation."[75]

As one academic states, "It is always a conflict of interest issue researchers have. How do you justify a student's work on a project that could eventually benefit a company? Universities could encourage faculty to take initiatives for eventually commercializing things – for translating research and technologies. They [academic researchers] should be a part of this because they typically know the most about this technology."

"The fact is, innovation occurs within startups. That's where things happen versus the old model which typically started within academia," Robert Elde says. "We need to collectively support entrepreneurship to create a greater continuum of research and innovation."[75]

Eric Kaler, incoming President of the University of Minnesota notes, "I do see and understand the value of these collaborations between the University of Minnesota and industry. It is important to the University, and to society, for innovations to be moved into the marketplace in an appropriate way so that they can be further developed and used. I look forward to helping the University continue to be a place where research results can have a practical impact."[76]

Food Versus Industrial Use

Converting agricultural commodities into industrial products is a controversial issue. It has been raised in relationship to biofuels production and is part of the conversation surrounding biobased plastics as well. Some people are concerned that, in the rush to reduce reliance on petroleum through biobased fuels and products, we are taking food away from a hungry world.

"Many companies who would be early supporters of this industry are not excited because

(Photo courtesy of Segetis, Inc.)

of (real or perceived) concerns about bioplastics competing with food, just like in the biofuel sector," observes Jim Kleinschmit, IATP.[22]

"What dictates the use of a commodity is its highest value. If food use is a commodity's highest value, it is bid up for that use," says Jim Palmer.[77]

According to *BioPlastics-Investor*, the concerns about competition between food stocks and bioproducts must be dealt with. "Current estimates place an ever-increasing demand on the roughly 10 percent of the plant that is suitable for crop growth, which could seriously impair the world's ability to feed itself. Moreover, crops are also being harnessed as an alternative fuel source, corn fuel, ethanol biofuel and cellulose ethanol for instance, which adds up to the many uses of agricultural products," the publication asserted.[78]

"However, new technological advances will allow some bioplastics to be made from agricultural waste products, as well as the crops them-

selves, which would not only alleviate some of the burden for crop space, but assist in creatively dealing with waste from the food production industry."[78]

In an effort to balance the production of bioplastics with concerns about agricultural sustainability and the conversion of food products to industrial products, Green Harvest Technologies works in conjunction with the Institute for Agricultural Trade Policy (IATP) on the Working Landscape Certificates (WLC) initiative, which is modeled in the energy sector's Renewable Energy Certificates. It is a market-based initiative that allows manufacturers, retailers and consumers of biobased plastics to help farmers grow biobased feedstock crops in a more sustainable manner.

Based in the Twin Cities and founded in 2007, Green Harvest Technologies has a patent in process to make biobased durable transparent bottles from PLA. "Our process stretches and aligns the polymer chains to increase heat resistance and durability. We've been able to take PLA's glass transition rate from 105 degrees Fahrenheit up to 150 to 155 degrees, which now makes it equivalent to PET – and we're doing that with 100 percent PLA with no additives," Patrick Kenney with Green Harvest says.[79]

"We have a priority on doing the green chemistry and polymer engineering work to establish certified material formulations we will use in product. It's all about proof of concept that materials will perform in productized form," Kenney continues. "We are choosing the most promising biopolymers from around the world and taking a 'science to solutions' approach. We will have a pilot plant for prototype production using the advanced materials developed."[79]

Kenney says the company is applying the "12 Principles of Green Chemistry" in their business model. The 12 Principles of Green Chemistry were developed by Paul Anastas, then of the U.S. Environmental Protection Agency, and John C. Warner to outline what the definition of "green chemistry" means in practice.[10]

"Highlighting a subset of the principles, in

Corn and PLA (polylactic acid) resins that go into bioplastics. *(Photo by Rolf Hagberg Photography)*

gredients in material formulations will be transparent, performance characterizations will be clear and tested, and material is designed to avoid toxicity and will have a clear repurposing plan when entering the waste stream," Kenney notes.[79]

Green Harvest is gaining interest from the reusable bottle market, including souvenir bottles and entertainment markets. "We've also drawn high interest in applying our technology in baby bottles and in pharmaceutical bottles," Kenney adds. Green Harvest intends to manufacture products and take them to market themselves. To that end, they are looking to partner with and acquire one or more injection molding companies. Once the process and products have proven themselves in the marketplace and built brand recognition, Green Harvest may consider licensing the technology or becoming a custom manufacturer for other companies.[79]

An example referenced earlier in this report, Stonyfield Farm is making yogurt cups from PLA. Green Harvest Technologies sells them Working Landscape Certificates. "They purchased certificates for acreage that produces the amount of corn it takes to manufacture the amount of PLA they use in their yogurt cups – equivalent to about 500 acres," says Kenney with Green Harvest Technologies.[79]

"If we can start to shift our choice of feedstocks for biorefining to help farmers get new markets for other kinds of crops . . . then the sector becomes so extraordinarily better that it would be very hard for it not to succeed."
–Jim Kleinschmit, IATP

Brian Schmitz of Mullinix Packages adds, "Many customers will not use plastics that take from the overall food supply, creating shortage of supply and higher food prices. We need to make products from biomass other than corn."[80]

Jim Lunt of Jim Lunt & Associates says that uses of alternative agricultural feedstocks can also address this situation to some degree. "Wheat straw, corn stover, corn cellulose and wood pulp – these can all be the source of natural fibers that can be used to reinforce plastics," he says. "They give plastics stiffness and strength – and they are already used in automotive interior panels and nonbearing parts." These composite materials make use of feedstocks that are not part of the food chain.[30]

"There are some plastics that are going to be produced from corn and some from soybeans," says Tim Welle of the BioBusiness Alliance. "When you look at the next process of biobased chemical development, forestry is going to be involved. As far as what feedstock group is going to benefit most, it is hard to say. A majority of plastics produced in high volumes today are coming from corn. There is biobased insulating foam and quite a few products emerging from soybeans and other types of oils. Biobased composites that use agriculture fibers are another interesting opportunity."[67]

Chad Ulven, NDSU, has been looking at hybridizing different types of biomasses to gain greater stability in products. "When I fill a plastic to replace a talc or calcium carbonate, I don't just fill it 100 percent with sunflower, rice hull or oat hull because my thought on it is, 'Okay, if you get this material up and running, what happens if you have a bad year for that commodity? How are you going to maintain production?' So, instead, I have been digging in and finding what is the cellulose, hemi-cellulose, lignin content and the residual fats and proteins; then I mix or hybridize different biomasses so I maintain a constant constituent breakdown. I mix and match many different biomasses so I have a constant cellulose, lignin, fats and protein content so I know how that filler is going to behave," Ulven explains.[66]

IATP's Kleinschmit feels that the focus needs to be on the big picture. "It is not just about plastics. We aren't going to solve our energy problems, or eliminate our petroleum dependence, because of biofuels or any other single form of renewable energy. We have to look at everything through the refining stream. Bioplastics are just one component of an overall biorefining system that includes energy, lubricants and more," he explains.[22]

He adds, "If we can start to shift our choice of feedstocks for biorefining to help farmers get new markets for other kinds of crops that we know are good for the farm and environment (such as perennial grasses), and then are able to recapture many of the nutrients at the end-of-life, then the sector becomes so extraordinarily better that it would be very hard for it not to succeed."[22]

Another consideration, according to Tim

Gerlach, Minnesota Corn Growers Association, is the potential impact of biomass recovery. "How much can you remove and still maintain your soil quality? You can remove biomass. We know that you can do that without hurting the soil. It is just the question of how much. If you are taking corn, there may be more nutrients on the bottom third of the stock, so you want to remove the top two-thirds and leave that bottom to keep your soil healthy. Or you may want to remove it and not do it for the next year or two, and then do it again. Those are some of the things that we have to figure out yet," says Gerlach.[59]

Waste Stream Management

While the initial push in bioplastics was toward compostability, the fact is that the infrastructure needed to ensure biodegradable performance under optimum conditions simply does not exist. Consumers do not know how or where to access the composting environment required. This is one reason for increased interest in durables rather than compostables. Jim Lunt notes that the Federal Trade Commission is considering a ruling that says, in effect, if the product would never actually be separated for composting, the product cannot claim to be compostable.

"We have to figure out the infrastructure for end-of-life more quickly for these [biobased] materials. I think that is where the opportunity truly lies since that is where we'll see the greatest and immediate advantage of these materials over their petroleum-based counterparts. We have to increase composting, digesting and other appropriate end-of-life strategies," comments Jim Kleinschmit, IATP.[22]

"A lot of this relates to state-based and federal-based policy," Kleinschmit continues. "There has to be some level of product stewardship put in place for us to truly achieve what is needed. While this won't be easy, I do think it can be achieved if we take some simple steps."[22]

NatureWorks, and others in the industry, have created a system whereby post-industrial and post-consumer Ingeo® – including bottles – are bought back after use and recycled to capture the lactic acid. "Source recycling works," says Jim Lunt. "If the system is in a stadium or other closed system where you know you can collect large quantities, this approach can be successful."[30]

"I think a big hurdle for all of us to overcome is aligning the value chain and helping build out the infrastructure for renewable, disposal options – enabling consumers to have access to industrial composting and other new technologies like anaerobic digestion," says Debra Darby of Telles. "This might mean NatureWorks wanting to recycle products so they can collect the lactic acid – or Mirel becoming part of a composting stream or anaerobic digestion source for bioenergy. There is added value to this industry that needs to be developed further."[63]

"Sure you can dispose of them, perhaps recycle them and reuse them, but the one advantage of these is that they are biodegradable so that they will eventually just disappear," comments Friedrich Srienc, Professor at the University of Minnesota's BioTechnology Institute.[4]

Green Harvest Technologies is working on establishing "closed loop" collection systems within captive environments as a way to begin building a recycling structure. The company is focusing on providing both its plastics products and the collection/recycling infrastructure to venues such as education institutions, sports facilities, healthcare facilities and large employers. "The workplace is a big one if we could just provide bioplastics materials just for the lunch hour, all of the plastics that end up going into the trash," says Patrick Kenney of Green Harvest.[79]

Kenney says his company is working with a Boston-based healthcare system on just such a project. They are working to identify general plastic products used in early life care that Green Harvest can provide, as well as the recapture and recycling infrastructure around that product. The non-toxic characteristics of bioplastic products are particularly important during vulnerable health stages, such as maternity, birthing, neonatal and pediatrics.[79]

"We have to figure out the infrastructure for end-of-life more quickly for these [biobased] materials. I think that is where the opportunity truly lies."
- Jim Kleinschmit, IATP

"Green Harvest Technologies has a clear path into product markets of U.S. healthcare," he continues. "We are aligned with some major healthcare providers that have a passion for sustainability. They are committed to test prototypes and bring bioplastic products into use. They recognize the many benefits of moving to sustainable plastic products that perform. This is a clear, mission-driven initiative."[79]

According to Kenney, most of the products in healthcare need to be either semi-durable or durable. Most of them are used once with one patient and then discarded. "Our vision for these environments is to set up a separate collection stream, differentiating between what has been contaminated with organic matter and what hasn't; setting up a separate collection stream, and then being able to get enough critical mass to justify shipping to where it can be recycled," he says.[79]

"Going the route of recycling with PLA means working with a company like BioCor," says Kenney, "which is involved in using hydrolysis to break down PLA from polylactic acid to lactic acid and then reselling that into the market as lactic acid. Recycling strategies for other bioplastics require additional infrastructure."[79]

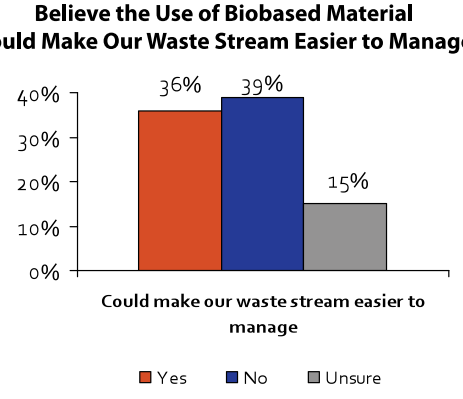
From Jim Kleinschmit's perspective, of IATP, the need to address these issues is critical. "You are never going to get the rewards you want – or should get – for producing a beneficial product if everything is treated the same in the end. We need to help encourage manufacturers from the beginning to produce products that are truly compostable. We don't want to let them fall into the trap of, 'I will mix a little bit of this petroleum plastic in because nobody is really watching.' Currently, that isn't seen as a major problem, as most of these products don't go to a composter, but end up in landfills just like all of the other non-recyclable plastics. But that can't be the future. If the bioplastic industry settles for becoming just 'another plastic,' then much of the value of this new industry will be lost," he says.[22]

Steve Kelley of the Humphrey Institute agrees. "As we are trying to develop these compostable products, we have to keep in mind that it is not easy to compost them. When we were talking to consumers at the State Fair, they would ask, 'Where can we recycle this or send this stuff to be composted?' There aren't that many places. And, it is not convenient. I think paying attention to the development of the composting side of things as part of our waste stream [is important]," Kelley says.[50]

Indeed, an advisory group for biobased products issued recommendations in a 2009 report to the European Commission calling for product-specific legislation that would allow biobased plastic to enter all waste collection and recovery systems, including composting, recycling and energetic recovery. "Biobased plastics certified compostable ... should gain unhindered access to biowaste collection," the report suggested.[81]

What can Minnesota policymakers do near-term to address end-of-life issues within this sector? According to Kleinschmit from IATP, one of the answers is to expand composting.

"I think [we need to] open up yard waste composting to include food and bioplastics. We have to be appropriate and make sure we are not causing problems with factors such as odor, but good composters know how to handle that. The greatest and fastest opportunity to show the value and move ahead in bioplastics is making our composting and organics collection and separation more robust," Kleinschmit notes.[22]



Source: Russell Herder Renewable Materials Survey, 2010

At the same time,

experts such as Kleinschmit note that it is important to recognize that it will require initial funding. "It will cost money to do it right. But, I think it will save us enough that it is a very smart investment. It's not like we have a lot of other options out there."[22]

There are other dimensions to this issue. When a manufacturer changes the specifications or characteristics of the raw materials or components they use, that can also have an effect on the waste stream from that facility. This could affect permitting and environmental compliance or reporting – adding cost and risk for the manufacturer.

When asked whether they feel biobased material could make their operation's waste stream easier to manage, Minnesota plastics manufacturers have mixed feelings. Thirty-six percent said such material could be advantageous, while 39 percent disagreed and another 15 percent were unsure.[3]

"It is remarkable to see the thought that is going into the innovation process with those involved in the production of biobased materials," says Jennifer Wagner-Lahr, Senior Project Development Director at AURI. "There are so many goals beyond performance and economics – and much more altruistic in terms of environmental and human benefits – compostability, renewable inputs, as well as zero tolerance for toxicity. There is a real opportunity to get it right from the get-go. If the industry can do this, then the sky is the limit."[72]

Funding

Securing funding for biobased material research can be challenging and time-consuming. Though his program has been successful, it can be difficult, according to Chad Ulven, NDSU.

"This area of research really doesn't have a home within any of the federal agencies," Ulven notes. "If you look at the USDA, this biomaterials and bioproducts kind of thing is toward the end of the list. Above it is fuel and then everything else that are very valuable things that the USDA does for farming; don't get me wrong. So, it really doesn't have a solid home within the USDA. It doesn't really have a solid home in the Department of Energy, but it is the fifth or sixth item on their list. NSF the same way and the EPA the same way. So, where do you go for funding for this if nobody really, on a federal level, accepts this area as a primary goal for funding?"[66]

Likewise, obtaining funding from private sources can be a challenge. "Venture capitalists spend 98 percent of their money on phase two or three companies. People with money are conservative right now. They are not sure about the politics. They are not sure about taxation. They are not sure about the recession really being over. All of those things will keep the money in their pocket," says one manufacturer who shared his frustration.

While Olga Selifonova, of Reluceo, acknowledges that securing necessary funding can be a challenge, she feels developers must prove the efficacy of their solutions – and work just as hard to find receptive resources to back them. "A big part of any innovation is capital. No good ideas can change things if there are no financial means to make them happen," says Selifonova. "I truly believe that people who have something worthwhile can find initial funding. But, of course, development requires a large sum of money. It is really important that you start building relationships with people who are interested in what you develop, so that they will invest."[68]

Cora Leibig with Segetis believes that the State of Minnesota should play a significant role. "If the state really wants this vision to come alive, I think anything the State can do to help motivate capital investment would be good. We already have the R&D and the technology. We have a lot of the downstream businesses and upstream businesses. There's an R&D tax credit that is nice. Anything that motivates capital investment, that's really the missing link."[82]

Securing funding for biobased material research can be challenging and time-consuming.

Promise and Potential of Bioplastics

Where Opportunity Lies for Minnesota

"Where is the greatest potential? There is no single answer."
- Olga Selifonova, Reluceo

While challenges exist in biobased manufacturing, industry experts agree that the opportunities are significant within both existing – and perhaps non-existing – product categories, according to Olga Selifonova of Minnesota-based Reluceo.

Selifonova remarks, "Where is the greatest potential? There is no single answer. It is about how we can apply the knowledge that we have acquired from petroleum chemistry and the industry it created. We must look at the renewable world with new eyes and say, 'Can we try to create non-toxic substitutes and make them with renewable feedstocks?' It is not easy, but it's possible." She continues, "But, people have a tendency to work on things that are known and proven. Few are venturing – like the phrase from Star Trek – 'To boldly go where no one has gone before.' I think we need to step back and try to invent new things, because we know that petroleum is finite. We need disposable, durable and non-toxic goods – all the things that we enjoy today, but done using different chemistry."[68]

Nearest-Term Opportunities

- Pressure-sensitive adhesives
- Foam
- Hardened plastics
- Packaging
- Certain types of non-load-bearing or non-critical-performance molded products
- Vertical integration: owning several states of the value stream – from manufacturing to distribution – either directly or through partnerships and agreements

Promising Product Sectors

Steve Kelley, who leads the Center for Science, Technology and Public Policy at the Humphrey Institute and is a co-principal investigator with the chemists and chemical engineers at the Center for Sustainable Polymers, believes some of the strongest potential exists within creating safer and compostable materials. From an economic standpoint, Kelley believes there are three product areas with strong potential – one being pressure-sensitive adhesives.

"Right now, post-it notes and stamp adhesives are not necessarily from renewable sources. So how could you develop biobased materials that have the right characteristics? The Center for Sustainable Polymers is doing the research on that. The second one is foams. What they are researching is how you can make foams – often from soybean mills – that are less toxic and still have the performance characteristics that folks want. A lot of those foams, in order to get the properties buyers want, have to have toxic chemicals added to them," Kelley says.[50]

Kelley continues, "The third area is hardened plastics. There are some drawbacks with corn-based plastic in terms of heat resistance or other types of things. So, how can you include more biobased materials in them to improve their performance and still keep some of the attractive environmental things like compostability?"[50]

Some believe the nearest-term opportunities lie in packaging and certain types of non-load-bearing or non-critical-performance molded products because of the lessened liability within those sectors. A bioplastics handle for a lawn tractor may be an easier investment "sell" to an OEM versus a steering wheel.

According to Tim Welle, BioBusiness Alliance, bioplastics offers the opportunity to boost manufacturing within Minnesota's smaller communities. "That is hopefully going to be a big part of the bioprocess and infrastructure in the state," Welle says, adding that there are other sectors that could thrive.[67]

Green Harvest Technologies' Patrick Kenney says he sees two courses of action for companies. "One is using products that biobased material fits in today, for instance, the reusable durable bottle is economical. Whereas the bottles for bottled water are economical to do; they're just not profitable to do. You're going to be using up all of your profit to do that."[79]

(Photo courtesy of Segetis, Inc).

"We certainly want to continue to have the resources and intellectual capacity, but it doesn't have a big economic development impact on Minnesota unless we are manufacturing here."
- Steve Kelley, Humphrey Institute

Kenney sees greater opportunity in vertical integration: owning several stages of the value stream – from manufacturing to distribution – either directly or through partnerships and agreements. "If you don't vertically integrate, you're paying for each of those steps to have their own infrastructure and capital, as well as their own profit margin," he says. "I see real opportunity in controlling that all of the way through. In this way, you can work with one stream of equipment that doesn't need retuning all of the time – and be able to trim down the expenses and capture the margins across each of those steps."[79]

"The emerging markets for biorenewable polyurethane foams are the places where foam cushioning is really important – seating, bedding, furniture applications," says Marc Hillmyer of the University of Minnesota. "As we get into more and more insulating applications, I think that offers even larger potential than housewares and furniture."[52]

"There are companies that mix polyurethane foams on site for use in insulating your home, and that might be an opportunity to utilize some of this new technology," Hillmyer adds.[52]

The Minnesota Advantage

What is particularly exciting, Humphrey Institute's Steve Kelley points out, is Minnesota's unique opportunity to excel. "The area of greatest opportunity is the intersection of corporate need for safer materials, with research on how to take biomaterials and give them the right characteristics, along with Minnesota having an available natural resource base. Essentially, we stand to capitalize on our currently strong corporate base in chemicals with the intellectual capacity at the University of Minnesota and our natural resources. All three areas lock together," says Kelley.[50]

The Minnesota Advantage
- Intellectual capital
- Innovative spirit
- Environmental mindset
- Rich agricultural resources
- Receptive manufacturing community
- Proven track record in fostering biocatalysis

And, as Kelley notes, this triad of opportunity is fundamental for the economy. "We certainly want to continue to have the resources and intellectual capacity, but it doesn't have a big economic development impact on Minnesota unless we are manufacturing here," he observes.[50]

Kelley comments, "I don't know how to define economically what the take-off point is or how we say, 'Now this is a big deal.' But I can see us ramping up to that point. I don't think we are starting at zero; we are starting a couple feet up the ramp."[50]

Robert Elde, Dean of the College of Biological Sciences at the University of Minnesota, and H. Ted Davis, former Dean of the Institute of Technology, agreed in "Biocatalysis and its Synergy with Healthy Ecosystems" that the State of Minnesota is particularly well-suited to host and support an industry wherein plant matter can be transformed into many products that now use petro-chemicals.

"In terms of technological capacity, Minnesota has the academic resources, the innovative spirit, a large agricultural base that could be utilized for source materials, and a proven track record in fostering life sciences companies in general and biocatalysis specifically. In addition, Minnesota already has the critical piece of an investment community that is predisposed to investing in high-risk life science endeavors (i.e., medical devices)," Elde and Davis observed.[83]

"Furthermore, important intangibles make Minnesota the right place to develop the biocatalysis industry: academic leaders at the University of Minnesota are willing to champion initiatives designed to support biocatalysis and Minnesotans are generally inclined toward environmentally friendly activities."[83]

From the private sector, Olga Selifonova of

Reluceo, agrees. "I truly believe that Minnesota is very well-positioned to become a leader in the biobased economy. I think we have the raw materials. I think we have the people. I think we have great cities to really be a leader in this country," she says.[68]

The state already has clusters of renewable-materials companies that are converting agricultural products into biofuels, chemicals and bioplastics. According to the BioBusiness Alliance, more than 75 Minnesota academic, private and public organizations are now involved in biomass catalysis and synthesis; more than 80 Minnesota organizations work in materials science; and at least a dozen Minnesota companies, large and small, produce renewable bioplastics and biopolymers.[5]

"It is clear that Minnesota has the feedstocks, infrastructure and knowledge in the ag processing industry to develop the biorefinery concept," observes Michael Sparby, Senior Director of Project Management at AURI. "This will allow farmers and processors to start moving their products from commodities into higher-value biomaterials."[84]

"The positive part about Minnesota is that we have the soybeans and the crushing facilities," says Jim Palmer of the Minnesota Soybean Board. "To complete the circle, we need the companies and the technology to be able to utilize and build the biobased products here."[77]

Taryl Enderson, General Manager for Minnesota Soybean Processors in Brewster, MN, says added value for Minnesota farmers is paramount. "We would like to move our farmer-producers to a more vertically integrated market position, and retain more value from soybeans for our producers. Bioplastics represents that kind of opportunity."[85]

In spite of Minnesota's strength and potential for building the biobased industry, however, there have been opportunities missed. Elevance Renewable Sciences, Inc. actually had its start in Minnesota. "Elevance is in Illinois because Illinois provided a more attractive home for Elevance than Minnesota did," says Andy Shafer, Executive Vice President of Sales and Marketing at Elevance. "There was some interaction with the State, but it wasn't very aggressive ... There are a lot of resources that Minnesota has, but they haven't been coordinated to really pull the things together to drive a lot of growth."[86]

Elevance employees prepare specialty chemical samples for the company's development partners.
(Photo courtesy of Elevance Renewable Sciences, Inc.)

Leveraging Minnesota's Strength in Biofuels

Doug Cameron of Alberti Advisors sees opportunity to leverage Minnesota's biofuels industry into the green chemicals category, which operates at the molecular level in discovering ways to replace petroleum-based products, such as resins, with biobased sources. For example, Cameron points to Segetis, a Twin Cities-based company that is making biobased plasticizers to replace petro-based products that are of concern in terms of human toxicity. One of the basic building blocks of the Segetis technology is levulinic acid, which they currently source from China due to lack of availability in the United States.[6]

"The real critical issue is getting the supply of levulinic acid, and all of the other pieces are pretty easy," Cameron says. "If some corn plant wanted to dedicate some effort to making lev-

"The positive part about Minnesota is that we have the soybeans and the crushing facilities. To complete the circle, we need the companies and the technology to be able to utilize and build the biobased products here."
-Jim Palmer, Minnesota Soybean Board

There is potential opportunity to leverage Minnesota's biofuels industry into the green chemicals category, which operates at the molecular level in discovering ways to replace petroleum based products such as resins with biobased sources.

ulinic acid, I'm sure that Segetis would be really interested in talking to them. So that's another Minnesota connection."[6]

Cora Leibig of Segetis, Inc. underscores that need. When asked if Segetis was sourcing the cellulose and starch needed for levulinic acid in Minnesota, she responds, "I wish we were. What it takes is a biorefinery ... for breaking down corncobs or cellulose to form the levulinic acid we need as a source. Right now, that is done in China."[82]

Both Leibig, and her Segetis, Inc. colleague, Brian Tockman, believe that there is potential in using Minnesota's leadership in biofuels as a foundation for the next state of green chemicals, many of which can be used in plastics. "Instead of collecting corn kernels, you'd be collecting corn cobs," Leibig says. "The assets that are used for making ethanol are quite different from the assets that would make levulinic acid, so you need to invest in the capital infrastructure to do that production."[82]

"Anytime there is the ability to invest additional capital on an existing site, you're able to leverage all the previous infrastructure investment. So, we think there are several locations in Minnesota and the Upper Midwest where you can have an effective biorefinery campus," Tockman adds. "You have common wastewater, common utilities, common feedstock and product handling and transport ... It's not that you can use the same fermentation vessels, because it's different technology, but you could have them be adjacent and share all of those other resources."[87]

"In this business, it is all about diversification," says Mike Jerke, General Manager of Chippewa Valley Ethanol Company in Benson, MN. "The biorefinery concept provides new products and markets to expand opportunities for the industry."[88]

Andy Shafer, with Illinois-based Elevance, says the industry will likely develop in the same manner as petrochemicals. "I believe models develop in terms of what is most efficient and attractive. The petrochemical industry tends to have the monomers for chemicals and the building blocks for fuel at refineries on an integrated site. I don't think the renewable industry will likely develop in a different manner," he says. "I think you'll see both fuels and key building-block chemicals coming off the same refinery assets. Ultimately, the most competitive sites will be ones that are integrated."[86]

According to Shafer, Elevance is building one of the world's largest biorefineries in Indonesia – and is in the advanced stages of looking at sites in North America to acquire and retrofit its technology. "We can add our technology to that infrastructure for a slight and incremental capital cost, diversify the product mix and upgrade its value substantially to the point where it becomes a viable integrated asset."[86]

Cameron also notes a New York-based company called Novomer – a chemistry company using carbon dioxide to make plastic intermediates – which, to some degree, is a competitor to biobased plastics. "Ethanol plants provide a very concentrated, very pure carbon dioxide stream. It's a lot easier to get carbon dioxide from an ethanol plant than it is from like a coal plant. So some of these companies that can use carbon dioxide as a feed stock should be thinking about combining with an ethanol plant," he adds. "Everybody is going to be happy if you can use carbon dioxide. Most of the fermentation processes will be based on corn or corn starch, but every one of them is looking at ways to use biomass."[6]

University of Minnesota experts Friedrich Srienc and John Barrett see it this way: "Typical fermentations to produce these plastics require the use of refined – that is, expensive – feedstocks, such as glucose." They continued, "To address this issue, researchers are investigating the use of less refined feed sources, for example, biomass and waste streams from other processes. Ideally, PHAs could be produced as part of a larger biorefining operation. For example, producing PHAs using glycerol waste from biodiesel production or CO2 from ethanol production, thereby offsetting the overhead costs of utilities and infrastructure ... Also, for bioplastics to retain their image as environmentally

"PHAs could be produced as part of a larger biorefining operation ... using glycerol waste from biodiesel production or CO2 from ethanol production."
- John S.F. Barrett and Friedrich Srienc, University of Minnesota

friendly alternatives that are truly superior to petroleum-derived plastics, processes should be designed in such a way that the need for toxic solvents in product recovery and purification is eliminated."[37]

In addition to the potential for producing PHAs from glycerol waste, a 2009 Informa Economics report developed for the Agriculture Utilization Research Institute noted that additional products that may be produced from a soy-based biorefinery may include soy-based foamed plastics, polyols, methyl soyate, fatty acids, waxes, alkyd resins, adhesives, epoxy resins, soy-based resin reinforced composites, soy-based nanocomposites and lubricants. [53]

Fillers, such as clay, talc, glass and paper, are commonly used in plastics to increase strength. These fillers also serve to reduce costs related to the actual plastic resin used. Using biobased fillers, such as corn stover, soybean hulls and even chicken feathers, is being explored – as is the use of a co-product of ethanol production.[89]

Distillers dried grains (DDG) and distillers dried grains with solubles (DDGS) appear to be strong candidates as reinforcement for plastics. The high fiber content, coupled with a molecular structure that is suitable for binding, are attributes that make DDG and DDGS particularly attractive in this application. Preliminary research indicates that concentrations between 25 and 50 percent worked best as fillers in plastics. While DDG/DDGS is not as strong as glass fiber, it may be suitable for applications where strength is not so much as issue, such as ceiling panels or door liners. Research on the use of distillers' grains in plastics is being conducted at Northern Illinois University and at Iowa State University.[89]

Can the University of Minnesota play a role in capitalizing on this opportunity? Paul Rothweiler, of Aspen Research, says, "Absolutely! It fits the skill sets at the University. They have a wonderful chemistry program there, and some very brilliant professors. If they could find alternative, more efficient reaction schemes for converting ethanol and other small molecules produced by microbes, they can start to make larger molecules – and those larger molecules will be used in application that petroleum is currently used and ethanol is not."[38]

Rothweiler adds, "The other problem with ethanol is they need to work on the total energy costs with forming ethanol from sugars and cellulose; there's still work to be done there."[38]

The Potential of Public-Private Partnerships

Many of the experts interviewed as part of this report saw an opportunity for collaboration and public-private partnership focused on a biobased plastics initiative for Minnesota. An example: the Ontario BioAuto Council has a mission to position the province first in the race to meet the growing demand for affordable, sustainable biobased products. The council brings together Ontario's distinct advantages in the growing biobased economy, and helps ensure participants have every opportunity to succeed.[90]

Ontario has clear advantages for biobased initiatives. It houses the largest North American auto parts and assembly industries, some of which are already using and producing parts from plant-derived feedstocks. Ontario is also a continental stronghold for research and production in agriculture and forestry, providing new plant varieties and expertise in plant oils, starches and fibers. And the provincial chemical and plastics sectors are thriving, worth an estimated $20 billion each. Industry leaders, investors and innovators from these areas all connect through the Ontario BioAuto Council.[90]

The Council's focus is biomaterials, such as flexible biobased foams for car seats and wood-fiber composites for automotive and construction applications. With a $5 million investment fund from the Government of Ontario, the council is providing support for biomaterials ventures and commercialization. With sustainability as its cornerstone, the Ontario BioAuto Council connects the ends of the value chain, and meets economic and environmental challenges head-on. Ontario has the natural resources needed for a strong biobased economy,

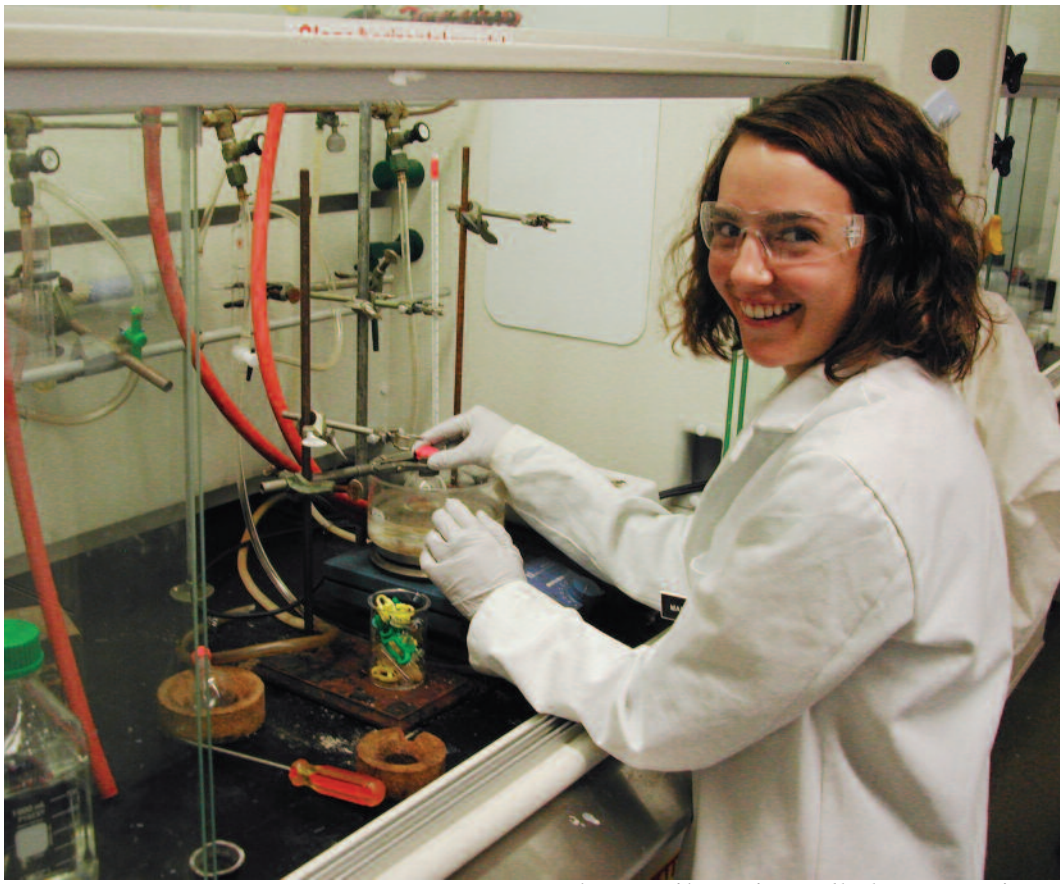


Photo courtesy of the Center for Sustainable Polymers, University of Minnesota

and the industrial capacity to advance new initiatives. The Ontario BioAuto Council is the conduit for those strengths.[90]

"We believe that building on the foundation of polymer science excellence at the University of Minnesota, we're going to be one of the world's leading centers in this area," says Marc Hillmyer of the Center for Sustainable Polymers at the University of Minnesota. It is this type of leadership and innovation that many feel can serve as a solid foundation for developing Minnesota's biobased plastics industry.[52]

Paul Rothweiler, of Aspen Research, says, "What I would like to see is more support for the University in helping to get fundamental research going on some of these newer materials and the related recycling processes. In a capitalistic environment, you should say, 'Those who are going to make money should invest money.' But, when you start looking at the unknowns and uncertainty in this area of application, there is a hesitancy to fund them – and the ultimate result is that the work doesn't happen. So, society, as the benefactors from this work, needs to place more emphasis in getting some of the research done. As that work resolves those risks and unknowns, the investors will follow – and we will all win."[38]

"Now, at the same time, there needs to be a very robust transfer of technology from academia to industry because, without that transfer, we will end up with technology sitting on the shelf that won't contribute to society," Rothweiler adds.[38]

He continues, "So, there needs to be those two: we need to help the universities perform the initial research, and ensure entrepreneurs will be able to translate that into commercially viable materials. With that, bio will then have the potential to become the new market we all

"We're going to be one of the world's leading centers in this area."
- Marc Hillmyer, Center for Sustainable Polymers, University of Minnesota

Raising the profile of what is already happening in Minnesota could be a key to spurring additional interest, technology and development.

want it to be. They need a kick-start."[38]

"Assuming these technologies are developed, and there is a robust tech-transfer bridge between the university system and industry, we should then consider providing entrepreneurs a slight incentive for commercializing it," Rothweiler adds. "That could be in the form of a tax break, or selling the material for a specified period of time. I realize that proposal could be perceived as reducing the tax income of government and subsequently taking money away from other government programs, but when I sit back and take a look at the benefits of commercializing those materials will bring, I think there is good justification for that proposal."[38]

Andy Shafer, of Elevance, says that interfacing with higher education can be a challenge. "Intellectual property is the key to driving all of this. If that can't be managed, distributed and shared, then you can't attract the investment necessary to grow young companies," he says. "All of that has to be managed so that it flows easily."[86]

At the same time, Minnesota must get proactive in capitalizing on opportunities that present themselves. Doug Cameron of Alberti Advisors was part of the group that started Elevance, a Chicago-based company that is developing chemistry from vegetable oils. "That's a big sad story for Minnesota. It was started at Cargill, and then one of the lead investors in the spinout decided that, as part of their investment, they wanted to move it to Chicago," he says. "Minnesota didn't put up much of a fight, and so this whole, big vegetable oil company that's doing extremely well and raising lots of money left Minnesota to go to Chicago. It's just too bad."[6]

John Souter, of Accent Signage, believes that raising the profile of what is already happening in Minnesota could be a key to spurring additional interest, technology and development. "Shoppers in Lakewinds, near where I live, don't know that the technology that creates the biodegradable bags they use to carry out their groceries – Ingeo® PLA – was developed by NatureWorks. And, they have no clue that this company is only a mile or so down the road from the store."[43]

Souter says that Minnesota media needs to be more informed – and engage. "One of the things that upset me over the years as a scientist with 3M, is the apparent apathy of our media to the scientific development within our community," he says. "For example, we've had some incredible inventions at 3M that generated billions of dollars, but were never really covered in any detail – perhaps the exception being Post-it® notes. Unless the media starts to understand what local companies are doing here with green technologies, and actually start to cover these on a regular basis, you will have a few more great companies like NatureWorks that very few people know about."[43]

Huhtamaki, headquartered in Espoo, Finland, estimated that 285,000 BioWare® cups and 12,000 deli containers made of Ingeo™ and used by climate change delegates effectively eliminated the amount of greenhouse gas generated by driving an average European automobile 12,305 miles.
(Photo courtesy of NatureWorks)

Making It Work

The Process to Successful Adoption of Biomaterials in Plastics Manufacturing

Adoption of biobased materials is going to be based on what manufacturers know about petroleum-based plastics.

Building on the Petroleum Experience

We have had a century to figure out how to use petroleum-based sources in plastics. The adoption curve for biobased materials in manufacturing is following a similar path, though certainly at an accelerated rate – driven by technology, innovation, environmental concerns, unstable oil supply and fluctuating prices.

Paul Rothweiler, of Aspen Research, says that adoption of biobased materials is going to be based on what manufacturers know about petroleum-based plastics. "Many of the things we did with petroleum-based materials, we're going to do with biobased materials. Essentially, it's the same molecule and, in some cases, it's exactly the same molecule as the petroleum-based materials," he says. "Much of what we do today will remain the same. What that fundamentally means is our learning curve for adopting these biobased materials will be short, because we can leverage 100 years of petroleum-based chemistry, processes and applications."[3]

Olga Selifonova, of Reluceo, agrees that adoption of sustainable, biobased products is inevitable, but believes innovation won't necessarily be rapid. "It will take time. It is still very early in the development, but expectations are very high. Now that buyers are asking, it is a chance for innovators to try to look for new solutions that can compete in terms of performance and price."[68]

"The potential really ranges from whatever plastics are currently being used to very high-specialty products."
- Friedrich Srienc, BioTechnology Institute, University of Minnesota

According to *American Recycler*, biobased plastics are expanding into two different ends of the performance scale – biobased commodity plastics for packaging and similar use; and technical biobased plastics for automotive, electronic and consumer goods applications. While short-term challenges exist related to the economic slump with project expansions, the article noted that, "... in the long-term, the challenges are more structural, such as enhancing the recycling infrastructure as well as technical properties for bioplastics."[91]

Quoting Brian Balmer of Frost & Sullivan from the article, "Bioplastic suppliers should focus on improving product performance and the depth of their product range if they are to succeed in the rapidly evolving markets for biobased plastics. End users need to be made aware of the various alternatives available in biobased plastics, with a clear definition of the performance and end-of-life characteristics of each of these biobased plastics."[91]

According to Jim Palmer with the Minnesota Soybean Board, one of the best models for soy-based products moving into petroleum-based territory is in the area of printers' inks. "While soybean ink was slightly higher in initial cost, the industry discovered that the quality, the environmental and worker safety, and the ease of clean-up far surpassed petroleum ink," he says. "Now, soy inks dominate the market in many printing applications. I think the same could happen with bioplastics. Manufacturers might pay a little more if they can offset that price increase through meeting environmental standards."[77]

"The processes have to be further developed," says Friedrich Srienc, Professor at the BioTechnology Institute, University of Minnesota. "The petro-chemical industry really evolved over many decades. [Bioplastics] are not really fully matured yet; they can be improved. The manufacturing processes and the research and development are all a part of that. We need to find out how to better modify the properties these plastics have so that they can be used for whatever application you can dream of. The potential really ranges from whatever plastics are currently being used to very high-specialty products."[4]

Supplier-Manufacturer Collaboration

Raw materials providers (e.g., resins, polyols) must convince manufacturers to consider the use of biobased materials – and many times must work in partnership with them in a virtual research and development role to discover the use, opportunities and challenges involved.

Manufacturers need to figure out how to use these biobased materials in their processes without compromising efficiency, equipment and profitability – while assuring their customers of consistent performance, reliability and competi-

(Photo courtesy of Northern Contours)

tive cost. Manufacturers who purchase biobased components from others must know, without a doubt, that these products will meet safety and testing standards and will not jeopardize their customer experience with their brand or product.

In other words, there are a number of hurdles to adopting biobased plastics – but just as many opportunities. One of the most significant hurdles is the reluctance of manufacturers to invest time and money in pilot testing bioplastics as an alternative to what they have always done.

Patrick Kenney says his company, Green Harvest Technologies, is trying to address the issue. "One of our primary objectives is to take the initiative that companies are very reluctant to do – the development work and the manufacturing – to establish that biobased materials can work in products and in the marketplace," he says. "Our focus is on developing product that uses bioplastics, making the right bioplastics formulations, leveraging the capabilities that manufacturing technology and processes can bring to make those materials perform in a product."[79]

"The product owners aren't convinced the material can perform. If a product owner asked

a plastic molder to make a product from PLA, they would mold it," says Kenney.[79]

Managing Costs for Competitiveness

But there is considerable cost and risk for manufacturers trying to meet a request for the use of bioplastics. "There is the cost of repositioning the equipment and re-characterizing the equipment, and the product owners would be relying on the manufacturer to get the material to perform in their product. Most manufacturers aren't qualified to do that development work," Kenney adds.[79]

Mullinix Packages, Inc. of Fort Wayne, IN, uses PLA from NatureWorks to make high-heat foodservice lids for a major cup supplier. According to Brian Schmitz, Vice President of Sales, the demand for biobased materials stemmed from limited market demand in specific geographic regions of the country. "We adopted PLA as a request from a customer," he says. "Many people talk about bio, but once they recognize the premiums attached, which are traditionally 20 to 30 percent over petroleum-based products, they reconsider. Less than two percent of our business is biobased."[80]

Anticipating where the market is headed has proven successful for Accent Signage, an architectural interiors and ADA signage company in the Twin Cities. John Souter of Accent Signage says, "If you do not have a business model that is based on supplying the end consumer with what they would like, as opposed to what you'd like to sell them, you'd better reinvestigate what you're doing."[43]

A 20-year veteran of 3M, Souter uses a multi-attribute analysis (MAA) to determine market trends for his company. "It's a mathematical model that enables you to get a pretty good prediction of what's going to happen, assuming that you're fairly accurate with your input data," he says. "As a wholesale company, we define the difference between a customer and a consumer. In other words, if we just followed the normal market approach of only listening to the voice of our customer and not considering the end user – as well as technology trends – we would have missed the boat on green technology. Many companies are using green-washing to look as if they are at the forefront of this movement."[43]

The MAA analysis led Accent Sig-

"The product owners aren't convinced the material can perform."
- Patrick Kenney, Green Harvest Technologies

nage to develop its Materia™ line of interior ADA signage systems, some of which use NatureWorks PLA. Most importantly, Accent Signage has been able to offer this line of products at the same price as non-biobased signage. "That was a conscious attribute in the multi-attribute model. We asked if the product was likely to fly at a 20 percent price premium. We thought, no, it would not, and I think we've been proven right," Souter adds. "One of the things that you find with the end consumer is that everyone wants to do the right thing, but few are willing to pay a premium for it."[43]

Mike Riebel with Biovation also believes that cost competitiveness of biobased plastics is achievable now. "Green is good, as long as you're within 10 percent of the competitive products. To get more than that is difficult," he says. "These biomaterials can be competitive, as long as they are engineered and developed with that in mind. Also, we're looking at higher-value applications. One of the things we've learned is that biomaterials aren't just a simple replacement. They can be engineered to replace something of much higher value with the right technology."[44]

Patrick Kenney notes that biobased materials are heavier and denser than the high-tech plastics currently used. For example, the bottled water available at Walmart is packaged in a lightweight PET bottle that is virtually paper-thin. When it's empty it can crush easily, so the machines that make these bottles have been tuned to handling very lightweight material, using high pressure and high heat.[79]

"If you were to make that same bottle with a PLA, it would probably have twice as much material, and it would be a slower process. You couldn't use as high heat; you'd have to use lower pressure. You'd have to reset all of the dials on the machine, in a sense, because you have a different recipe, so then you're producing a lower volume as well. That lower volume drives up the price," Kenney says.[79]

In the case of resins or polyols, the actual experiences of manufacturers – and consumers – with biobased products are dependent to a great degree on what happens to these biobased ingredients once they get into the manufacturing process. Purchasers of raw biobased products may use them in their own formulations, which may or may not produce optimum results. In order to mitigate these concerns, it is important for biobased "raw material" suppliers to work as "research partners" with their customers.

Photo courtesy of Segetis, Inc.

RENUVA™ and BIOH™ are two examples of commercially available products derived from vegetable oils, such as soybean oil.

The Dow Chemical Company produces RENUVA™. According to company literature, RENUVA™ utilizes a proprietary process to break down the oil, functionalize it – and then reconstruct the molecules for greater quality and consistency.[92]

According to Dow, the RENUVA™ process also eliminates odors typically associated with other biobased polyols. Additionally, this chemistry provides the opportunity to design polyols with a variety of specifications and attributes for optimum performance in specific applications.[92]

RENUVA™ is being used for seating foams, carpet backing, steering wheels, vehicle arm rests and head rests, bedding and furniture, and noise and vibration mitigation in vehicles. It is also being used in adhesives, protective coatings, and even footwear. The Green Footwear Project

led by Dow Italia is showcasing high-quality, stylish shoes using RENUVA™ polyurethane as a way to reduce the carbon "footprint" of footwear – and demonstrate that renewable resources can be an attractive and beneficial alternative for manufacturers.[92]

BIOH™ is a series of soy-based polyol products developed by Cargill and introduced in 2005. Based on promising soy-oil polymerization technology first developed at Pittsburg State University in Kansas, BIOH™ is being positioned at this point as a renewable, biobased alternative in the polyurethane foam industry for furniture, bedding, and vehicle seating and cushioning. Serta mattresses are using BIOH™ extensively in their inner spring mattresses. BIOH™ is used to replace a portion of the non-renewable petroleum-based chemicals traditionally used to manufacture foams. Commercial foams are typically made with 5 to 20 percent renewable content from BIOH™ polyols.[93]

One factor in the consistency and performance of biobased materials is the consistency and quality of the source of the biomass being used (e.g., corn, soybeans). With its relationship to Cargill, BIOH™ (although it is made from soybeans) is similar to Mirel®, in that its parent company has a long history in agricultural commodities and can, to some degree, bring a greater sense of quality control to the commodities used in its innovative biobased products and technology.

Paul Rothweiler, of Aspen Research, believes that biobased products are being considered while companies battle the unpredictability in the oil markets. "Corporations have a lot invested in being economically sound, and watch price fluctuations very closely," he says. "Companies must make sure they can produce products that are going to withstand oil price fluctuations. Biosourced materials are one of those things you look at and say, 'I need this in my portfolio to ensure stability.'"[38]

Partnership Through the Value Chain

Addressing costs is a real issue – but one that can sometimes be best addressed through close working relationships.

"Our internal policy is to use renewable or recyclable materials wherever you have cost parity. If a renewable or biobased material or recyclable material is the same cost, that's the right thing to do," Jay Olson of John Deere says.[27]

Olson adds that their manufacturing partner for the biobased seat cushion deserves a lot of credit for their commitment to finding ways to attain cost parity. "We brought this to them, they evaluated it, and they grabbed it and championed it because they also believed it was the right thing to do. And it was a cost improvement for them. They'll be able to produce a biobased seat cushion at the same cost as petroleum-based. That will put them in a leadership position because, over time, it will become less

Addressing costs is a real issue – but one that can sometimes be best addressed through close working relationships.

(Photo courtesy of NatureWorks)

"People who are strictly manufacturers could team up with some of these development groups who can work out the formulations – and help them get into the business."
- Doug Cameron, Alberti Advisors

cost than the petro-based," Olson says.[27]

Successful adoption of biobased materials can benefit significantly from full buy-in at every step. "Every link of the chain has a commitment to it, otherwise it doesn't get pulled through. It takes a champion in each line to each supplier, both externally and then the internal value chain as well, with all of the different functions within a company – product engineering, supply management, manufacturing and marketing. It's definitely a team focus, because if there's one part of the link that doesn't support it or doesn't meet their needs, then that's a barrier," Olson comments.[27]

Andy Shafer, of Elevance, says, "You have to look at the value chain. The monomer company is going to have to work with someone to get the polymer made. The polymer company is going to have to work with someone to get it converted into the fabricated article. Then, that fabricated article is going to have to get to an end user to actually use that injection-molded part, thermoformed package or whatever it may be."[86]

"At each step in the supply chain – the value chain – you're going to have different sets of issues and requirements to overcome: the ability to process, the right physical properties, the economics and the equipment required to manufacture the next step in the chain," Shafer adds. "Whatever it may be, all those factors have to be addressed."[86]

Doug Cameron, of Alberti Advisors, says that adopting biobased materials into a manufacturing environment is no small commitment. "Even if it's a very similar molecule, the fiber size is going to be slightly different and the processing speed is going to be different, so it's not a situation where you're going to flip back and forth," he says. "You would probably need to have dedicated line. You'll probably have to work with the engineers and do some testing and tweaking."[6]

Brian Schmitz of Mullunix Packages says, "We have to take great care in manufacturing, including extensive clean up between running biobased and petroleum based products. Additionally, biobased materials have limited conditions of use due to low heat deflection temperatures and brittleness."[80]

"The people who figure it out are going to have an opportunity. I have consulted with a number of companies that are setting up services or building expertise in how to formulate and make product based on these new polymers," says Doug Cameron of Alberti Advisors. "The people are going to have to put a little bit of work into reformulating and looking at their products, and it's not going to be trivial."[6]

Cameron sees opportunity for collaboration. "People who are strictly manufacturers could team up with some of these development groups who can work out the formulations – and help them get into the business."[6]

"We're very open to partnerships," says Cora Leibig with Segetis, Inc. "We believe that it's important for us to grow our business so that we attract the partnerships we need. We need supply chain partnerships; partnerships with biomass owners who can help us get a more local supply of levulinic acid; and we welcome partnerships downstream for formulating materials, as well as manufacturing partnerships for our own particular materials."[82]

"Minnesota has been a great place," Leibig adds. "There are a number of consumers of our products and formulators of our products right here in the Twin Cities and throughout Minnesota."[82]

Paul Rothweiler of Aspen Research agrees that education is key. "There is an education level associated in working with biobased plastics – especially with entrepreneurs, some of whom have come to us and want a biobased plastic for a specific application," he says. "For example, if you tell me that your product is going to have UV exposure, you cannot substitute PLA directly for acrylates because PLA has esters that break under UV exposure."[38]

Recommendations

What Should Happen Next

To address the challenges and maximize opportunities, the following action steps are recommended:

Educate

Proactively shape awareness, attitudes and understanding of the economic, health and environmental benefits of biobased products among consumers, retailers, manufacturers, and the financial and agricultural communities. Education and information exchange could stimulate demand and ensure closer alignment of product and buyer needs, as could sharing success stories of biobased development initiatives.

Support Minnesota educational institutions in shaping the skills and mindsets necessary for sustainable development. Globally, business and industry are recognizing the need to engender green thinking within their management teams and corporate strategic plans. By teaching future leaders the environmental and long-term economic benefits of sustainability, academia can provide future leaders with the tools necessary for such decision-making.

Provide education to manufacturers to help ease transition of using biobased material in their operation.

Conduct a "connect the dots" conference which brings resin/polyol providers together with university researchers, start-ups, manufacturers and venture capital to discuss what is happening, who is doing what and to begin networking Minnesota ideas, research and businesses that can help each other succeed.

Evolve group into a community of innovation to help nurture potential of biobased manufacturing in Minnesota.

Aggressively raise the media profile, through the efforts of AURI, industry partners and leaders of the agricultural community, about what is happening in Minnesota related to biobased plastics, green chemicals and bioproducts.

Collaborate and Support

Nurture an investment environment more favorable to stimulating innovation and market development. Measures should be explored that increase access to capital, particularly for developing sustainable products for new or existing markets.

More robust technology transfer. A guide or website that incorporates services available to increase biobased opportunities.

Create an innovation ecosystem involving academic institutions, nonprofits and the private sector that encourages knowledge sharing and joint ventures. A more open and collaborative environment made possible through stakeholder dialogue could accelerate innovation and product development.

- Industry and academic partnerships to support a strong research and development environment
- Forums for sharing of best practices

Encourage a strategic approach toward developing and manufacturing biobased products, supported by comprehensive and coordinated legislative actions in such areas as agricultural, environmental and industrial policy. Input to ongoing strategies and decisions should address the full product value chain from renewable raw material to final end product. Doing so could ensure sustainable market growth and support eventual job creation.

Find ways to leverage Minnesota's strong biofuels foundation and leverage it in the next generation green chemicals marketplace.

Support financing of demonstration projects and onsite assistance to manufacturers to further encourage adoption and up scaling of biobased production and innovations. As part of enhancing manufacturing receptivity and trial, further communicate the long term economic and brand differentiation benefits of biobased products to help facilitate dynamic market development.

Investigate the possibility of using ethanol and biodiesel plants as the centerpiece for a biorefinery "campus," including incubators for start-up green chemical companies, biomaterials research and development, and manufacturing using biobased materials, including the use of distillers grains as plastics strengtheners and the emerging research on using waste glycerol from biodiesel production to produce bioplastics.

Consider a biobased plastics manufacturing pilot plant facility in which manufacturers, bioplastics resin/polyols suppliers and product developers could test processes and products before scaling up to full production.

Remove Barriers

Create a clearer and more positive regulatory environment for sustainability. More proactive and collaborative engagement between government, academia and industry could be beneficial.

Support the development of closed system collection, recycling and composting of biobased plastics in large companies, athletic facilities, etc. (e.g., University of Minnesota, Cargill, Twins Stadium).

Conduct a pilot study of a community-based composting infrastructure whereby residents could bring compostable materials – including bioplastics – to a single neighborhood composting location. Turn it into an education project.

Thought Leader Forum

Thought Leader Forum

Following the completion of the *Biobased Products: Focus on Bioplastics Repor*t, AURI brought together a small group of industry thought leaders. These thought leaders have significant experience in biobased materials, innovation and industry development in the upper Midwest region and assisted in vetting the findings in this report.

The intention of the gathering was to 1) gauge responses to the report; 2) understand thought leader priorities as they relate to the report; 3) determine next steps; and 4) explore additional considerations before moving forward.

Attendees

Participants included start-up entrepreneurs, established mid-sized biobased materials companies, former executives from Fortune 500 companies, commodity group representatives, researchers and higher education administrators. Each brought a unique perspective and set of resources that will be called upon to establish a vibrant biobased materials industry in Minnesota.

The meeting was facilitated by Dick Gross, a professional facilitator with over fifteen years of experience garnering insights and building consensus in the public and private sector.

Responses to the Report

Participants found the report thought-provoking. Issues of time to market, access to capital, intellectual property protection, and talent development were discussed. The group shared several success stories within the biobased materials industry that we can learn from. They also noted that the bioplastics industry is in its infancy and changing rapidly. Participants felt that this report captures the current state of the industry in Minnesota in the midst of a very global market. The group also expressed concerns that the growing pains of the industry will be amplified in the highly connected and social networking environment – successes and failures will be immense.

Priorities and Recommendation of Thought Leader

Each of the recommendations contained in this report were discussed by the group. The facilitator asked participants to amend, remove or add to the recommendations in the report. Participants were then asked to prioritize the revised list of recommendations. The ten highest ranking recommendations were:

1. Nurture an investment environment including the provision of an infrastructure/clearinghouse mechanism.
2. Encourage a strategic approach.
3. Leverage Minnesota's strong biofuels foundation and investigate ethanol plants as potential centerpieces for a biorefinery campus, potentially structured as co-ops (two recommendations combined).
4. Proactively shape awareness, attitudes and understanding of the biobased materials industry, including what it is today, addressing the food versus biobased industry, and sustainability issues.
5. Create an innovation ecosystem that includes the entire biobased materials system, from production to consumers, and focuses on sustainability.
6. Educate manufacturers about biobased materials and their appropriate use (this is pre-consumer education).
7. Hold a "Connect the Dots" conference.
8. Evolve this group and others into an innovation community.
9. Take a more regional approach.
10. Support Minnesota educational institutions.

Next Steps

Following the official release of the report, a "Connect the Dots" conference will be held to engage a broader audience. At this conference, participants will not only connect with others involved in this industry, but will begin working on the priorities identified in the report and potentially other priorities brought forward by participants of the conference. Hopefully, this conference will lay the groundwork for the establishment of an innovation community centered on biobased materials.

Additional Resources Needed

Thought leaders identified additional research that could provide important information for the biobased materials industry, especially as it relates to a concerted effort to move the industry forward:

- An analysis/assessment of the technical, economic and environmental vitality and potential of biobased materials industry.
- Quantify the amount and type of funding resources needed to jumpstart the industry in Minnesota and regionally.
- Since this report looked specifically at bioplastics, there is an opportunity to focus on other applications of biobased materials, such as lubricants, films, biobased polymers, polyurethanes, fabrics, packaging, etc.

Lastly, thought leaders were asked to identify additional individuals and organizations that should be a part of future activities of a community centered on the biobased materials industry.

- State agencies – Department of Employment and Economic Development, Minnesota Department of Agriculture, Minnesota Pollution Control Agency, others
- The cellulosic sector (e.g., forest industry, more ag industry)
- Manufacturing industry representatives
- Investors
- End-users
- Other sectors of the biomaterials industry beyond plastics

Appendix

Definitions

Biobased: Products that are made from biological renewable raw materials such as plants and trees. The term excludes food, traditional paper and wood products, but also biomass as an energy source. Biobased products are often considered a substitute for fossil-based products, and are felt to leave a smaller ecological footprint (i.e., generate less waste, use less energy and water).

PLA: Stands for polylactide – a versatile polymer that is made from lactic acid. Lactic acid is made from dextrose by fermentation. Dextrose is made from cornstarch, which is derived from carbon dioxide and water.

Biodegradable: Describes products that can be decomposed – but not necessarily 100 percent degraded – in a microbial environment after disposal.

Compostable: Products that are 100 percent biodegradable.

Recyclable: Products that are not biodegradable or compostable, but still have useful physical or chemical properties after serving their original purpose and can, therefore, be reused or remanufactured.

Sustainable: Encompasses issues of environment, health, social and economic justice, as well as material resource sustainability throughout the entire life cycle of bioplastics from feedstock production to management of the bioplastic product after its intended use.

Biobased Content: The amount of biobased carbon in the material or product as fraction or percent weight of the total organic carbon in the material or product.

Bioplastics: Plastics in which 100 percent of the carbon is derived from renewable agricultural and forestry resources such as corn starch, soybean protein, and cellulose. They are not a single class of polymers but rather a family of products that can vary significantly from one another.

Organic: Material(s) containing carbon based compound(s) in which the carbon is attached to other carbon atom(s), hydrogen, oxygen, or other elements in a chain, ring or three-dimensional structure.

Biomaterial: Any material made from annually renewable plant matter (as opposed to non-renewable prehistoric plant material, fossil fuels), including agricultural crops and residues, and trees. Sustainable biomaterials are those that are sourced from sustainably grown and harvested cropland or forests; manufactured without hazardous inputs and impacts; healthy and safe for the environment during use; and designed to be reutilized at the end of their intended use such as via recycling or composting.

BioPreferred℠
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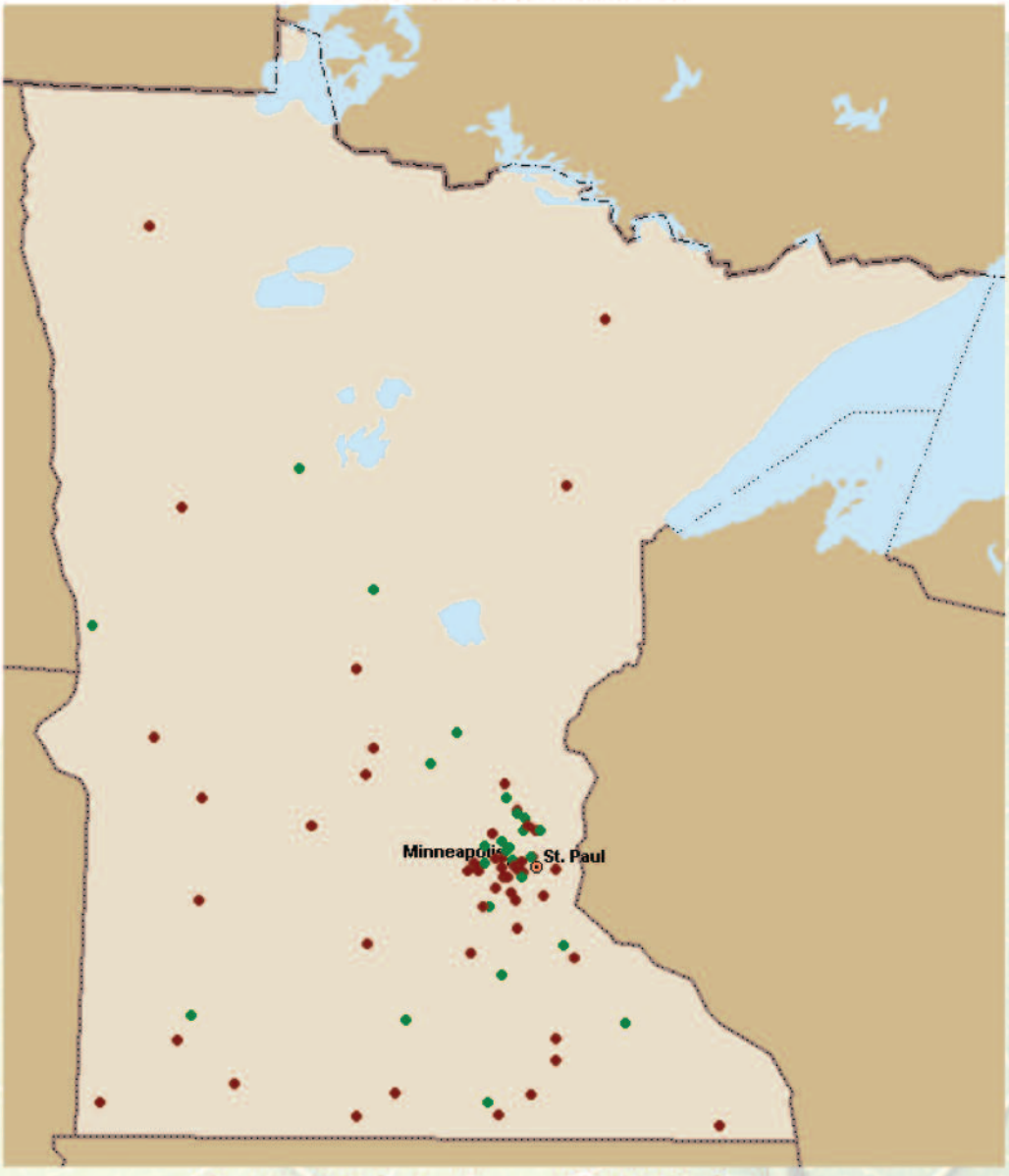
USDA
United States Department of Agriculture

Companies in Minnesota



Companies in Minnesota

City	Company	City	Company
Albert Lea	• Agra Resources Coop.	Mankato	• Environ Biocomposites Manufacturing, LLC
	• Daisy Blue Naturals		• Ridley Block Operations
	• KleenTec	Minneapolis	• AVEDA Corporation
Atwater	• Bushmills Ethanol, LLC		• BioForce Enviro-Tech Inc.
Baxter	• LINDAR Corporation		• Cargill Industrial Oils and Lubricants
Becker	• Biocorp North America		• Chemstar Products Company
	• Simply Neutral		• Eniva Corporation
Benson	• Chippewa Valley Ethanol Company, LLP		• Entropy Solutions
	• Future Products Inc.		• Herban Cowboy
Blooming Prairie	• DiaServe Inc.		• Majestic Tree Care Inc.
Bloomington	• Ardore Candles		• Mrs. Meyer's Clean Day
Burnsville	• Dianne's Custom Candles, LLC		• Natural Built Home
Campbell	• SoyCandleWorks		• Restore Products
Cannon Falls	• Clark Valley Soy Company		• SoyMade Scents
	• Sustane Natural Fertilizers Inc.		• Target
Circle Pines	• Northern Technologies International Corporation		• The Thymes
Claremont	• Al-Corn		• Warner Tool Products
Cold Spring	• Mississippi Topsoils Inc.		• Caldrea
Cook	• HillWood Products Morris		• Denco, LLC
Currie	• Environmental Dust Control Inc.	Nevis	• Minnesota Emu Inc.
Detroit Lakes	• Pet Care Systems Inc.	New Prague	• All Paper Recycling Inc.
Eagan	• Cool Clean Technologies	Newfolden	• Made By Melanie
Fairmont	• Rosen's Inc.	Osseo	• Crescent Products
Faribault	• Faribault Mills	Plymouth	• Ultra Green, LLC
Edina	• SoySoft Inc.	Princeton	• BioMatrix International
Floodwood	• Mat Inc.		• Crystal Cabinet Works Inc.
Golden Valley	• Liberty Carton Company	Prior Lake	• Basket Ease
	• McLaughlin Gormley King Co.	Rochester	• Bubbles by Brooks
	• StarchTech Inc.	Roseville	• UV Color Inc.
Granite Falls	• Grante Falls Energy, LLC	Saint Francis	• Soy Radiant
Ham Lake	• Quality Blending Inc.	Saint Joseph	• USA Solutions
	• White Oaks Candles, LLC	Saint Paul	• 3M
Heron Lake	• Heron Lake BioEnergy, LLC		• CHS Inc. / Cenex
Hollandale	• North American Mat Co.		• Cortec Corporation
Hopkins	• High Five, LLC	Shakopee	• Conklin Company Inc.
Inver Grove Heights	• Cenex	Shoreview	• Multi-Clean
Lakeville	• Copper Creek Candles Inc.		• Recyclaholics
Lino Lakes	• React-NTI		• Safe and Clean
Little Falls	• Central Minnesota Ethanol Coop.	Slayton	• Soy Scents by Joan Inc.
Long Lake	• Baltix Furniture Inc.	Spring Park	• Petzlife Products Inc.
	• Bugg Products, LLC	Wayzata	• Vetbasis
Luverne	• Agri-Energy, LLC	Winnebago	• Corn Plus, LLC
Mabel	• Steuart Laboratories	Winthrop	• Heartland Corn Products

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