Agbioscience as a Development Driver:
Minnesota's Agbioscience Strategy

November 2013

Performed for: AURI (Agricultural Utilization Research Institute)
Performed by: Battelle Technology Partnership Practice

Thanks in part to funding by:
Minnesota Corn Research & Promotion Council
Minnesota Soybean Research & Promotion Council

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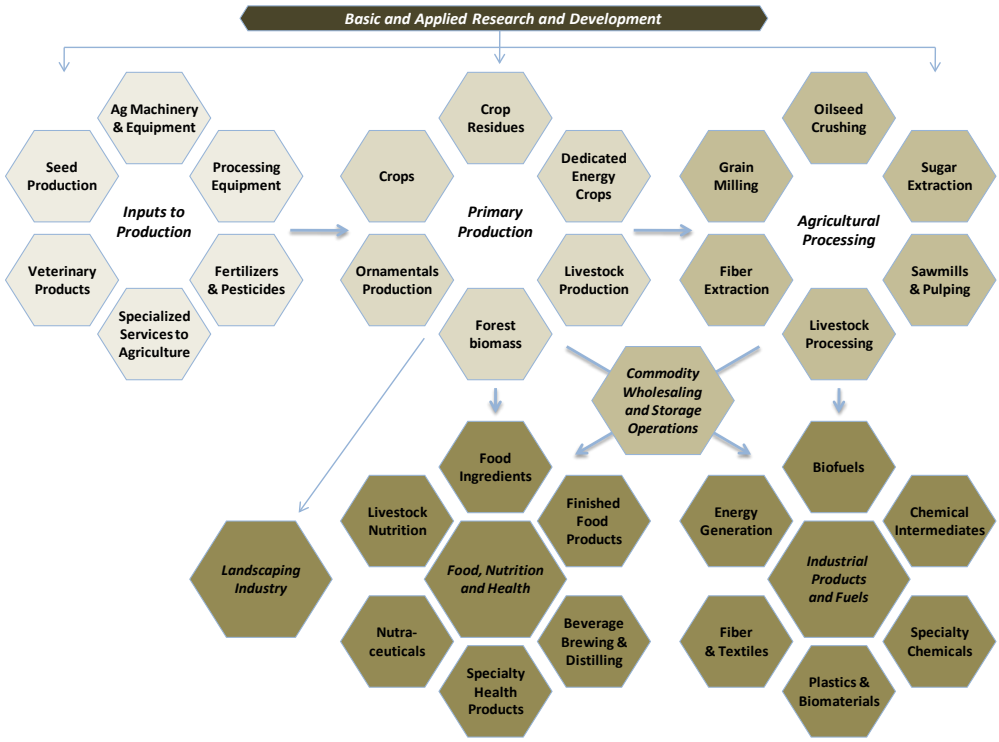
Executive Summary

In today's global knowledge-based economy, competitive advantage is best achieved in an environment that proactively stimulates innovation, knowledge transfer and technology commercialization. Michael Best, a leading scholar of growth and development across regions, notes in *The New Competitive Advantage*:[1]

> *Regions can be thought of as developing specialized and distinctive technology capabilities, which give them unique global market opportunities. The successful pursuit of these market opportunities in turn reinforces and advances their unique technological capabilities. Regional specialization results from cumulative technological capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization.*

The U.S. is a global leader in science and innovation related to agriculture and associated biosciences (collectively termed "agbioscience" herein). Within Minnesota, farmers and related industry are engaged in economic activity across this value chain, centered on crop and livestock production, but also including the development of inputs for production (agriculture equipment, seeds, agricultural chemicals, etc.) and the downstream conversion of agricultural products into a wide variety of value-added food, feed, fiber, fuel and industrial biobased products. This diverse and complex value chain, rooted in Minnesota's highly productive agriculture production system, is illustrated in Figure ES-1:

Figure ES-1: The Minnesota Agbioscience Economy



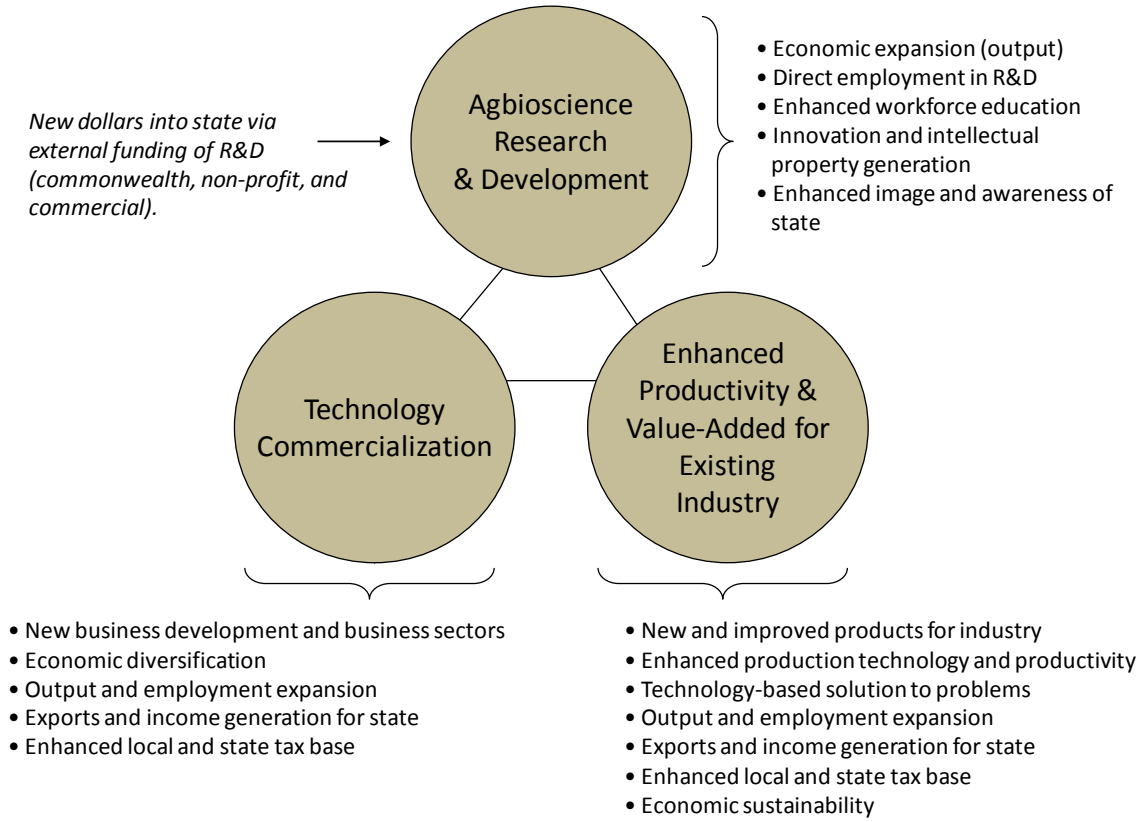
[1] Michael Best. "The New Competitive Advantage: The Renewal of American Industry." Oxford University Press, 2001.

AURI and other thought leaders within Minnesota recognize that modern agbiosciences represent a powerful tool for economic development along multiple pathways. Through performing and facilitating agbioscience research and development (R&D), working to transfer innovations and know-how into practice, and spurring the development of new and expanded business enterprise, AURI, the University of Minnesota, and other engaged institutions are facilitating:

- An expansion of high-paying jobs in agbioscience R&D and education
- The discovery of innovations to increase agricultural production in Minnesota and the transfer of knowledge and technology to protect and expand the value of agricultural and forest commodities and products
- The development of novel technologies and intellectual property for commercialization by existing or new business entities
- The diversification of the Minnesota economy into new industries that leverage biomass and biobased inputs for industrial applications.

Figure ES-2 illustrates the key economic benefits associated with the State of Minnesota's investment in AURI and other core R&D and agbioscience development assets in the state.

Figure ES-2: Economic Development Benefits Associated with Agbioscience Development



Recognizing the diversity and potential scale of economic opportunities associated with agbiosciences, AURI determined that the next phase of agbioscience-based economic development in Minnesota would benefit from having a formal assessment of agbioscience R&D core competencies performed. Having an in-depth understanding of R&D core competencies and assets will help AURI identify and understand established and emerging platforms of technologies and capabilities that could form the future launch pads for further advanced agbioscience-based economic development in Minnesota. AURI approached the Battelle's science and technology-based economic development consulting group, the Technology Partnership Practice (TPP), to:

- Undertake a quantitative and qualitative evaluation of established and emerging agbioscience core competencies in Minnesota to identify established and emerging platforms for Minnesota agbioscience-based economic development
- Develop a strategy and action plan to guide key actions and investments for agbioscience-based development in Minnesota.

This report is focused on how to help ensure that a historic industrial anchor for Minnesota, the agbiosciences, also offers outstanding growth opportunities for the future. This report addresses how industrial and academic partners might better align around the key technology platforms represented in their respective spheres, which in turn will lead to globally competitive agbioscience R&D, its commercialization, and the subsequent creation of high-paying jobs for Minnesota citizens across the entire state.

Minnesota's Agbioscience Technology Platforms

Minnesota enjoys a diversity of agbioscience R&D core competencies that represents the foundation of know-how upon which Minnesota can continue to support agbioscience innovation and generate new businesses, economic expansion, and jobs. However, individual core competencies are not sufficient to support agbioscience innovation and spur growing and emerging markets. Increasingly, agbioscience innovation requires going beyond single disciplines through transdisciplinary approaches that explore the interfaces and merge boundaries of multiple fields of research in order to solve increasingly complex problems. To maximize the development potential of its agbioscience core competencies, Minnesota needs to consider how these core competencies can be integrated into broader strategic technology platforms to serve growing and emerging market opportunities.

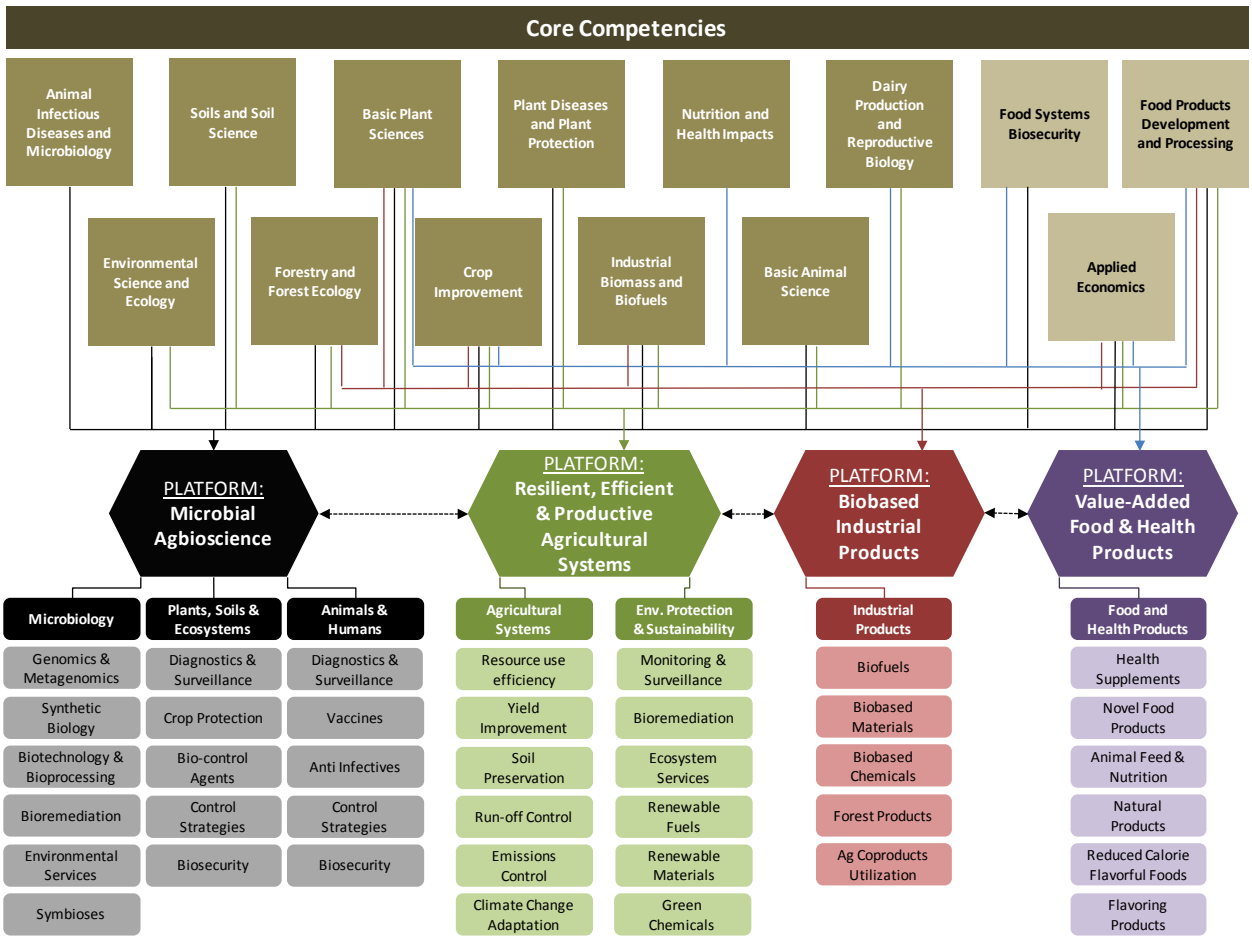
In the case for Minnesota, it is evident that four major agbioscience platforms (Table ES-1) can leverage the majority of Minnesota's agbioscience and associated core competencies.

Table ES-1: Recommended Minnesota Agbioscience Development Platforms

Platform	Primary Focus	Applications
Microbial Agbioscience	Utilizes the broad and deep microbiology, genomics, ecological science, infectious disease (plant, animal, human), biosecurity and other related areas of expertise to undertake transdisciplinary studies and promote innovation to combat agricultural and zoonotic pathogens and to utilize microbes and microbial communities to accomplish economic functions.	• Identification and characterization of pathogenic organisms • Identification, characterization and modification of organisms for biotechnology and bioremediation applications • Diagnostics, sensors, monitoring and surveillance technologies • Anti-infective agents and vaccines • Disease resistant agricultural crops • Organisms for bio-control applications and industrial applications (natural, genetically modified, or synthetic) • Inoculants and microbial ecologies for soil enhancement or growing media
Resilient, Efficient & Productive Agricultural Systems	Utilizes the outstanding ecological and environmental science research capacity in Minnesota, in combination with agriculture and agricultural systems expertise, to develop new and novel approaches and technologies for sustainable agricultural production for Minnesota and the world.	• Crops efficient in the use of inputs and natural resources • Technologies to increase agricultural yield • Soil preservation of agronomic land, and strategies for improvement of marginal soils • Methods and technologies to reduce or eliminate run-off of chemicals and manure from agricultural operations • Control of emissions from agriculture • Adaptation of agricultural systems, crops and livestock to climate variability and climate change • Systems for sensing and monitoring agriculture and forestry related pollutants and emissions • Bioremediation technologies for agriculture applications • Quantification and valuation strategies for ecosystem services • Application of biomass and biobased resources to renewable energy and other sustainable industrial applications in materials and chemicals
Biobased Industrial Products	Researching, developing and evaluating potential industrial biobased products (biofuels, materials, chemicals and value-added forest products) that are produced from farm and forestry outputs. Feedstocks may comprise primary agricultural and forestry crops, newly developed or enhanced crops, and value-added utilization of agriculture and forestry coproducts, and coproducts generated from downstream value-added industrial and food processing.	• Biofuels from primary agriculture/forestry output and coproducts/waste-streams • Biobased materials and composite structural products • Green chemicals and biobased chemicals and polymers
Value-Added Food and Health Products	Researching, developing and evaluating advanced nutrition and health products that are produced from farm and forestry outputs. Feedstocks may comprise primary agricultural and forestry crops, newly developed or enhanced crops, and value-added utilization of agriculture and forestry coproducts, and coproducts generated from downstream value-added industrial and food processing.	• Identification and characterization of functional phytochemicals and natural products with health promotion activity • Development of advanced and functional food products • Development of value-added agricultural product-based health supplements • Enhanced animal feed/nutrition products • Reduced calorie foods with enhanced flavor/sensory characteristics • Flavoring products

Multiple identified core competencies connect to each of these four platforms. Connections are illustrated in Figure ES-3, together with functional R&D and associated opportunity areas associated with each platform.

Figure ES-3: Core Competencies, Associated Platforms, and Opportunities

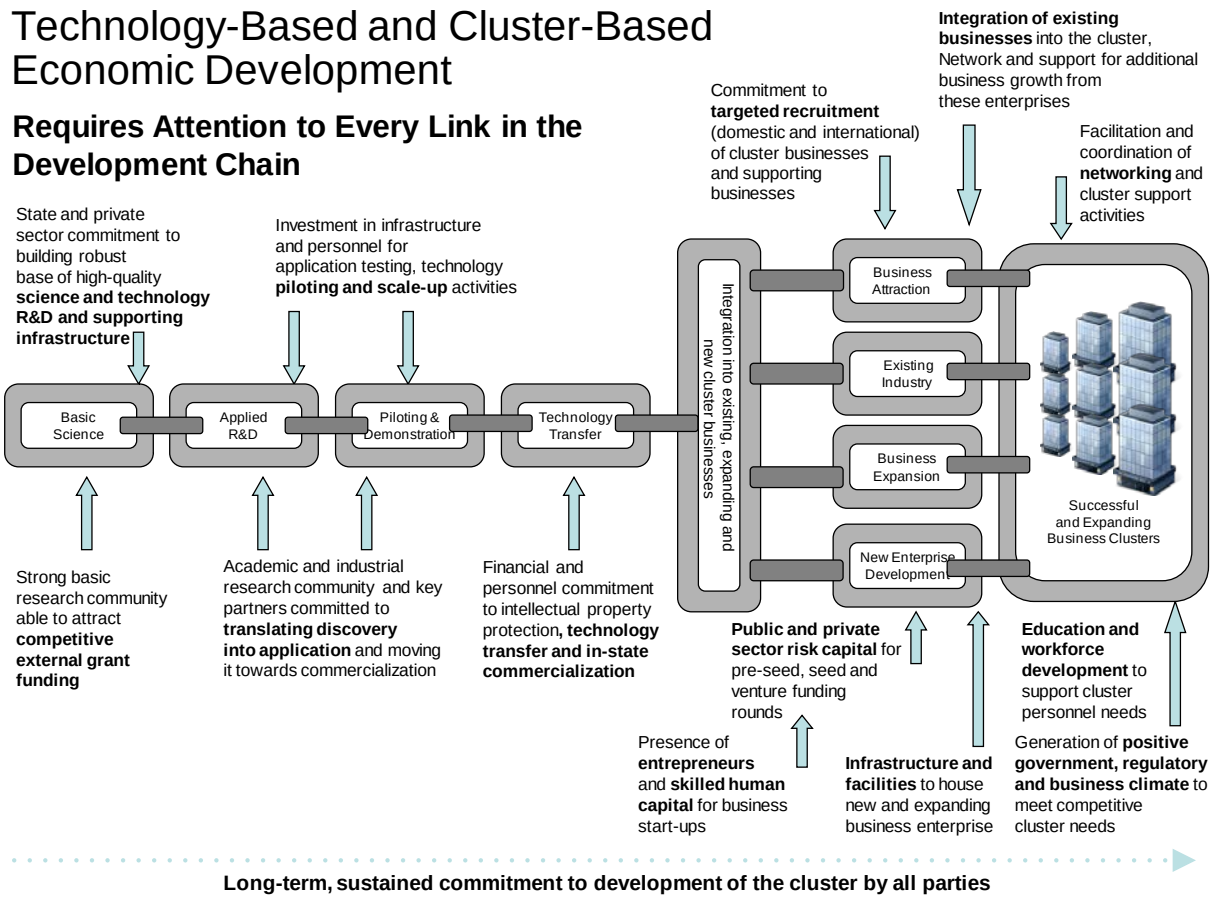


Advancing Development Plans for Targeted Agbioscience Technology Platforms

The identification of the four agbioscience technology platforms for Minnesota is not an end in itself, but rather a starting point for Minnesota to move ahead in overall agbioscience development. These agbioscience technology platforms align with the specific research core competencies found across industry and research institutions in Minnesota and have the potential to lead to products in new markets. In order for Minnesota to realize the potential of these technology platforms, it is essential to advance bold but also realistic development plans that incorporate “outside the box” thinking about how best to create the strong, systematic linkages across Minnesota’s industry and academic enterprises to ensure Minnesota is taking advantage of its agbioscience technology capabilities to remain strong in both its academic and industry settings.

It is important to recognize that for agbioscience economic development to occur at all, an entire interconnected sequence of positive factors, or what Battelle terms a "commercialization chain" or "innovation ecosystem", has to be in place that connects and strengthens the drivers of innovation and industry development, namely technology, talent and capital. If links in the commercialization chain either inadequately address economic needs or are missing altogether, a sustainable technology cluster able to generate quality jobs is unlikely to develop (see Figure ES-4).

Figure ES-4: Technology-Based Commercialization Chain



A key mechanism for unlocking the full potential of a state's research assets is to advance technology commercialization activities that are involved in enterprise development and support. This includes conducting due diligence, business planning, mentoring and coaching, pre-seed to seed and later stage risk capital financing, and a serial entrepreneurial talent pool to create, grow and attract businesses.

Critical components within such an innovation system include developing programmatic initiatives that:

- Accelerate the commercialization of university-developed technologies

- Foster value-added private sector/academic collaborations that focus on transdisciplinary, applied research that solves key agricultural production and related industrial needs
- Provide in-depth support at all stages of the enterprise creation and business launch cycle.
- Offer an integrated system for multi-use facilities and shared-use equipment targeted to scaling technology companies
- Address the need for risk capital at all stages of the technology development and commercialization life cycle. An even more critical element given the ongoing global risk capital shortages.

The end goal for a Minnesota Agbioscience Strategy is to create an environment in which:

- Cutting-edge, commercially-relevant agbioscience research leads to applied technologies and product innovations that have commercial application within key agbioscience technology platforms and industry sectors of Minnesota
- Technological advancements quickly make their way into the hands of entrepreneurs and industry leaders who create new products, form new agbioscience companies, or transfer the technology to existing Minnesota agbioscience companies
- Agbioscience companies are able to secure the needed resources to move innovative products into the market place with the support of outstanding supply chain partners, expert management teams, and sufficient financial capital
- Existing agbioscience industry clusters are supported and emerging clusters are formed as a result of Minnesota's technological strengths thereby creating global comparative advantage as a result of the mutual proximity, connections, and shared specialized infrastructure, labor markets and services.

A set of common challenges and imperatives has emerged across the four agbioscience technology platforms regarding the "missing links" in the commercialization chain that are holding Minnesota back from reaching its full agbioscience development potential. The common challenges center around four main needs:

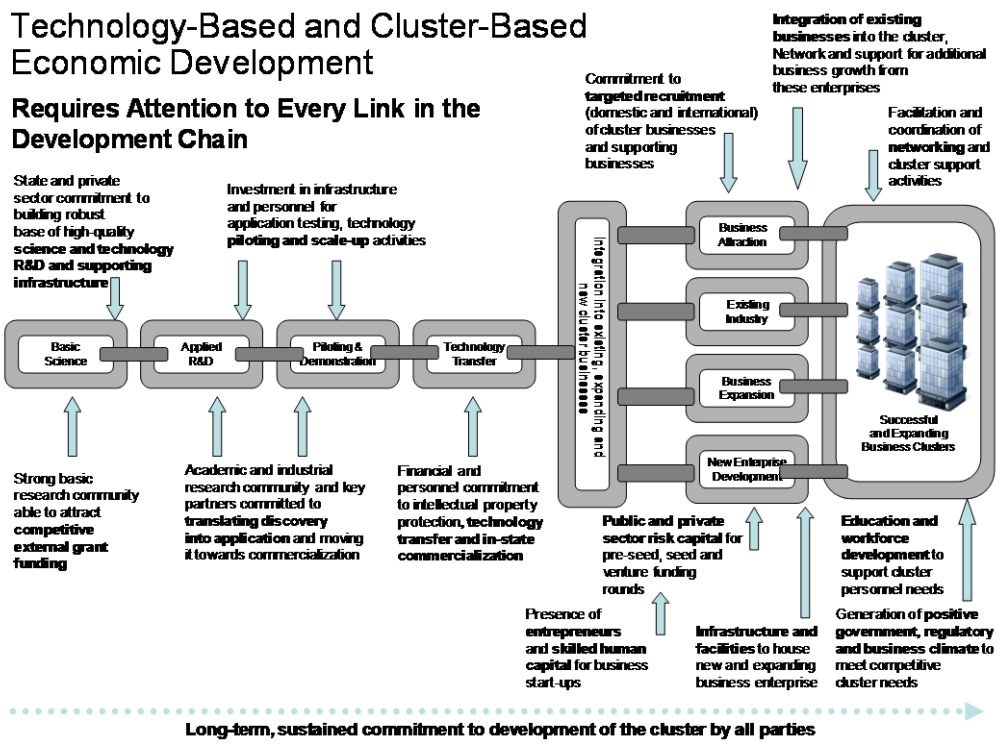
- Academic research efforts that are applied in nature, transdisciplinary in focus to adequately cover the complexity of the technology platforms, and designed to meet present and future agricultural production and related-industrial needs
- Commercialization focus that brings new products to market to increase the global competitiveness of Minnesota's private sector around each of the technology platforms
- Entrepreneurial ecosystem that addresses both the lack of human capital (entrepreneurial management talent) as well as risk capital
- Strategic partnership/networks that address broad, transformative technology platform issues.

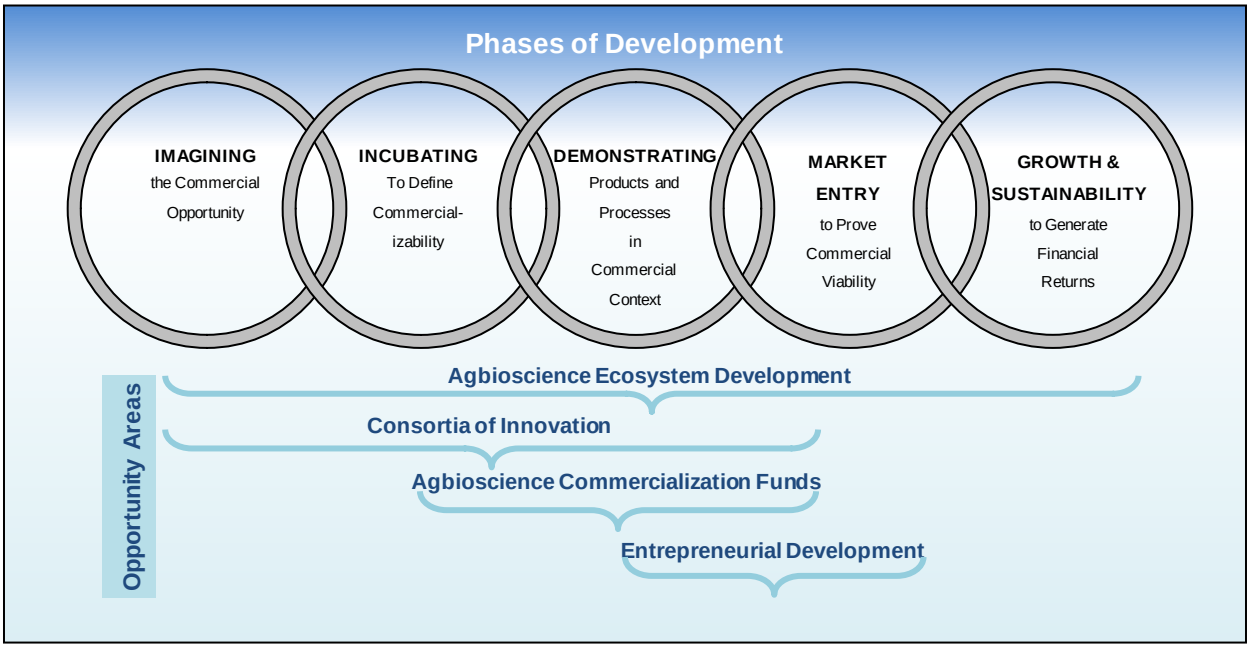
To address these common challenges, a continuum of actions/initiatives is presented that are designed to advance agbioscience development by focusing on four cross-cutting areas of opportunity:

- **Opportunity 1:** Form Cluster Networks around the identified agbioscience technology platforms to foster strategic partnering to tackle broad transformative initiatives
- **Opportunity 2:** Establish competitively designated Consortia of Innovation around Minnesota's four identified agbioscience technology platforms
- **Opportunity 3:** Build upon Minnesota's existing commercialization funds to support proof of concept and commercialization activities in order to advance technologies related to the four identified agbioscience technology platforms
- **Opportunity 4:** Design and sustain a robust, agbioscience-specific, entrepreneurial ecosystem to build a stronger, indigenous industry base in Minnesota around the four agbioscience technology platforms.

These four areas of opportunity, if implemented, will reach across the five phases of agbioscience development to help create a robust innovation ecosystem in which the agbioscience industry can thrive and flourish in Minnesota. Figure ES-5 depicts graphically where each opportunity area falls within the phases of development, and therefore what functions those efforts must seek to fulfill within the commercialization chain.

Figure ES-5: Minnesota's Agbioscience Development Strategy



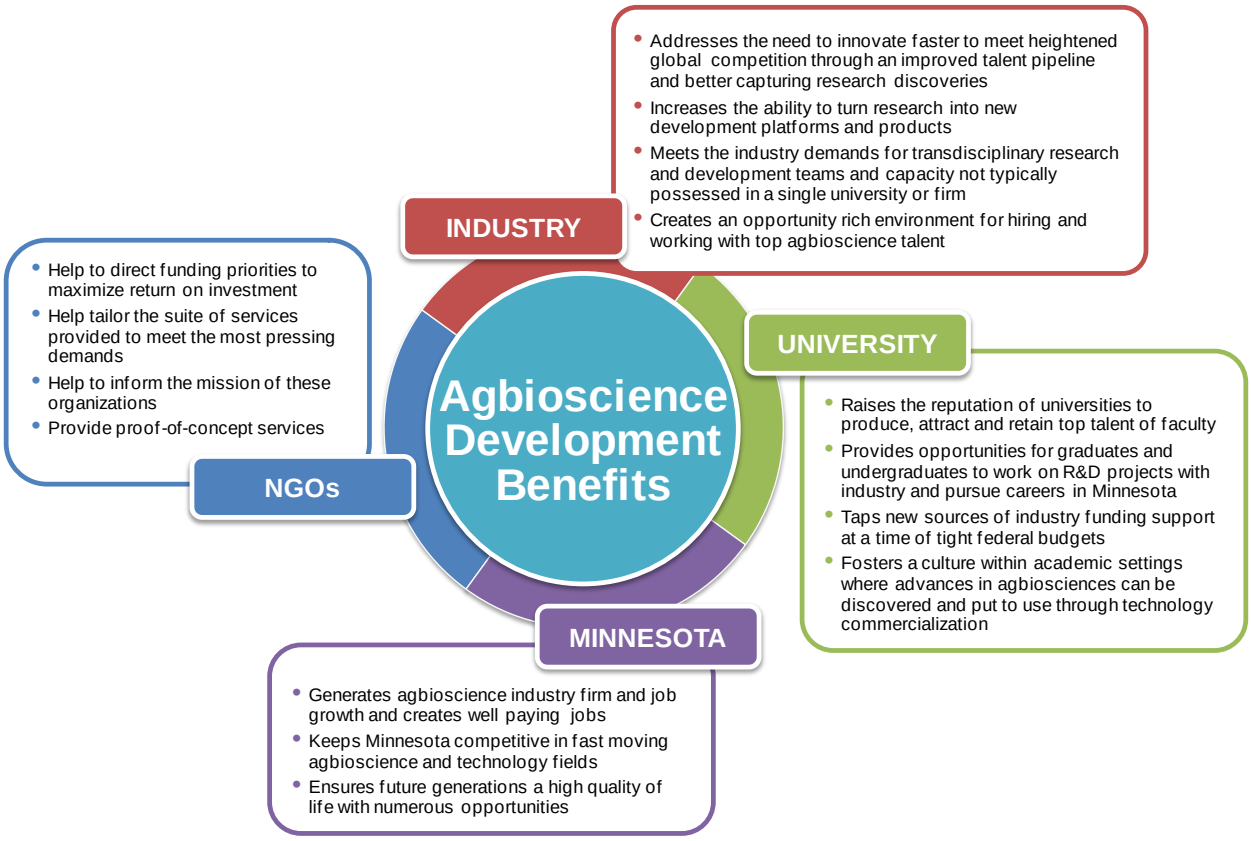


Conclusion

To advance the agbioscience sector in Minnesota, it is critical to further public-private partnerships that align the needs of the agbioscience industry with university research core competencies to foster technology commercialization and new product development efforts. In this way, Minnesota's agbioscience sector will be better able to take advantage of growing and emerging global market opportunities. The pace of such public-private partnerships is rapidly accelerating as the agbioscience sector looks to share with outside partners even more of the R&D burden (and risk) in the face of global competition and industrial challenges. For the private sector, this development has resulted in more open innovation approaches that tap the ideas and capabilities of others rather than solely relying on internal research programs for innovation and new product development.

The Agbioscience Development Strategy laid out in this report provides the rationale for the development of four technology platforms that are critical for the future growth of Minnesota's agbioscience industry. The benefits of the agbioscience development strategy to industry, universities, non-governmental organizations (NGOs), state government and other key stakeholders are summarized in Figure ES-6.

Figure ES-6: Benefits of the Agbioscience Development Strategy to Industry, Universities, NGOs, and the State of Minnesota



By aligning with and implementing this strategy, Minnesota, based on its globally competitive and unique assets, has the opportunity to incentivize agbioscience development across the state. It is

important to note, however, that Minnesota's is not alone. Numerous competitors across the nation and around the world see similar opportunities and are investing significant resources to realize economic gains. Implementing this strategy is an effort that Minnesota must engage in if it wishes to maintain and further develop its global strengths in the agbiosciences and realize subsequent economic impacts.

I. Introduction

A. Background

The character of the global economy is changing at a dramatic pace as science and technology continue to significantly impact the economic growth and wealth of both developed and developing nations. Knowledge, innovation, and intellectual capital are now at the forefront of assets driving national, state and regional economic progress. As Atkinson and Ezell illustrate, innovation "has now become the key factor in determining most nations' economic success".[2] Success in this innovation economy depends on the presence, capabilities, and linkages between key research drivers—research universities, government research institutions, non-profit research institutes and industry R&D centers.

One of the key areas of science and innovation in which the U.S. sustains leadership is in agriculture and associated biosciences (collectively termed "agbioscience" herein). Particularly in the North Central region of the U.S., including in Minnesota, agriculture remains a high-output, high-productivity industry that relies on a flow of innovations (in terms of both technologies and management practices) to sustain increases in output and maintain competitiveness in the global marketplace.

A recent report by Battelle highlights the importance of the North Central region to U.S. agricultural output, noting that:

> *The North Central states comprise only 21% of U.S. land area, but together account for fully 44% of all US agricultural commodities and 45% of U.S. agricultural exports. In multiple major commodity categories, the region is highly important and productive—responsible for 83% of U.S. soybean exports, 85% of feed grain exports, 60% of live animal and meat exports and 51% of wheat exports.*[3]

Production agriculture represents one important component in a vertically integrated agbioscience value chain. Within Minnesota, farmers and related industry are engaged in economic activity across this value chain, centered on crop and livestock production, but also including the development of inputs for production (agriculture equipment, seeds, agricultural chemicals, etc.) and the downstream conversion of

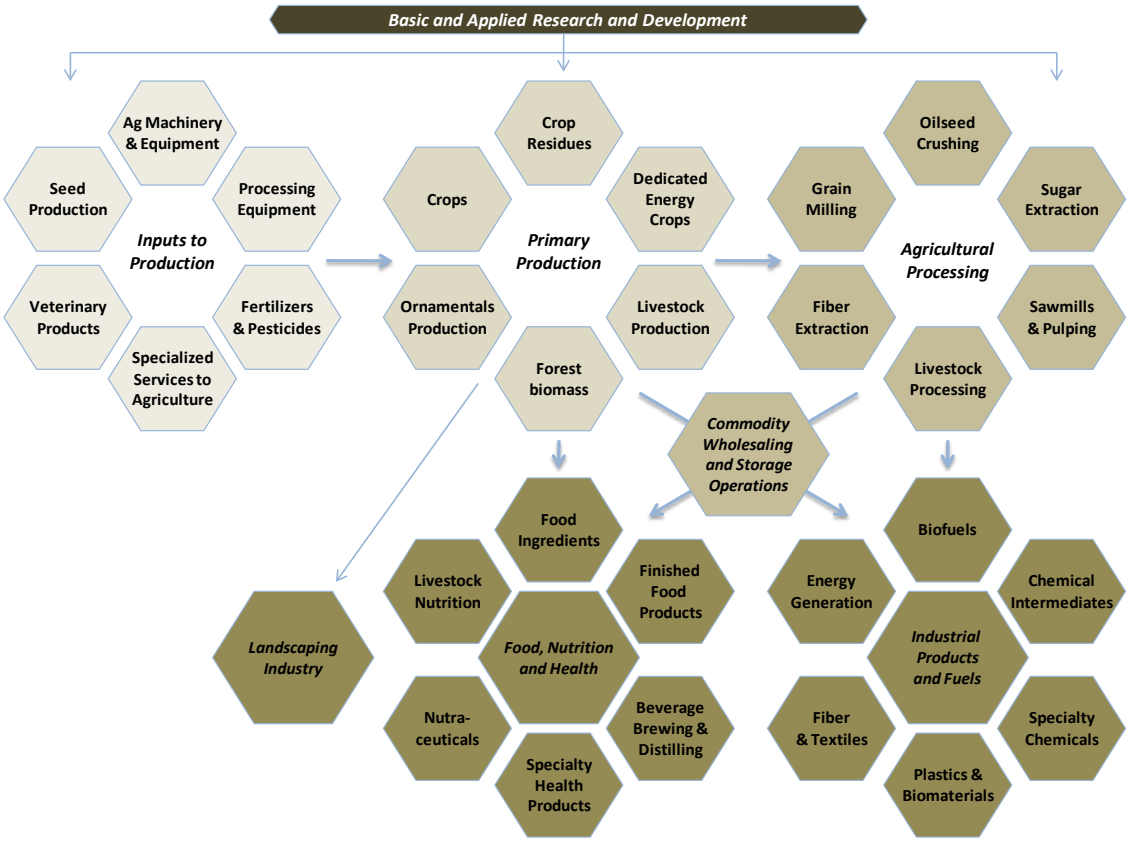
> "The U.S. is at the forefront in innovating and leveraging advanced technologies and bioscience knowledge advancements to enhance productivity and sustainability in food production and to create expanding economic opportunities in new advanced biobased products for fuels, chemicals, materials, healthcare products and a broad range of additional applications.
>
> Within the United States, the twelve-state North Central region is a leading agricultural powerhouse. Home to intensive agricultural productivity and many of the largest and most innovative companies in agbioscience and biobased development, the North Central region represents a concentrated and vertically integrated agricultural economic engine for the nation. In the North Central region new and advanced inputs to agriculture are developed, production technologies innovated and advanced, and new applications for agricultural and forest biomass developed for use as fuels, industrial feedstocks, health products and other key value-added uses."
>
> *"Power and Promise: Agbioscience in the North Central United States."* Battelle Technology Partnership Practice, 2011.

[2] Robert D. Atkinson and Stephen J. Ezell. "Innovation Economics: The Race for Global Advantage". Yale University Press. 2012.

[3] *"Power and Promise: Agbioscience in the North Central United States."* Battelle Technology Partnership Practice, 2011.

agricultural products into a wide variety of value-added food, feed, fiber, fuel and industrial biobased products. This diverse and complex value chain, rooted in Minnesota's highly productive agriculture production system, is illustrated in Figure 1:

Figure 1: The Minnesota Agbioscience Economy – From R&D through Inputs, Production, Processing and Applications



The agbiosciences value chain is complex not just in its vertically integrated structure, but also in terms of its uniquely variable operating environment conditions. Consider, for example, that unlike almost any other industry, agriculture has to contend with significant annual challenges:

- Highly variable weather patterns, rainfall volumes, soil conditions and other environmental factors
- Waxing and waning diseases, pests, weeds and natural threats to production
- Primary production spread across a very large volume of independent production entities each having to make their own individual decisions
- Sales into global commodity markets over which producers have little influence
- Increasing pressures to meet global challenges in food security while sustaining environmentally sustainable production practices

- Variable governmental policies, regulations and other factors that influence market structure and the production environment.

Minnesota has a large and specialized industry base that employs more than 213,000 or 9 percent of state private sector jobs, a base that is 27 percent more concentrated in jobs relative to the national average. Minnesota has numerous specialized strengths within the agbiosciences including primary agricultural production; food, nutrition, and health; inputs to production; commodity wholesaling and storage; and agricultural processing. In terms of production agriculture, the USDA State Agricultural Overview for 2011[4] shows that Minnesota contains 79,800 individual farms occupying over 26.8 million acres and producing almost $13.2 billion in products sold. In terms of forest resources, Minnesota contains over 15.9 million acres of timberland and harvested over 210 billion cubic feet of growing stock in 2011.[5] In 2009 the value of forest products shipments in Minnesota stood at $7.8 billion. Together, the food and wood products sectors in Minnesota account for a significant component of manufacturing in the state, with "food products" being the largest manufacturing sector in the state (as measured by employment) and "forest products manufacturing" ranked fifth.[6]

While production agriculture and forestry are distributed across a large number of individual producers, Minnesota also contains segments of the value-added agbioscience production chain that comprise multiple large and significant companies. In food processing and manufacturing, for example, Minnesota is home to nine companies with sales over $1 billion, with major enterprises including Cargill with $119.5 billion in FY2011 revenues, General Mills ($12.5 billion in 2011 food sales), Hormel Foods ($7.9 billion in 2011 food sales) and Land 'O Lakes ($4.3 billion). CHS, Inc. is a diversified company with sales in food, feed and industrial ag products ($36.9 billion in 2011 revenues) while Cargill, similarly diversified across the agbioscience value chain, is the largest privately held company in the U.S. with $119.5 billion in FY2011 revenues. Analysis by Jean Kinsey and Koel Ghosh at The Food Industry Center of the University of Minnesota[7], indicate that in 2009 there were 156 food processing/manufacturing companies in Minnesota with a combined revenue of $197.3 billion (and 31,565 employees) and 279 food distribution/wholesaling operations with combined revenues of $10.2 billion (11,093 employees).

Likewise, Minnesota's forest products and wood products industries comprise an important value-added manufacturing sector for the state. A 2012 report by the Minnesota Department of Natural Resources[8] notes that forestry, logging and forest products manufacturing generated 31,300 direct jobs in the state (in 2009) and post-harvest processing added approximately $24 per $1 in stumpage value. Within the state, this industry produces multiple value-added products, with major sub-sectors including converted paper products, paper and paperboard, window and door components, kitchen cabinets and cabinet parts, store fixtures, wood office and residential furniture, pallets and crating, millwork, and wood shavings (primarily supplied to the poultry industry).[9]

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[4] http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_MN.pdf
[5] http://www.nrs.fs.fed.us/pubs/rn/rn_nrs134.pdf
[6] http://files.dnr.state.mn.us/forestry/um/forestresourcesreport_11.pdf
[7] Jean Kinsey and Koel Ghosh 2010. "Food Companies in Minnesota: How Many are There? The Food Industry Center, University of Minnesota. Accessed online at: http://ageconsearch.umn.edu/bitstream/58445/2/MN%20Food%20Co.Report%20-%20Final.pdf
[8] "Minnesota's Forest Resources 2011." Department of Natural Resources, Division of Forestry. State of Minnesota. June 2012. Accessed online at: http://files.dnr.state.mn.us/forestry/um/forestresourcesreport_11.pdf
[9] Ibid

Minnesota has also been on the leading edge of biofuels industry development within the United States. Analysis by the Minnesota Department of Agriculture indicates that in 2011 the ethanol industry alone in Minnesota supported more than 12,600 jobs and generated over $5 billion in total economic activity within the state. Ongoing work in biofuel production efficiencies, next generation advanced biofuels, and the production of value-added biobased chemicals, polymers and materials will help this industry to further diversify into the future.

Clearly, agriculture, forestry and their associated value-chain industries represent a highly important component of the Minnesota economy. Distributed throughout the state, with production of value-added operations in every Minnesota county, the industry is exceptionally important to economic and community sustainability in both rural and urban Minnesota. Minnesota's agbioscience industry, however, like much of the national agbioscience sector, is facing challenges to remain competitive and grow. The strategic emphasis of this study can provide a useful assessment of opportunities to advance cutting-edge R&D within the state to grow technology-based agbioscience companies, both new and mature, by connecting this R&D with industry.

B. AURI's Role in Advancing Agbioscience and Associated Economic Development in Minnesota

Minnesota has been particularly progressive and proactive in supporting the growth and development of the agbioscience industry through the state-funded institution the Agricultural Utilization Research Institute (AURI), which focuses on increasing the value of agriculture and associated industries within the state economy. Likewise, the state supports the growth and the development of its natural resources, including the forestry industry, through the Natural Resources Research Institute. AURI was created and funded by the Minnesota legislature with the goals of:

- "Research and development of innovative new uses or value improvements for Minnesota agricultural commodities and products, including the identification and expansion of new and existing markets
- Implementation of basic and applied research to support innovation, technology and growth of the agricultural industry
- The development of renewable energy and biobased opportunities from Minnesota agricultural commodities and coproducts."[10]

AURI is particularly "committed to finding new uses for traditional, unexplored or overlooked agricultural resources." [11] The Institute contains scientists and technologists, business development and project management personnel who work with producers, commodity groups, businesses, universities and entrepreneurs to develop new value-added uses for agricultural commodities and coproducts. AURI is able to work with its diverse base of clients to perform research, undertake scientific assessments and evaluations of products and technologies, and to assist in evaluating the business case for commercialization of agbioscience innovations. It uses both its own in-house staff and leverages a network of professionals across the state to deliver its services.

[10] AURI Mission. Accessed online at: http://www.auri.org/about-auri/mission/
[11] Ibid

AURI's work is complementary to that provided by universities and colleges in Minnesota in agbioscience R&D, education and extension activities. The University of Minnesota, as one of the nation's largest Land-grant Universities, is a nationally recognized institution noted for both its performance of basic and applied agbioscience research, as well as for the translation of research-based innovations into practice via the Extension Service. In addition, numerous agbioscience-related research and teaching assets can be found throughout the Minnesota State Colleges and Universities (MNSCU) system, and these assets partnered with industry, government and non-profits further fosters agbioscience development across the entire state. Likewise, industry in the state undertakes its own in-house R&D, especially within the large agribusiness companies located within Minnesota.

Taken together, the assets, capabilities, resources and know-how of AURI, the University of Minnesota, other higher education research institutions, and industry R&D labs, no doubt constitute a highly robust signature asset for Minnesota. With agbiosciences representing a significant pathway to innovations and value-added products that meet grand global challenges (such as food security, energy security, environmental sustainability and stewardship), there are likely to be many opportunities for Minnesota to expand its already significant agbioscience economy moving forward.

C. Purpose of this Study

AURI and the State of Minnesota are correct in recognizing that modern agbiosciences represent a powerful tool for economic development along multiple pathways. Through performing and facilitating agbioscience R&D, working to transfer innovations and know-how into practice, and spurring the development of new and expanded business enterprise, AURI, the University of Minnesota, the Minnesota State Colleges and Universities (MnSCU) system, and other engaged institutions are facilitating:

- An expansion of high-paying jobs in agbioscience R&D and education
- The discovery of innovations to increase agricultural production in Minnesota and the transfer of knowledge and technology to protect and expand the value of agricultural and forest commodities and products

Core Competencies and State Technology-Based Economic Development

In pursuing future activities, states are learning that research institutions must nurture the development of specialized areas of expertise, or "core competencies". According to Hamel and Prahalad in their widely acclaimed business strategy book, *Competing for the Future*, "Core competencies are the gateways to future opportunities. Leadership in a core competence represents a potentiality that is released when imaginative new ways of exploiting that core competence are envisioned."[1]

Core competencies are those focused areas where research institutions can bring a critical mass of activity—as measured by research, talent generation, and unique facilities & resources—along with an identified measure of excellence. Also, in the future, it is not just having deep strengths in single disciplines that will matter, but advancing inter-disciplinary fields that can apply technology convergence to addressing key research problems and applications development. As the *Chronicle of Higher Education* notes, "[interdisciplinary] partnerships are proliferating in academe—and slowly changing the face of science—because they offer the best hope for answering some of the thorniest research subjects."[2]

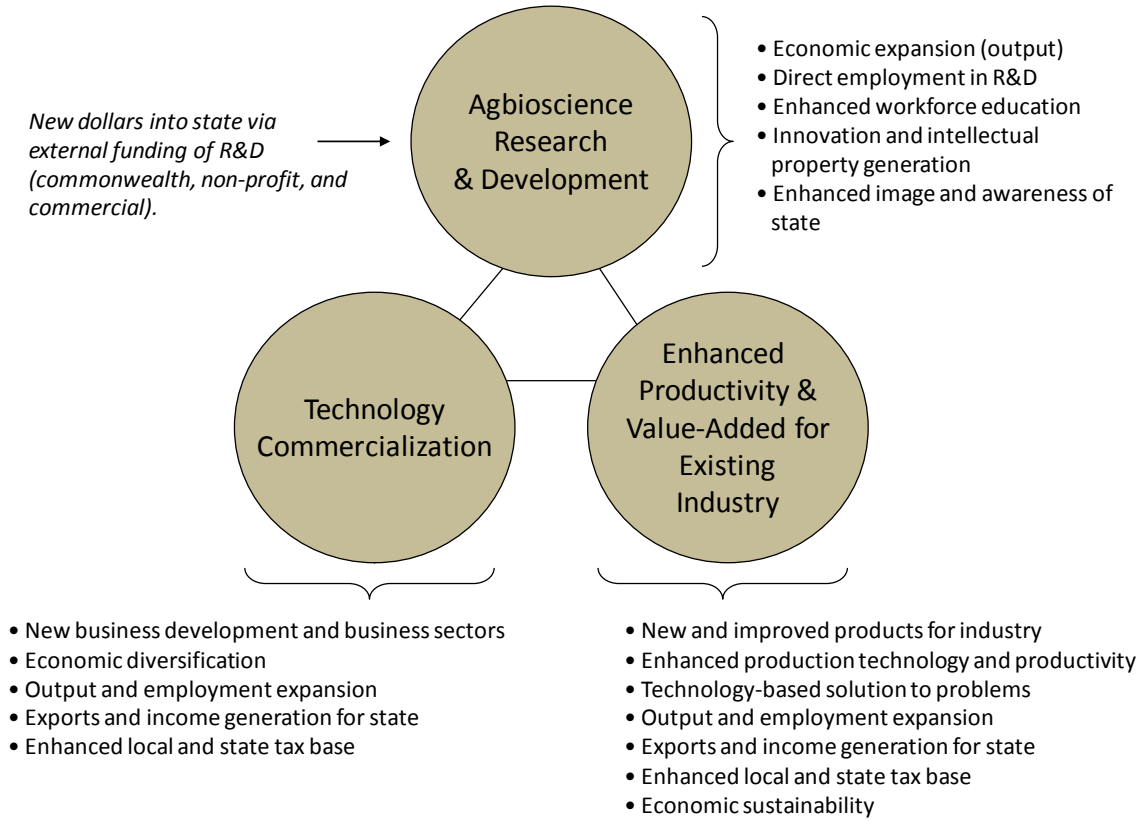
[1] Hamel and Prahalad, *Competing for the Future*, Harvard Business Press, 1994, pg. 90 and 217.

[2] Jeffrey Brainard, "U.S. Agencies Look to Interdisciplinary Science," *Chronicle of Higher Education,* June 14, 2002.

- The development of novel technologies and intellectual property for commercialization by existing or new business entities
- The diversification of the Minnesota economy into new industries that leverage biomass and biobased inputs for industrial applications.

Figure 2 illustrates the key economic benefits associated with Minnesota's investment in AURI and other core R&D and agbioscience development assets in the state.

Figure 2: Economic Development Benefits Associated with Agbioscience R&D and Associated Support Services



Recognizing the diversity and potential scale of economic opportunities associated with agbiosciences, AURI determined that the next phase of agbioscience-based economic development in Minnesota would benefit from having a formal assessment of agbioscience R&D core competencies performed. Having an in-depth understanding of R&D core competencies and assets will help AURI identify and understand established and emerging platforms of technologies and capabilities that could form the future launch pads for further advanced agbioscience-based economic development in Minnesota. AURI approached the Battelle Memorial Institute's science and technology-based economic development consulting group, the Technology Partnership Practice (TPP), to:

- Undertake a quantitative and qualitative evaluation of established and emerging agbioscience core competencies in Minnesota to identify established and emerging platforms for Minnesota agbioscience-based economic development
- Develop a strategy and action plan to guide key actions and investments for agbioscience-based development in Minnesota.

In consultation with a Steering Committee convened by AURI and drawn from the AURI Board of Directors, their designees, and other key stakeholders, Battelle undertook a four-step process to advance agbioscience development around identified technology platforms. Each of these platforms aligns with the specific core competencies found within and across the state's industry and research institutions.

- **Step One** involved conducting the core competency assessment through both quantitative and qualitative analysis, as reported in Section II
- **Step Two** involved identifying technology platforms that align multiple core competencies found across industry and universities around specific market opportunities, as reported in Section III
- **Step Three** involved interviewing industry executives, research leaders from universities and academic health organizations, government leaders, and non-profit and foundation representatives for agbioscience technology platforms to guide the identification of specific technology platform options and development plans
- **Step Four** involved preparing the final report.

This report is focused on how to help ensure that a historic industrial anchor for Minnesota, the agbiosciences, also offers outstanding growth opportunities for the future. This report addresses how industrial and academic partners might better align around the key technology platforms represented in their respective spheres, which in turn will lead to globally competitive agbioscience R&D, its commercialization, and the subsequent creation of high-paying jobs for Minnesota citizens across the entire state.

II. Assessing Agbioscience Core Competencies in Minnesota

In today's global knowledge-based economy, competitive advantage is best achieved in an environment that proactively stimulates innovation, knowledge transfer and technology commercialization. Michael Best, a leading scholar of growth and development across regions, notes in *The New Competitive Advantage*:[12]

> *Regions can be thought of as developing specialized and distinctive technology capabilities, which give them unique global market opportunities. The successful pursuit of these market opportunities in turn reinforces and advances their unique technological capabilities. Regional specialization results from cumulative technological capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization.*

One of the key elements for creating the potential for technology-based development (including agbiosciences-based economic development) is a rigorous analysis of the existing research and innovation competencies found within innovation clusters. Within Minnesota, in agbiosciences, there are multiple organizations and R&D entities with capabilities upon which future economic advances may be built. These include industry R&D groups, higher education institutions, including the University of Minnesota as the state's land-grant university, the MnSCU system, AURI, and other parties.

Without a strong R&D foundation within universities and research institutions, it is difficult for any state or nation to initiate or sustain major technology-based industrial development. In agbioscience, it is clear that Land-grant Universities and other state institutions of higher education are particularly important contributors to basic and applied research—especially research targeted at the specific needs and characteristics of their "home" agronomic environment. While multinational and domestic agbioscience companies also perform very important R&D activities, the "local environment dependency" of agricultural production lends itself to the customization of solutions to meet local needs, and academic research institutions play a critical role in providing that function (as well as feeding novel innovations into domestic and multinational agbioscience companies for commercialization). In Minnesota, the base of basic and applied R&D capability within the University of Minnesota, and in smaller niche areas within the MnSCU system, is supplemented by the very applied, business-development oriented research and assistance services provided by AURI.

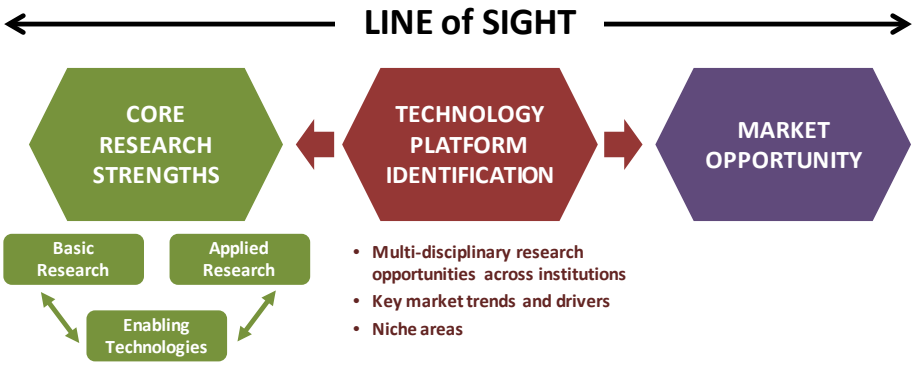
Because research is the driving force behind innovation and commercialization within the agbioscience field, and because research core competencies have been shown to be the foundation of technology cluster development, it is imperative that AURI and other key stakeholders in Minnesota have a formal understanding of the state's agbioscience core competencies.

[12] Michael Best. "The New Competitive Advantage: The Renewal of American Industry." Oxford University Press, 2001.

A. Methodological Approach Used to Assess Agbioscience Core Competencies in Minnesota

Underpinning the successful translation of research strengths into economic development opportunities requires the recognition of the importance of "market-driven" processes (Figure 3). The traditional model of commercialization assumes a "research-driven" pathway. This research-driven commercialization process proceeds in a pipeline fashion from basic research leading to a major scientific breakthrough, to applied research leading to product development, and ending with industrial manufacturing and marketing. While that process can and does work in some instances, the shortcomings of the research-driven approach are that it is too divorced from commercialization and product development needs (the voice of the market) and has uncertain line-of-sight to economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality and continuous market feedback."[13]

Figure 3: Market Opportunity, Technology Platforms and Core Competency Assessment



The components of a core competency can ideally bring together basic research, enabling technology, and applied research activities with a "line of sight" that moves seamlessly to address specific needs and market opportunities, and can form robust technology platforms. Core competency areas that lack this linkage and connection to needs and market opportunities typically offer more limited economic development opportunities.

B. Defining Core Competencies

There is no one single source of information that serves to identify core research competencies and focus areas. Rather, a variety of integrated and complementary analyses are required to help identify a state's current position and areas of focus that may lead or contribute to future growth.

In identifying core research focus areas, Battelle's objective is to identify those fields where there is a critical mass of activity ongoing along with some measure of excellence. This does not mean, however, that other fields of research excellence may not be present within the subject institutions. What it does mean is that these other research strengths are found in relatively limited pockets and so offer more limited opportunities upon which to build—but may still contribute in some manner.

[13] Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC: Council on Competitiveness), pp. 9-10.

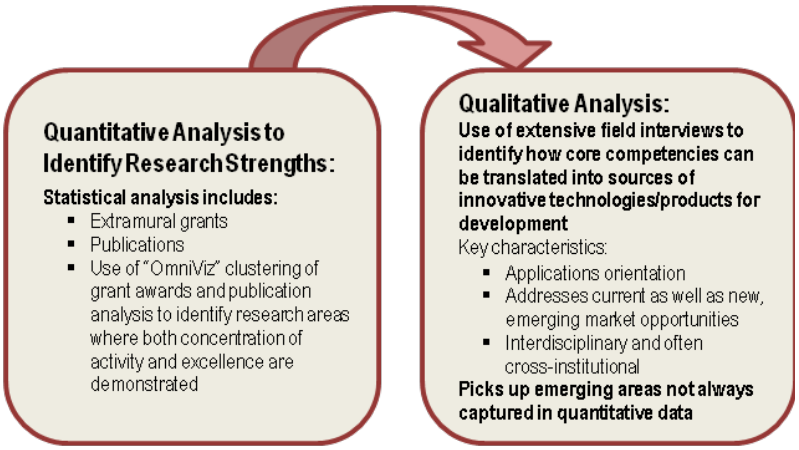
Several tests can be used to identify a core competency:

1. Is it a significant source of competitive differentiation? Does it provide the basis for a unique signature?
2. Does it comprise a critical mass of scientists and technologists?
3. Does it transcend a single business? Does it cover a range of businesses, both current and new?
4. Is it challenging for competitors to compete with and imitate?
5. Is there a line-of-sight to knowledge-transfer and commercialization of innovations arising from this R&D focus?

C. Approach to Identifying Agbioscience Core Competencies

Battelle identifies research core competencies using both quantitative and qualitative methods, as illustrated in Figure 4.

Figure 4: Quantitative/Qualitative Analysis



- Quantitative assessment uses statistical information on extramural grants and publications—as well as application of Battelle's software tool OmniViz™ to identify research clusters—to develop an understanding of the characteristics of agbioscience research within the institutions being assessed.
- Qualitative work includes extensive interviews with key administrators, scientists, and researchers across the research drivers found in the R&D-performing institutions.

Battelle's quantitative assessment starts with an in-depth examination of areas of critical mass in agbiosciences research and development. This quantitative review uses multiple data resources:

- OmniViz™ pattern recognition analysis of publication abstracts to identify distinct clusters of R&D activity
- Analysis of peer-reviewed life science publication statistics
- Presence of dedicated university centers or institutes designed to leverage institutionally identified areas of focus and excellence
- Links to existing or emerging agbioscience companies or specific agricultural applications in Minnesota.

The Battelle OmniViz™ analysis performs specialized real text cluster analysis of R&D activity as set out in publications data. Battelle uses the OmniViz™ pattern recognition software, to group publications abstracts based on the actual use of words in the abstracts and titles, allowing for free association based on the usage of words and phrases, rather than forcing clustering based on preselected key words. Thus,

the analysis goes beyond predetermined, high level classifications, such as publication field. Instead, this process analyzes the text of the abstracts for each publication to identify how these key indicators connect or "cluster" around key themes.

The performance of the clustering analysis involves the following steps (see Figure 5):

Step 1 – Content Development: A data set is developed with sufficient descriptive content.

Step 2 – Pattern Recognition: The analysis generated by OmniViz™ creates clusters in which publications, grants, and patents have apparent relationships and produce a series of words to describe and link these cluster areas.

Step 3 – Interpretation and Grouping by Battelle Review: The identification of key themes and groupings that result from an OmniViz™ cluster analysis requires an experienced research analyst to cull through the cluster items and help interpret and explain the types of technologies and specific activities that are represented.

Figure 5: Method for Using OmniViz™ Cluster Analysis

The OmniViz™ cluster used a custom dataset containing 5,987 input records. The dataset comprised:

- Publication records (published from January 2005 through September 2012) classified in agbioscience and related fields with at least one Minnesota-based author. These records, which include article title, abstract, key discipline classifications, and key words, were obtained from Thomson Reuters Web of Knowledge (using Current Contents Connect).
- Certain Web of Knowledge macro-discipline classifications were included in their entirety for this analysis. These included: plant sciences; agriculture and agronomy; entomology and pest control; veterinary medicine; animal health; agricultural chemistry; biotechnology and applied microbiology; and food science and nutrition.
- Additionally specific "ag-related" journals within the following Web of Knowledge fields were also included within the analysis: microbiology; animal sciences; molecular biology; genetics; aquatic sciences; immunology; environmental ecology; biochemistry and biophysics; cell and developmental biology; biology; soil science; earth sciences and multidisciplinary. This approach allowed for a more agriculture and ag-production-focused analysis, while not overwhelming the dataset with biomedical and other discipline records found within these broad Web of Knowledge fields.
- Finally, the customization of this OmniViz™ input file for this analysis also included 15 curriculum vitae of AURI staff members provided by AURI. This allows for the ability to see areas of university research focus in which AURI staff are also engaged.

It should be noted that the OmniViz™ search captures only publications produced while authors were employed as faculty or staff of Minnesota institutions. As such the analysis likely under-represents capabilities in some areas where there may have been major recent hires at the institutions (representing personnel whose previous publications would be categorized under their previous institution, and thus omitted). Similarly, the analysis may capture some capabilities that have since

been diluted in Minnesota by specific researchers leaving the state for other research employment opportunities.

Battelle also conducted extensive interviews with a substantial volume of university, AURI, and industry research leaders to validate the quantitative assessment and to gain additional insights regarding research strengths, opportunities, challenges, and future directions. In total, Battelle interviewed over 150 individuals across Minnesota in performing the core competency evaluation work. The questions that the Battelle team explored in the core competency assessment focused on the following:

- In which fields of science and technology are the institutions receiving significant levels of funding, especially funding from "gold standard" external sources, such as federal agencies?
- In what agbioscience and technology fields do the research institutions demonstrate a substantive and influential record of publication?
- In what agbioscience and technology areas are patents and other intellectual property being generated?
- What areas of research are connected to significant industry relationships?
- What areas of agbioscience and associated technologies do the subject institutions self-identify as being institutional core competencies and priorities?
- Based on identified core competencies, what economic development opportunities can be identified for Minnesota?

Evaluating the answers to these questions, the Battelle team is able to provide insights into the agbioscience research base, and draw implications as to how these research strengths may best intersect with Minnesota's agricultural industry, associated technological industries and economic base.

In addition, the research team also accessed individual researcher and research team web pages and other accessible research resources to add further intelligence to the core competency considerations. Battelle wishes to thank the participating universities, research institutions and individual researchers who met with the Battelle analysis team over the course of the project. The institutions were extremely helpful in facilitating meetings, hosting Battelle staff on campus, and providing follow-on information in response to Battelle inquiries.

D. Core Competencies Data Findings

Bringing together the results from the cluster analysis with the broader measures of research and development activity, along with the validation from interviews, Battelle found 11 research core competency areas. The high number of core competency areas points, by itself, to the strong potential for further agbioscience development in Minnesota. The 11 core competencies include:

- Animal Infectious Diseases and Microbiology
- Environmental Science and Ecology
- Soils and Soil Science
- Forestry and Forest Ecology
- Basic Plant Sciences
- Crop Improvement
- Plant Diseases and Plant Protection
- Industrial Biomass and Biofuels
- Nutrition and Health Impacts
- Basic Animal Science
- Dairy Production and Reproductive Biology.

The evaluation of the core competencies by key criteria is shown in Table 1 and summarizes the findings from:

- OmniViz™ publications cluster analysis
- Publishing volume and citations indices data
- Presence of dedicated university research centers or stated as a strategic thrust of research by the institution
- Notation regarding whether the competency was raised as such in interviews.

Table 1: Summary of Agbioscience and Associated Discipline Strength Areas by Key Criteria

	Evident Research Clusters (OmniViz™ Analysis) 2007–July 2012	USI Volume of Papers Published and Citation Index 2005 through 2010	Dedicated Research Centers or Stated Thrusts[14]	Interviews Validated as an Area of R&D Strength or Concentration
Research Strength Area	√√√ >500 publications √√ 200–499 publications √ 50–199 publications	√√√ >500 papers and citation indexes generally >1.1 √√ > 500 papers and citation index <1.1 OR >250–499 papers and citation index >1.1 √ >50 to 249 papers and citation index generally >1.0	Yes or No (Comments)	Yes or No

[14] All listed centers are at the University of Minnesota unless otherwise stated.

	Evident Research Clusters (OmniViz™ Analysis) 2007–July 2012	USI Volume of Papers Published and Citation Index 2005 through 2010	Dedicated Research Centers or Stated Thrusts[14]	Interviews Validated as an Area of R&D Strength or Concentration
Animal Infectious Diseases and Micro-biology	√√√ 845 records 6 OmniViz™ clusters[15]	√√√ Immunology 777 (1.1) Veterinary Medicine 514 (1.16) Infectious Diseases 291 (1.45) Microbiology 453 (1.16) Virology 180 (0.97)	YES Center for Animal Health and Food Safety Swine Disease Eradication Center Institute for Molecular Virology Veterinary Diagnostics Laboratory Center for Immunology (multidisciplinary) Complimentary expertise in human diseases within Center for Infectious Diseases and Microbiology Translational Research and the Center for Infectious Diseases Research and Policy	YES
Environ-mental Science and Ecology	√√√ 593 records 6 OmniViz™ clusters[16]	√√√ Ecology 561 (1.51)[17] Biodiversity Conservation 100 (1.45) Environmental Studies 120 (1.39) Environmental Science 679 (1.15) Marine and Freshwater Biology 150 (1.06) Limnology 125 (1.0) Water Resources 158 (0.91)	YES. Institute on the Environment Center for Integrated Natural Resources and Agricultural Management Center for Changing Landscapes Center for Environment and Natural Resource Policy Water Resources Center Minnesota Institute for Sustainable Agriculture Large Lakes Observatory Limnological Research Center USDA-ARS – Climate Change and Agriculture Center for Environmental, Earth and Space Studies at Bemidji State University Aquatic Biology Program at Bemidji State University Large River Studies Center at Winona State University	YES

[15] 845 records: 276 in "infectious diseases," "260 in porcine infectious diseases," 146 in "virology, vaccines and influenzas," 66 in "bovine infectious diseases," 65 in "e-coli infectious disease and pathogenicity" and 32 in "infectious disease assays."

[16] 593 records: 217 in "water and agricultural uses thereof", 180 in "forest soils and ecosystems", 118 in "forest ecology", 46 in "environmental and climate impacts of livestock emissions, 16 "lake sedimentation and ecology" and 16 "plant invasive species an ecosystems".

[17] First number listed is the number of publications and the second number listed is the citations index.

	Evident Research Clusters (OmniViz™ Analysis) 2007–July 2012	USI Volume of Papers Published and Citation Index 2005 through 2010	Dedicated Research Centers or Stated Thrusts[14]	Interviews Validated as an Area of R&D Strength or Concentration
Soils and Soil Science	√√√ 918 records[18] 3 OmniViz™ clusters[19]	√√ Agricultural Soil Sciences 77 (1.09) Agronomy 279 (1.25)	YES Soil Testing Laboratory (service oriented) U of M Department of Soil, Water and Climate St. Cloud State University's Environmental Soils Center and Environmental Instrumentation Center	YES
Forestry and Forest Ecology	√√√ 612 records 3 OmniViz™ clusters[20]	√ Forestry 157 (1.04)	YES Cloquet Forestry Center Center for Forest Ecology Forest Products Management Development Institute	YES
Basic Plant Sciences	√√ 340 records 7 OmniViz™ clusters[21]	√√ Plant Sciences 505 (1.0) Genetics and Heredity 643 (1.04) Biochemistry and Molecular Biology 1,172 (0.93)	YES Microbial and Plant Genomics Institute Center for Genome Engineering U of M Departments of Plant Biology and Agronomy and Plant Genetics Minnesota State University Moorhead's Department of Biology	YES
Crop Improve-ment	√√ 484 records[22] 3 OmniViz™ clusters[23]	√√ Plant Sciences 505 (1.0) Genetics and Heredity 643 (1.04) Mycology 40 (4.11) Agronomy 279 (1.25)	YES Noted research thrusts and excellence in improvement of various crops including wheat breeding and genetics, barley, and horticultural crops such as apples	YES
Plant Diseases and Plant Protection	√√ 412 records 4 OmniViz™ clusters[24]	√√ Mycology 40 (4.11) Agronomy 279 (1.25) Plant Sciences 505 (1.0)	YES Cereal Disease Laboratory USDA Cereal Diseases Laboratory USDA ARS Rust Laboratory Plant Biosecurity Level III facilities U of M Department of Plant Pathology	YES

[18] Note: "forest soils and ecosystems" with 180 records, is in this category and in "Environmental Science and ecology" and in "Forestry and Forest Ecology"

[19] 918 records: 657 in "soil science", 81 in "legume/root nitrogen fixation", 180 in "forest soils and ecosystems".

[20] 612 records: 314 in "forestry and forest management", 118 in "forest ecology", and 180 in "forest soils and ecosystems."

[21] 340 records: 71 in "flowering and plant reproductive biology", 76 in "temperature/growth and plant range", 72 in "crop seeds and plant development", 63 in "indole biosynthesis", 25 in "basic genetics" 21 in "plant sugars and biochemistry" and 12 in "basic genomics".

[22] Note, both "wheat/barley plant pathogens and resistance" and "wheat/barley and fusarium" are included in this research strength area and in "plant diseases and plant protection."

[23] 484 records: 121 in "wheat and barley genetics and improvement", 203 in "wheat/barley plant pathogens and resistance", 160 in "wheat/barley and fusarium".

	Evident Research Clusters (OmniViz™ Analysis) 2007–July 2012	USI Volume of Papers Published and Citation Index 2005 through 2010	Dedicated Research Centers or Stated Thrusts[14]	Interviews Validated as an Area of R&D Strength or Concentration
Industrial Biomass and Biofuels	√√ 438 records 2 OmniViz™ clusters[25]	√√ Agriculture – Energy and Fuels 86 (0.75) Engineering – Chemical 213 (1.27) Biotechnology and Applied Microbiology 553 (1.0)	YES Biodale – Biotech Research Services Center for Biorefining Biotechnology Institute Initiative for Renewable Energy and the Environment Center for Sustainable Polymers Materials Research, Science and Engineering Center U of M Department of Bioproducts and Biosystems Engineering St. Cloud State University's Algae Research Program Center for Environmental, Earth and Space Studies at Bemidji State University	YES
Nutrition and Health Impacts	√√ 247 records 6 OmniViz™ clusters[26]	√√ Food Science and Technology 283 (1.11) Nutrition and Dietetics 418 (1.18)	YES Healthy Foods, Healthy Lives Institute Hormel Institute Minnesota Obesity Center Obesity Prevention Center Nutrition Coordinating Center Center for Youth Health Promotion	YES
Basic Animal Science	√√ 232 records 3 OmniViz™ clusters[27]	√√ Agricultural Dairy and Animal Science 188 (1.15) Genetics and Heredity 643 (1.04)	YES Key areas of research currently include: Molecular, Cellular, Developmental, and Growth Biology Genetics (quantitative, molecular and functional) Physiology and Cell Signaling Reproduction Nutrition (ruminant and non-ruminant) Production Systems	YES
Dairy Product-ion and Repro-ductive Biology	√√ 335 records 2 OmniViz™ clusters[28]	√ Agricultural Dairy and Animal Science 188 (1.15)	YES Center for Dairy Health Management and Food Quality	YES

[24] 412 records: 203 in "wheat/barley plant pathogens and resistance," 160 in "wheat/barley and fusarium," 35 in potato/tuber genetics and blight resistance, and 14 in "pine tree rusts and associated plant pathology"
[25] 438 records: 363 in "corn biomass and biofuels" and 75 in "plant oils, biofuels and processes."
[26] 247 records: 121 in "adolescent human nutrition," 52 in "soy isoflavones/fat and nutrition," 38 in "flavors," 31 in "breakfast cereal nutrition," 21 in "food minerals and human child development," and 12 in "fish fatty acids and nutrition."
[27] 232 records: 119 in "animal muscle biology," 79 in "poultry genomics" and 34 in "ruminant digestion"
[28] 335 records: 274 in "dairy cattle and milk production" and 61 in "cattle fertility and reproductive cycles."

Additional detail regarding each core competency can be found in Appendix A.

Three areas of research strength were identified either through interviews or notation of the presence of a research center, but were not readily available by referencing the OmniViz™ or USI publications analysis. These three areas can and should be drawn upon to advance Minnesota's agbioscience sector, even though these academic strengths do not currently rise to the level of a core competency. These additional areas include:

- **Food Production and Processing:** both with the focus of AURI programs and services, as well as the University of Minnesota's Food Industry Center that has distinctive food processing pilot plant facilities available for internal research or for industry use.
- **Food System Biosecurity:** an emphasis of the National Center for Food Protection and Defense (NCFPD), a Department of Homeland Security Center of Excellence addressing "the vulnerability of the nation's food system to attack through intentional contamination with biological or chemical agents."[29] It should be noted that publications in this arena may be incorporated in the infectious animal/human diseases and plant pathology related core competencies above.
- **Applied Economics:** with the University of Minnesota Department of Applied Economics located on the St. Paul campus and faculty therein active in work with environmental and agricultural fields of study.[30] There are also additional applied economics programs throughout the MNSCU system.

E. Summary

Minnesota has a robust agbioscience research and development enterprise led by the strengths of the University of Minnesota but found across its academic institutions, which in turn offers the state a rich base of capabilities and know-how.

The next section considers how this base of agbioscience core competencies can enable Minnesota to advance select agbioscience technology platforms that are aligned to promising global market opportunities.

[29] http://www.ncfpd.umn.edu/

[30] USI data show "Agricultural Economics" with only 41 papers (and a citation index of 0.96), however "Economics" shows 149 publications and an above average citation index of 1.09.

III. Identifying Minnesota's Agbioscience Technology Platforms

As previously noted in Section II, Minnesota enjoys a diversity of agbioscience R&D core competencies that represents the foundation of know-how upon which Minnesota can continue to support agbioscience innovation and generate new businesses, economic expansion, and jobs. However, individual core competencies are not sufficient to support agbioscience innovation and spur growing and emerging markets. Increasingly, agbioscience innovation requires going beyond single disciplines through transdisciplinary approaches that explore the interfaces and merge boundaries of multiple fields of research in order to solve increasingly complex problems. To maximize the development potential of its agbioscience core competencies, Minnesota needs to consider how these core competencies can be integrated into broader strategic technology platforms to serve growing and emerging market opportunities.

In other words, not all core competencies are created equal in terms of their overall scale, their associated commercialization potential, or line-of-sight to major markets. Thus, several factors need to be taken into account when moving from core competencies to actual technology development platforms. Ideally a **PLATFORM** should:

- Be built on a cluster of competencies with a significant base of R&D and established institutes or centers to build upon
- Contain a clustering of existing businesses and institutions with interests in similar products, markets, feedstocks, processes, supply chains or technologies
- Represent a platform around which public/private partnerships may be developed to promote shared interests and encourage the development of a favorable operating environment for platform growth
- Be associated with a significant potential market with robust growth prospects and an achievable line-of-sight for bringing new products and technologies to serve market demands.

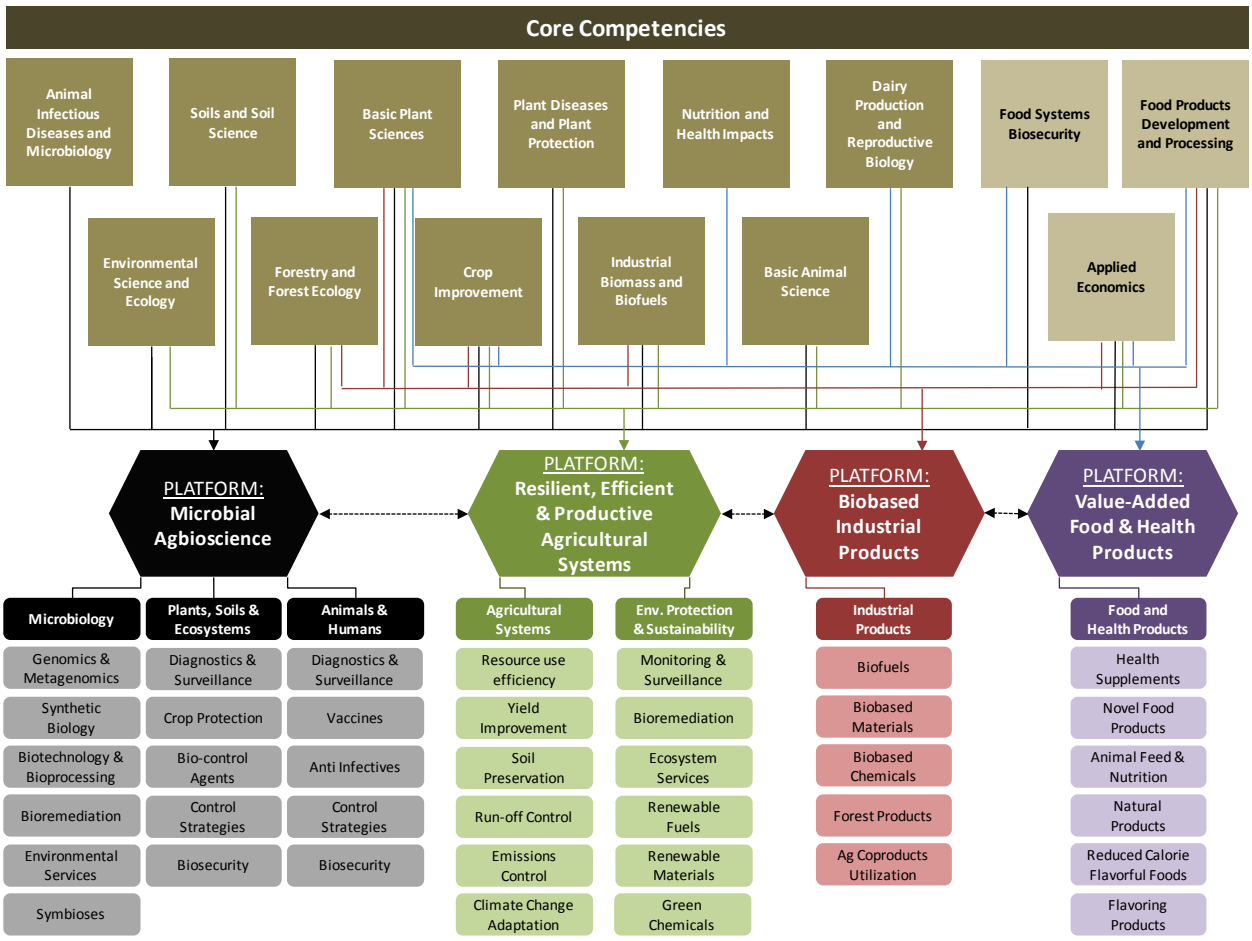
In the case of Battelle's analysis, **it is evident that four major agbioscience platforms (Table 2) can leverage the majority of Minnesota's agbioscience and associated core competencies.**

Table 2: Recommended Minnesota Agbioscience Development Platforms

Platform	Primary Focus	Applications
Microbial Agbioscience	Utilizes the broad and deep microbiology, genomics, ecological science, infectious disease (plant, animal, human), biosecurity and other related areas of expertise to undertake transdisciplinary studies and promote innovation to combat agricultural and zoonotic pathogens and to utilize microbes and microbial communities to accomplish economic functions.	• Identification and characterization of pathogenic organisms • Identification, characterization and modification of organisms for biotechnology and bioremediation applications • Diagnostics, sensors, monitoring and surveillance technologies • Anti-infective agents and vaccines • Disease resistant agricultural crops • Organisms for bio-control applications and industrial applications (natural, genetically modified, or synthetic) • Inoculants and microbial ecologies for soil enhancement or growing media
Resilient, Efficient & Productive Agricultural Systems	Utilizes the outstanding ecological and environmental science research capacity in Minnesota, in combination with agriculture and agricultural systems expertise, to develop new and novel approaches and technologies for sustainable agricultural production for Minnesota and the world.	• Crops efficient in the use of inputs and natural resources • Technologies to increase agricultural yield • Soil preservation of agronomic land, and strategies for improvement of marginal soils • Methods and technologies to reduce or eliminate run-off of chemicals and manure from agricultural operations • Control of emissions from agriculture • Adaptation of agricultural systems, crops and livestock to climate variability and climate change • Systems for sensing and monitoring agriculture and forestry related pollutants and emissions • Bioremediation technologies for agriculture applications • Quantification and valuation strategies for ecosystem services • Application of biomass and biobased resources to renewable energy and other sustainable industrial applications in materials and chemicals
Biobased Industrial Products	Researching, developing and evaluating potential industrial biobased products (biofuels, materials, chemicals and value-added forest products) that are produced from farm and forestry outputs. Feedstocks may comprise primary agricultural and forestry crops, newly developed or enhanced crops, and value-added utilization of agriculture and forestry coproducts, and coproducts generated from downstream value-added industrial and food processing.	• Biofuels from primary agriculture/forestry output and coproducts/waste-streams • Biobased materials and composite structural products • Green chemicals and biobased chemicals and polymers
Value-Added Food and Health Products	Researching, developing and evaluating advanced nutrition and health products that are produced from farm and forestry outputs. Feedstocks may comprise primary agricultural and forestry crops, newly developed or enhanced crops, and value-added utilization of agriculture and forestry coproducts, and co-products generated from downstream value-added industrial and food processing.	• Identification and characterization of functional phytochemicals and natural products with health promotion activity • Development of advanced and functional food products • Development of value-added agricultural product-based health supplements • Enhanced animal feed/nutrition products • Reduced calorie foods with enhanced flavor/sensory characteristics • Flavoring products

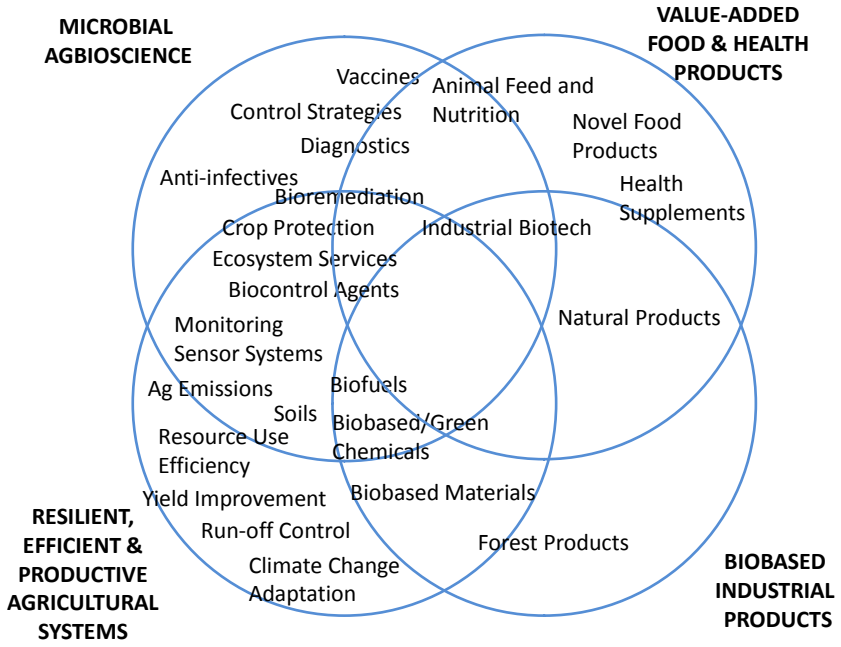
Multiple identified core competencies connect to each of these four platforms. Connections are illustrated in Figure 6, together with functional R&D and associated opportunity areas associated with each platform.

Figure 6: Core Competencies, Associated Platforms, and Opportunities



It should be noted that between these four platforms there are certain overlaps and synergies in core competencies and market opportunities that suggest advantages to cross-platform transdisciplinary collaborations. The Venn diagram shown in Figure 7 illustrates some of these synergies between the four platforms.

Figure 7: Core Competencies and Platform Intersections



A. Platform 1: Microbial Agbioscience

Platform Description: This platform coordinates, utilizes, and leverages the broad and deep microbiology, genomics, ecological science, infectious disease (plant, animal, human), biosecurity and other related areas of expertise within Minnesota to undertake transdisciplinary studies and promote innovation to combat agricultural and zoonotic pathogens and to utilize microbes and microbial communities to accomplish economic functions.

Rationale: Microbes have evolved to fit into almost every niche in the physical environment of Earth and their biodiversity has been estimated to run into the millions of species.[31] Scientists at Los Alamos National Laboratory calculate that there may be upwards of one million species per gram of soil (with most comprising rare species).[32] The microbial biosphere is not only huge in biodiversity, it is also significant in terms of its impact on other life, with microbes providing nutrient and compound cycling services essential to the operation of natural ecosystems. Microbes and all other forms of life interact in mutualistic[33], commensalistic[34] or parasitic interactions, with important impacts including (but not limited to):

[31] Jon Copley, 2005. "Millions of bacterial species revealed underfoot." New Scientist, 25 August 2005.
[32] Ibid
[33] Mutualistic relationships are symbioses in which two different species of organisms have interdependency in which each gain benefit from the other.

- Provision of nutrition services to the host (e.g., digestion in animals or provision of minerals and fixed nitrogen for plants)
- Provision by microbes or a community of microbes of defense against harmful microbes
- Provision of ecosystem services in terms of oxygen, carbon and nitrogen cycling
- Production of chemical compounds
- Causation of diseases.

Microbes are of fundamental importance to agriculture, in terms of their beneficial ecosystem and host/microbe symbiotic services, and their potential for causing disease. Modern genomics and post-genomic techniques, advanced biotechnology capabilities, and other advancements in the practice of basic and applied science, are opening new and important pathways for the application of microbiology to fundamental needs in advancing food security, assuring enhanced human health, enhancing environmental sustainability, and providing new tools for economic advancement and growth.

University R&D Strengths: The core competency analysis reveals that microbiology is both a broad and deep competency within Minnesota's academic research base. At the University of Minnesota, the presence of basic biological sciences, agricultural sciences, veterinary medicine, human biomedical sciences, environmental and ecological sciences and engineering and associated disciplines provides a particularly rich community of scientists with microbial interests and a diverse base for the application of microbiology to key challenges. With robust molecular biology, genomics, metagenomics and imaging capabilities, Minnesota is well equipped to undertake basic analytical and characterization studies. Likewise, the base of expertise in ecology and environmental science, agriculture and plant sciences, animal sciences and veterinary medicine, and human biomedical science, provides a rich base for the application of microbiology to applied problems and challenges.

The core competency analysis tables in Appendix A outline many of the assets and capabilities relevant to this platform. Some of the most notable assets include:

- Microbial genomics
- Virology
- Immunology and vaccines
- Mycology and fungal pathogens
- Applied animal infectious disease work in pigs, cattle and avian species
- Biotechnology (enhancing the understanding of microbes through their use in fermentation and industrial biotech processes)
- Biosecurity as it relates to pathogens deliberately introduced to disrupt the U.S. food supply
- Fundamental and applied work in animal nutrition and digestion
- Basic plant and soil sciences.

[34] A commensalistic relationship exists when one organism gains a benefit from another without harming the other, while in a parasitic relationship the benefit to one organism may be to the detriment of the other.

The platform has the potential to incorporate the investment in, and work of, multiple existing centers, institutes and collaborative work teams at the University of Minnesota and beyond, including for example:

- Microbial and Plant Genomics Institute
- Center for Genome Engineering
- National Center for Food Protection and Defense
- Center for Animal Health and Food Safety
- Swine Disease Eradication Center
- Institute for Molecular Virology
- Veterinary Diagnostics Laboratory
- Center for Immunology (multidisciplinary)
- Center for Infectious Diseases and Microbiology Translational Research
- Center for Infectious Diseases Research and Policy
- Biodale – Biotech Research Services
- Center for Biorefining
- Biotechnology Institute
- Initiative for Renewable Energy and the Environment
- Institute on the Environment
- Center for Sustainable Polymers
- Materials Research, Science and Engineering Center
- USDA Cereal Disease Laboratory and University of Minnesota Cereal Disease Lab
- University of Minnesota Plant Biosecurity Level III facilities
- Center for Forest Ecology.

Cross-walking the Technology Platform to Minnesota's Industry Base[35]: The microbial agbioscience research platform is designed to encompass an array of research strengths in microbiology, genomics, ecological science, infectious disease, biosecurity, and other related areas. With respect to industrial applications, these span scientific and technology-based pursuits relating to and ranging from: biotechnology, genomics, bioremediation and environmental services, diagnostics, crop protection, bio-control agents, biosecurity, vaccine development, and more. While it is somewhat challenging to cross-walk these areas of deep institutional research to their industrial applications through federal industry codes, the following table lists those industries most closely linked to these fields and breakthrough applications and the framework for industry economic analysis.

Table 3: Defining the Microbial Agbioscience Sector in Minnesota

NAICS Code	NAICS Industry Title
115112	Soil preparation, planting, and cultivating
311222	Soybean processing
311223	Other oilseed processing
311225	Fats and oils refining and blending
311313	Beet sugar manufacturing
322110	Pulp mills
325320	Pesticide and other ag. chemical mfg.
325411	Medicinal and botanical manufacturing
325413	In-vitro diagnostic substance manufacturing
325414	Other biological product manufacturing
541380*	Testing laboratories
54171*	Physical, engineering and biological research
562910	Remediation services

*Includes only the share of industry activities that are primarily in the life sciences/biosciences.

With a varied, though clearly life sciences related set of applications and markets, the microbial agbioscience sector in Minnesota is sizable and rapidly growing. In 2011, the sector employed just over 10,000 individuals across 523 business establishments, and employment is increasing. Over the past decade, Minnesota microbial agbioscience related companies have increased their employment base by

[35] To strategically connect the AURI/university research-supported technology platforms with state companies and industries, an assessment of those Minnesota industry sectors most closely tied to the technology platforms is crucial. By examining the current size and concentration of industries linked to the platforms, along with recent performance trends, a more complete picture of viable agbioscience development opportunities becomes clear. Battelle cross-walked the identified technology platforms with federal industrial classification codes (NAICS) at the most detailed level in order to provide a sense of the depth of industry activity and the state's competitiveness in those sectors with which they are closely linked. This quantitative analysis, along with a qualitative assessment, will inform strategic research investments that can best align with industry development.
Each of the four technology platforms is presented here, in turn, as a distinct industry-based profile of its economic footprint in Minnesota with respect to employment, business establishments, and employee wages. The sectors cannot and should not be combined or directly compared as some detailed industry components overlap the sectors to enable each to be defined as completely as possible on its own. The federal data used in this analysis come from the Bureau of Labor Statistics and represent a virtual census of industry reporting for those that participate in the unemployment insurance program (about 98 percent of all U.S. private employment).

nearly one-third (32.2 percent). This compares to a national growth rate for the sector of 22 percent since 2001. As a result of outpacing the nation overall, Minnesota is gaining market share in this important industry sector.

The industry sector essentially meets the average employment concentration seen nationally in the microbial agbioscience sector with a location quotient (LQ) of 0.95 in 2011. State or regional location quotients (LQs) measure the degree of job concentration within the state relative to the nation. A state with a LQ greater than 1.0 is said to have a concentration in the sector. When the LQ is significantly above average, 1.20 or greater, the region is said to have a "specialization" in the sector. As of 2011, the microbial agbioscience sector had an LQ of 0.95 meaning Minnesota nearly mirrors the nation in terms of what one would expect to see relative to national averages.

However, it is important to note that through continued growth that outpaces the nation, this sector could become a highly concentrated (becoming a specialized sector) in the coming years. Workers in this sector earn more than $74,000 per year, on average, or 55 percent greater than the average Minnesota private sector worker. This wage premium reflects the demand for high-skilled talent in an industry sector driven by scientific and technological advances.

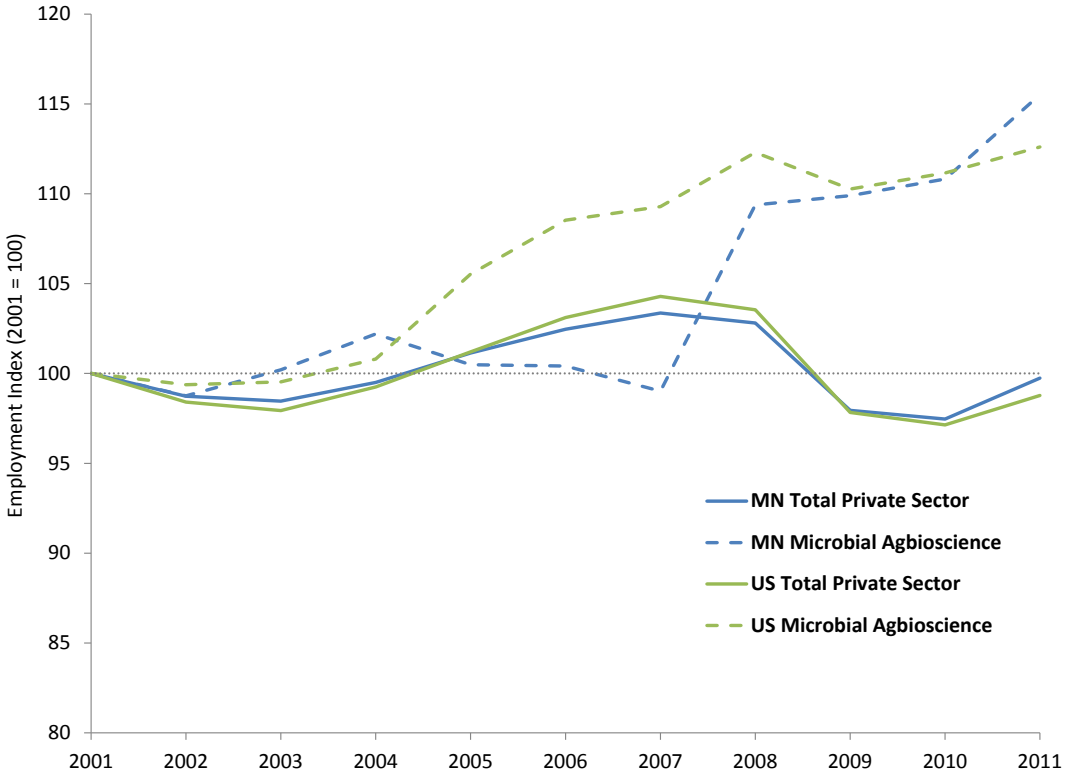
Table 4: Employment and Related Metrics for the Microbial Agbioscience Sector, 2011

Metric	Microbial Agbioscience	
	Minnesota	U.S.
Establishments, 2011	523	23,038
Establishments Change, 2001-11	32.2%	22.1%
Establishments Change, 2007-11 (Effects of Recession)	20.1%	15.5%
Employment, 2011	10,022	510,353
Employment Change, 2001-11	15.5%	12.6%
Employment Change, 2007-11 (Effects of Recession)	16.7%	3.0%
Location Quotient, 2011	0.95	n/a
Average Annual Wages, 2011	$ 74,475	$ 90,090

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

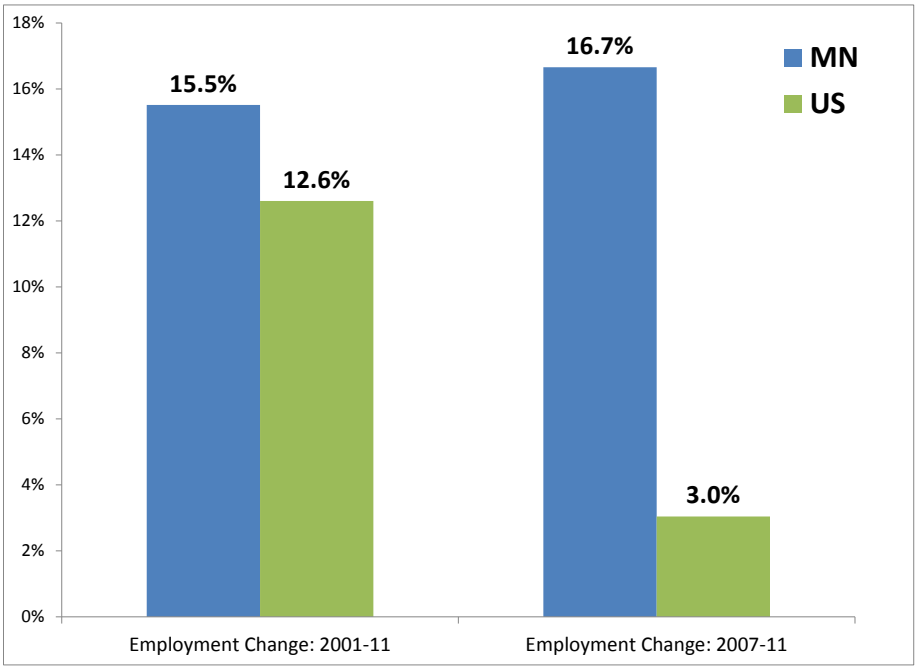
Employment in the microbial agbioscience sector was largely stagnant from 2001 through 2007, averaging a 0 percent change during this period (see Figure 8). Interestingly, after the national economy peaked in 2007 and the recession took hold, the Minnesota sector accelerated growth. In 2008, the state sector added about 900 jobs or 10 percent to its employment base and maintained growth in subsequent years. Nationally, the industry sector has grown more steadily since 2004.

Figure 8: Employment Trends in the Private and Microbial Agbioscience Sectors, 2001–11



This robust industry growth during and through the recession is evident in Figure 9 which shows what drove the job growth for Minnesota came during this 2007 through 2011 period and well outpaced the U.S.

Figure 9: Employment Trend in the Microbial Agbioscience Sector, Minnesota vs. U.S., 2001-11 and 2007–11



The experience for each component of the broader microbial agbioscience sector can differ greatly; however, the recent job growth in Minnesota has come from growth in nearly every component industry subsector. By examining three key employment-related performance measures related to strategic industry targeting the detailed industry components of the microbial agbioscience sector can be categorized to gauge its strength or emergence. These metrics answer the following:

- Is the industry specialized in its concentration relative to the nation (location quotient)?
- Is the industry growing in Minnesota?
- If the state industry is growing is it outpacing national growth and thus growing its competitive share?

Based on the answers to these questions, the sectors could be placed into one of four key designations related to industry targeting:

- Current Strengths – those industries that are specialized, growing, and outpacing national growth
- Emerging Strengths – those industries that are not yet specialized but are growing and outpacing national growth
- Priority Retention Target – those industries that are specialized and growing but are lagging performers relative to the nation
- Specialized Retention Target – those industries in which the state is specialized but is no longer growing.

Table 5: Identifying Detailed Industry Strengths for the Microbial Agbioscience Sector in Minnesota

Classification	**Specialized** (20% or higher employment concentration compared with national avg)	**Job Generator** (Generated new jobs over the 2001–11 period)	**Outpacing National Job Growth** (Job Growth from 2001–11 exceeded national avg)	**Minnesota Biobased Industrial Products & Services**
Current Strength	✓	✓	✓	• In-vitro diagnostic substance mfg • Soybean processing
Emerging Strength		✓	✓	• Soil preparation, planting, and cultivating
Priority Retention Target	✓	✓		• N/A
Specialized Retention Target	✓			• Beet sugar mfg • Fats and oils refining and blending

Note: detailed industry analysis limited to industries with at least 200 jobs in 2011.
Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Linking industry strengths with the research-based microbial agbioscience technology platform finds opportunities to leverage combined strengths in a bioscience-related technology sector—in-vitro diagnostic substances with its rapid growth and highly specialized state industry base. Further, core agbioscience industries such as the agricultural processing of soybeans and beet sugar as well as the refining and blending of fats and oils are specialized industrial areas in which research competencies can be further leveraged. In terms of crop surveillance and control strategies, the soil preparation, planting, and cultivating sector is modest in size though emerging with strong growth.

Evidence of Innovation Driving the Future Development of the Technology Platform:

Within a technology platform, a number of indicators can be examined to begin to develop a sense of the level of innovation or commercialization that is occurring to drive a technology platform into the future. Such measures include the level of patenting by industry and academia within a given technology platform, the level of risk capital being invested within a technology platform, and the level of SBIR (Small Business Innovation Research) grants being awarded within a given technology platform.

Patents: Utilizing patents as a means to understand the innovation environment of a state is useful in many ways. By analyzing patents, a picture emerges of not only the level of patent activity in a state within a given technology platform, but also key industrial drivers of that innovation. For instance, larger companies with relatively high levels of innovation can be identified that could have a significant role in moving the technology platform forward in the future. Patenting may also play an important role in securing funding for startups that represent emerging areas of opportunity.

The patent analysis focuses primarily on patents issued since 2009. However, given the often lengthy patent application process, the analysis also considers patent applications from 2007 and 2008 that are still in process. In the period investigated, Minnesota companies have applied for 37 and have been awarded 50 patents related to the microbial agbioscience technology platform. Table 6 identifies the companies and academic institutions that represent 87 applications and awards.

Table 6: Minnesota Microbial Agbioscience Patents and Applications

	Applications & Patents
ECOLAB, INC.	34
EPITOPIX, LLC	18
UNIVERSITY OF MINNESOTA, THE REGENTS OF	16
CAMAS INCORPORATED	4
NEWPORT LABORATORIES, INC.	3
3M INNOVATIVE PROPERTIES COMPANY	2
RECEPTORS LLC	2
SYNTHETIC GENOMICS, INC.	2
6SOLUTIONS, LLC	1
CARGILL, INC.	1
KWG TECHNOLOGY	1
MINNTECH CORPORATION	1
PROTATEK INTERNATIONAL, INC.	1
SARTEC CORPORATION	1
Grand Total	**87**

Note: The applications and issued patents are distinct records—applications concluding the process with an issued patent are only counted as a patent.

Risk Capital: Most people realize that the discovery of new knowledge resulting in the development of new technologies is a very expensive process running, in some cases, into millions of dollars. What many people do not realize is that the costs associated with developing and taking a technology product or service to market are also very substantial. Major costs incurred after the research has been completed include proof –of-concept costs, the cost of assessing the market to determine the competition, the likely market, and the price points for competitive advantage; developing a prototype; preparing a marketing and sales plan; and scaling up for manufacturing. Finally, actual product distribution, sales, and marketing must be undertaken. These activities require the availability of sufficient capital to finance business growth and economic development.

Yet, few sources of funding bridge the gap between the points at which (1) a discovery has been identified and demonstrated and (2) a business case has been validated and venture or other debt capital can be obtained. It is also difficult to obtain seed and early-stage investment because venture funds, as they have become larger, tend to make larger, later-stage investments. As a result, angel investors have also moved downstream (further away from pre-seed and seed investments), making more post-seed and later-stage investments than previously. This trend has been exacerbated during the recession which has caused venture firms to invest primarily in their portfolio companies who do not have other options for accessing capital. So, in addition to the difficulty of obtaining translational research and pre-commercialization funding, firms are facing a gap at the start-up phase, as well. Table 7 shows the necessary activities, financing sources, and levels of investment for technology companies at various stages of their development.

Table 7: Agbioscience Company Financing Needs

	Concept	Translational Research/ Precommercialization	Pre-seed/Seed	Early-Stage	Growth
ACTIVITIES	Conduct R&D Identify discoveries with possible commercial potential	Assess potential of technology Identify market Develop prototype Test and validate Demonstrate proof of concept at lab scale Protect IP Optimize engineering License or form business	Establish business function Secure initial financing	Prepare business strategy Put serial management team in place Secure follow-on financing Begin initial sales and marketing	Begin full-scale production Staff up for sales and marketing
FINANCING SOURCES	Conventional peer-reviewed federal grant support	• Within university: Grants funded with university, State, or industry dollars • Nonuniversity: Grants funded by public and philanthropic support • SBIR I	• Friends and family • Pre-seed/seed funds • Angel investors • SBIR II	• Early seed-stage venture capital • Publicly supported investment funds	• Venture funds • Equity • Commercial debt • Industry (strategic alliances, mergers, and acquisitions)
LEVEL OF INVESTMENT	Varies	$50,000 to $500,000	Up to $1 million	$1 million to $2 million	> $2 million

Companies receiving risk capital investments, either through angel, pre-seed, seed, venture capital investments and/or Federal Small Business Innovation Research (SBIR) funding, typically possess innovative technologies with the potential to be commercialized and brought to market. Emerging companies like these can be engines for growth within a specific technology platform. The level of venture financing within the microbial agbioscience technology platform was examined over the past decade to understand the presence of emerging microbial agbioscience firms within Minnesota. From 2002 through 2012, eight companies received more than $125 million. Table 8 lists the level of funding by microbial agbioscience-related company.

Table 8: Microbial Agbioscience Venture Capital Investments, 2002–2012

Company	Equity Invested (millions)
Bio-control agents	
Gentra Systems, Inc.	6.70
MicroBiologics, Inc.	3.00
Biotechnology and Bioprocessing	
Medisyn Technologies Ltd	3.02
Diagnostics and Surveillance	
Orasi Medical, Inc.	7.73
Transoma Medical Inc.	48.28
Genomics and Metagenomics	
AppTec Laboratory Services, Inc.	37.80
Vaccines	
Aurora Pharmaceutical LLC	5.00
CNS Therapeutics, Inc.	16.05

SBIR award funding can be an important source of non-dilutive risk capital for agbioscience firms. SBIR funding within the microbial agbioscience technology platform over the past four years was examined to understand the presence of emerging microbial agbioscience firms within Minnesota. Table 9 lists the one Minnesota company that received a microbial agbioscience-related SBIR award during this time period.

Table 9: Microbial Agbioscience SBIR Awards Investments, 2010-2013

Company	2010	2011	2012	2013	Grand Total
Innovative Surface Technologies, Inc.	$ 172,763				$ 172,763

Major Funding Resources: This platform would benefit from access to a wide range of funding sources. At the federal level, microbiology and associated applications are relevant to funding from USDA, NIH, NSF, EPA, DOD, CDC, NASA and the DOE. The impact of infectious diseases on plant and animal agriculture likewise opens opportunities for commodity group and industry research sponsorship. Major foundations also have program area interests in impacted areas relating to disease, agricultural productivity and food security.

Global Market Potential: Commercial microbes and microbial products have a number of different markets with a variety of end products. These include the following[36]:

- Agriculture: fertilizers, pesticides, and animal feed additives (microbes being utilized include B. thuringiensis, bacillus pumilis, rhizobium, and spirulina)

[36] BCC Research. *Microbial Products: Technologies, Applications and Global Markets.* April 2011.

- Manufacturing: baked and fermented foods, biopolymers, industrial enzymes, commodity and specialty chemicals (microbes being utilized include saccharomyces cerevisiae and acetobacter xylinus)
- Energy: biofuels, enhanced oil recovery, fuel cells, direct hydrogen production (microbes being utilized include e. coli, cunninghamella japonica, geobacter sulfurreducens, and enterobacter aerogenes)
- Environment: environmental monitoring, hazardous waste bioremediation, oil spill and residue cleanup, wastewater treatment (microbes being utilized include vibrio fischeri, pseudomonas, and alcanivorax borkumensis)
- Healthcare: probiotics and drug manufacturing (microbes being utilized include E. coli).

The total global market for microbes and microbial products was worth more than $144 billion in 2010. The 2016 market is projected to exceed $259 billion, a 10.7 percent projected compound annual growth rate (CAGR). Most of this market consists of products, such as biopharmaceuticals and biofuels, made using yeasts, bacteria, and other microbes. Healthcare is the largest end-user market for microbes and microbial products at $90.5 billion in 2010, increasing to $100.4 billion in 2011 and $169 billion in 2016. Energy is the second-largest end-user sector at $44.1 billion in 2010, $44.5 billion in 2011, and $67.1 billion in 2016. Biofuels production, especially ethanol, underscores the importance of this sector. Manufacturing is the third-largest sector of the market, with sales of $7.4 billion in 2010, $8.6 billion in 2011, and $19.1 billion in 2016. Agricultural and environmental applications of microbes and microbial products, while billion-dollar markets, account for relatively small shares of the overall market.[37]

In summary, markets for innovations and technologies stemming from work in this platform are diverse and of very large scale. They include markets for human and animal health products (vaccines, diagnostics, anti-infectives, drugs and biologics), agricultural markets (disease resistant plants, soil inoculants, seed coats, biocontrol agents, food safety technologies), industrial biotechnology applications (microorganisms and related enzyme products for biotechnology processes uses in the production of biopharmaceuticals, biofuels, polymers and specialty chemicals), and applications in environmental protection (diagnostics, sensors, bioremediation systems, etc.)

B. Platform 2: Resilient, Efficient & Productive Agricultural Systems

Platform Description: This platform uses and leverages the outstanding ecological and environmental science research capacity in Minnesota, in combination with agriculture and agricultural systems expertise, engineering expertise, and basic sciences expertise, to develop new and novel approaches and technologies for sustainable agricultural production, environmental protection and remediation applications for Minnesota and the world.

Rationale: Food security is a major issue for much of the world's seven billion people, and into the future expansion of the global population will exacerbate the challenge. Since the vast majority of

[37] Ibid.

farmland is already in production (including a significant volume of poor quality land of marginal agronomic quality), it is absolutely imperative that current agronomic land be managed for long-term sustainability and that agricultural yield per acre of land be increased. There are, however, inherent tensions between increasing agricultural yield and preserving the global environment and its ecosystems. Feeding seven billion people already comes at a significant environmental cost in both the developed and developing world, with such associated issues as:

- Ecosystem loss and deforestation – as natural ecosystems are destroyed to press land into agricultural farmland (often this land is of marginal agronomic quality and unsustainable as productive agronomic land)
- Environmental impacts of agricultural chemicals and run-off, including pesticide drift, eutrophication associated with fertilizer run-off, and watershed sedimentation from soil erosion
- Climate change impacts of agricultural emissions, including carbon dioxide, methane and nitrous emissions and also the changing of landscape cover characteristics (affecting albedo, land temperature, carbon dioxide absorption and water cycling)
- Natural resource consumption, especially including water resource depletion and overdrafting of aquifers and surface waters
- Agronomic land degradation, whereby land in agricultural production loses its productivity over time due to non-sustainable practices leading to increased soil salinity, loss of top soil and soil fertility declines.

Developing sustainable agricultural systems is thus critical to the long-term sustainability of humankind and the Earth's environment and ecosystems. This represents a complex, multi-faceted and trandisciplinary challenge—and with challenge comes opportunity for the development of innovations and technologies.

While agriculture generates some environmental challenges, it is also the source of potential solutions to other environmental and sustainability challenges. Work to increase agricultural yields or the functional nutrition characteristics of foods serve to reduce pressures to push more land into agronomic production. Work to increase crop inputs-use efficiency (such as the development of crops with enhanced water-use efficiency or nitrogen-use efficiency) reduces input requirements. Furthermore, the development of special crop varieties with inherent or engineered pest or disease resistant characteristics reduces the need for pesticide applications. Increasingly, agriculture and forestry is becoming the source of novel, sustainable energy, biobased chemicals, biopolymers and biobased materials that can supplant the use of non-sustainable resources such as fossil fuels. Opportunities, therefore, exist for R&D based innovations and development that will enhance the environmental sustainability of agriculture and leverage agriculture to produce renewable industrial commodities.

University R&D Strengths: The broad nature of the challenges, and the variety of R&D disciplines needed to address complex challenges, makes Minnesota an ideal location in many respects for work in this arena. The University of Minnesota is one of very few major research universities with broad and deep research excellence in agriculture and agronomy, forestry, and environmental science and ecology. Likewise the University has world class expertise in engineering disciplines (such as chemical engineering, and biological and biosystems engineering) and basic sciences (such as biological sciences and chemistry). The breadth of the issue and associated disciplines also provides multiple opportunities

for other Minnesota colleges and universities to contribute to research and education. Also, as a major farming and forestry state, Minnesota has a business stake in assuring the long-term sustainability of its agricultural and forestry systems, and can use its higher education and research assets (including University of Minnesota Experiment Station and Extension assets) for assessing agricultural impacts and piloting solutions and new technologies. Minnesota has also been on the front lines in developing the first steps towards a renewable biobased industrial economy (see additional information related to the third Platform).

This agbioscience platform builds upon an existing base of assets and investment in environmental sustainability and agricultural sustainability R&D. Multiple identified core competencies are a natural fit as contributors to this platform's development, including:

- Scientists working in agronomy, soil science, animal science, and other agbioscience disciplines who are focused on agricultural production systems and sustainability
- Minnesota's world class cluster of faculty working in environmental science, environmental studies and ecology
- Minnesota's substantial base of crop and plant scientists and other agronomic experts working to enhance agricultural production yields and to reduce inputs required for high-productivity agriculture
- A robust base of R&D in academe and industry seeking ways to optimize the use of biomass in developing sustainable biobased fuels, chemicals and materials.

Key examples of relevant centers and institutes within Minnesota include:

- Minnesota Institute for Sustainable Agriculture
- USDA-ARS – Climate Change and Agriculture
- Institute on the Environment
- Center for Integrated Natural Resources and Agricultural Management
- Center for Changing Landscapes
- Initiative for Renewable Energy and the Environment
- Center for Environment and Natural Resource Policy
- Water resources Center
- Large Lakes Observatory
- Limnological Research Center
- Microbial and Plant Genomics Institute
- Center for Forest Ecology
- Center for Environmental, Earth and Space Studies at Bemidji State University
- Aquatic Biology Program at Bemidji State University
- Large River Studies Center at Winona State University.

Cross-walking the Technology Platform to Minnesota's Industry Base: The unique research strengths and competencies in Minnesota around ecological and environmental science, in combination with expertise in agricultural systems form a platform for advancing new approaches and technologies relating to sustainable agricultural production—the resilient, efficient and productive agricultural systems platform. From an industry perspective, these research areas link to activities that include environmental consulting and remediation services, life sciences R&D, seed development activities within the R&D and the farm supplies wholesaling sectors, renewable fuels and green chemicals, as well

as yield improvement capabilities within the agricultural support activities in terms of soil preparation and cultivation (see Table 10).

Table 10: Defining the Resilient, Efficient, and Productive Agricultural Systems Sector in Minnesota

NAICS Code	NAICS Industry Title
115112	Soil preparation, planting, and cultivating
325193	Ethyl alcohol manufacturing
325199	All other basic organic chemical mfg.
325311	Nitrogenous fertilizer manufacturing
325312	Phosphatic fertilizer manufacturing
325314	Fertilizer, mixing only, manufacturing
424910	Farm supplies merchant wholesalers
541620	Environmental consulting services
54171*	Physical, engineering and biological research
562910	Remediation services

*Includes only the share of industry activities that are primarily in the life sciences/biosciences.

The industry linkages to the technology platform form a sizable combined resilient, efficient, and productive agricultural systems sector in Minnesota with 12,513 jobs spread among more than 1,000 individual business establishments. The sector is growing, adding 6.5 percent to its employment base over the decade and 12.6 percent to its base of establishments. In recent years, however, the state sector has seen a modest overall decline in jobs (-0.7 percent) since the economic peak in 2007 through the deep national recession years that followed. Minnesota's employment in resilient, efficient, and productive agricultural systems has a concentration very similar to that seen nationally, with a LQ of 0.94 in 2011.

Table 11: Employment and Related Metrics for the Resilient, Efficient, and Productive Agricultural Systems Sector, 2011

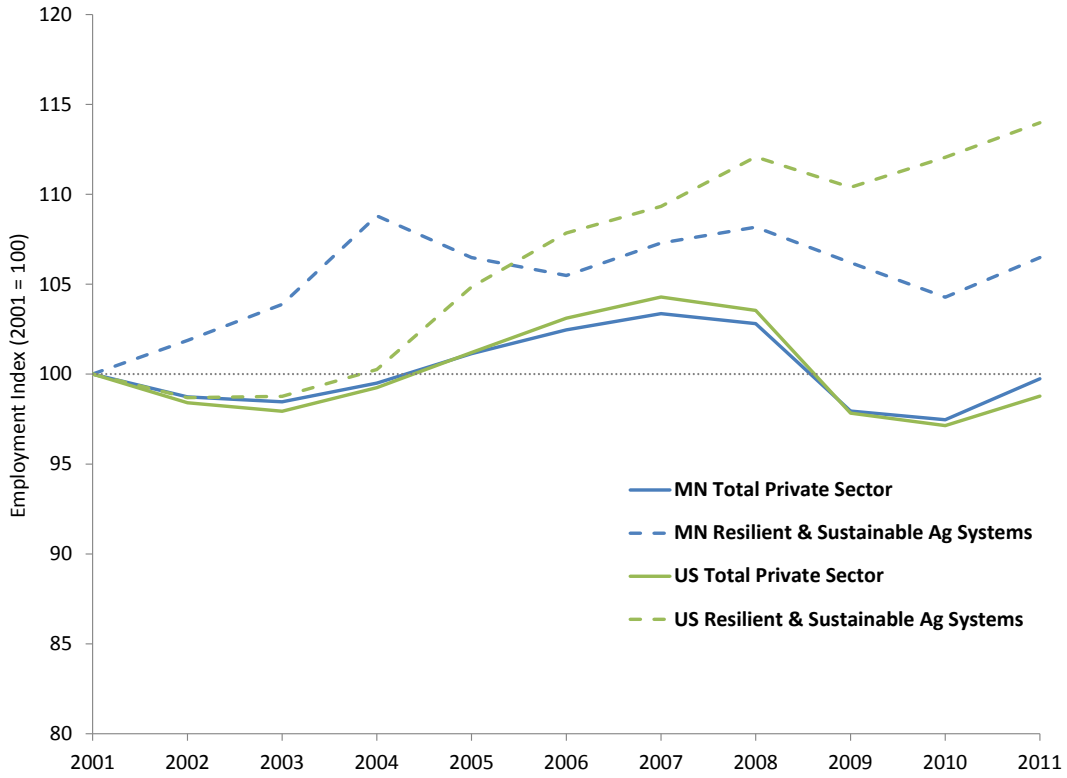
Metric	Resilient & Sustainable Agricultural Systems	
	Minnesota	U.S.
Establishments, 2011	1,083	43,394
Establishments Change, 2001-11	12.6%	16.2%
Establishments Change, 2007-11 (Effects of Recession)	4.3%	8.7%
Employment, 2011	12,513	645,349
Employment Change, 2001-11	6.5%	14.0%
Employment Change, 2007-11 (Effects of Recession)	-0.7%	4.3%
Location Quotient, 2011	0.94	n/a
Average Annual Wages, 2011	$ 71,751	$ 81,472

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Since the mid-2000s, the national resilient, efficient, and productive agricultural systems sector has outpaced that for Minnesota with respect to job growth (see Figure 10). The Minnesota industry has experienced ups and downs in employment though it rounds out the decade-long period with job

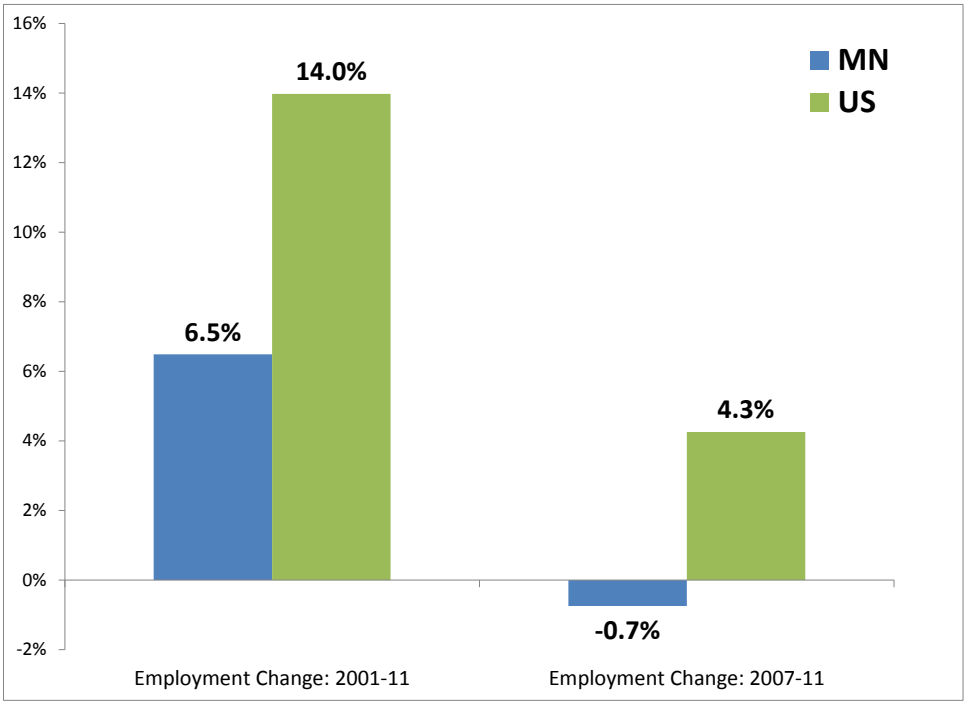
growth again in 2011 (up 2.1 percent over the year). Despite the fluctuating trend for Minnesota, the resilient, efficient, and productive agricultural systems sector has been a net job grower for the state, outpacing the overall private sector. In addition, this represents growth among quality, high-skilled jobs that pay, on average, nearly $72,000 per year.

Figure 10: Employment Trends in the Private and Resilient, Efficient, and Productive Agricultural Systems Sectors, 2001–11



While Minnesota has not kept pace with national growth in the sector (see Figure 11), it is clearly a thriving industry sector in the U.S., which signals opportunity for a state to grow, particularly when its research competencies align well with the industry.

Figure 11: Employment Trend in the Resilient, Efficient, and Productive Agricultural Systems Sector, Minnesota vs. U.S., 2001–11 and 2007–11



Over the past decade, Minnesota has grown key segments of its resilient, efficient, and productive agricultural systems industry base, including: ethanol production (up 189 percent); environmental consulting (up 22 percent); life sciences R&D (up 7 percent); and soil preparation, planting, and cultivating (up 3 percent). Further, the state has a specialized employment concentration in ethanol production (LQ is 3.49) as well as in farm supplies wholesaling (LQ is 2.25) where much of the seed development activities occur.

By further examining three key employment-related performance measures related to strategic industry targeting the detailed industry components of the resilient and sustainable agricultural systems sector can be categorized to gauge its strength or emergence. These metrics answer the following:

- Is the industry specialized in its concentration relative to the nation (location quotient)?
- Is the industry growing in Minnesota?
- If the state industry is growing is it outpacing national growth and thus growing its competitive share?

Based on the answers to these questions, the sectors could be placed into one of four key designations related to industry targeting:

- Current Strengths – those industries that are specialized, growing, and outpacing national growth

- Emerging Strengths – those industries that are not yet specialized but are growing and outpacing national growth
- Priority Retention Target – those industries that are specialized and growing but are lagging performers relative to the nation
- Specialized Retention Target – those industries in which the state is specialized but is no longer growing.

Table 12: Identifying Detailed Industry Strengths for the Resilient, Efficient, and Productive Agricultural Systems Sector in Minnesota

Classification	**Specialized** (20% or higher employment concentration compared with national avg)	**Job Generator** (Generated new jobs over the 2001–11 period)	**Outpacing National Job Growth** (Job Growth from 2001–11 exceeded national avg)	**Minnesota Biobased Industrial Products & Services**
Current Strength	✓	✓	✓	• Farm supplies merchant wholesalers
Emerging Strength		✓	✓	• Soil preparation, planting, and cultivating
Priority Retention Target	✓	✓		• Ethanol mfg/Biofuels
Specialized Retention Target	✓			• N/A

Note: detailed industry analysis limited to industries with at least 200 jobs in 2011.
Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Research competencies identify opportunities for Minnesota to be a leader in resilient, efficient and productive agricultural systems. Linkages to related industries reveal a growth sector in Minnesota with current and emerging strengths in the large and highly specialized farm supplies wholesale industry which includes the establishments often engaged in seed development, as well as in agriculture support activities such as soil preparation, planting, and cultivating. A specialized and growing ethanol/biofuels industry is a priority retention target for the state given it has slightly lagged the U.S. in recent years.

Evidence of Innovation Driving the Future Development of the Technology Platform: Within a technology platform, a number of indicators can be examined to begin to develop a sense of the level of innovation or commercialization that is occurring to drive a technology platform into the future. Such measures include the level of patenting by industry and academia within a given technology platform, the level of risk capital being invested within a technology platform, and the level of SBIR (Small Business Innovation Research) grants being awarded within a given technology platform.

Patents: Utilizing patents as a means to understand the innovation environment of a state is useful in many ways. By analyzing patents, a picture emerges of not only the level of patent activity in a state within a given technology platform, but also key industrial drivers of that innovation. For instance, larger companies with relatively high levels of innovation can be identified that could have a significant role in

moving the technology platform forward in the future. Patenting may also play an important role in securing funding for startups that represent emerging areas of opportunity.

The patent analysis focuses primarily on patents issued since 2009. However, given the often lengthy patent application process, the analysis also considers patent applications from 2007 and 2008 that are still in process. In the period investigated, Minnesota companies have applied for 90 and have been awarded 330 patents related to the resilient, efficient, and productive agricultural systems technology platform. Table 13 identifies the companies and academic institutions that represent the 420 applications and awards.

Table 13: Minnesota Resilient, Efficient, and Productive Agricultural Systems Patents and Applications

	Applications & Patents
MONSANTO TECHNOLOGY, LLC	149
PIONEER HI-BRED INTERNATIONAL, INC. (DU PONT)	145
SYNGENTA PARTICIPATIONS AG	41
MERTEC LLC	38
DOW AGROSCIENCES LLC	16
AGRIGENETICS, INC.	7
CARGILL, INC.	7
M.S. TECHNOLOGIES, LLC	6
AGRO-K CORPORATION	3
CHEMSTAR PRODUCTS COMPANY	1
REMEDIATION AND NATURAL ATTENUATION SERVICES INC	1
SEGETIS, INC.	1
SUNTAVA, LLC	1
SYNGENTA SEEDS, INC.	1
TEGRASEAL Products, LLC	1
UNIVERSITY OF MINNESOTA, THE REGENTS OF	1
WINEHAVEN, INC.	1
Grand Total	**420**

Note: The applications and issued patents are distinct records—applications concluding the process with an issued patent are only counted as a patent.

Risk Capital: Companies receiving risk capital investments, either through angel, pre-seed, seed, venture capital investments and/or Federal Small Business Innovation Research (SBIR) funding, typically possess innovative technologies with the potential to be commercialized and brought to market. Emerging companies like these can be engines for growth within a specific technology platform. The level of venture financing within the resilient, efficient, and productive agricultural systems agbioscience technology platform was examined over the past decade to understand the presence of emerging resilient, efficient, and productive agricultural system firms within Minnesota. What was discovered was the fact that from 2002 through 2012, no venture capital investments were made in Minnesota companies related to this technology platform.

Minnesota fared better when SBIR funding within the resilient, efficient, and productive agricultural systems technology platform over the past four years was examined. Table 14 lists the three Minnesota companies that received resilient, efficient and productive agricultural systems-related SBIR awards during this time period.

Table 14: Resilient, Efficient, and Productive Agricultural Systems SBIR Awards Investments, 2010–2013

Company	2010	2011	2012	2013	Grand Total
BioCee	$ 200,000				$ 200,000
United Science, LLC	$ 150,000	$665,899		$499,869	$ 1,315,768
Scenic Valley Farm		$ 98,815			$ 98,815
	$ 350,000	**$764,714**		**$499,869**	**$ 1,614,583**

Major Funding Resources: As with the Microbial Agbioscience platform, a Sustainable Agricultural Systems platform, by virtue of its multi-disciplinary nature and the broad scope of issues addressed, has the potential to compete for funding from multiple federal agencies. Such funding sources may include, but not be limited to, the USDA, EPA, DOD and DOE and may, potentially, gain funding in areas related to toxicology/environmental health from NIH. By addressing multiple, global grand challenges a broad variety of other funding sources may be relevant, including international development organizations (e.g., UN-FAO, World Bank) and major foundations and environmental organizations. Traditional agricultural funders, such as commodity groups and industry may also favor R&D leading to work that reduces production inputs, increases agricultural yield, and encourages the use of biobased resources as industrial inputs.

Global Market Opportunities: Sustaining the global population (currently standing at 7 billion persons, and anticipated to rise to more than 9 billion by 2050[38]) is driving the agbioscience industry to develop resilient, efficient, and productive methods to ensure the continuation of increasing agricultural yields while at the same time maintaining, and in some cases improving, soil quality through advances in agricultural biotechnology. Improvements in technology, agricultural techniques, and pest control have allowed farmers to expand crop production on the limited arable land available. It is important to note, however, that this expansion in productivity has come with a price in soil erosion, pesticide-tolerant weeds and insects, and concerns about the safety of foods used for both human and animal consumption.

Demand for agricultural biotechnology products in the U.S. is forecasted to reach $17.7 billion in 2016 based on annual growth of 5.9 percent from 2011.[39] Advances will stem from ongoing introductions of value-added products that boost crop and animal farm productivity. Transgenic seeds and plants are expected to dominate demand, accounting for 87 percent of the total in 2016. Advances will continue to be driven by the introduction of more expensive transgenic seeds with specialized characteristics such as drought tolerance. Animal vaccines are expected to offer the fastest growth overall, boosted by new products that can protect animals from diseases formerly not able to be effectively controlled. Finally, new product development is expected to focus on improving farm productivity, which includes

[38] United Nations, Department of Economic and Social Affairs, Population Division (2011*). "World Population Prospects: The 2010 Revision."* See: http://esa.un.org/unpd/wpp/index.htm
[39] The Freedonia Group, Inc. *Biotechnology – Agriculture: United States.* May 2012.

transgenic seeds that can reduce the application of pesticides and increase crop yields, animal diagnostics that can identify favorable and unfavorable traits, and animal vaccines for new applications.[40]

Looking globally, while North America continues to be the leading region for agricultural biotechnology product sales, markets are growing rapidly in South America and Asia. North America accounted for an estimated $7.3 billion in agricultural biotechnology product sales in 2012. The North America market is forecasted to grow at a CAGR of 7.7 percent to reach a forecast value of $10.5 billion in 2017. The second major market for agricultural biotechnology is what is termed the "rest of the world" (ROW), which includes South America, Africa, the Middle East and Australia. The main markets for ROW are South America and Africa. Key countries are Brazil, Argentina, Paraguay and South Africa. ROW accounted for $5.1 billion in agricultural biotechnology product sales in 2012, and is forecasted to grow at a CAGR of 10 percent to reach a forecast value of $8.3 billion in 2017. Finally, the third main market for agricultural biotechnology is Asia, with a value of $1.9 billion in 2012. This market is forecasted to grow at a CAGR of 21.3 percent to reach a forecast value of $5 billion by 2017. The main countries driving this growth are China and India.[41]

This platform has the potential to develop solutions, innovations and technologies with application across a wide range of markets. Examples of applications may include: crops developed to be efficient in the use of inputs and natural resources; technologies to increase agricultural yield; soil preservation of agronomic land, and strategies for improvement of marginal soils; methods and technologies to reduce or eliminate run-off of chemicals and manure from agricultural operations; emissions control technologies; adaptation of agricultural systems, crops and livestock to climate variability and climate change; systems for sensing and monitoring agriculture and forestry related pollutants and emissions; bioremediation technologies for agriculture applications; quantification and valuation strategies for ecosystem services; and, application of biomass and biobased resources to renewable energy and other sustainable industrial applications in materials and chemicals.

D. Platform 3: Biobased Industrial Products

Platform Description: This platform focuses on researching, developing and evaluating potential industrial biobased products (biofuels, materials, chemicals and value-added forest products) that are produced from farm and forestry outputs. Feedstocks may comprise primary agricultural and forestry crops, newly developed or enhanced crops, and value-added utilization of agriculture and forestry coproducts, and coproducts generated from downstream value-added industrial and food processing.

Rationale: This platform focuses on maximizing the capture of economic value within Minnesota from products produced from farms and forests. While Minnesota does have a significant base of industry engaged in value-added agricultural processing, food manufacturing and biofuels production, it is still the case that a significant volume of primary agricultural commodities leave the state with limited value-added to them. R&D and platform services designed to increase value-added to biomass and commodities produced in Minnesota are the rationale for this platform.

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[40] Ibid.

[41] BCC Research. *Agricultural Biotechnology: Emerging Technologies and Global Markets.* July 2012.

University R&D Strengths: It is readily evident from the core competency analysis that Minnesota enjoys a considerable base of capabilities and assets in relation to value-added products development and production. Within Minnesota's academic R&D base, there are many assets that focus on development relevant to this platform. Some of the most notable competencies include:

- World-class chemical engineering capabilities and a broad range of multi-disciplinary scientists working in biofuels, sustainable polymers and biobased products R&D, including the University of Minnesota's Center for Sustainable Polymers

- Expertise in plant biochemistry and plant improvement relevant to the development of plants with enhanced output and functional characteristics

- A highly engaged Department of Applied Economics at the University of Minnesota who's economists are working in multi-disciplinary teams with other scientists and faculty in evaluating the economics and potential markets for alternative products from agricultural and forest commodities and resources.

In addition, AURI focuses its work in areas that are related to developing biobased industrial products. These areas of focus include:

- **Coproducts** – creating uses for waste-streams and enhancing the value-added to low value coproducts produced in agriculture, forestry and downstream processing/manufacturing operations

- **Biobased Products** – whereby agricultural and forest produced resources are used to generate sustainable alternatives to typically petrochemically-derived feedstocks for polymers, lubricants, sealants, construction and fabrication materials, and bulk and specialty chemicals

- **Bioenergy** – producing solid and liquid fuels for use in electricity generation, combined heat and power and transportation applications. Biomass presents the only renewable resource for the production of liquid fuels, and multiple new technologies are being developed domestically and globally for next generation biofuel production processes. Developing next generation fuels builds upon Minnesota's existing leadership in first generation ethanol/biodiesel fuels.

Cross-walking the Technology Platform to Minnesota's Industry Base: The intersection of Minnesota's R&D competencies and industry strengths in developing value-added agricultural and forest products, including biofuels, bioenergy, biomaterials, wood, and paper industries, form the rationale for the biobased industrial products sector. The spectrum of existing and even some potential industry engagement in this sector, as well as key industry-led R&D activities are reflected in the NAICS-based industry definition shown below. This definition is used in the analysis that follows to profile the current trends, recent status, and potential opportunities for the sector in Minnesota.

Table 15: Defining the Biobased Industrial Products Sector in Minnesota

NAICS Code	NAICS Industry Title
311222	Soybean processing
311223	Other oilseed processing
311225	Fats and oils refining and blending
321113	Sawmills
321114	Wood preservation
321211	Hardwood veneer and plywood manufacturing
321212	Softwood veneer and plywood manufacturing
321213	Engineered wood member manufacturing
321219	Reconstituted wood product manufacturing
321912	Cut stock, resawing lumber, and planing
322110	Pulp mills
322121	Paper, except newsprint, mills
322122	Newsprint mills
322130	Paperboard mills
325191	Gum and wood chemical manufacturing
325193	Ethyl alcohol manufacturing
325199	All other basic organic chemical mfg.
325211	Plastics material and resin manufacturing
325212	Synthetic rubber manufacturing
325221	Cellulosic organic fiber manufacturing
325222	Noncellulosic organic fiber manufacturing
325314	Fertilizer, mixing only, manufacturing
54171*	Physical, engineering and biological research

*Includes only the share of industry activities that are primarily in the life sciences/biosciences.

The biobased industrial products sector in Minnesota has a sizable footprint with nearly 11,000 employees spanning 415 individual business establishments in 2011 (see Table 16). And while its physical presence has grown in adding establishments, the sector has shed jobs over the past decade. Since 2001, its industries have decreased employment by more than 2,100 jobs or 16.5 percent, matching the national decline over that same period (see Figures 12 and 13).

While the statewide jobs total for the biobased industrial products sector is quite large, its concentration relative to national sector is lagging as evidenced by its location quotient. As of 2011, the biobased industrial products sector had a LQ of 0.75 meaning Minnesota has just 75 percent of the industry base one would expect to see relative to national averages.

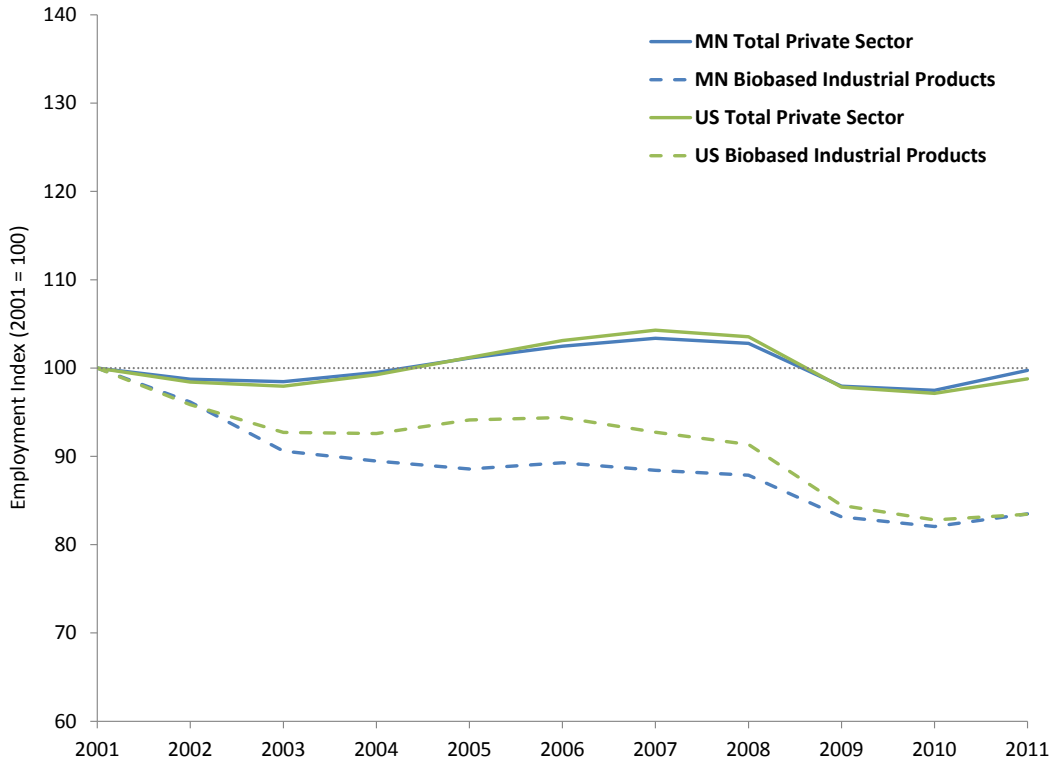
Table 16: Employment and Related Metrics for the Biobased Industrial Products Sector, 2011

Metric	Biobased Industrial Products	
	Minnesota	U.S.
Establishments, 2011	415	20,386
Establishments Change, 2001-11	31.4%	7.9%
Establishments Change, 2007-11 (Effects of Recession)	12.8%	6.8%
Employment, 2011	10,797	698,544
Employment Change, 2001-11	-16.5%	-16.6%
Employment Change, 2007-11 (Effects of Recession)	-5.6%	-10.0%
Location Quotient, 2011	0.75	n/a
Average Annual Wages, 2011	$ 75,366	$ 81,485

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

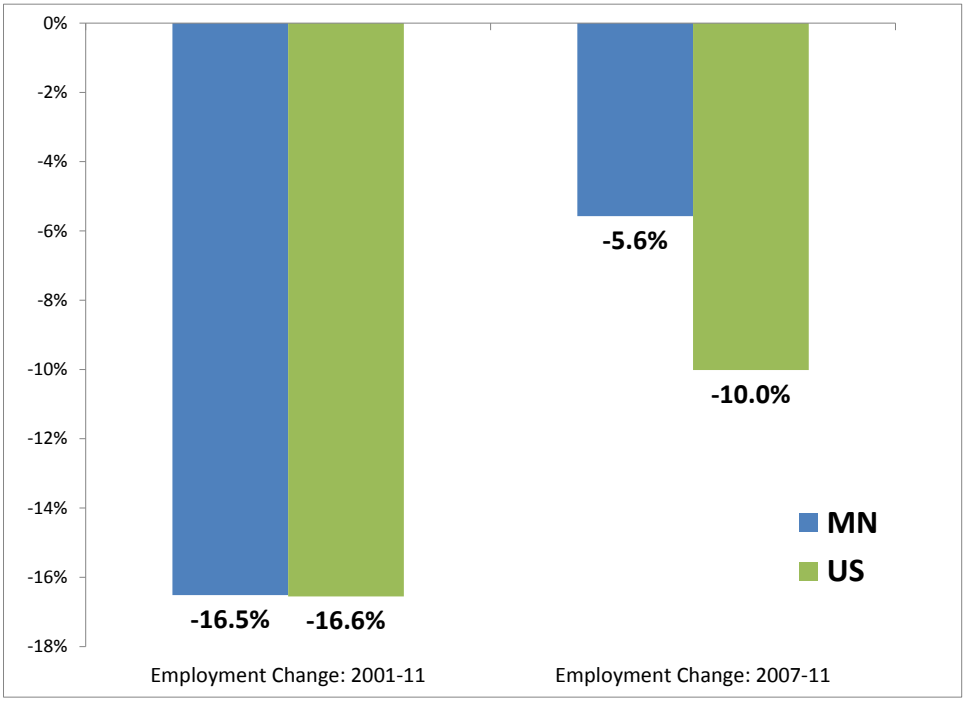
Minnesota companies in the biobased industrial products sector have seen an overall decline of 16.5 percent and largely tracked the national trend over the decade (see Figure 12). Through the middle part of the decade from 2003 through the peak of the economic expansion in 2007, the state sector held relatively steady shedding just 2.4 percent of jobs before seeing a larger decline during the recession. There is evidence of stabilization both in Minnesota and nationally, however, with employment gains over the year from 2010 to 2011, up 1.7 percent and 0.8 percent, respectively.

Figure 12: Employment Trends in the Private and Biobased Industrial Products Sectors, 2001–11



To further highlight recent trends in Minnesota compared with the U.S. and to gauge the impacts of the deep national recession, Figure 13 provides net employment trends. Job changes are shown for the biobased industrial products sector for two key periods—the full longer-term trend over the decade (2001–2011) and the more recent trend from the peak in the business cycle in 2007 through 2011, the second full year of the relatively modest economic recovery. While the overall decade showed nearly the same double-digit jobs losses, Minnesota has fared better, though still shed jobs, through the recession and early recovery years declining by 5.6 percent while the nation declined by 10.0 percent.

Figure 13: Employment Trend in Biobased Industrial Products, Minnesota vs. U.S., 2001–11 and 2007–11



Despite the negative employment trend and lagging degree of concentration in the overall sector, opportunities to advance commercial activity leveraged through research strengths within and across the sector are evident as one drills down into its detailed components. The biobased industrial products sector is broad with the potential to influence and drive industrial activity across segments already present in the state such as selected wood and paper products, biofuels, and sizable R&D activities in addition to areas without much industry presence though have the potential to grow such as biobased chemicals and polymers.

The sector's largest components include innovation driving activities in commercial life sciences R&D, paper mills, newsprint mills, and ethanol/biofuels manufacturing. Three of four of these larger detailed industries have seen steady job growth, though the fourth, paper mills, has seen its job base cut in half over the decade to 2011. Given these differing experiences and outcomes for industries within the sector it is useful to categorize the sectors based on recent performance.

By examining three key employment-related performance measures related to strategic industry targeting the detailed industry components of the biobased industrial products sector can be categorized to gauge its strength or emergence. These metrics answer the following:

- Is the industry specialized in its concentration relative to the nation (location quotient)?
- Is the industry growing in Minnesota?
- If the state industry is growing is it outpacing national growth and thus growing its competitive share?

Based on the answers to these questions, the sectors could be placed into one of four key designations related to industry targeting:

- Current Strengths – those industries that are specialized, growing, and outpacing national growth
- Emerging Strengths – those industries that are not yet specialized but are growing and outpacing national growth
- Priority Retention Target – those industries that are specialized and growing but are lagging performers relative to the nation
- Specialized Retention Target – those industries in which the state is specialized but is no longer growing.

Table 17: Identifying Detailed Industry Strengths for the Biobased Industrial Products Sector in Minnesota

Classification	**Specialized** (20% or higher employment concentration compared with national avg)	**Job Generator** (Generated new jobs over the 2001–11 period)	**Outpacing National Job Growth** (Job Growth from 2001–11 exceeded national avg)	**Minnesota Biobased Industrial Products & Services**
Current Strength	✓	✓	✓	• Newsprint mills • Soybean processing • Wood preservation
Emerging Strength		✓	✓	• Plastics material and resin manufacturing
Priority Retention Target	✓	✓		• Ethanol mfg/Biofuels
Specialized Retention Target	✓			• Paper, except newsprint, mills • Reconstituted wood product mfg • Fats and oils refining and blending

Note: detailed industry analysis limited to industries with at least 200 jobs in 2011.
Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Looking across the identified detailed industry strengths in Minnesota's biobased industrial products segment one can see distinct opportunities for state research strengths to align with growing and/or highly specialized industry partners. From paper mills and wood products to agricultural processing and ethanol and biofuels, there are significant opportunities for industry linkages. Beyond paper mills, most

of these segments are relatively modest in size (fewer than 800 jobs) but are demonstrating a specialized base and/or emergence in the state.

Evidence of Innovation Driving the Future Development of the Technology Platform: Within a technology platform, a number of indicators can be examined to begin to develop a sense of the level of innovation or commercialization that is occurring to drive a technology platform into the future. Such measures include the level of patenting by industry and academia within a given technology platform, the level of risk capital being invested within a technology platform, and the level of SBIR (Small Business Innovation Research) grants being awarded within a given technology platform.

Patents: Utilizing patents as a means to understand the innovation environment of a state is useful in many ways. By analyzing patents, a picture emerges of not only the level of patent activity in a state within a given technology platform, but also key industrial drivers of that innovation. For instance, larger companies with relatively high levels of innovation can be identified that could have a significant role in moving the technology platform forward in the future. Patenting may also play an important role in securing funding for startups that represent emerging areas of opportunity.

The patent analysis focuses primarily on patents issued since 2009. However, given the often lengthy patent application process, the analysis also considers patent applications from 2007 and 2008 that are still in process. In the period investigated, Minnesota companies have applied for 111 and have been awarded 119 patents related to the biobased industrial products technology platform. Table 18 identifies the companies and academic institutions that represent the 230 applications and awards.

Table 18: Minnesota Biobased Industrial Product Patents and Applications

	Applications & Patents
CARGILL, INC.	125
NATUREWORKS, LLC	12
ECOLAB, INC.	11
SEGETIS, INC.	7
RELCO UNISYSTEMS CORPORATION	6
BIOVATION, LLC	4
DRATHS CORPORATION	4
KFI INTELLECTUAL PROPERTIES L.L.C.	4
Tate & Lyle Ingredients Americas, Inc.	4
UNIVERSITY OF MINNESOTA, THE REGENTS OF	4
6SOLUTIONS, LLC	3
CROWN IRON WORKS COMPANY	3
G.D.O. INC	3
MCNEFF RESEARCH CONSULTANTS, INC.	3
NOVUS ENERGY, LLC	3
RENESSEN LLC	3
SARTEC CORPORATION	3

SYNGAS TECHNOLOGY INC.	3
3M INNOVATIVE PROPERTIES COMPANY	2
DOW GLOBAL TECHNOLOGIES INC.	2
EARTHCLEAN CORPORATION	2
ELEVANCE RENEWABLE SCIENCES, INC.	2
NEWBIO E. SYSTEMS, INCORPORATED	2
SUNTAVA, LLC	2
ADHERENT LABORATORIES, INC.	1
ASPEN ACQUISITION CORPORATION	1
CLEARWATER TECHNOLOGIES INC.	1
CORTEC CORPORATION	1
DATA MACHINE INTERNATIONAL	1
DONALDSON COMPANY, INC.	1
GRAINVALUE, LLC	1
GREENFLAME PRODUCTS, LLC	1
HARRIS CONTRACTING COMPANY	1
HydoChar LLC	1
MAT, INC.	1
ONCE TECHNOLOGIES, INC.	1
PET CARE SYSTEMS, INC.	1
Grand Total	**230**

Note: The applications and issued patents are distinct records—applications concluding the process with an issued patent are only counted as a patent.

Risk Capital: Companies receiving risk capital investments, either through angel, pre-seed, seed, venture capital investments and/or Federal Small Business Innovation Research (SBIR) funding, typically possess innovative technologies with the potential to be commercialized and brought to market. Emerging companies like these can be engines for growth within a specific technology platform. The level of venture financing within the biobased industrial products technology platform was examined over the past decade to understand the presence of emerging biobased industrial firms within Minnesota. From 2002 through 2012, three companies received more than $175 million. Table 19 lists the level of funding by biobased industrial product-related company.

Table 19: Biobased Industrial Products Venture Capital Investments, 2002–2012

	Equity Invested (millions)
Biobased Chemicals	
BioAmber, Inc.	94.50
Segetis, Inc.	64.76
Biofuels	
Advanced BioEnergy, LLC	18.10

SBIR award funding can be an important source of non-dilutive risk capital for agbioscience firms. SBIR funding within the biobased industrial product technology platform over the past four years was examined to understand the presence of emerging biobased industrial product firms within Minnesota. Table 20 lists the six Minnesota companies that received biobased industrial product-related SBIR awards during this time period.

Table 20: Biobased Industrial Products SBIR Awards, 2010–2013

Company	2010	2011	2012	2013	Grand Total
Cortec Corporation	$ 150,000				$ 150,000
Northern Technologies Int. Corp.	$ 70,000		$500,000		$ 570,000
Clean Plus, Inc.	$ 398,739				$ 398,739
Applied Colloids	$ 142,568	$ 99,557			$ 242,125
Butrolix, LLC		$149,972			$ 149,972
Sartec Corporation	$ 150,000				$ 150,000
	$ 911,307	**$249,529**	**$500,000**		**$ 1,660,836**

Major Funding Resources: The development of biobased industrial products is a comparatively challenging space in which to secure federal funding. Because the work is by nature applied, more traditional funding resources from agencies such as the NSF are quite limited in applicability. There is potential federal funding in biofuels and biobased products spaces however, via agencies such as the DOE. Commodity groups are funders of work to develop biobased industrial products, seeking to encourage the development of new uses for their producers' commodities. Funding for research may also be available from individual corporations. In the biofuels and biobased products arenas, for example, major companies such as Chevron, Exxon and BP are funding significant biofuels and biochemicals efforts, while likewise chemical companies such as Ashland and DuPont are active in alternative renewable chemicals research funding.

Global Market Potential: Through the last century, human activity has depleted approximately half of the world's reserves of fossil hydrocarbons. These reserves, which took over 600 million years to accumulate, are non-renewable, and their extraction, refining, and use contribute significantly to human emissions of greenhouse gases and the warming of the planet. In order to sustain human development going forward, a carbon-neutral alternative must be implemented. A key promising technology is biological synthesis; that is, biobased production of chemicals, fuels, and materials from plants that can

be re-grown. Modification of bacteria and enzyme products, in combination with new biotechnology tools and techniques, provides unique new pathways to the production of fuels, bulk chemicals, specialty chemicals, plastics and other industrial products.

Increasing concerns about climate change are helping fuel the trend toward development of biobased industrial products. The future for such products, however, is complicated by many factors, including unpredictable pricing for oil and agricultural crops, fickle public opinion, the role of governments across the globe, corporate commitment and new technology.

For the purpose of this market analysis, biobased industrial products can be separated into two major market segments: biomaterials and biofuels. Biomaterials generally carry a price premium compared to petroleum-based pricing, which is sometimes significant. In some cases, the premium is justified based on superior performance properties. In many cases, however, biomaterial products carry a premium simply because they are more expensive to make. Adding to the problem, they are often competing against pure commodity products, such as polyethylenes and polystyrenes.[42] Furthermore, although specifics vary widely, biomaterial products generally have weaker thermal properties than petroleum-based products. As a result, for example, there is an increasing trend toward blending bioplastics with petroleum-based plastics for durable applications.[43] For major gains to be made in terms of increasing market share for biomaterials versus petroleum-based materials, these technological and cost hurdles will have to be overcome.

Biomaterial demand in the U.S. reached $3.3 billion in 2011, an increase from $2.4 billion in 2006. Biomaterial demand in the U.S. is forecasted to reach $4.6 billion in 2016, representing yearly growth of 6.9 percent from $3.3 billion in 2011.[44] Gains will be supported by ongoing efforts to increase sustainability, as this will generate opportunities for more environmentally compatible products that are derived from non-petroleum-based resources. Additionally, continued technological advancements and rising production capabilities will boost demand for biomaterials, making them more competitive with petroleum-based materials in terms of both performance and price. However, the inherent volatility of the biomaterial industry may serve to constrain overall advances, as plantings and harvests of key inputs to biomaterial products will remain subject to unpredictable weather patterns and political uncertainties.

Similar to biomaterials, the development of the biofuels market depends on a number of interrelated factors, including the price of oil, the ready availability of inexpensive feed materials, continued government support (financial and legislative), improvements in process technology that cuts costs for the next generation of biofuels, competition from other alternatives to fossil-based products, and the development of coproducts to help offset costs and maximize returns. For example, dried distillers grains (DDG), a coproduct of corn ethanol manufacture, can be sold for use in livestock feed, adding up to 15 percent to producers' incomes. Carbon dioxide (CO2) also is captured by some ethanol plants and sold for reuse. Glycerin, a coproduct of biodiesel production, has application in a range of industries including pharmaceuticals manufacturing and food processing.

The Great Recession of 2008 had a negative impact on the biofuels industry. The industry was hurt by the deteriorating credit market for constructing new plants. The credit crisis also slowed the raising of

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[42] BCC Research. *Global Markets and Technologies for Bioplastics.* February 2012.
[43] Ibid.
[44] Freedonia. *Natural Polymers: United States.* November 2012.

new funds for projects, the rate of initial public offerings (IPOs) and forced consolidation of biofuels units. The financial crisis caused the U.S. dollar to rise in foreign exchange markets, and thus U.S. exports became less profitable. This caused a decline in agricultural commodity prices since many of these products are exported. Biofuels companies who purchased these commodities in the futures market suffered losses, further dampening the market. As a result of these factors, the overall growth in biofuels slowed in 2009 and 2010.

The most recent market report available indicates that from 2000 to 2008 global biofuel production more than tripled, although it accounted for less than 3 percent of worldwide transportation fuel supplies. In North America, production grew from 2 billion gallons in 2002, a market value of $2.4 billion, to almost 20 billion gallons in 2008 and a market value of $30.3 billion. By 2013, production levels are forecasted to increase by a compound annual growth rate (CAGR) of 3 percent. However, market value is forecast to drop to a CAGR of -1.6 percent from 2008 to 2013, and a market value of $34.3 billion, due to falling ethanol prices.[45]

In world regions outside of North America, the biofuels market was worth about $303 billion in 2008 and is forecasted to rise at a 7.2 percent CAGR to $42.8 billion in 2013. Most market growth will take place in a few EU member states, the Asia Pacific region, and in South America. A percentage of the increase reflects a return to prior production levels following dipping output in 2007, 2008, and early 2009.[46]

Using Minnesota agricultural products in the production of biobased industrial products represent pathways to increasing the value of Minnesota commodities and specialty agricultural products. Minnesota's early leadership in biofuels development provides a platform of knowledge and market engagement for moving into next generation biofuels and biorefinery-based chemical, polymer, and material products.

E. Platform 4: Value-Added Food & Health Products

Platform Description: This platform focuses on researching, developing and evaluating advanced nutrition and health products that are produced from farm and forestry outputs. Feedstocks may comprise primary agricultural and forestry crops, newly developed or enhanced crops, and value-added utilization of agriculture and forestry coproducts, and coproducts generated from downstream value-added industrial and food processing.

Rationale: This platform focuses on maximizing the capture of economic value within Minnesota from products produced from farms and forests. While Minnesota does have a significant base of industry engaged in value-added agricultural processing and food manufacturing, it is still the case that a significant volume of primary agricultural commodities leave the state with limited value-added to them. R&D and platform services designed to increase value-added food and health products produced in Minnesota are the rationale for this platform.

[45] BCC Research. *Liquid Biofuel: The North American Market.* March 2009.
[46] Ibid.

University R&D Strengths: It is readily evident from the core competency analysis that Minnesota enjoys a considerable base of capabilities and assets in relation to value-added food and health development and production. Within Minnesota's academic R&D base, there are many assets that focus on development relevant to this platform. Some of the most notable competencies include:

- Expertise in plant biochemistry and plant improvement relevant to the development of plants with enhanced output and functional characteristics
- A strong multi-disciplinary base of scientists working in nutrition, nutrition products and associated human development. Plus a significant base of faculty working in animal nutrition
- Food products pilot plant facilities and direct academic-industry relationships in food products development and processing technologies
- World-class expertise in food flavors/sensory sciences
- A highly engaged Department of Applied Economics at the University of Minnesota who's economists are working in multi-disciplinary teams with other scientists and faculty in evaluating the economics and potential markets for alternative products from agricultural and forest commodities and resources.

In addition, AURI focuses a significant portion of its activities to assisting in the development of value-added processed food products and new foods with enhanced functional characteristics for health.

Cross-walking the Technology Platform to Minnesota's Industry Base: It is abundantly clear that Minnesota has a large, highly specialized, and leading food manufacturing sector and associated supply chain. In food manufacturing alone, the state has an employment base of nearly 44,000 jobs and a strong, specialized location quotient of 1.46 in 2011. The state is home to numerous corporate headquarters including General Mills, Hormel, Land O' Lakes, and Cargill.

While the state's strength in food manufacturing is vitally important to the foundation of the value-added food and health products sector and research platform in Minnesota, the industry linkages and analysis conducted here are more refined to analyze only those segments where research competencies identified are most likely to have a more direct impact in terms of enhancing the characteristics of raw food inputs and products. These value-adding characteristics could include flavor or other sensory characteristics or nutrition. In addition, the sector branches out based on related research strengths to include health products such as vitamins and supplements as well as natural products which in Minnesota must include the activities of Aveda, a leader in plant-based cosmetics and toiletries (hence why the toilet preparation manufacturing industry is included).

Table 21: Defining the Value-Added Food & Health Products Sector in Minnesota

NAICS Code	NAICS Industry Title
311211	Flour milling
311212	Rice milling
311213	Malt manufacturing
311221	Wet corn milling
311222	Soybean processing
311223	Other oilseed processing
311225	Fats and oils refining and blending
311230	Breakfast cereal manufacturing
311313	Beet sugar manufacturing
311411	Frozen fruit and vegetable manufacturing
311421	Fruit and vegetable canning
311511	Fluid milk manufacturing
311512	Creamery butter manufacturing
311513	Cheese manufacturing
311930	Flavoring syrup and concentrate manufacturing
311942	Spice and extract manufacturing
312120	Breweries
312130	Wineries
312140	Distilleries
325411	Medicinal and botanical manufacturing
325620	Toilet preparation manufacturing
424910	Farm supplies merchant wholesalers
54171*	Physical, engineering and biological research

*Includes only the share of industry activities that are primarily in the life sciences/biosciences.

The industry linkages to research competencies for value-added food and health products form a very large and specialized structure in which to leverage strengths. Sector companies in Minnesota employ 22,649 across 915 business establishments in 2011. While the state sector has experienced an overall modest 5 percent employment decline over the decade, it remains specialized in terms of its concentration of industry jobs relative to the national average. Its location quotient for 2011 was 1.31 or a 31 percent greater concentration in these sectors relative to the national average.

Table 22: Employment and Related Metrics for the Value-Added Food & Health Products Sector, 2011

Metric	Value-added Food & Health Products	
	Minnesota	U.S.
Establishments, 2011	915	30,695
Establishments Change, 2001-11	9.2%	13.9%
Establishments Change, 2007-11 (Effects of Recession)	1.2%	9.6%
Employment, 2011	22,649	832,352
Employment Change, 2001-11	-5.4%	3.7%
Employment Change, 2007-11 (Effects of Recession)	-0.4%	1.0%
Location Quotient, 2011	1.31	n/a
Average Annual Wages, 2011	$ 61,130	$ 73,655

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

The employment trend for Minnesota in the value-added food and health products sector diverged from the U.S. in 2005 and while the state saw job losses the national sector had modest, steady gains (see Figure 14). Since 2007, the trend for Minnesota has been relatively stable and though the sector has not regained its jobs lost early in the decade it did see a job gain in 2011.

Figure 14: Employment Trends in the Private and Value-Added Food & Health Products Sectors, 2001–11

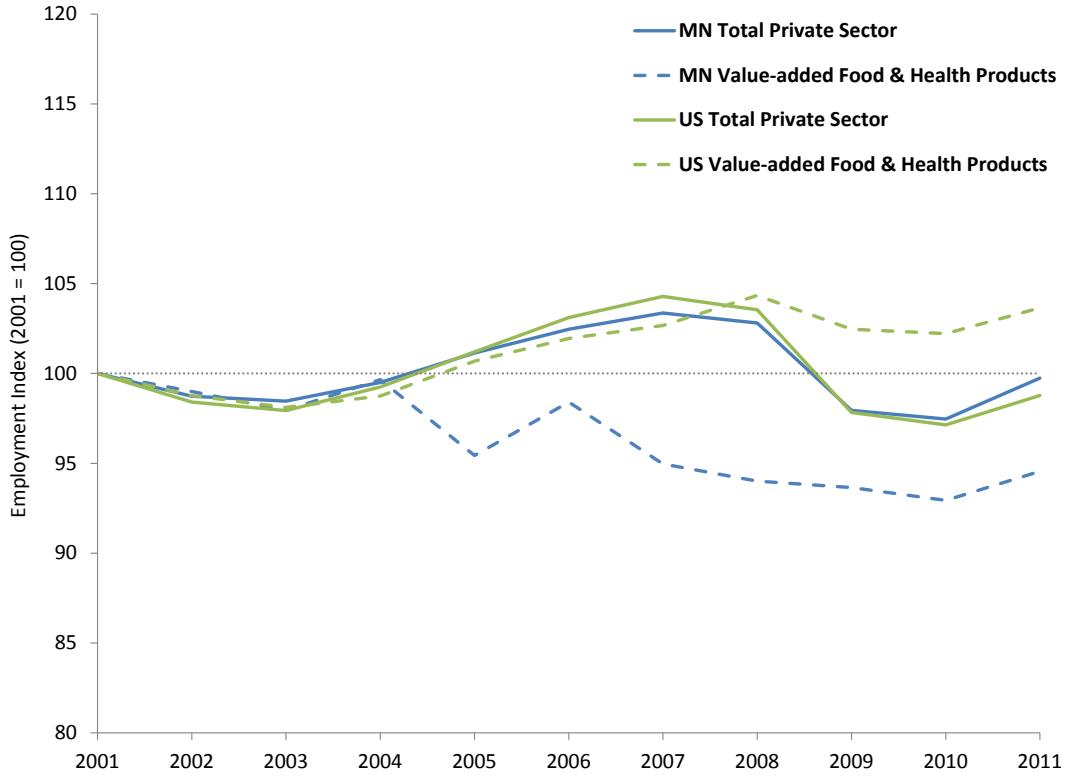
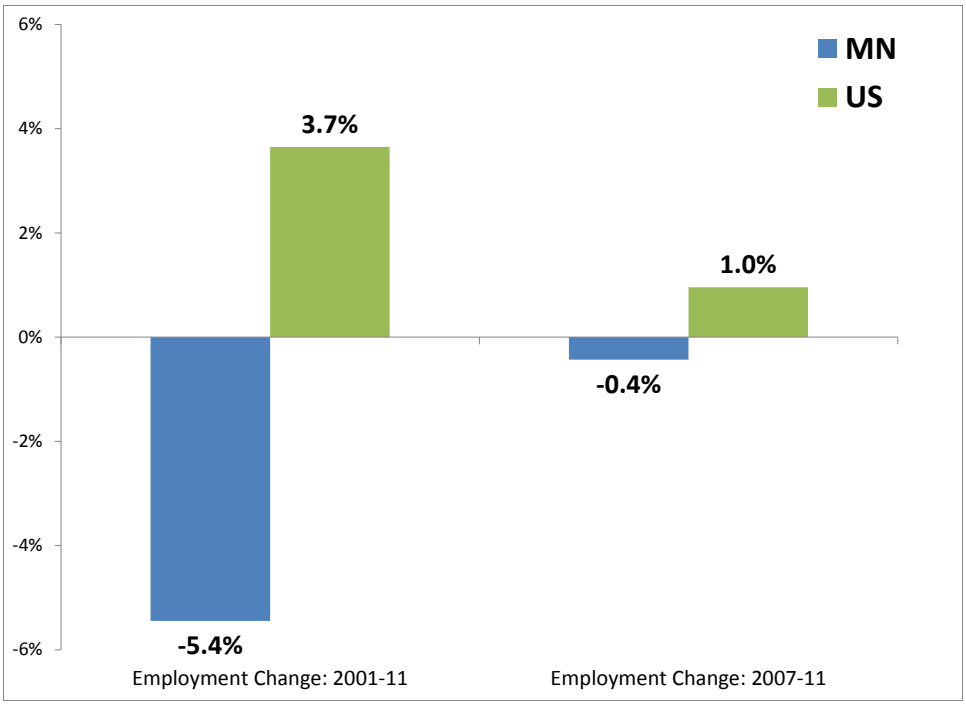


Figure 15: Employment Trend in the Value-Added Food & Health Products Sector, Minnesota vs. U.S., 2001-11 and 2007–11



The value-added food and health products sector has a large and varied base in Minnesota with the largest component in core life sciences R&D driving innovation within and among companies followed by numerous food manufacturing components including cheese, fruit and vegetable canning, beet sugar, cereal, and milk. More than half (12) of the 23 detailed industries that make up the industry linkages to this research platform have a specialized employment concentration in Minnesota, reflecting the highly specialized industrial applications and opportunities in the state. These specializations extend beyond food to include a key wholesale sector conducting seed development to the natural sundry products developed by Aveda.

By further examining three key employment-related performance measures related to strategic industry targeting the detailed industry components of the value-added food and health products sector can be categorized to gauge its strength or emergence. These metrics answer the following:

- Is the industry specialized in its concentration relative to the nation (location quotient)?
- Is the industry growing in Minnesota?
- If the state industry is growing is it outpacing national growth and thus growing its competitive share?

Based on the answers to these questions, the sectors could be placed into one of four key designations related to industry targeting:

- Current Strengths – those industries that are specialized, growing, and outpacing national growth
- Emerging Strengths – those industries that are not yet specialized but are growing and outpacing national growth
- Priority Retention Target – those industries that are specialized and growing but are lagging performers relative to the nation
- Specialized Retention Target – those industries in which the state is specialized but is no longer growing.

Table 23: Identifying Detailed Industry Strengths for the Value-Added Food and Health Products Sector in Minnesota

Classification	**Specialized** (20% or higher employment concentration compared with national avg)	**Job Generator** (Generated new jobs over the 2001–11 period)	**Outpacing National Job Growth** (Job Growth from 2001–11 exceeded national avg)	**Minnesota Biobased Industrial Products & Services**
Current Strength	✓	✓	✓	• Farm supplies merchant wholesalers • Soybean processing • Malt mfg • Distilleries • Creamery butter mfg
Emerging Strength		✓	✓	• Breweries
Priority Retention Target	✓	✓		• N/A
Specialized Retention Target	✓			• Fruit and vegetable canning • Cheese mfg • Toilet preparation mfg • Beet sugar mfg • Breakfast cereal mfg • Flour milling • Fats and oils refining and blending

Note: detailed industry analysis limited to industries with at least 200 jobs in 2011.
Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Minnesota has clear opportunities to advance value-adding characteristics to novel food and health products at the intersection of key strengths with respect to both research and corporate activity. At present a significant volume of primary agricultural commodities leave the state with limited value-added to them. Given the highly specialized continuum of food and natural products companies and significant private sector R&D base in the agbiosciences, this leakage should be stemmed. A large and varied set of component industries, particularly in food and agricultural processing as well as in natural

products, can be linked to research competencies in the R&D and evaluation of potential value-added products as shown in the industry assessment above.

Evidence of Innovation Driving the Future Development of the Technology Platform: Within a technology platform, a number of indicators can be examined to begin to develop a sense of the level of innovation or commercialization that is occurring to drive a technology platform into the future. Such measures include the level of patenting by industry and academia within a given technology platform, the level of risk capital being invested within a technology platform, and the level of SBIR (Small Business Innovation Research) grants being awarded within a given technology platform.

Patents: Utilizing patents as a means to understand the innovation environment of a state is useful in many ways. By analyzing patents, a picture emerges of not only the level of patent activity in a state within a given technology platform, but also key industrial drivers of that innovation. For instance, larger companies with relatively high levels of innovation can be identified that could have a significant role in moving the technology platform forward in the future. Patenting may also play an important role in securing funding for startups that represent emerging areas of opportunity.

The patent analysis focuses primarily on patents issued since 2009. However, given the often lengthy patent application process, the analysis also considers patent applications from 2007 and 2008 that are still in process. In the period investigated, Minnesota companies have applied for 163 and have been awarded 125 patents related to the value-added food and health products technology platform. Table 24 identifies the companies and academic institutions that represent the 288 applications and awards.

Table 24: Minnesota Value-Added Food and Health Product Patents and Applications

	Applications & Patents
CARGILL, INC.	118
GENERAL MILLS, INC.	66
PURINA FEED LLC (LAND O'LAKES)	15
NESTEC, S.A.	13
MICHAEL FOODS, INC.	12
ZINPRO CORPORATION	11
LAND O'LAKES, INC.	9
BIOPOLYMER ENGINEERING (D/B/A BIOTHERA)	6
BIOENERGY, INC.	5
HORMEL FOODS CORPORATION	5
SARTEC CORPORATION	4
UNIVERSITY OF MINNESOTA, THE REGENTS OF	4
AMERILAB TECHNOLOGIES, INC.	3
SCHWAN'S FOOD MANUFACTURING, INC.	3
TECHMIX, INC.	3
KIP BIOTECH LLC	2
CAN TECHNOLOGIES, INC.	1

CNS, INC.	1
CONAGRA FOODS INC.	1
ECOLAB, INC.	1
JRW Technologies, LLC	1
PANDORA SELECT PARTNERS L.P. AND WHITEBOX HEDGE HIGH YIELD PARTNERS, L.P.	1
STONE ARCH FOODS, LLC	1
VISION PROCESSING TECHNOLOGIES, INC.	1
~Individually Owned Patent	1
Grand Total	**288**

Note: The applications and issued patents are distinct records—applications concluding the process with an issued patent are only counted as a patent.

Risk Capital: Companies receiving risk capital investments, either through angel, pre-seed, seed, venture capital investments and/or Federal Small Business Innovation Research (SBIR) funding, typically possess innovative technologies with the potential to be commercialized and brought to market. Emerging companies like these can be engines for growth within a specific technology platform. The level of venture financing within the value-added food and health products technology platform was examined over the past decade to understand the presence of emerging value-added food and health products industrial firms within Minnesota. From 2002 through 2012, three companies received more than $20 million. Table 25 lists the level of funding by value-added food and health products -related company.

Table 25: Value-Added Food and Health Products Venture Capital Investments, 2002–2012

	Equity Invested (millions)
Biothera, Inc.	3.50
Endres Processing, LLC	7.80
NIB, Inc.	9.05

SBIR award funding can be an important source of non-dilutive risk capital for agbioscience firms. SBIR funding within the biobased industrial product technology platform over the past four years was examined to understand the presence of emerging biobased industrial product firms within Minnesota. What was discovered was the fact that during that time period, no SBIR grants were awarded to Minnesota companies related to this technology platform.

Major Funding Resources: The development of value-added food and health products is a comparatively challenging space in which to secure federal funding. Because the work is by nature applied, more traditional funding resources from agencies such as the NSF are quite limited in applicability, particularly in the food products space. There is potential federal funding in advanced nutrition products, however, via agencies such as the NIH. Commodity groups are funders of work to

develop value-added products, seeking to encourage the development of new uses for their producers' commodities. Funding for research may also be available from individual corporations

Global Market Potential: Food companies, already under intense competitive pressure within their historic product lines, are looking at the functional food, beverage, and supplement market for help. Though the value-added food and health product industry is less than 10 percent of the total food industry, the market offers significant growth opportunities and wider profit margins. Overall, the increasing effectiveness of the new products entering the market in terms of satisfying health claims, along with growing consumer health awareness, and the promise of higher profit margins is luring almost all of the major multi-national corporations into the market.

One of the reasons for this growing market is the fact that an increasing number of consumers are focusing on consuming functional foods and beverages, nutritional supplements and alternative medicines as a means to maintain health and wellness. Value-added food and health products provide a potential means for consumers to reduce out-of-pocket costs for primary medical services and prescription drugs, as well as live a longer and healthier life. Moving forward, the market is expected to continue to grow at a strong rate for three primary reasons:

- The elderly population is expanding: More than 1 billion people globally will be over the age of 50 by 2015; this group is likely to experience one or more chronic age-related disease and seek some form of treatment through nutraceutical products. Longer life expectancies will also increase overall spending for these consumers.
- Young consumers' focus on health: Increased media attention and the increase of available online information is raising health awareness for the young. Increased awareness creates greater concern, which leads to purchase decisions. The recent uncertainty related to the future of the U.S. health care system has also motivated consumers to engage in preventative health care.
- Obesity epidemic: The World Health Organization (WHO) reports that more than 500 million adults globally are obese and an additional 1.0 billion are overweight. Excess weight is the prime cause of hypertension and cardiovascular disease, along with many other conditions. These specific diseases are the leading causes of death among adult populations. Both excess weight and its associated disease states can be treated with nutraceutical products.

Around the globe, traditional food processing and manufacturing companies are largely entering the value-added food and health product market to compensate for the lower margins being realized in the traditional food industry. For instance, while the nutraceutical market is comparatively smaller than the overall food market, it offers the opportunity for higher profit margins. Retail prices for such products are typically 25 percent to 500 percent above comparable conventional foods as consumers are willing to pay more for additional benefits.[47] Large beverage giants, seeing a continuous drop in sales of carbonated drinks over the past several years, are entering the functional beverage segment with noncarbonated sports and energy drinks. The functional food products market opportunities are more varied, with analysts seeing large untapped segments such as meat and flour, while confectionery,

[47] BCC Research. *Nutraceuticals: Global markets and Processing Technologies*. July 2011.

breads, and snacks represent more mature markets globally.[48] Overall, the U.S. is leading the global nutraceuticals market with more than 33.1 percent of the market share in 2010, and this market is anticipated to grow at a 6.5 percent compound annual growth rate (CAGR) from 2011 to 2016.[49]

Interestingly, growth in the value-added food and health product market has implications for the flavors and flavor enhancers market due to their ability to mask the sometimes unpleasant taste of functional additives. Demand for flavors and flavor enhancers totaled $2.5 billion in 2010 based on advances of 3.6 percent per year[50], and is anticipated to grow at a steady state for the foreseeable future. More than 1,500 different flavoring materials are used by the food and beverage industry, and the final formulation of a flavor for use in an individual product may require more than 100 components.

Using Minnesota agricultural products in the production of value-added food products, advanced/functional foods, and as the basis for the extraction of functional phytochemicals/nutrients for health products represent pathways to increasing the value of Minnesota commodities and specialty agricultural products. Similarly, value-added feed and animal nutrition products have market potential.

[48] Ibid.
[49] Ibid.
[50] Freedonia. *Food and Beverage Additives.* August, 2011

IV. Advancing Development Plans for Targeted Agbioscience Technology Platforms

A. Introduction

The identification of the four agbioscience technology platforms for Minnesota is not an end in itself, but rather a starting point for Minnesota to move ahead in overall agbioscience development. These agbioscience technology platforms align with the specific research core competencies found across industry and research institutions in Minnesota and have the potential to lead to products in new markets. In order for Minnesota to realize the potential of these technology platforms, it is essential to advance bold but also realistic development plans that incorporate "outside the box" thinking about how best to create the strong, systematic linkages across Minnesota's private sector and academic enterprises to ensure Minnesota is taking advantage of its agbioscience technology capabilities to remain strong in both its academic and industry settings.

To guide the substance of these development plans, AURI arranged for industry executives, agriculture production leaders, research leaders from universities, government leaders, and non-profit representatives to be interviewed by Battelle representing the four technology platform areas identified:

- Microbial Agbiosciences
- Resilient, Efficient and Productive Agricultural Systems
- Biobased Industrial Products
- Value-Added Food and Health Products.

The key topics framing the discussions during each of the interviews included:

- Addressing the specific objectives and priorities that each participant would like to achieve through strategic collaborations between industry and universities
- Validating the assessment of the particular technology platform area prepared by Battelle, in consultation with the Steering Committee, to ensure that it was complete and fully reflected the core competencies found in Minnesota's industry and research institutions
- Identifying the specific and distinctive market and technology opportunities around which Minnesota's industry sectors and universities are best suited to collaborate
- Putting forward specific actions needed to address development challenges facing Minnesota in its efforts to be a global leader in the technology platform area.

While each of the agbioscience technology platforms had specific development issues and opportunities to best realize the alignment of industry and academic research capabilities, one critical outcome of interviews was the discovery that there was a common, cross-cutting set of challenges and actions needed to advance all four agbioscience technology platforms. In a nutshell, there was also a common

recognition that Minnesota lacked an innovation ecosystem that could drive critical private sector/academic partnerships as well as foster the commercialization of new product development.

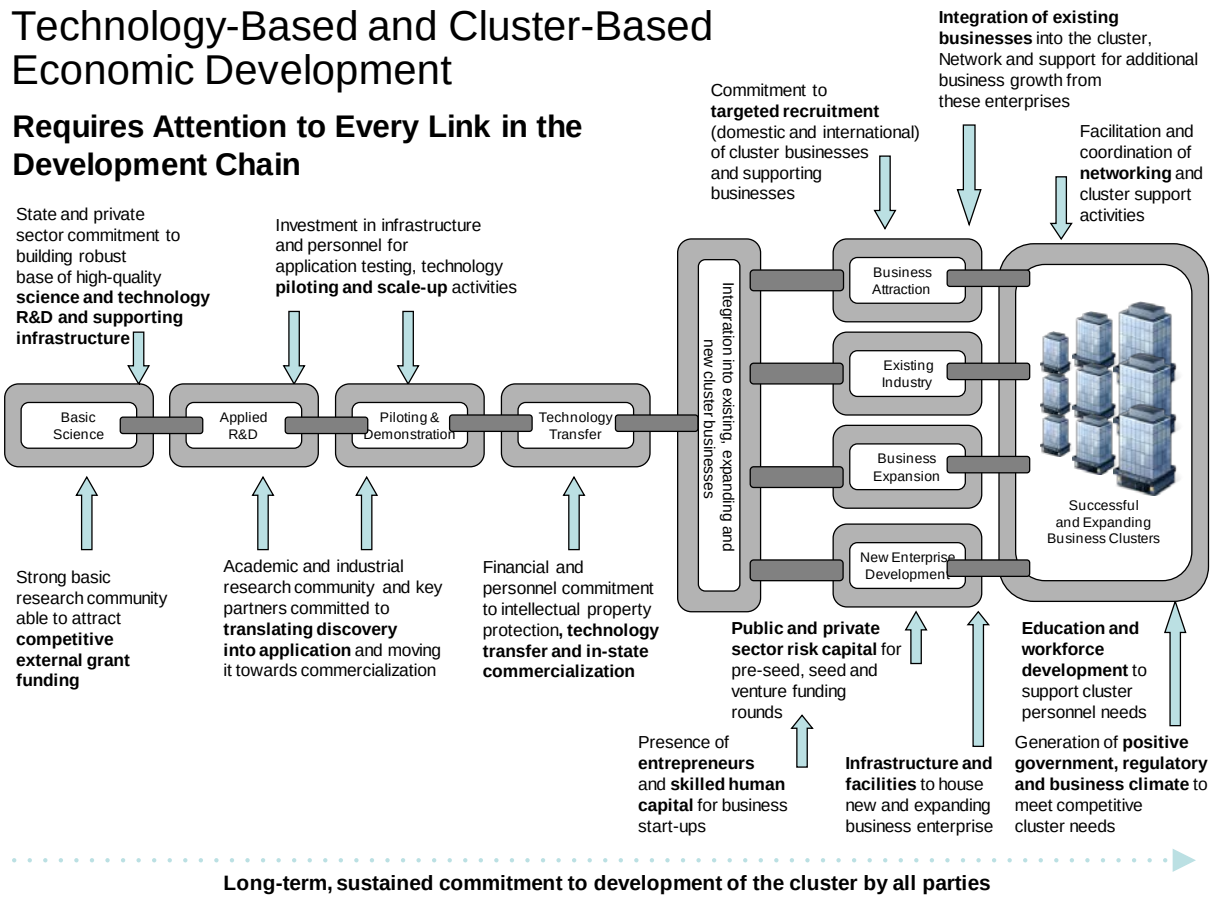
This section, thus, starts with background information on why such an innovation ecosystem is critical in developing a robust, technology-based economy. This is then followed by a discussion of the common challenges facing each of the four technology platforms and actions that are cross-cutting and critical for Minnesota to address. Finally, for each technology platform, specific actions are identified to advance specific areas of development based on the unique nature of each platform.

In considering both the cross-cutting actions to address the common objectives as well as the specific development opportunities for each agbioscience technology platform, Battelle used its broad expertise and knowledge of best practices to offer insights from model initiatives and programs from across the nation and the globe.

B. Background – Importance of the Commercialization Chain

For agbioscience economic development to occur at all, an entire interconnected sequence of positive factors, or what Battelle terms a “commercialization chain” or “innovation ecosystem”, has to be in place that connects and strengthens the drivers of innovation and industry development, namely technology, talent and capital. If links in the commercialization chain either inadequately address economic needs or are missing altogether, a sustainable technology cluster able to generate quality jobs is unlikely to develop (see Figure 16). It is also important to note that needs vary greatly based on where a company is at within its life cycle (start-up, small, medium, or large company) as well as potentially its location (urban versus rural).

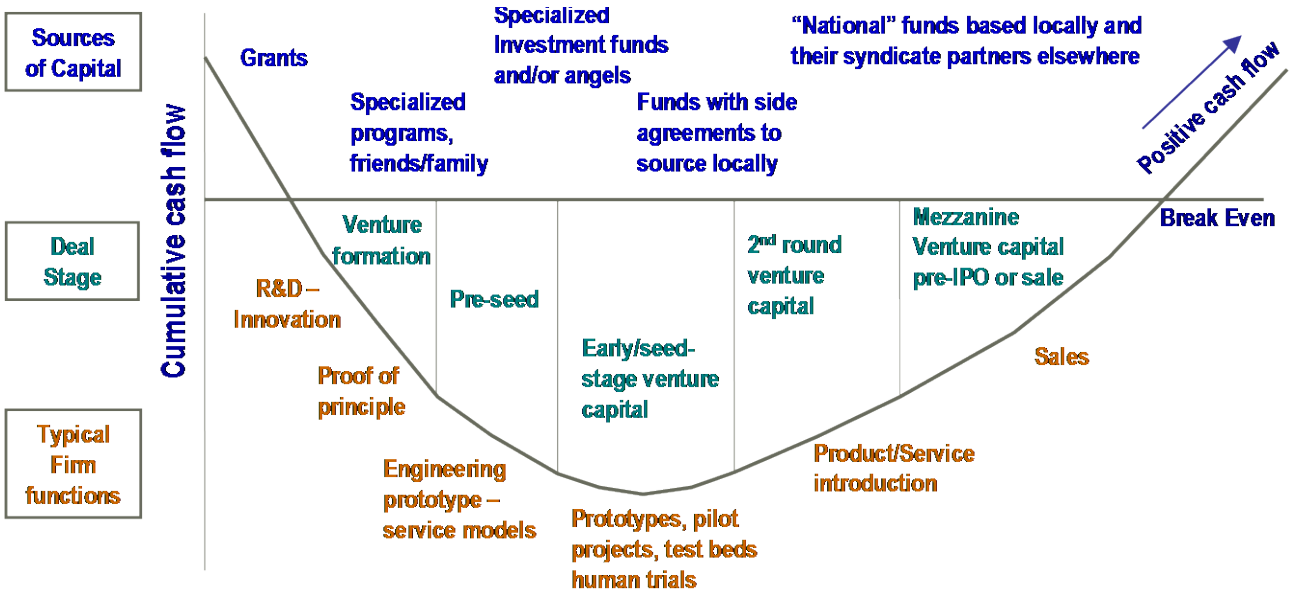
Figure 16: Technology-Based Commercialization Chain



A key mechanism for unlocking the full potential of a state's research assets is to advance technology commercialization activities that are involved in enterprise development and support, including due diligence, business planning, mentoring and coaching, pre-seed to seed and later stage risk capital financing, and a serial entrepreneurial talent pool to create, grow and attract businesses. Consequently, programs such as business accelerator services and infrastructure such as research parks and incubators represent, together, a system critical to diversifying and growing a knowledge-based future economy.

Technology commercialization initiatives need to be concerned with the technology life-cycle and how a state can address what many refer to as the "Valley of Death." This "Valley of Death" (see Figure 17) helps illustrate the need for a continuum of support, services, and assistance from the private and public sectors as a technology enterprise is conceived, developed, formed, grown, and reaches maturity.

Figure 17. Valley of Death in State Innovation Systems



Critical components within such an innovation system include developing programmatic initiatives that:

- Accelerate the commercialization of university-developed technologies
- Foster value-add private sector/academic collaborations that focus on transdisciplinary, applied research that solve key agricultural production and related-industrial needs
- Provide in-depth support at all stages of the enterprise creation and business launch cycle
- Offer an integrated system for multi-use facilities and shared-use equipment targeted to scaling technology companies
- Address the need for risk capital at all stages of the technology development and commercialization life cycle—an even more critical element given the ongoing global risk capital shortages.

The end goal for a Minnesota Agbioscience Strategy is to create an environment in which:

- Cutting-edge, commercially-relevant agbioscience research leads to applied technologies and product innovations that have commercial application within key agbioscience technology platforms and agbioscience sectors of Minnesota
- Technological advancements quickly make their way into the hands of entrepreneurs and industry leaders who create new products, form new agbioscience companies, or transfer the technology to existing Minnesota agbioscience companies

- The agbioscience sector is able to secure the needed resources to move innovative products into the market place with the support of outstanding supply chain partners, expert management teams, and sufficient financial capital
- Existing agbioscience clusters are supported and emerging clusters are formed as a result of Minnesota's technological strengths thereby creating global comparative advantage as a result of the mutual proximity, connections, and shared specialized infrastructure, labor markets and services.

C. Cross-Cutting Challenges and Actions for All Four Agbioscience Technology Platforms

A set of common challenges and imperatives has emerged across the four agbioscience technology platforms regarding the "missing links" in the commercialization chain that are holding Minnesota back from reaching its full agbioscience development potential. The common challenges center around four main needs:

- Academic research efforts that are applied in nature, transdisciplinary in focus to adequately cover the complexity of the technology platforms, and designed to meet present and future agricultural production and related-industrial needs
- Commercialization focus that brings new products to market to increase the global competitiveness of Minnesota's agbioscience sector around each of the technology platforms
- Entrepreneurial ecosystem that addresses both the lack of human capital (entrepreneurial management talent) as well as risk capital
- Strategic partnership/networks that address broad, transformative technology platform issues.

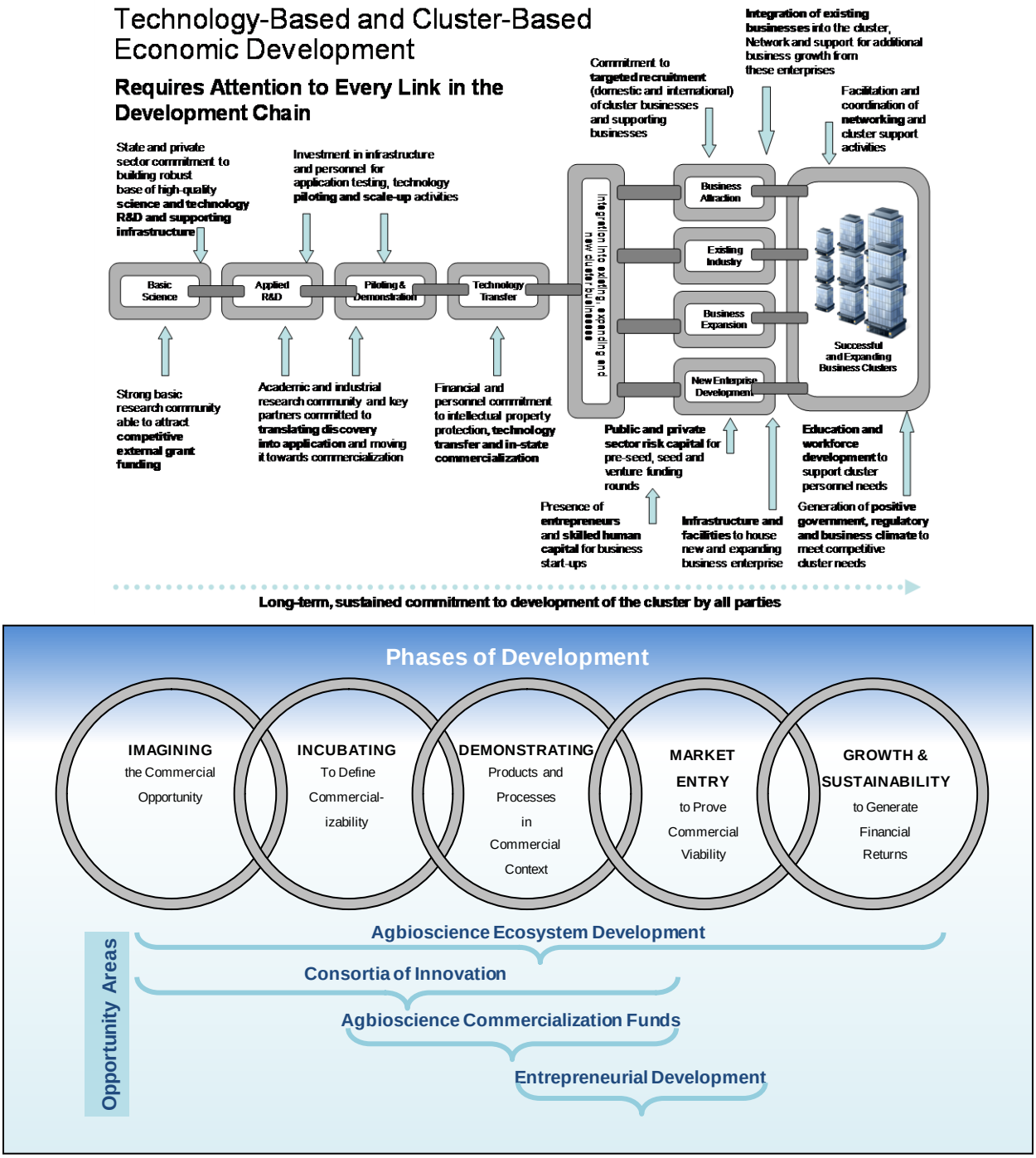
To address these common challenges, a continuum of actions/initiatives is presented in the following strategy that is designed to advance agbioscience development by focusing on four cross-cutting areas of opportunity:

- **Opportunity 1:** Form Cluster Networks around the identified agbioscience technology platforms to foster strategic partnering to tackle broad transformative initiatives
- **Opportunity 2:** Establish competitively designated Consortia of Innovation around Minnesota's four identified agbioscience technology platforms
- **Opportunity 3:** Build upon Minnesota's existing commercialization funds to support proof of concept and commercialization activities in order to advance technologies related to the four identified agbioscience technology platforms
- **Opportunity 4:** Design and sustain a robust, agbioscience-specific, entrepreneurial ecosystem to build a stronger, indigenous industry base in Minnesota around the four agbioscience technology platforms.

These four areas of opportunity, if implemented, will reach across the five phases of agbioscience development to help create a robust innovation ecosystem in which the agbioscience industry can thrive and flourish in the State of Minnesota. Figure 18 depicts graphically where each opportunity area falls within the agbiosciences phases of development, and therefore what functions those efforts must seek

to fulfill within the commercialization chain. Each opportunity area is described in further detail in the narrative that follows.

Figure 18: Minnesota's Agbioscience Development Strategy



OPPORTUNITY ONE: FORM CLUSTER NETWORKS AROUND THE IDENTIFIED AGBIOSCIENCE TECHNOLOGY PLATFORMS TO FOSTER STRATEGIC PARTNERING TO TACKLE BROAD TRANSFORMATIVE INITIATIVES.

Networking between industry representatives, academic R&D leaders, technology intermediary organizations, and the public sector has been a proven staple of technology-based economic development for multiple states. Whether formalized through collaborative institutes (such as those formed under the Ohio Third Frontier program), via special non-profit groups (such as Biowa guiding Iowa's biobased products sector development), through general industry technology councils (such as the Pittsburgh Technology Council), or more ad hoc, there should be little doubt that regular contact and dialogue between industry, academia, and the public and non-profit sectors can be the spark that leads to broad transformative initiatives.

Raising awareness and building relationships is a foundational building block for establishing stronger collaborations between industry, academia, and the public and non-profit sectors. Many of the individuals interviewed voiced a concern that Minnesota lacks the reproducible and sustainable mechanisms that will allow academic, private, and public organizations to learn about each other's approaches and capabilities in agbioscience development. All too often, organizational silos exist that limit how the private sector, academia, and the public and non-profit sectors understand the opportunities for engagement and collaboration with one another.

Activities within academic research centers as well as at AURI are currently ongoing to break down these walls and foster value-added dialogue and collaboration around broad transformative initiatives. For instance, AURI has created the Rural Innovation Network (RIN). The purpose of RIN is to 1) generate ideas for value-added agriculture, 2) select the best ideas that have the potential to create the greatest return for existing ag industry, and 3) implement those ideas in the marketplace to grow Minnesota's economy. The RIN focuses on collaboration with other organizations, such as commodity organizations and economic development organizations, to determine the highest impact projects and research. Once that research is done, AURI disseminates that information to the businesses and entrepreneurs who are looking for ways to take those ideas to commercialization.

Efforts such as this need to be fostered and further developed. There are a number of activities that can be undertaken to improve awareness and foster relationship building that can serve each of the agbioscience technology platforms areas. A few examples are provided below:

Hold symposiums and regular workshops on key topics of interest that profile agricultural production and related-industry identified market needs and share research and development activities across industry and universities.

Among best practices in this regard is the North Carolina Biotechnology Center's (NCBC) support for Intellectual Exchange groups. The exchange groups are organized by NCBC to create a "dynamic research and information-sharing environment" and have been organized by special interest areas, which currently include bioprocessing and process development, plant molecular biology, virology, immunology, chromatin and RNA. In total, Intellectual Exchange groups have approximately 40 meetings per year, with thousands of attendees. The NCBC also supports in collaboration with the Center for Entrepreneurial Development, a bi-monthly Biotech Forum to provide a meeting place for entrepreneurs, executives, professionals and academicians actively involved in the biotechnology

industry. Each forum consists of a 75 minute panel followed by a networking reception. Plus, NCBC, together with CED, holds an annual life sciences conference.

For Minnesota, each technology platform should hold a multi-day symposium where agricultural production, related industry, and university researchers from across the University of Minnesota and MnSCU System involved in the technology platform can come together for intense discussion and examination of the most advanced aspects of their field, and provide a valuable means of disseminating information and ideas in a way that cannot be achieved through the usual channels of communication—publications and presentations at large scientific meetings. Recently the Arkansas Research Alliance, with support from the Rockefeller Institute, has used a similar, multi-day symposium to bring industry executives and university researchers together around specific technology platforms to learn more about each other and to explore opportunities for broader collaboration. It is envisioned that from these initial symposiums/workshops, the proposed Consortia of Innovation (see Opportunity Area Two) will be further informed.

Offer sabbaticals and stipends for academics to spend time in industry as well as for industry scientists to spend time in academia. There is no better way to build relationships than to create the experience of working together. It allows not only a sharing of knowledge, but a better appreciation of the culture and specific requirements found between the worlds of academia and industry.

Visiting scientists programs are not at all unusual within academia. They are often used by specialized research centers to provide broader exposure to unique methods and techniques to the research community as well as to establish broader collaborations. It is less typical to have industry scientists spend time in academia. It is particularly important for industry scientists to gain exposure to research leaders and to the technology transfer processes at different universities.

Another approach is the use of visiting scientists from academia to industry. This is particularly important to do if academia is to learn about the market opportunities and the requirements facing industry in bringing innovation to the marketplace. Technology transfer staff at universities should also be part of this effort so that they can get a better understanding of the drivers for industry product development efforts and industry licensing practices.

There have been well-received initiatives across states that focus on linking graduate students with industry, but few efforts to have faculty be visiting scientists with industry. The former New Jersey Commission on Science and Technology offered for many years a New Jersey Technology Fellowship Program through which the Commission paid stipends to recent Ph.D.'s (within 6 months on either side of receiving a degree) who agreed to be placed for a 2-year postdoctoral fellowship with a New Jersey technology company (all fields) that had selected the student for the program. The fellowship paid $65,000 in the first year and $75,000 in the second, with an additional $10,000 toward an expense budget. The company was required to have New Jersey as its principal place of business, 75 percent of its employees in-state, total revenue less than $10 million, and a minimum of three employees or consultants each employed at least 25 hours a week. The fellow was required to be in good standing with the conferring university, though foreign students were not eligible.

Pursue pro-active university policies to support and encourage collaborations. University policies can have significant impact on the willingness and interest of researchers to pursue private sector collaborations. Universities should ensure that promotion and tenure policies provide incentives for researchers to pursue private sector partnerships and intellectual property generation.

Another critical issue is addressing conflicts of interest. Across all technology areas, universities need to focus on effectively managing conflicts of interest rather than being too restrictive and seeking simply to eliminate them. It is important for universities to provide straight-forward processes for disclosing conflicts, counseling and assisting researchers as they seek to address conflicts, and taking seriously conflict of management committees to oversee the process.

Finally, it is important for universities to have predictable and streamlined processes in which the private sector can take ownership of intellectual property from sponsored research with universities and for licensing technologies. Recently, the University of Minnesota enacted policy that allows a company sponsoring research at the university to pre-pay a fee and receive an exclusive worldwide license at a set royalty rate. While this change has been applauded by industry, it was also noted that many are not aware of these recent efforts, and the reputation of the University regarding technology transfer continues to be widely unfavorable. Persistence as well as messaging will be paramount in continuing to reach out to industry.

Engage the community college system across Minnesota to provide vocational career training pathways for high school and post-secondary students focused on agbioscience sector career opportunities.

As the economy becomes more complex and competitive the labor market becomes more complex and confusing – for students, parents, job seekers, employers, and educational leaders. For younger and many middle-aged employees and employees-to-be, the rules of job success and likely career paths in the economy they are entering are significantly different than the economy that shaped their parents' experience and careers. This is one place where it is difficult for older generations to pass on experience and knowledge to the next generation. Previous education and career paths do not work as well, or in some cases are not even available, in the global economy.

This substantive change in labor market expectations and pathways has very significant implications for Minnesota's agbioscience sector. When there is confusion and lack of knowledge in any marketplace, people will fall back on the tried-and-true "certainties" that they believe they know, and they will avoid areas that are unfamiliar to them (or their parental or educational advisors). This risk-avoiding behavior is natural, and the labor market is no exception. In this case, it means that students, parents, employees, and institutions will tend to gravitate toward educational activities and careers in "known" fields with clear career paths and industry awareness,

Aligning Regional Resources via Career Pathways

"Career pathways" is a term for a framework by which regions can better align publicly supported [education and workforce] systems to build a workforce customized to the needs of local labor markets. A career pathway is a series of connected education and training programs and support services that enable individuals to secure employment within a specific industry or occupational sector, and to advance over time to successively higher levels of education and employment in that sector.

Career pathways target jobs in industries important to local economies. They are designed to create both avenues of advancement for current workers, jobseekers and new and future labor market entrants and a supply of qualified workers for local employers. They also serve as a strategy for strengthening the "supply chains" that produce and keep a region's knowledge workforce up to date. The specific form and content of a career pathway will depend on the particular industries targeted, the requirements of employment and advancement in the target sectors, and the existing infrastructure for education and workforce development in those sectors.

Jenkins, D. "Career Pathways: Aligning Public Resources to Support Individual and Regional Advancement in the Knowledge Economy." Workforce Strategy Center. August 2006.

such as healthcare, public administration, teaching, and finance. In contrast, newer areas of technology within the agbioscience field are not as well known.

On an institutional level, the educational and workforce training career structures, linkages, and job advancement practices that served to provide skills and knowledge to a past generation are now no longer effective for a new generation of employees, and a new set of economic challenges. The labor market rules of success and failure have been and are continuing to be reinvented by the forces of globalization. Because of this, there is an important need to reinvent not only individual knowledge of how the labor market now works ("career literacy"), but also to create a new set of structural relationships between students, employees, educational institutions, and industry. Many would argue that it is misleading to put students through an education and training process designed for the economy of the 1960s to 1980s, and expect them to succeed in the dramatically reinvented global economy of 2010 and beyond.

One relatively new tool essential in helping Minnesota adapt its agbioscience workforce to this new economy is the creation and support of "career pathways." Career pathways is a new and somewhat multipurpose term covering activities focused on more effectively coordinating a community's or state's educational institutions with the workforce needs of the economy. If the agbioscience sector aspires to build a competitive advantage based on its workforce and human capital assets, then developing a set of defined career pathways with local high schools, community colleges, and 4-year institutions is a critical action step.

In addition, the ability of students to move seamlessly from one level of education to the next in their chosen field of study without missing a beat in obtaining their ultimate educational goal, whether it be an associate's degree, bachelor's degree, or advanced degree, is critical. This seamless integration is achieved through enhancing real partnerships between all educational institutions in Minnesota across the various levels that result in students achieving their long-term learning goals.

Common Features of Career Pathways

Career pathway programs and structures vary greatly, given the variation between industry and job targets; however, common elements are as follows:

- **Jointly produced occupation "road maps" that show how education and industry intersect for occupation and advancement potential**
- **User-friendly linkages between remedial, educational and occupational training**
- **Heavy reliance on specific occupational data, job progression patterns, and job requirements**
- **Course content defined in terms of competencies required for jobs and, where possible, tied to industry skill standards and certifications**
- **Training and education offered in modules that represent clear stepping stones to advancement**
- **Training offered at times, places, and with support services to enable maximum participation**
- **Outreach and bridge building to middle, high, and vocational schools**
- **Blending of private and public funding**

Provide incentives to higher education institutions to work with agricultural producers and related-industry to review and adopt new multidisciplinary curricula, including offering related degrees and certificates, and provide innovative workforce programs in the agbiosciences.

For Minnesota to be a leader in the agbiosciences in general, and specifically in the identified technology platforms, its higher education institutions must constantly innovate, ensuring that the necessary interdisciplinary programs are in place to educate, train, and graduate the future workforce as well as to keep the existing workforce up to date through life-long learning efforts. For the state to remain

competitive, it must have agile higher education institutions that can quickly respond and change curricula and program offerings.

A consensus emerging among those working in the education and training field is that improving the effectiveness of the workforce development system will require adopting a "demand-side strategy," built on a market-driven approach that builds on employers' economic interests. Critical to these efforts are

- Building the bridges to employer needs through ensuring skill standards for education and training that meet industry requirements
- Having educational institutions focus on creating closer connections between students and employers
- Creating much closer applied-research collaborations between educational institutions and employers.

Minnesota's higher education institutions, including the University of Minnesota and the MnSCU System, should examine how they can "fast track" changes in their curricula to best position the state to secure sufficient personnel in the identified technology platform areas, thereby ensuring an adequate supply of workers to local employers. Key to Minnesota's successful competitions with other states is having a much better talent pool available in the new and emerging agbioscience multidisciplinary fields.

Georgia's Intellectual Capital Partnership Program

Georgia has been very active in the field of technology workforce development through the Intellectual Capital Partnership Program (ICAPP). ICAPP was created to meet the immediate needs of new and expanding technology companies for workers, including the bioscience industry. ICAPP trains workers for high-demand technology jobs whenever a low supply of qualified employees exists, and leverages the resources of Georgia's colleges and universities to provide customized, accelerated educational programs to meet the specific needs of employers. ICAPP achieves its mission through five programs:

- ICAPP Access products provide user-friendly, "one-stop shop" access that makes the resources of the University System easily available to Georgia businesses.
- ICAPP Advantage is a direct economic development incentive that helps companies meet immediate human resources needs. Through ICAPP Advantage, Georgia's public colleges and universities expedite the education of highly skilled workers to meet a company's workforce needs for knowledge workers in high demand but low supply.
- ICAPP Needs Assessment works to match the programs of Georgia's colleges and universities with the needs of Georgia's current and prospective employers and industries. This "supply and demand" approach, while fundamental in business, is on the cutting edge of higher education.
- ICAPP Strategic Response Initiatives create model academic programs to address the shortage of knowledge workers, such as information technology professionals.
- ICAPP Regional Programs support collaborations among University System institutions and other public-private organizations to find regional answers to specific regional economic development needs.

ICAPP has been used and can continue to be tapped to meet the workforce needs of the state's bioscience companies. For example, ICAPP provided assistance to Monsanto by educating 20 team leaders for a facility in Augusta that produces bovine somatotropin, a synthetically produced hormone that increases milk production in cows. During a second phase, ICAPP educated 130 unit specialists in chemistry, biochemistry, and microbiology.

Foster a proactive business climate with incentives conducive to the development of agricultural production and related agbioscience industries.

For Minnesota to compete on a global scale for the expansion, attraction and robust development of the agbioscience sector, specifically in the identified technology platforms, it must have a proactive tax and

regulatory environment that encourages the future development of the agbioscience sector within the state.

Key business climate factors that need to be taken into consideration in building a technology-driven state economy include the following:

- Costs of doing business, including tax structure, regulatory climate, predictability and stability of public sector policy, and access to and responsiveness of economic development incentives
- Technology infrastructure, including computing and communications infrastructure; real estate infrastructure, such as research parks, incubators and accelerators, wet labs, multitenant space, and pilot plants
- A high quality of life, including costs of housing, recreation, arts and culture, outdoor activities, and downtown amenities. This area is becoming increasingly more important for attracting and retaining managerial and technical talent
- General business leadership.

Given the competiveness of global markets, Minnesota needs strong state leadership focused on strategic investments and policies. Building state economies around the technology-intensive agbioscience sector requires a comprehensive approach, including encouraging the formation of new firms, the retention and expansion of existing firms, and selective recruitment of firms from outside the state. The next three opportunity areas address the creation, expansion, and attraction of firms by increasing their access to research and technology within the state's higher education systems, encouraging greater applications of technology to their product lines and processes, and helping firms in access the risk capital that will enable them to grow and scale their businesses. However, these opportunities will go unrealized if a competitive business climate is unable to be obtained. Continued discussions between the private sector and government, facilitated through organizations such as AURI, Agri-Growth Council, BioBusiness Alliance, Farm Bureau, Farmers Union, etc., must be timely and productive if Minnesota is going to be able to realize its significant agbioscience opportunities.

Resources Required: Incorporated into AURI's annual budget and eventually into the operating budgets of the Consortia of Innovation (see Opportunity Area Two).

Implementation: AURI should initially lead the cluster network effort to ensure that activities begin quickly. AURI is already actively engaged in tackling broad agbioscience transformative initiatives. For instance, AURI has overseen the development of the Minnesota Renewable Energy Roundtable. The mission of Minnesota's Renewable Energy Roundtable is to take action on the immediate challenges and opportunities facing the state, region and nation using Minnesota's assets. The goal is two-fold: 1) Ensure that Minnesota is recognized as a leader in renewable energy knowledge, application and utilization; and 2) Create an implementation platform for moving short and long-term strategic action forward. The participants of the Roundtable represent more than 217 Minnesota organizations, agencies and businesses. Partner organizations include: University of Minnesota, Minnesota State Colleges and Universities, Department of Commerce, and Minnesota Department of Agriculture. Overtime as the Consortia of Innovation are developed, the efforts should be conducted jointly. In addition, partnerships between the private sector, academia, other non-profits, and the government will be critical in order to mobilize the resources and talents that will be needed to bring solutions to many of these issues.

OPPORTUNITY TWO: ESTABLISH COMPETITIVELY DESIGNATED CONSORTIA OF INNOVATION AROUND MINNESOTA'S FOUR IDENTIFIED AGBIOSCIENCE TECHNOLOGY PLATFORMS.

New global realities are reshaping the landscape in which U.S. regions and states must compete. International competition, the increasing pace of development and rapid diffusion of technologies, the growing convergence of technologies, along with a new focus on "open innovation," continue to reshape the competitive technology landscape. A new paradigm has emerged in which leading technology companies are looking to universities and innovative emerging companies for new technologies, rather than investing as many resources in internal high-risk R&D work as in the past. As a result, more and more companies are looking for opportunities to partner with research universities. Universities are looking to corporations and entrepreneurs to provide an avenue to move their discoveries into applications.

In order to build a strong, agbioscience-driven state economy, Minnesota must focus on the following key building blocks in the development of its Consortia of Innovation:

- **Build connections among and between research institutions and agricultural producers and related industry within the identified technology platforms.** Within the identified technology platforms, Minnesota's research assets and resources are considerable; but, because they are spread across different departments, centers, and sometimes institutions, they are not always optimized nor are potential partners aware of them. Ensuring that the research agendas of the Consortia of Innovation address agricultural production and related industry interests requires increased connectivity among and between higher education institutions, farmers, and industry. State investments should require evidence of consortium building to form value-added public/private partnerships.
- **Encourage building of multiple, reinforcing relationships among research institutions and between research institutions and agricultural producers and related industry.** Collaboration through transdisciplinary research teams is increasingly driving the research enterprise in higher education, production, and industry. Individuals with backgrounds and expertise in diverse fields are being brought together to address the most complex agbioscience research questions facing the world today. Higher education institutions building stature and reputation are recruiting transdisciplinary teams of talent and expertise. To the extent that this expertise can be brought together across higher education institutions and between higher education, producers, and related industry, Minnesota can more quickly build its capacity in its technology platforms through collaboration. "Networks" of collaborators can result from these efforts, which contribute to building a critical mass of research expertise and, ultimately, a critical mass of technologies, product expertise, and firms nearby. Concentrations of research knowledge and related production and industry strengths already have begun to form through efforts across a number of Minnesota's existing research centers as well as through AURI's thought-leader networks. Further networking can catalyze the speed and scale of these efforts and specifically target them toward Minnesota's four agbioscience technology platforms.
- **Establish means to better ensure technology commercialization capabilities drive the research agenda.** To differentiate Minnesota's approach to research investments, they must (1) be integrally tied to and require establishment of mechanisms, approaches, tools, and programs that link producers and industry needs to research agendas, and (2) have seamless efficient systems to pull research and its associated technologies quickly into the private marketplace to address these

needs. This, of course, is more likely if producers and related industry is involved initially in problem definition. But, this differentiation also requires that financial support be provided for market assessments of research, adequate equity capital is available around which to form firms with breakthrough prospects, licensing and technology transfer is predictable, and valuation is realistic.

- **Provide discretionary funding support to encourage institutional partners to seek and secure new opportunities.** The state's investments in building applied research capacity also must include support to encourage education/industry joint ventures to seek and secure federal and private funds. Having planning funds to put together joint ventures and encouraging private/public partnerships can help Minnesota secure federal and industrial funding that further support the four identified technology platforms.

Innovation Consortium Characteristics: The Consortia of Innovation are envisioned as specialized applied research centers around one of Minnesota's identified agbioscience technology platforms. As such, they will:

- Be a collaborative applied research effort leveraging and incorporating research assets found across the University of Minnesota, MnSCU System, AURI, federal laboratories, and private industry related to the technology platform
- Seek and incorporate production and industry input into its research agendas so that the work of the Consortium is designed to solve industrial needs
- Recruit and build research teams around Eminent Scholars and industry fellows
- Provide industry with access to a collection of university-based shared/open user facilities on a user friendly, fee for service basis. Not only do the firms have access to sophisticated equipment but they also have access to people with the expertise to run the equipment
- Leverage state funds with multifold increases in federal and industry support
- Play an important role in building the state's educated talent base in the transdisciplinary fields required by the technology platform work by offering new curricula, internships and work-study opportunities, as well as increasing the pipeline of graduates
- Have a board of directors with decision-making authority that includes producers, related industry, higher education, and other key stakeholders from the non-profit and government sectors

Core Programs and Functions of Consortia of Innovation: Each Consortium of Innovation will represent a collaboration among and between academia, producers, and related industry. Each Consortium will focus on one of the identified technology platforms. Each Consortium will, depending on its core technology focus, address the continuum of work—applied research and technology development, reduction to practice, licensing and commercialization to existing firms, and helping form new firms. User-inspired research, with interaction and close connection to its industry partners, will be the guiding principles for each Consortium. In addition, each Consortium will pursue scholarly refereed research that has a dual purpose: to build research stature and address industry interests in knowledge generation.

While it would not be prudent to be too prescriptive regarding the design of each of the four Consortia of Innovation as many of the planning decisions needs to be driven through an in-depth planning process that will be unique to each specific platform's industrial needs, the following narrative provides core programs that each Consortium of Innovation should consider pursuing.

Foster the development of human capital

Part of each Consortium's functions will be to help recruit and attract faculty to serve as **Eminent Scholars**. Consortia will have access to funds for start-up packages to help them recruit Eminent Scholars to become associated with the Consortium. Start-up packages involve providing supplemental salaries, financing a team of researchers, outfitting one or more laboratory facilities, and further expanding the faculty base around a specific research area.

In addition to Eminent Scholars, each Consortium of Innovation should establish several **industry fellows** who will be selected from private industry, will work on a sustained multi-year basis at the Consortium, and be funded by the Consortium. Industry fellows will ensure that the types of research undertaken at the Consortium, the focus areas selected, and the approaches to technology commercialization reflect how industry develops and acquires technology for product development, design, and manufacture.

Facilitate public-private partnerships

The academic and private sector worlds differ in many ways. Intellectual property protection, differences in time horizons, and other issues often present challenges to private sector-university partnerships. Recognizing these challenges, states have developed various mechanisms, such as providing matching grants for research partnerships and creating consortia where industry and academic researchers can work together on collaborative projects, to encourage and facilitate such partnerships. Today's programs focus on fostering relationships and communications across and between universities who generate new discoveries, emerging technology companies focused on new product development and larger companies seeking to meet the needs of existing and emerging markets.

The most common and, in Battelle's experience, one of the most effective means of fostering greater university and private sector interaction is to provide matching grants for research partnerships. Such programs help build relationships between academic researchers and the private sector

Oregon Nanoscience and Microtechnologies Institute (ONAMI)

The Oregon Nanoscience and Microtechnologies Institute (ONAMI) is an example of a public/private partnership that was seeded with state dollars. ONAMI is a collaboration of four Oregon's universities (Oregon Health and Science University, University of Oregon, Oregon State University (OSU) and Portland State University), a national laboratory (Pacific Northwest National Laboratory – PNNL), industry and the investment community. It is one of three "Signature Research Centers" created by the State of Oregon. ONAMI's mission is to accelerate research and commercialization of materials science and related device and system technology in Oregon.

ONAMI seeks to achieve its mission by

- Providing matching funds for federal and private collaborative research projects
- Providing industry with access to a collection of university-based shared/open user facilities on a user friendly, fee for service basis. Not only do the firms have access to sophisticated equipment but they also have access to people with the expertise to run the equipment.
- Providing commercialization funding and business development services. ONAMI provides proof-of-concept grants that enable university researchers to conduct commercialization activities and helps link entrepreneurs to sources of private capital.
- Holding periodic conferences and seminars and providing opportunities for networking among industry and academic researchers.

ONAMI received both capital and operating support from the State of Oregon. Between March 2006 and April 2011, ONAMI distributed $14.75 million in grants to Oregon universities, helping to attract more than $100 million in federal and industry R&D funding. Between 2004 and 2008, awards to Oregon's universities for nanotechnology and microtechnology R&D tripled and seven new companies were created based on nanotechnology and microtechnology discoveries. Companies working with ONAMI have raised more than $70 million for research projects to help dramatically grow research revenue in Oregon and accelerate commercialization of resulting technology.

and provide support for activities that may lead to investments of private capital and commercialization of new technologies.

Minnesota's proposed Consortia of Innovation must focus their efforts on facilitating public-private partnerships. To this end, each Consortium will have funds available to undertake research—from basic to applied—that is sponsored jointly with Minnesota producers and related industry. This **Private Sector Matching Program** will require significant private sector match. This program is designed to increase the level of relationships and connectivity of Minnesota's producers and related industry with higher education. In addition, private sector representatives can serve as majority members of the board of each Consortium of Innovation and on advisory committees and in work groups within the Consortium to assess and determine research areas to pursue. The private sector also can undertake sponsored research as well as enter into licensing agreements with the Consortium.

Consortia can help better position Minnesota for securing federally designated status in their respective platform areas, bringing additional **federal funds** into the state and helping further build the state's research stature. By working with industry, Consortia can develop and form **joint ventures** and consortia around niche opportunities identified by their working partnerships.

Foster Technology Commercialization

Technology commercialization should receive considerable focus and attention at each Consortium. Unlike traditional university-based centers, the Consortia of Innovation will be designed to incorporate considerations of commercial application throughout the organization. Researchers, given more information and knowledge about industry needs, will carry out their research in the same fashion, but they will now work on areas of interest to industry. The Agbioscience Commercialization Fund described in Opportunity Area Three can help build a critical mass of firms based on the Consortium's technological discoveries. Finally, it will be critical for the Consortia of Innovation to have strong linkages with the entrepreneurial efforts described under Opportunity Area Four. Having access to entrepreneurial support services and risk capital will dramatically increase the spin-off and new start-up rates.

Selection of Consortia: Since the Consortia of Innovation will be focused on the previously identified technology platforms, it is anticipated that each Consortium will leverage and build upon the academic core competency strengths identified across Minnesota's research base, which includes existing research centers that have been established within these scientific fields.

Consortia will be selected on a competitive basis. The following key criteria and evidence must be submitted with Consortium applications to be considered for designation:

- Consortium membership identified, including agricultural producers, key industry drivers, higher education research assets from across Minnesota, and other key stakeholders, such as non-profits and government agencies
- Collaborative approaches clearly articulated among the key partners
- Evidence that the resources of all the various research institutions across the state have been brought together in a proposed Consortium to maximize speed at which scale and reputation can be established in the selected technology platform
- Evidence that the Consortium has been designed to meet agricultural production and related industry needs including the private sector driving the research agenda and production and related industry-desired services and functions being provided to turn research into technology

Colorado Renewable Energy Collaboratory

The Colorado Renewable Energy Collaboratory is a research consortium among four leading research institutions—the Colorado School of Mines, Colorado State University, National Renewable Energy Laboratory, and the University of Colorado at Boulder. The Collaboratory works with industry partners, public agencies, and other universities and colleges to:

- Create and speed the commercialization of renewable energy technologies, energy management systems, and energy efficiency
- Support economic growth in Colorado and the nation with renewable energy industries
- Educate energy researchers, technicians, and workforce.

The Collaboratory pursues its missions through six research centers that focus on biorefining, biofuels, solar photoconversion, wind energy, carbon management and energy efficiency. The research centers unite world-class researchers with industry leaders. Each center pursues both shared (public) and sponsored (proprietary) research. Industry members may also sponsor fellowships for graduate and post-doctoral students at the research centers. In demonstration of the State of Colorado's commitment to renewable energy research leadership, the state provides matching funds to the Collaboratory centers' shared research programs.

The four Collaboratory institutions and their research affiliates operate under a single administrative structure, with one institution serving as the administrative lead. Research can be conducted on any of the four Collaboratory campuses, depending on the location of the principal investigator, key researchers, and appropriate laboratories.

Private-sector companies are invited to join the Collaboratory research centers, and benefit from in-depth interaction with the four Collaboratory Institutions through a single point of contact. Research can be performed at any of the four campuses by faculty members, scientists, post-doctoral researchers, students, and visiting corporate staff—all coordinated through a single administrative lead institution.

Intellectual property generated as a result of research funded through the Shared Research Program is available to all member companies via nonexclusive, royalty-free licenses.

Membership fees for the centers are set at $50,000 per year for companies with 500 or more employees (including all affiliated entities) and $10,000 per year for companies with fewer than 500 employees (including all affiliated entities). A minimum two-year membership commitment is required. All member companies receive full membership benefits, including access to IP, a seat on the Advisory Panel, the ability to vote on research proposals, and access to all CRSP research symposia.

Fees are used to fund pre-competitive research. Center sponsors are provided with the opportunity to access, on a non-exclusive basis, right-to-practice Intellectual Property (IP) rights. Sponsors may also choose to fund competitive research whereby the sponsors obtain exclusive access and right-to-practice Intellectual Property rights produced from this affiliation.

The Collaboratory's structure encourages membership among small and large companies – both domestic and international; government agencies; non-profit organizations; and venture capitalists. The diversity in membership promotes networking, innovation, and ultimately, the sustainability of the Center.

- Technology platform focus clearly identified, including evidence of market niches and market opportunities from this focus
- Leverage of other non-state resources and use of requested state funds to fill gaps (state funds to be used as the last, not the first, resort). Plans to move toward self-sufficiency need to be identified and long-term funding plans should be proposed, recognizing that some ongoing state financial support will be needed
- Proposed specialized facilities
- Technology commercialization objectives likely to result in benefits to Minnesota's economy

- Comprehensive and innovative design and program selection showing core program components including research and technology, talent/workforce, technology commercialization, and economic development
- Identification of authority, roles, and functions of the Board of Directors
- Management of intellectual property coming out of the Consortium's work.

Resources Required: It is anticipated that $3 to $5 million in funding from higher education would be required for each of the four anticipated Consortia of Innovation in its initial years of operation, which in turn would need to be matched by other sources of funds in a 2:1 ratio. The initial higher education resources could be found from aligning current assets or by seeking additional state funding. It is anticipated that once established, each Consortium could become self-sustaining over time from federal, industrial, and commercial grants and contracts.

Implementation: Four Consortia of Innovation, one for each of the agbioscience technology platforms identified, should be selected for designation and funding through a competitive, objective, and transparent process. Selected Consortia should be able to illustrate the following components in their proposed work plans: active partnerships and participation by Minnesota producers and related industry, inclusion of platform-related research assets from across Minnesota's various research institutions, meritorious scientific and technical research agendas, sound commercialization plans, evidence of avenues to foster and embed trandisciplinary practices, and a clearly articulated understanding of the economic impact that the Consortium will need to achieve in terms of advancing the technology platform in Minnesota. Subject matter experts should be compiled to judge the merit of each application from both a technical as well as market potential aspect. The review panel recommendations should then be presented to an oversight body that should be charged with final award decisions.

Finally, it should be noted that in many ways these Consortia of Innovation will undergo the same "growing pains" as a start-up company typically experiences. Therefore, it will be critical that the Board of Directors, driven by engaged agricultural producers and related-industry members, remain actively involved. In order to ensure that the core mission of the Consortium—to drive the growth of an industry cluster in Minnesota around a specific technology platform—is not forgotten or subverted as the Consortia evolve, it will be important to establish either a "stage-gate" process or milestone payments in terms of guiding the allocation of funding. The bottom line is that all of the stakeholders will need to be firmly committed to defining and then tracking agreed upon measures of success in order to ensure that management can guide the Consortium in the desired direction.

OPPORTUNITY THREE: BUILD UPON MINNESOTA'S EXISTING COMMERCIALIZATION FUNDS TO SUPPORT PROOF-OF-CONCEPT AND COMMERCIALIZATION ACTIVITIES IN ORDER TO ADVANCE TECHNOLOGIES RELATED TO THE AGBIOSCIENCE TECHNOLOGY PLATFORMS

It has become increasingly common for states to provide funding for activities needed to determine the commercial potential of a discovery and to advance the technology to the point at which a product can be launched into the market. Such commercialization funding seeks to support companies with a clearly defined potential path to market entry within two to three years.

Commercialization funds support prototype development, testing and validation, and marketing research. Such funding is typically needed in one of two scenarios. First, it is often needed to

commercialize university-owned IP at the highest value—and sometimes to license it at all—as such technology usually is at an early stage of development and requires additional studies or a working prototype before it can be shown to have commercial value. It also is sometimes necessary to surround the original discovery with additional patents and protections. These activities are almost never fundable through conventional peer-reviewed federal programs and, if they are to take place at all, must be separately funded under a different set of criteria focused mainly on economic development.

The second scenario is further downstream when a company is ready to move an innovative product/service into the market but needs to be able to prove commercial viability. Typical projects include:

- Commercial scale demonstrations in market use conditions;
- Manufacturing scale-up beyond pilot plant
- Final customer validation, product certification, and/or regulatory certification
- Acquisition of exclusive Intellectual Property rights
- Launch of next generation of products, services or processes
- Design engineering/packaging
- Market research and strategic business plan development.

Fortunately for Minnesota's agbioscience industries, Minnesota has been one of the states that has been engaged in funding agbioscience-related commercialization projects through two different efforts: AURI's Product Development Services program and the Minnesota Department of Agriculture's Bioenergy Grants.

AURI's Project Development Services (PDS) program assists in the identification and development of new processes or technologies for agricultural processing and commodity utilization, focusing primarily at the proof-of-concept product development stage. The PDS program operates on a 1:1 cost-share basis. To access cost-share assistance, an applicant must be actively working with an AURI project development team. AURI personnel, labs and pilot plants are available to assist Minnesota-based clients through scientific technical and project development assistance, including but not limited to technical feasibility; economic or market feasibility; product and process development; product evaluation and testing; and sourcing materials, equipment and services. Up to $100,000 is available per project; $200,000 lifetime maximum for a company. Typical awards range from $3,000 to $30,000.

The Minnesota Department of Agriculture's Bioenergy Grant Program provides grants that support the mission of the NextGen Energy

Georgia Research Alliance's VentureLab Program

GRA's VentureLab was created to move university technologies out of the lab and into the marketplace and to grow university-based start-up companies in Georgia. To accomplish these goals, GRA awards the following:

- Phase I grants (up to **$50,000**) to university researchers to answer the question, "Is it commercially feasible to build a company around this technology?"
- Phase II grants (up to **$100,000**) to university researchers to continue prototype development and formulate a company.
- Phase III loans (up to **$250,000**) to eligible VentureLab companies that have a fully executed license from the university. These companies must also have Georgia-based management. The noncollateralized loan has favorable repayment terms and conditions.

Since 2002, GRA has evaluated the commercial potential of more than 300 inventions or discoveries at universities. The most promising of these were awarded VentureLab grants to help fund the technology research necessary to further develop the invention or discovery. This process has led to the formation of more than 80 early-stage companies that employ more than 450 people and have attracted $300 million in private equity investment.

Board. The NextGen Energy Board's primary focus is examine the use of the state's resources to decrease its reliance on fossil fuels; to increase Minnesota's use of home grown energy sources; to work towards agricultural and natural resource sustainability; and to ensure rural economic vitality.

It is recommended that Minnesota leverage its investments to date and build upon these existing commercialization efforts. First, funding should be provided to increase AURI's ability to provide Product Development Service for proof-of-concept projects. It is anticipated that AURI will provide technical services for each project to assists in the identification and development of new processes or technologies within one of the four technology platforms. If the technical need is not an area of expertise for AURI staff, then AURI will provide proof-of-concept grants of up to $50,000 that can be used to support early-stage commercialization activities as long as the project lead can prove they either have the commercialization expertise or are working with another organization that has this expertise, such as the Consortia of Innovation. The grants would be awarded on a competitive basis by AURI. It is anticipated that the funding would be primarily focused on deal flow derived from both university researchers involved with one of the Consortia of Innovation and/or companies with a commercialization opportunity within one of the four identified technology platforms.

Secondly, a later-stage commercialization grant program should be developed, leveraging the Minnesota Department of Agriculture's Bioenergy Grant Program, which would provide matching grants of up to $250,000 with a 1:1 match requirement to support later-stage commercialization activities described within the second scenario above. Again, deal flow would be anticipated from both successful proof-of-concept projects emanating from AURI's PDS program, the Consortia of Innovation, as well as small and medium-sized firms that are seeking to expand into different markets based on the four technology platforms.

Resources Required: It is estimated that an initial pool of $5 million, which in part would be matched, would sufficiently capitalize both funding streams.

Implementation: Awards for both levels of funding should be made through a competitive, objective, and transparent process to make awards to projects based on proposals that reflect meritorious scientific and technical content, sound business and commercialization plans, and potential for positive impacts on the economic conditions of the agbioscience technology cluster in Minnesota. AURI would be tasked with administering the expanded PDS program utilizing its in-house subject matter experts to award projects as well as measure return on investment of the program. For the later-stage commercialization fund administered by the Minnesota Department of Agriculture, subject matter experts should be compiled to judge the merit of each application from both a technical as well as market potential aspect. The review panel recommendations should then be presented to an oversight body that should be charged with approving the allocation of grants in addition to measuring the return on investment of the grants made.

OPPORTUNITY FOUR: DESIGN AND SUSTAIN A ROBUST, AGBIOSCIENCE-SPECIFIC, ENTREPRENEURIAL ECOSYSTEM TO BUILD A STRONGER, INDIGENOUS INDUSTRY BASE IN MINNESOTA AROUND THE FOUR TECHNOLOGY PLATFORMS.

Key to Minnesota realizing the growth of an agbioscience industry cluster will be the entrepreneurs who can turn innovation into successful businesses. Innovation, in and of itself, will not necessarily translate into economic activity. Rather, it is the application of a technology and its introduction into the marketplace that results in economic growth. A number of studies point to the importance of entrepreneurship in changing regional economies. Starting with David Birch's work and validated by the Office of Advocacy of the U.S. Small Business Administration (SBA) and further refined by studies commissioned in recent years by the Kauffman Foundation and others, it is clear that technology, innovation, and entrepreneurship drive economic growth. "The large portion of entrepreneurial firms and the significant number of jobs created by newer, small firms in the U.S. are a strong indication that the entrepreneurial sector with its flexibility and capacity to adapt quickly is poised to become an even more important protagonist in the future economic growth of the country."[51]

Indeed, research demonstrates that entrepreneurial activity is closely tied to a state or region's level of economic growth. The Global Entrepreneurship Monitor (GEM), a leading research consortium that seeks to improve understanding of the link between entrepreneurship and national economic growth, suggests that levels of entrepreneurship may account for as much as one-third of the variation in economic growth among regions, states, and nations.[52]

However, catalyzing entrepreneurial activity is a challenge for many states. It is often stated that entrepreneurship is a "contact sport", and the barriers and obstacles to being able to scale a firm is significant, particularly technology firms. The three areas that entrepreneurs indicate are their greatest obstacles are talent, capital, and sales. Of these, the most significant obstacle to creating and growing entrepreneurial companies is the lack of experienced management talent. For many states, there simply is no cadre of experienced, serial entrepreneurs who know how to turn an idea or a product into a successful venture. Such serial entrepreneurs are needed not only to lead new ventures but also to serve as mentors to help fledgling entrepreneurs develop their skills and increase their chances of success. They have contacts in the investor community, can recognize quality deals, and help to generate deal flow that helps firms access capital markets.

The second challenge facing entrepreneurs is access to capital. Entrepreneurs require access to capital at each stage of their development, from early-stage, proof-of-concept and prototype development to Series A and B venture financing. States that have limited risk capital in which to invest end up leaving their entrepreneurial companies on the "runway" unable to take off and reach their growth potential.

The third challenge that entrepreneurs face is to find customers and markets. Entrepreneurship assistance programs usually focus primarily on providing financial, business planning, and incubator support to start-up companies to increase their chance of survival. And indeed, start-up companies face many obstacles. But, just because a start-up company remains in existence doesn't mean that success has been achieved. For many of these companies, the real challenges come when they are ready to grow. Once they have a management team and an organization in place, have obtained investment

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[51] Global Entrepreneurship Monitor: National Entrepreneurial Assessment USA 2003 Executive Report, p. 7. See www.kauffman.org/items/cfm/536, 11/11/04.

[52] Global Entrepreneurship Monitor 1999 Executive Report, p. 10.

capital, and are ready to move to the next level, fewer resources are available to assist these companies in finding customers, identifying new markets, and generally increasing sales—all factors that will determine the level of their contribution to the economic health of the communities in which they reside. In addition, firms have difficulty keeping up with the competition, being aware of new discoveries that may affect their markets, and supporting continued product development, obstacles which can be lessened through closer interactions with universities and their researchers.

Interviews with entrepreneurs, faculty inventors, CEOs of companies, economic developers and venture capitalists suggest that it can be difficult to access in Minnesota sophisticated, value-added entrepreneurial support services tailored to the unique agbioscience markets as well as risk capital across the financial continuum. Two approaches that states have taken to impact their entrepreneurial ecosystem and meet these needs are:

- Providing comprehensive in-depth support to entrepreneurs to enable them to obtain private capital
- Foster the creation of indigenous agbioscience pre-seed/seed fund.

The bottom line is that finding different and unique ways to support entrepreneurs and the growth of entrepreneurial agbioscience companies must be a critical component in Minnesota's efforts to build and sustain an agbioscience industry cluster. Through Minnesota's Business First Stop, the State of Minnesota has been working to streamline the development process for complex business startups that involve financing, licensing, permitting, and regulatory issues that overlap multiple state agencies by helping to coordinate all state agencies that have a role in the development process. While this effort is certainly a positive step in helping to foster the entrepreneurial culture in the state, more must be done to support the specific needs of agbioscience companies, particularly those within the four identified technology platforms. Specifically, two actions should be pursued:

Provide a comprehensive set of services for agbioscience entrepreneurs and start-up companies to better position them to obtain private investment capital.

Agbioscience entrepreneurial firms need many resources, including management talent, technology, capital, and professional expertise. They often need assistance in determining economic feasibility and identifying markets and distribution channels. They may also need access to specialized equipment and laboratories and to expertise to solve technical issues that arise during product development. They must be able to recruit key personnel and have access to small amounts of pre-seed capital.

Minnesota should consider developing an agbioscience entrepreneurial center that could link a variety of different organizations, including Minnesota's Business First Stop and AURI's Applied Technology Programs, and Colleges of Business and associated programs across the University of Minnesota, MnSCU System, and Community College System, to provide the following services:

- Provide organizational documentation, preliminary technology and market assessments, and start-up strategic planning
- Provide management and in-depth business planning support to technology entrepreneurs and start-up companies
- Link companies to mentors
- Conduct due diligence
- Provide consultation and ongoing entrepreneurial education

- Prepare companies to seek venture financing
- Link companies to sources of capital
- Support development of angel networks.

The following narrative provides additional details as to the types of services an agbioscience-specific entrepreneurial center would provide.

Business Development and Commercialization Support. Leveraging the existing support services currently provided by AURI and Minnesota's Business First Stop, an agbioscience entrepreneurial center could ensure that comprehensive, in-depth business development and commercialization support services are readily available and easily accessible to entrepreneurs and start-up agbioscience companies. Start-up and emerging technology companies need access to professional expertise, assistance in conducting market research and developing marketing strategies, and help in determining economic feasibility. They also need to access to quality facilities with specialized equipment and laboratories, the ability to recruit key personnel, a support infrastructure familiar with technology businesses, and access to small amounts of pre-seed capital.

States and regions have been focusing significant efforts over the last decade on ways to help entrepreneurs and companies to commercialize new technologies. These programs help entrepreneurs and companies in transforming ideas or innovations into products ready for manufacture, marketing and distribution. Several states including Ohio, Pennsylvania, Georgia, and Oklahoma have created dedicated centers that offer a full range of commercialization support services.

Entrepreneurial assistance can help increase deal flow, make entrepreneurs more investment-grade deal ready, and increase the level of private investments in agbioscience firms. It is proposed that the agbioscience entrepreneurial center serve as a single point of entry for agbioscience start-up companies that can assess their needs, guide them through the commercialization process, and link them to a comprehensive network of commercialization assistance services. Services of the agbioscience entrepreneurial center should include conducting technology and market assessments and providing specialized SBIR assistance, business mentoring, and matchmaking support. In return for providing business development assistance, the bioscience entrepreneurial center could share in the royalty/equity stream should a client successfully develop its company. It is also envisioned that the one-stop agbioscience entrepreneurial center would work closely with each Consortia of Innovation described earlier.

Business Mentoring and Managerial Support. The agbioscience entrepreneurial center could also play a role in addressing companies' needs for business mentoring and managerial support. Time and again, interviewees from emerging agbioscience companies noted that Minnesota lacks seasoned entrepreneurs experienced in the agbioscience field. The lack of such talent in the state may result in firms moving elsewhere in search of managerial talent.

One innovative solution to the lack of experienced managers would be for the agbioscience entrepreneurial center to develop a team of seasoned agbioscience professionals to serve as a talent pool for start-ups in Minnesota (entrepreneurs-in-residence). Whether recruited from inside or outside of Minnesota, this team of experienced agbioscience executives would accept the position with the understanding that within 12 to 18 months they would likely be placed in the role of senior leadership in one of Minnesota's start-up, agbioscience firms. Until this occurred, the individual would serve as a

mentor to an existing firm and assist in the implementation of the agbioscience entrepreneurial center initiatives.

Resources Required: It is estimated that $750,000 to $1 million annually will be required to cover the operations of the Agbioscience Entrepreneurial Center, which will include providing in-depth commercialization assistance to entrepreneurs and start-up bioscience companies and administering the Agbioscience Pre-Seed/Seed Fund. Approximately $1–$1.6 million per year would be needed to recruit agbioscience experts to Minnesota.

Implementation: It is proposed that either an agbioscience specific entrepreneurial development center be created that leverages the services of both AURI and Minnesota's Business First Stop, as well as SBDCs and other more general entrepreneurial efforts that can be found around the state, or the activities described above be included in the service offerings of one of these organizations . If this function is added to one of the existing organizations, it would be anticipated that with the additional funding the organization would bring into their staff mix agbioscience entrepreneurial development experts as well as develop an agbioscience-specific Entrepreneurs-in Residence program. The key to the success of the agbioscience-specific entrepreneurial efforts will be to have highly-qualified technical and agbioscience business experts to provide mentoring and guidance to Minnesota's agbioscience start-up companies to help them grow and scale their activities in the state throughout every phase of the development process.

Foster the creation of indigenous agbioscience pre-seed/seed fund.

An agbioscience pre-seed/seed fund would provide post-angel but pre-venture financing desperately needed by agbioscience entrepreneurs. This stage of funding, which usually requires $250,000 to $2 million in individual investments, constitutes a critical private sector market gap for investment dollars as this size investment is usually too small for larger venture funds to consider. If Minnesota can address this market gap, which is not unique to the state, Minnesota will be better positioned to build a critical mass of agbioscience firms.

Having a locally managed, indigenous pre-seed/seed fund dedicated to the agbiosciences is absolutely essential for building the "farm club" of firms, which as they gain experience and need additional funds to expand become candidates for "major league" funding from larger more diversified venture funds both in the region and from outside the region. The presence of a strong local agbioscience investment fund is needed to attract outside regional and national funds to invest in Minnesota.

Recognizing that building a critical mass of technology firms is unlikely without pre-seed and seed stage financing, many states and regions have developed programs to increase the availability of early-stage capital. States and regions have taken a variety of approaches from capitalizing funds that make direct investments in companies, investing in privately managed venture funds, investing pension funds in venture capital, and using tax incentives to encourage investment in venture capital. In some cases, universities and foundations are investing a portion of their endowments in seed and pre-seed funding for technology companies. A number of states have used state dollars to create such investment funds.

The Oklahoma Seed Capital Fund (OSCF), for example, is a state-appropriated investment fund that makes concept, seed and start-up equity investments in Oklahoma businesses. The fund makes concept investments, typically in the range of $50,000 to $200,000 and seed investments, typically less than $500,000. Co-investors are required for both types of financing. The funds can be used to develop intellectual property, complete market assessments, implement business operations, and recruit key members of the management team. The OSCF is administered by i2E, Oklahoma's statewide technology

commercialization organization. In addition to making investments, i2E provides comprehensive in-depth support to entrepreneurs, including helping them to become investment grade.

The State of Ohio, through the Ohio Third Frontier, has also made significant investments to build its indigenous risk capital base through the Ohio Third Frontier Pre-Seed Fund Capitalization Program (PCFP). As a result of its program, the Ohio Third Frontier has helped establish Ohio as a leading location for early-stage risk capital investment through the capitalization of multiple Ohio-based Pre-Seed Funds. The goals of the Ohio Third Frontier PCFP are to:

- Increase the number of professionally managed Pre-Seed Funds investing throughout Ohio
- Increase the amount of early-stage capital being invested in Ohio technology-based companies
- Create a risk capital climate that supports the development, retention, and attraction of investable technology companies in Ohio
- Build a pipeline of technology company deal flow that increasingly attracts the resources of venture capital firms both within and outside of Ohio.

Through 2012, the Ohio Third Frontier has invested approximately $42 million in over 20 pre-seed and seed funds across the State of Ohio. These funds, in return, have leveraged over $2.3 billion in follow-on funding in nearly 350 companies that have created nearly 4,000 jobs.

It is envisioned that the proposed Minnesota Agbioscience Pre-Seed/Seed Fund would make investments in the form of equity positions ranging from $250,000–$2 million in agbioscience companies, focused on companies actively engaged in one of the four technology platform areas. It is proposed that the Minnesota Agbioscience Pre-Seed/Seed Fund be capitalized with a $5 million appropriation from the legislature over a two-year period. The fund would be required to match these dollars with other sources on at least a 3:1 basis**.** Additional investors could include university endowments, the private sector, entities such as the Minnesota Agri-Growth Council, and the philanthropic community.

Resources Required: State funding of $2.5 million over the next two fiscal years, for a total of $5 million, to be matched by $15 million in foundation, university, private industry and other private sources.

Implementation: The Minnesota Department of Agriculture should be tasked with developing a competitive RFP to seek proposals from experienced investment teams with technical expertise in the agbiosciences interested in developing an indigenous pre-seed fund in Minnesota. An award(s) should be made through a competitive, objective, and transparent process to ensure that fund management teams were chosen based on their investment and business acumen as well as their scientific and technical knowledge of the agbioscience field. Agbioscience subject matter experts as well as business investment/finance experts should be compiled to judge the merit of each application based on its investment strategy as well as source of deal flow. The review panel recommendations should then be presented to an oversight body that should be charged with approving the allocation of all Minnesota Agbioscience Pre-Seed/Seed Funds in addition to measuring the return on investment of the investments made.

D. Specific Development Issues and Opportunities for each Agbioscience Technology Platform

Turning to the specific agbioscience technology platforms identified for Minnesota, while all share common needs that fall within the context of the opportunities previously outlined, each stands out with its own unique issues and opportunities.

Microbial Agbioscience Technology Platform

Specific Challenges for Advancing This Technology Platform:

The challenges within the microbial agbioscience technology platform primarily relate to coordination of activity and achieving focus. Particularly within the University of Minnesota, there are a very broad range of research assets and programs upon which to draw. Work at the University of Minnesota crosses a complete spectrum from basic science inquiries in fundamental microbiology of individual microbes and complex microbial communities, through to applied scientific inquiry relating to:

- Phytopathology
- Plant/microbe interactions (both beneficial and destructive)
- Animal and livestock diseases (with a strong focus on translational research and infectious livestock diseases)
- Human pathogens and infectious diseases
- Pathogens, food safety and biosecurity.

A key challenge identified through interviews and key stakeholder discussions relates to developing an understanding of the complete suite of microbial sciences assets within the University and beyond and determining which could be linked or coordinated to provide a unique, signature collaborative in Minnesota focused on microbial agbioscience. The opportunity for economic development is significant, with the potential for innovation and applied technology development in:

- Diagnostics tools and technologies
- Surveillance and monitoring technologies and systems
- Livestock vaccines and medical treatments
- Improved plant species with disease resistance
- Novel biocontrol technologies using microbes and microbial communities
- Soil inoculants to enhance positive soil microbiological-ecosystem characteristics
- Seed coats with probiotic microbiota
- Microbial communities with the ability to conduct preprocessing functions beneficial to downstream bioprocessing for chemicals, fuels or other industrial applications.

There are certain facilities challenges that may also need to be addressed. While veterinary medicine at the University of Minnesota has a good track record in infectious disease work, its isolation facilities are antiquated and further investment is warranted there to build capacity and increase ability to be competitive for research grant funding. In addition, veterinary medicine at the University of Minnesota has identified a need for approximately $100 million in funding to bring online a new research building

with a focus on infectious diseases and associated microbiology and translational research. Having high quality isolation and containment facilities for infectious diseases research is a prerequisite for research that hopes to advance to the field-based research stage.

Development Actions to Pursue:

Key leaders within Minnesota in microbial sciences need to be brought together to discuss capabilities, assets, and resources, and to find common themes of interest around which transdisciplinary teams could be formed. Few institutions globally would have the combination of basic science, plant science, animal and veterinary science, and human biomedical sciences that exist at the University of Minnesota.

Some concepts for consideration based on Battelle's review of assets, capabilities and opportunities include:

- Development of facilities to build upon demonstrated strengths, and track record of innovation, in veterinary medicine and infectious diseases. Facilities could be developed that would serve as a resource for the study of pathogens not only for livestock/veterinary diseases, but for plants and other organisms also. The new AgriBio facility in Melbourne Australia, for example, represents such a facility established to facilitate world-class research in both animal and plant pathogens.
- Developing an institutional focus on plant viruses, seeking to elucidate a better understanding of mutualistic relationships between viruses and their host plants. Viruses may be identified that provide beneficial defense against other plant pathogens, or which positively influence the performance of a plant in terms of its functional characteristics or adaptability to stressors. Introducing viruses to a plant that has probiotic functions may be less challenging than the approach of enhancing soil microbial communities (where the shear diversity of bacteria/microbes present make it highly challenging to predict survivability of probiotic microbia).
- Building on existing excellence in plant rust diseases and in virology and mycology.
- Building upon the established reputation and resources of Minnesota in food safety research. This is seen as a high priority by industry representatives in the state and is a match to strong expertise in this arena at the University of Minnesota. Interests expressed by both the production agriculture commodity groups and food processing companies (e.g. General Mills, Hormel, Schwan Foods, etc.)
- Development of optimized growing media for agronomic environments in which microbial characteristics can be controlled – e.g. confined environment agriculture and hydroponics.
- Developing an institutional focus on rapid pathogen detection technology development, with such a platform able to work on pathogens impacting not only plant and livestock agricultural production, but also food safety and human health. Potentially focus in food safety to begin with, which was identified by Minnesota commodity group members as a high need area.
- Potential to tie together and coordinate cross-functional activities between the broad capabilities across the University of Minnesota in microbiology and genomics, food safety and biosecurity, and engineering work in sensors, nanosystems and biosystems engineering. To date, there has not been much in the way of formally integrating this work into transdisciplinary teams. It is likely that there is a need for more formal university structures, with access to funding, to encourage cross-department collaborations. The University is encouraging focused

transdisciplinary initiatives under the MN Drive concept, but an expansion of MN Drive may be required to provide the kinds of resources needed to really power transdisciplinary growth.

Resilient, Efficient, and Productive Agricultural Systems Technology Platform

Specific Challenges for Advancing this Technology Platform:

The University of Minnesota has undoubted expertise in environmental ecology, environmental science, and sustainable agricultural systems. There should be little doubt that great global import accrues to the development of high yield, high quality agricultural production systems that are economically and environmentally sustainable for the long-term (in terms of factors such as soil conservation, impacts on water availability and water quality, impacts on air quality, etc.). Unfortunately, agricultural practitioners and environmental scientists are too often viewed as in conflict with one another. Overcoming a challenge of mutual distrust needs to be achieved in order for producers, environmental scientists, and sustainability experts to work together to optimize productivity in resilient agricultural systems. The advantages of sustainable agricultural practices should be rather obvious to producers in terms of maintaining the productivity of their most valuable assets, their land, over the long-haul and for generations to come. However, the reality is that imperfect knowledge of available sustainable practices, combined with economic pressures to sustain high yields, means that many producers are operating outside the bounds of long-term sustainability.

In addition to the perceived and real communications challenges between resiliency experts and agricultural producers there is an economic development challenge in terms of realizing commercial opportunities from sustainability oriented solutions. Many solutions are routed in practices rather than specific technologies, and thus not well suited to creating technology-based enterprises (although they may be suited to the foundation of service businesses and environmental engineering solution providers).

Another challenge is grounded in the fact that those most in need of being introduced to sustainable agronomic practices and solutions are located in the developing world, and lack the resources to gain specialist consulting help or the networks to find solutions for themselves. This reality means that the funders of agricultural resiliency for overseas market applications will not be the producers themselves, but more likely governments, NGOs, and foundations focused on sustaining food security and preserving the environment and productive ecosystems.

Development Actions to Pursue:

There is a need to find funding that will support work oriented towards economic, cost-effective technologies for overseas application. Especially technologies for: micro fertilization, enhanced access to drought tolerant crops, economic pest control, and soil conservation. There would also be a market for cost effective technologies for monitoring NPK in fields and to assist in the efficient application of scarce and expensive chemicals.

Enhanced remote sensing capabilities by government or NGOs with feedback provided down to the local farmer level could also be a focus for development efforts – using smart phone and cellular communication networks for provision of data to farmers. Work in this promising area will require an infrastructure for technology development, technology screening, cost reduction, distribution and market testing/extension. There is an opportunity to coordinate University of Minnesota and other in-state resources across engineering, sensors, agronomy, environmental sciences, etc. to develop a

platform for resilient and cost-effective agricultural system technologies. The opportunity is for Minnesota to become recognized as the place for the funding and commercialization of low-cost, tech-based solutions for agricultural resiliency.

There is also a need for an international extension framework for the most "in need" countries – especially those with growing populations that are forcing marginal lands into production and depleting soils to the point of desertification (e.g. Sahel countries). Leveraging University of Minnesota extension and distance learning capabilities, portable communications technologies, and e-learning, together with cultural anthropology and linguistics capabilities would generate the kinds of interactions required to stimulate novel technology and practice diffusion modalities. Several major global grand challenges could be addressed by Minnesota building an international-extension to serve those regions most in need. Funding for this type of activity would need to come via international development organizations (e.g. the World Bank, OECD, WHO, UN-FAO), via major philanthropies (e.g. Gates Foundation) and government international aid agencies (e.g. US-AID).

For advanced technology development and applications for domestic and developed world agriculture, there are strong resources in Minnesota for being able to develop, study and monitor alternative agronomic practices and their effects on nutrient flows, water quality, positive engendering of ecosystem services, etc. Both the University of Minnesota and USDA/ARS have expertise in these areas for example. Examples of working programs in Minnesota are many, and as diverse as the development of alternative cropping systems going beyond the dominant soy/corn system, development of perennial-based cropping systems, and integrated biomass conversion technologies yielding bio char as a soil amendment and bioremediation filtration media. Other areas of focus suited to Minnesota work revolves around precision agriculture technologies, remote sensing, and the ability to micro-manage the application of agricultural chemicals.

There is also potential in Minnesota to integrate work taking place in alternative cropping systems for ecosystem management, expertise in the impacts of no-till agriculture and other newer agronomic techniques on plant/soil pathogen communities, and impacts on development or biomass-based industrial systems. Utilizing resources across biology, agronomy, soil science, engineering, plant pathology, etc., Minnesota is well-positioned to develop and evaluate novel agronomic systems and integrated value-chain solutions.

Biobased Industrial Products Technology Platform

Specific Challenges for Advancing This Technology Platform:

A key challenge of the biobased industrial products technology platform is finding funding to support the development of piloting and scale up facilities for demonstration of bioprocessing technologies. Iowa has had some success in developing good bioprocessing scale-up and piloting facilities and there may be potential for cross-border collaborations in this regard. This would help Minnesota to gain access to specialized resources in an affordable fashion, and Iowa to gain some business volume to help with the upkeep of their facilities. Minnesota does have some significant assets in this regard (such as fermentation facilities within the Biotechnology Institute), but extra-regional collaborations may make economic sense to advance the biobased industrial products platform.

When it comes to next generation lingo-cellulosic biomass-based biofuels and biobased chemicals there are challenges in Minnesota beyond the basic technological challenges faced by all. A primary issue relates to the fact that a large proportion of Minnesota's forest biomass is controlled by relatively small

woodland plot owners, and thus there may need to be an intermediary structure formed to facilitate reliable contracting and supply for biomass across a very large supply network.

While environmental preservation is a laudable goal, there is a balance to be struck between the economic use of valuable natural resources and their protection. Industry representatives and academic experts interviewed in Minnesota noted that there are large-scale resources (especially forest resources) in Minnesota that can see significantly increased utilization without harm to their resiliency and long-term sustainability. At the present time, however, there is disagreement amongst thought leaders regarding how to appropriately develop this industry sector and utilize the natural resources of the state. The bottom line is that a balanced approach is required in terms of state regulation and freedom for industry to operate to build economic development in Minnesota around underutilized biomass assets.

Development Actions to Pursue:

The biobased industrial products technology platform presents a broad variety of opportunities for Minnesota. Certainly, in terms of the development of biotechnology-based bioprocessing, the University of Minnesota Biotechnology Institute sustains a robust infrastructure and faculty/technicians with significant capabilities to work on solutions for the industry.

Several relatively novel areas of research identified in Minnesota lend themselves to further technology development from this platform, including (but not limited to):

- An overlap with the Microbial Agbioscience Platform and the University of Minnesota Biotechnology Institute and other resources in the development of expertise and applications for ”synthetic ecology” whereby two or more organisms are deployed in a forced synergism to perform biotechnology functions that one alone could not achieve. Such an approach to novel bioprocess organism community development would also benefit from the University of Minnesota’s capabilities in high throughput sequencing and bioinformatics.
- An emphasis on diesel fuels and related advanced fuel products produced from renewable biomass resources, leveraging the Center for Diesel Research.
- Sustainable polymer development and development of degradable biobased polymers for high value biomedical applications and for applications in advanced seed-coats, leveraging the Center for Sustainable Polymers.
- The pursuit of federal funding for establishing a renewable energy and biobased chemicals for northern climates research institute. Minnesota has built considerable expertise and faculty-to-faculty networks grounded in the Xcel Energy funding – but since this funding is now sunsetting, a means to sustain the strengths built around it needs to be found and the USDA and DOE should be evaluated as potential funders for a North Climates center.
- As noted previously, this platform requires significant piloting and scale-up facilities to go beyond proof of concept and to demonstrate that processes can work at a commercial scale. While Minnesota contains some of the required infrastructure, complementary infrastructure exists in other states, such as Iowa, and it behooves Minnesota to find ways to leverage the sunk cost of infrastructure of other states, rather than duplicate investments. Another excellent location to approach for piloting and scale up applications would be the Mid-Atlantic Technology, Research and Innovation Center (MATRIC) and the West Virginia Regional Technology Park located at the former R&D facilities of Union Carbide in Charleston, West

Virginia—a facility now set-up to accommodate contract pilot and scale-up work with industry and academe and staffed by experienced experimental chemists and production chemical engineers.

- Examination of opportunities to leverage underutilized forest resources in Northern Minnesota and to develop and/or identify suitable technologies to increasing value-added via bioprocessing of lingo-cellulosic biomass in that region of the state. The University of Minnesota Department of Bioproducts and Biosystems Engineering will be a particularly important resource for working on such applications, as will be the Center for Biorefining, which is doing important and promising work in fast pyrolysis technologies (using microwave technology) for the production of bio-oil and associated coproducts. With one of the top chemical engineering programs in the nation, the University of Minnesota has a deep base of expertise upon which to draw in this regard.
- AURI is viewed as being particularly active in the biomass utilization space and a good resource for working with the universities and industry in demonstrating technology market readiness and working towards commercialization of technologies in Minnesota.

Value-added Food and Nutritional Products Technology Platform

Specific Challenges for Advancing this Technology Platform:

Many of Minnesota's opportunities related to the value-added food and nutritional products technology platform revolve around the synergies found in the state between food science, nutrition, clinical testing of functional nutrient benefit, and the food processing industry. However, finding funding for value - added "food for health" research and commercialization activities is a challenge. While there is opportunity in Minnesota to bring together substantial human capital skills from the food industry, and academe in food science, nutrition, human medicine and animal nutrition, this is not a space that attracts the large-scale biomedical oriented, NIH-type funding volumes.

There is a need for specialized resources and funding for the pursuit of clinical research to prove efficacy of phyto-chemicals and other ag-derived functional nutrients (for both human and livestock nutrition applications). This requires time and dollars and a means to protect resulting intellectual property. An additional challenge in this space is that the long-term trials work needed to prove efficacy is expensive to perform, and yet the resulting functional nutrition and food/feed ingredient products that may result are unable to command the type of market price premium that human drugs command.

Another challenge is that the development of commercial operations from the research in this platform relates to gaining access to markets for new food products. Success in this market is difficult to achieve without gaining access to established distribution networks and securing retail shelf-space.

Development Actions to Pursue:

An area of promise is "foods for health." In this field, basic research can be applied to identify phytochemicals and plant constituents with pro-health characteristics and clinical research assets that may be deployed to validate functionality and health effects. The identification and enhanced expression of such chemicals in foods can lead to the production of high value "functional foods" or "nutraceutical" products and extracts that have value beyond commodity agricultural products. It can also result in the development of enhanced texture and flavors for low-calorie foods that the marketplace demands. Industry is interested because of the opportunity to produce high value

products, while academic research is valued because of its ability to identify food-to-health linkages and to validate these linkages through the academic clinical research infrastructure. Some development opportunities identified for Minnesota along this pathway include:

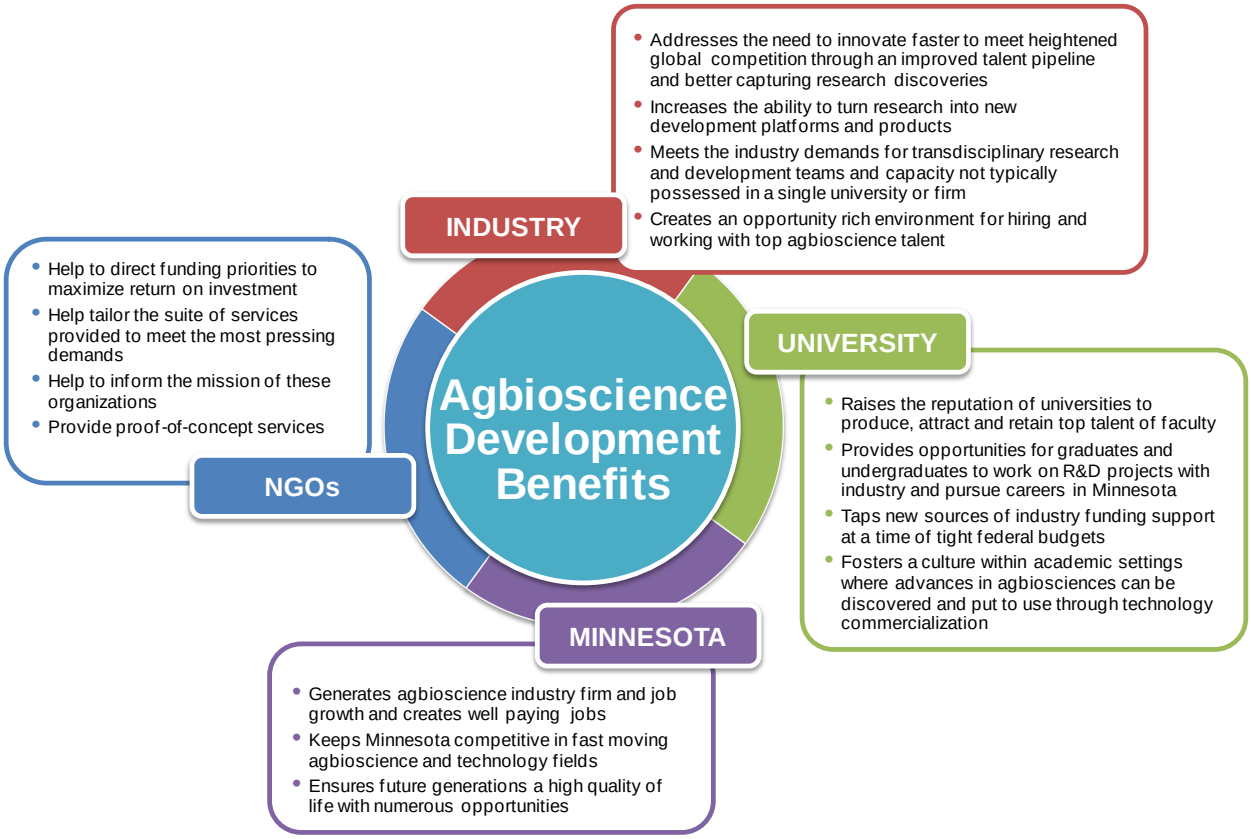
- Leveraging the significant number of major multi-national food companies in Minnesota to develop an advisory board and network designed to facilitate novel food and food ingredient product evaluation, testing, and (most importantly) facilitate new products gaining distributors and access to retail markets.
- Building upon the flavoring and sensory expertise in food science at the University of Minnesota to enhance relationships in product development with major food processing industries.
- Continuing AURI's ongoing work to assist small- and medium-sized food processors and entrepreneurs in the development and production of value-added branded food products. Pilot plant food industry facilities within the University of Minnesota can be leveraged to further systematic development of processed foods, and the aforementioned food industry advisory board may be leveraged to help advance products to successful market testing and launch.

V. Conclusion

To advance the agbioscience sector in Minnesota, it is critical to further public-private partnerships that align industry and university research core competencies with technology commercialization and new product development efforts within both large and small firms. In this way, Minnesota agbioscience firms will be better able to take advantage of growing and emerging global market opportunities. The pace of such industry-university partnerships is rapidly accelerating as agbioscience companies look to share with outside partners even more of the R&D burden (and risk) in the face of global competition and industrial challenges. For industry, this development has resulted in more open innovation approaches that tap the ideas and capabilities of others rather than solely relying on internal research programs for innovation and new product development.

The Agbioscience Development Strategy laid out in this report provides the rationale for the development of four technology platforms that are critical for the future growth of Minnesota's agbioscience industry. The benefits of the agbioscience development strategy to industry, universities, non-governmental organizations (NGOs), state government and other key stakeholders are summarized in Figure 19 below.

Figure 19: Benefits of the Agbioscience Development Strategy to Industry, Universities, NGOs, and the State of Minnesota



By aligning with and implementing this strategy, Minnesota, based on its globally competitive and unique assets, has the opportunity to incentivize agbioscience development across the state. It is important to note, however, that Minnesota's is not alone. Numerous competitors across the nation and around the world see similar opportunities and are investing significant resources to realize economic gains. Implementing this strategy is an effort that Minnesota must engage in if it wishes to maintain and further develop its global strengths in the agbiosciences and realize subsequent economic impacts.

Appendix A: Minnesota Agbioscience Core Competencies

The core competencies identified each contain specific niches of expertise, capabilities and infrastructural assets. Tables A-1 through A-11 highlight the key identified competencies.

Table A-1: Animal Infectious Diseases and Microbiology

Description	Infectious diseases are acquired diseases caused by infectious agents including viruses, bacteria, myco-bacteria, prions and parasites. Microbiology is the study of microscopic organisms and includes the sub-disciplines of virology, bacteriology, mycology and parasitology. Infectious disease microbiology studies infectious microorganisms and associated pathology. Also of direct relevance is immunology, which studies the immune system, including the role of immune system response to pathogens. Within agbiosciences, applied animal infectious disease research largely focuses on animals of economic significance (e.g., livestock and poultry) and methods for protecting livestock from disease causing pathogens and parasites. Approaches to livestock protection are varied, ranging through: disease surveillance; infectious disease diagnostics; prevention of disease via vaccines or vector control; and the development of animal health products such as veterinary biopharmaceuticals. More broadly, it can also incorporate approaches to generally improve the health of livestock thereby strengthening immune systems, and the design of animal production environments to reduce animal stresses and disease-propagating conditions. Livestock protection can also link to animal improvement, with potential approaches focused on the breeding of livestock for innate disease resistance characteristics.
Key Assets and Capabilities	This is a highly diverse "core competency", particularly within the University of Minnesota. It should be noted that while microbial sciences are not centrally coordinated across the U of M they represent clusters of very significant expertise contained in various colleges and departments (in agriculture, biological sciences, veterinary medicine and human medicine). Microbiology and infectious disease/pathogen expertise across the U of M is both broad and deep. Areas of strength observed by Battelle in the data and identified by interviewees as strengths include: • Microbial genomics • Virology • Immunology and vaccines • Fungal pathogens (although primary emphasis here is on plant pathogens) • Applied animal infectious disease work in pigs, cattle and avian species • Biotechnology (enhancing the understanding of microbes through their use in fermentation and industrial biotech processes. • Biosecurity as it relates to pathogens deliberately introduced to disrupt the U.S. food supply. Microbiology and associated disciplines including virology, bacteriology, mycology and parasitology provide a pathway to work across wide-ranging basic and applied agbioscience fields. The most abundant organisms on Earth, microbes have evolved to survive in every terrestrial and marine environment and their ecosystem impacts in terms of environmental services, symbiotic relationships with plants and livestock, nutrient cycling, and pathogenicity have extremely far reaching impacts on agriculture and agbioscience. Within Minnesota there are multiple existing centers and institutes focused on particular aspects of microbiology. While these assets differ in their microbial focus, it is clear that there is a broad base of microbiology expertise present in the state. Some of the key centers at the University of Minnesota include: • **Center for Animal Health and Food Safety** – A multidisciplinary center "creating and facilitating strong working relationships among food systems professionals and organizations, governmental entities, and academia." The Center "seeks to anticipate emerging food safety issues and promote effective, evidence-based solutions."[53]

[53] http://www.cahfs.umn.edu/About_Us/home.html

	• **Swine Disease Eradication Center** – Engaged in "research, teaching (professional and graduate), continuing education and certification related to many areas of swine health and production, with particular emphasis on disease control and eradication, and animal welfare."[54] • **Institute for Molecular Virology** –A multidisciplinary institute uniting "virus researchers from across the University of Minnesota in a strategic manner"[55] includes virologists studying basic virology and applications in human, animal and plant health. • **Center for Immunology** – Is a multidisciplinary center especially focused in basic immunological research across the U of M. "The Center for Immunology was established in 1995 as a University-wide multidisciplinary center to coordinate and promote efforts in basic immunology research, education and clinical applications at the University of Minnesota."[56] • **Veterinary Diagnostics Laboratory** – This lab provides rapid diagnosis of animal diseases, works to identify emerging diseases, and develops new diagnostic methods. In addition to the above centers and institutes there is complementary expertise in human diseases within **Center for Infectious Diseases and Microbiology Translational Research** and the **Center for Infectious Diseases Research and Policy**. The University of Minnesota's **Biotechnology Resource Center** has significant capacity for working with industrial microbes, and provides capabilities to grow a wide range of microorganisms from shake-flask to 240L fermenter scale and to recover the cells and/or metabolites. A particular area of expertise is the expression and purification of recombinant proteins.
Supporting Data	**OmniViz √√√** 845 records, 6 OmniViz clusters 276 in "infectious diseases", "260 in porcine infectious diseases", 146 in "virology, vaccines and influenzas", 66 in "bovine infectious diseases", 65 in "e-coli infectious disease and pathogenicity" and 32 in "infectious disease assays." **USI Publications and Citations Indices √√√** Immunology 777 (1.1), Veterinary Medicine 514 (1.16), Infectious Diseases 291 (1.45), Microbiology 453 (1.16), Virology 180 (0.97)
Potential Development Opportunities	• Enhanced productivity for domestic and international agriculture. • Molecular diagnostics • Vaccines • Anti-infective drugs and biologics • Reduced human health impact of livestock related zoonotic diseases • Healthier food animals with enhanced economic results (faster growth, leaner meat, etc.) • Reduced disease losses among livestock and poultry flocks • Commercial biomarkers • Commercial diagnostic tests and kits • Vaccines • Disease treatments

[54] http://www.cvm.umn.edu/sdec/
[55] http://www.virology.umn.edu/
[56] http://www.immunology.umn.edu/

Table A-2: Environmental Science and Ecology

Description	Environmental science focuses on "the application of biological, chemical, and physical principles to the study of the physical environment and the solution of environmental problems, including subjects such as abating or controlling environmental pollution and degradation; the interaction between human society and the natural environment; and natural resources management."[57] Ecology is the scientific study of the relationships that living organisms have with each other and with their natural environment. Overlapping with environmental science, applications of ecology are diverse, and include areas such as conservation biology, wetland management, natural resource management (agroecology, agriculture, forestry, agroforestry, fisheries) and urban ecology. In terms of applied environmental science and ecology, these disciplines can provide strategies and technologies for the prevention of negative externalities and for the remediation of environmental/ecosystem damage. Technologies, for example, may include sensing and diagnostic technologies, remediation technologies (including bioremediation), technologies for carbon or other atmospheric pollution capture or sequestration, water purification technologies, etc. There is also increasing attention being paid to the concept of "ecosystem services" and the value to humankind provided by natural processes and ecosystems.
Key Assets and Capabilities	The University of Minnesota is well regarded for its scientific focus on environmental science, environmental studies and ecological sciences. The breadth and depth of faculty in these disciplines has resulted in the formation of several key centers and institutes: • **Institute on the Environment** – While addressing environmental and ecological challenges and sustainability from broad perspectives, the Institute on the Environment has a dedicated focus area in tackling land use and food security issues from local to global scale, incorporating the balancing agricultural production and environmental protection. The Institute is also advancing new approaches to assessing the value of ecosystem goods and services. • **Center for Integrated Natural Resources and Agricultural Management** – focuses on integrated land use systems and integrates U of M and external organizations considering agroforestry land use and sustainability. • **Center for Changing Landscapes** – A collaboration between the U of M College of Design and CFANS focused on landscape planning and natural resource management. • **Center for Environment and Natural Resource Policy** – Conduct interdisciplinary studies on the issues associated with natural resource management. Key focus areas include: biomass and biofuels; natural resource governance; private forest land management; forest land values and forest practices. • **Water Resources Center** – One of the USA's 54 water resource research institutes, focuses on freshwater water resources. Agricultural impacts on water quality is one of the Center's research focus areas. • **Minnesota Institute for Sustainable Agriculture** – a collaborative initiative bringing U of M faculty and extension professionals together with external members to focus on sustainable agricultural practices. • **Large Lakes Observatory** – Located at the U of M Duluth, the Large Lakes Observatory studies major lakes worldwide in terms of aquatic chemistry, circulation dynamics, geochemistry, acoustic remote sensing, plankton dynamics, sedimentology and paleoclimatology. • **Limnological Research Center** – studies lake sediments an heir paleorecord of environment and climate change. Bemidji State University also has focused a significant portion of its teaching and research resources on environmental science, environmental studies and ecological sciences. Two major programs are: • **Center for Environmental, Earth and Space Studies** - Applied environmental research in the Center focuses on both generic and regional problems related to pollution impacts and abatement, and natural resource utilization and protection. Special features of the Center include:

[57] National Center for Education Statistics. *Classification of Instructional Programs*. United States Department of Education, Institute of Education Sciences, 2000.

	laboratories and equipment devoted to ecological, chemical, microbiological, and toxicological studies. • **Aquatic Biology Program** – Located at the H.T. Peters Aquatics Laboratory on Lake Bemidji, the program focuses on lake, riverine and wetland ecology issues related to water chemistry, carbon dynamics, invertebrates, plankton, aquatic plants, and fish. Bemidji State University is also in the planning stage in the creation of a Northern Minnesota Water Institute, which will incorporate a Water Testing Laboratory. **Winona State University's** Large River Studies Center conducts research on large river ecosystems and associated bodies of water. It is also responsible for disseminating information about the upper Mississippi River and other large river ecosystems to local, regional and scientific communities.
Supporting Data	**OmniViz √√√** 593 records, 6 OmniViz clusters. 217 in "water and agricultural uses thereof", 180 in "forest soils and ecosystems", 118 in "forest ecology", 46 in "environmental and climate impacts of livestock emissions, 16 "lake sedimentation and ecology" and 16 "plant invasive species an ecosystems". **USI Publications and Citations Indices√√√** Ecology 561 (1.51)[58], Biodiversity Conservation 100 (1.45, Environmental Studies 120 (1.39), Environmental Science 679 (1.15), Marine and Freshwater Biology 150 (1.06), Limnology 125 (1.0) and Water Resources 158 (0.91)
Potential Development Opportunities	• Bioremediation • Sensors, monitoring technologies and diagnostics • Economically valued ecological services

[58] First number listed is the number of publications and the second number listed is the citations index.

Table A-3: Soils and Soil Science

Description	Soil science is the study of soil including soil formation, soil classification and mapping; physical, chemical, biological, and fertility properties of soils; and these properties in relation to the use and management of soils.[59] For agriculture, soils (along with climate) are one of the key variables of the production environment, playing a central role in the selection of crops, individual crop species, rotation strategies, fertilization and nutrient management strategies, water management strategies and disease management. Soils also harbor a complex ecosystem of microorganisms which have biologically mutualistic, commensalistic or parasitic interactions with plants and each other. Soil improvement seeks to enhance the positive production characteristics (structural, physical, nutritive, etc.) of the soil in relation to agricultural land use.
Key Assets and Capabilities	The University of Minnesota demonstrates a substantial publishing volume in soil science. This work is largely contained within faculty associated with the U of M Department of Soil, Water and Climate, with research focused on "key biological, chemical and physical processes occurring in the soil matrix, as well as soil interactions with other key components (atmosphere, water and vegetation) of the earth system."[60] Research teams focused in: biogeochemistry; soil environmental microbiology; nutrient management; pedology, and soil physics As with many other areas of strength at the University, there is a robust volume of work taking place in soil microbiology, examining the structure and function of soil microorganisms that are involved the processes of nitrogen fixation, biodegradation and bioremediation of organic and inorganic compounds. Faculty research is also directed at using genomic, molecular, and classical methods to examine the interactions of soil microorganisms with their abiotic and biotic components of soil ecosystems at both the basic and applied levels. There is also a significant amount of work occurring in nutrient management research focused on developing strategies to improve nutrient use efficiency for crop production. A primary goal is to optimize crop yield and quality using appropriate nutrient inputs while minimizing effects on the environment The USDA-ARS Soil and Water Management Research Unit has close relationships with soil science at the University of Minnesota and contains multiple adjunct faculty. The USDA research unit focuses on developing and testing agricultural management practices that improve water quality and soils and reduce emissions of greenhouse gases. The University of Minnesota also operates the service oriented Soil testing and Research Analytical Laboratories. The soil testing lab provides routine soil testing services and provides recommendations for soil improvement. **St. Cloud State University's** Environmental and Technological Studies Program includes the Environmental Soils Center, which undertakes research and instruction in topics related to soils and environmental quality, as well as the Environmental Instrumentation Center, which is designed primarily for environmental experimentation and analysis of air, water, and soils.
Supporting Data	**OmniViz √√√** 918 records, 3 OmniViz clusters 657 in "soil science", 81 in "legume/root nitrogen fixation", 180 in "forest soils and ecosystems". **USI Publications and Citations Indices √√** Agricultural Soil Sciences 77 (1.09), Agronomy 279 (1.25)
Potential Development Opportunities	• Soil and sub-soil enhancement through customized amendment and inoculants formulations • Municipal and farm organic waste utilization for soil amendments • Mechanical tools for sub-soil enrichment • Soil analysis tools and enhancement strategies • Soil microbiome enhancement

[59] Jackson, J. A. (1997). Glossary of Geology (4. ed.). Alexandria, Virginia: American Geological Institute. p 604
[60] http://www.swac.umn.edu/Research/Soil/index.htm

Table A-4: Forestry and Forest Ecology

Description	Forestry is the science of developing, caring for, or cultivating forests and the management of growing timber.[61] The science of forestry is built around the principle of multiple-use land management, though the harvesting and replanting of timber are the primary activities. The main objective is to maintain a continuous supply of timber through carefully planned harvest and replacement. Forest ecology studies forest ecosystems, their component parts and interrelationships (flora, fauna, microbiota, soils, and processes).
Key Assets and Capabilities	Minnesota contains large-scale forest resources, particularly in the northern counties of the state. These forest resources support not only recreational and natural resource preservation services, but also are managed in support of a vertically integrated lumber and forest products industry. **The Department of Forest Resources** at the University of Minnesota maintains active research programs in: forest biology and ecology; silviculture and forest management; resource management and public policy; watershed management and water quality; resource assessment and geospatial analysis; and recreation management and tourism. Some key centers and research assets in Minnesota include: **Cloquet Forestry Center** – This comprises the University of Minnesota's primary research and education forest. "The Center serves the research, teaching, and education needs of the natural resources community. It is also home to Extension's Cloquet Regional office. The Center includes 3,400 acres that support broad areas of research and education."[62] **Center for Forest Ecology** – Is a joint initiative of CFANS and the College of Biological Sciences at the University of Minnesota. The Center "brings together an interdisciplinary group of ecologists to study ecological processes at the physiological, community and landscape levels, and to apply findings to management initiatives."[63] **The Forest Products Management Development Institute** is an initiative of the University of Minnesota's Department of Bioproducts and Biosystems Engineering. The institute is primarily focused on education, with the goal of increasing "knowledge about wood products production and use, and associated issues strategies, and technologies on the part of forest products industry employees, key forest products consumer groups, and those involved in shaping national and regional forest policy."[64] The U of M is also engaged in multiple collaborative initiatives, such as the Aspen and Larch Genetics Project and Collaboration (at the North Central Research and Outreach Center in Grand Rapids), the Cooperative Park Studies Program (working with the National Parks Service), and the Minnesota Tree Improvement Cooperative.
Supporting Data	**OmniViz √√√** 612 records, 3 OmniViz clusters 314 in "forestry and forest management", 118 in "forest ecology", and 180 in "forest soils and ecosystems." **USI Publications and Citations Indices √** Forestry 157 (1.04)
Potential Development Opportunities	• Enhanced value of Minnesota forest resources • Engagement in wood products industries

[61] http://www.merriam-webster.com/dictionary/forestry
[62] http://www.forestry.umn.edu/CentersCooperatives/index.htm
[63] Ibid
[64] http://www.bbe.umn.edu/ExtensionandOutreach/BioproductsandRenewableEnergy/resources/FPMDI/mission/index.htm

Table A-5: Basic Plant Sciences

Description	Plant sciences and botany are largely synonymous and include the scientific study of plants including their physiology, molecular biology, cellular biology, structure (anatomy and morphology), genomics, biochemistry, reproduction, evolution, pathologies, and symbiotic relationships with microorganisms. Work in basic plant sciences underpins much of the progress made in commercial agricultural and horticultural crops, elucidating the fundamental mechanisms and structures that may be altered to achieve input or output trait improvement or other functional characteristics.
Key Assets and Capabilities	With the **Microbial and Plant Genomics Institute** the University of Minnesota has a broad umbrella institute, with a dedicated building and facilities, providing genetics and genomics studies ranging from epigenetics in plants through to marker assisted breeding. "The scientific aim of the Institute is to enhance the development of functional and translational genomics concomitantly with the expansion of bioinformatics capabilities and the development of specialized instrumentation."[65] Within the College of Biological Sciences at the University of Minnesota, the **Department of Plant Biology** has significant research undertakings in basic plant sciences in the areas of: genomics and bioinformatics; genes and developmental biology; plant metabolics and cell function; biotic interactions; plant responses to environmental stimuli; and biodiversity, evolution and ecosystem functions. Within CFANS, the **Department of Agronomy and Plant Genetics** performs research spanning basic sciences through applied crop improvement and crop breeding. The University maintains particularly noteworthy clusters of research in the genetics and breeding o: wheat; barley; oats; corn; soybeans, and forage crops. The **Department of Horticultural Science** has an active program of research, including plant breeding and genetics releasing cultivars of ornamentals, fruits and vegetables. The department also active research programs in plant growth and development and in value-added products from horticulture The **USDA-ARS** also is engaged in basic plant sciences with the **Plant Science Research Unit** located in St. Paul. This USDA research unit focuses on expanding understanding of the fundamental processes controlling energy content, increased production, improved quality, and enhanced use of alfalfa and other forages, soybean, oat, wheat, and wild rice. USDA researchers and collaborators "utilize this knowledge to develop germplasm and crop management schemes that lead to increased farm profitability and sustainability of the nation's resource base."[66] The University of Minnesota's **Center for Genome Engineering** serves an important research support function in providing the University research community with access to the latest research instruments, tools and techniques for conducting genetic and genomic analysis. **Minnesota State University Moorhead's Department of Biology** has focused efforts in the area of photosynthetic carbon metabolism of corn and specifically its impact on enzyme regulation.
+.023. **Supporting Data**	**OmniViz √√** 340 records, 7 OmniViz clusters 71 in "flowering and plant reproductive biology", 76 in "temperature/growth and plant range", 72 in "crop seeds and plant development", 63 in "indole biosynthesis", 25 in "basic genetics" 21 in "plant sugars and biochemistry" and 12 in "basic genomics". **USI Publications and Citations Indices √√** Plant Sciences 505 (1.0), Genetics and Heredity 643 (1.04), Biochemistry and Molecular Biology 1,172 (0.93)
Potential Development Opportunities	• Fundamental discoveries and technologies for plant improvement • Fundamental discoveries and technologies for plant protection • Enhanced functional characteristics for plants of economic value

[65] http://www.mpgi.umn.edu/AboutMPGI/index.htm
[66] http://www.ars.usda.gov/pandp/locations/locations.htm?modecode=36-40-10-00

Table A-6: Crop Improvement

Description	Crop improvement may be defined as the science of modifying crop plants to increase their value. Improvements to plants may be made using a variety of methods, such as traditional crossing and selective breeding methods, mutation technologies (using radiation) and the modern molecular techniques of tissue culture, genetic engineering and transgenics. Crop improvement may be deployed in the pursuit of multiple enhanced crop characteristics, such as: yield increases, pest and disease resistance, selective herbicide resistance, drought tolerance, nitrogen use efficiency, salt tolerance, and functional phytochemical content. Other goals may include the adaptation of crops to modern production techniques, harvesting technologies, and alteration of plant physiology/morphology to facilitate post-harvest processing. Increasingly crop improvement work is focusing on adaptation of crop plants to potential climate changes within their growing regions.
Key Assets and Capabilities	Robust cadre of researchers with tradition in plant breeding and molecular genetics. Applied work in maize, wheat, barley, alfalfa (USDA) and other forages. Also work in soybeans, sunflower, wheat grass and pennycress. Also track-record in horticultural crops, including apples (major IP $ generator), grapes, potatoes, woody ornamentals, florals and turf grass. Tends towards traditional breeding and marker assisted selection with limited work in transgenics. Work in both input and output traits. There is a distinct overlap between strength areas here and in the basic plant sciences arena, in particular: Within CFANS, the **Department of Agronomy and Plant Genetics** performs research spanning basic sciences through applied crop improvement and crop breeding. The University maintains particularly noteworthy clusters of research in the genetics and breeding o: wheat; barley; oats; corn; soybeans, and forage crops. The **Department of Horticultural Science** has an active program of research, including plant breeding and genetics releasing cultivars of ornamentals, fruits and vegetables. The department also active research programs in plant growth and development and in value-added products from horticulture The **USDA-ARS** also is engaged in basic plant sciences with the **Plant Science Research Unit** located in St. Paul. This USDA research unit focuses on expanding understanding of the fundamental processes controlling energy content, increased production, improved quality, and enhanced use of alfalfa and other forages, soybean, oat, wheat, and wild rice. USDA researchers and collaborators "utilize this knowledge to develop germplasm and crop management schemes that lead to increased farm profitability and sustainability of the nation's resource base."[67]
Supporting Data	**OmniViz √√** 484 records, 3 OmniViz clusters 121 in "wheat and barley genetics and improvement", 203 in "wheat/barley plant pathogens and resistance", 160 in "wheat/barley and fusarium" **USI Publications and Citations Indices √√** Plant Sciences 505 (1.0), Genetics and Heredity 643 (1.04), Mycology 40 (4.11), Agronomy 279 (1.25)
Potential Development Opportunities	Economic development may come via multiple pathways, including: 1) attraction of increased levels of external research funding to Minnesota institutions, 2) attraction of global agbiotech companies to co-locate or work with Minnesota research institutions, 3) introduction of enhanced crops and pasture species to Minnesota producers, thereby enhancing production and associated economic impacts, 4) transfer of novel innovations and technologies to new or existing Minnesota-based agbiotech companies. • Higher value and improved crops • Traits and genes with marketable value • New varieties and transgenic crops with enhanced traits and characteristics • Enhanced food crops and functional foods • Enhanced plants for use as biomass/feedstocks

[67] http://www.ars.usda.gov/pandp/locations/locations.htm?modecode=36-40-10-00

Table A-7: Plant Diseases and Plant Protection

Description	Plant diseases are caused by a variety of microorganisms, including fungi, bacteria, and viruses. They may also occur via attack by parasites (such as nematodes) or result from environmental conditions (physiological factors). In Minnesota and the Upper Midwest various forms of fungi, and fungi-like organisms, are a common cause of losses in economically significant crop plants such as wheat, barley, corn and soybeans. Plant Protection comprises the science of protecting plants from disease causing pathogens, parasites, insects and other pests, weeds and environmental stresses. Approaches to plant protection are varied, ranging through: surveillance; infectious disease diagnostics; plant improvement techniques for disease and pest resistance; weed control; invasive species surveillance and eradication; and the development of agrochemicals and natural products for herbicide and pesticide applications.
Key Assets and Capabilities	Minnesota is a clear hub of expertise in plant diseases, especially fungal plant diseases. In cereal crops, both the USDA-ARS and University of Minnesota have a joint focus on pathogens impacting wheat, barley and other crops – especially rust associated diseases and fusarium (both families of fungal pathogens). Work ranges from fundamental science work in microbiology, through to functional genetics and molecular biology of disease resistance, and strategies to create improved varieties of cereals with enhanced resistance. Taken together, the USDA/UM cluster in cereal diseases is broad in capabilities and well equipped, including operation of biosecurity level III facilities and secure greenhouses. The USDA Cereal Diseases Laboratory focuses on "reducing losses in wheat, oat, and barley to major diseases including leaf rust, stem rust, and Fusarium head blight" and addresses the challenge from both a pathogen biology perspective and plant improvement perspective. The USDA notes that program objectives are to: "(1) identify genes used by plants in defense against pathogens and determine their cellular and biochemical mechanisms of action; (2) elucidate molecular aspects of the expression of virulence in rust fungi; (3) identify and utilize rust resistance factors to protect small grain crops against existing and future pathogenic races in rust populations; (4) analyze population genetics of cereal rust fungi and devise strategies to enhance durability of resistance against diverse rust populations; (5) identify and characterize resistance in wheat and barley to Fusarium head blight and determine impacts of partial resistance on pathogen populations in crop residue; and (6) identify genetic factors for pathogenicity in *Fusarium* and explore ways to block their activity and minimize pathogen attack in small grains."[68]
Supporting Data	**OmniViz √√** 412 records, 4 OmniViz clusters 203 in "wheat/barley plant pathogens and resistance", 160 in "wheat/barley and fusarium", 35 in potato/tuber genetics and blight resistance, and 14 in "pine tree rusts and associated plant pathology" **USI Publications and Citations Indices √√** Mycology 40 (4.11), Agronomy 279 (1.25), Plant Sciences 505 (1.0)
Potential Development Opportunities	• Enhanced productivity for domestic and international agriculture. • Approaches to combating fungal and viral pathogens and development of associated plant improvement technologies • Disease resistance biomarkers • Molecular diagnostics • Endophytes/symbiotes for enhancement of plant disease resistance

[68] http://www.ars.usda.gov/main/site_main.htm?modecode=36-40-05-00

Table A-8: Industrial Biomass and Biofuels

Description	A biofuel is a fuel derived from living matter, or recently living matter (as opposed to fossil carbon fuels that come from ancient organic matter). Plant biomass is the leading source of renewable organic matter used for the production of biofuels, biobased chemicals, biopolymers and biobased materials. R&D work in industrial biofuels and biobased products ranges from development and characterization of biomass feedstocks (crop residues, woody biomass, plant sugars and plant oils) through harvesting and densification technologies and on into downstream processing technologies to convert biomass into value-added energy, chemicals or materials. Processing into higher value liquid fuels, chemicals and polymers uses three broad technology platforms—thermochemical processing (gasification), biochemical (e.g., fermentation), and chemical/oleochemical (catalytic reactions primarily). Multiple academic research disciplines contribute to the advancement of the industrial biobased economy including plant sciences, agronomy, forestry, agricultural engineering, chemistry and chemical engineering, polymer and materials sciences, and economics.
Key Assets and Capabilities	Minnesota was among the pioneering states in developing a biofuels industry, and the state enjoys an active base of companies involved in ethanol and biodiesel production. Institutions and businesses in the state are also engaged in next generation biofuels development and biorefinery process development for further value-added biobased chemicals and polymers. Among the key R&D resources present in the state are: • **Center for Biorefining** – This University of Minnesota Center operates with the mission of coordinating University efforts and resources to "conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas."[69] • **Center for Sustainable Polymers** – This University of Minnesota center focuses on research directed at harnessing the "renewable, functional, degradable and non-toxic ingredients provided by Nature for tomorrow's advanced plastics, foams, adhesives, elastomers, coatings and other macromolecular materials."[70] • **BioTechnology Institute** – The BioTechnology Institute (BTI) at the University of Minnesota provides "advanced research, training, and university-industry interaction in biological process technology, a major area of biotechnology research. The Institute is the central University of Minnesota vehicle for coordinated research in the biological, chemical, and engineering aspects of biotechnology and home to the President's Initiative on Biocatalysis. BTI faculty conduct research over a broad spectrum of disciplines, including microbial physiology, metabolic pathway engineering, genetics and cell biology, functional genomics, animal cell culture, biodegradation of hazardous materials, molecular evolution, biological diversity, green chemistry, natural product synthesis, protein engineering, and the development of biofuels and biopolymers from renewable resources."[71] • **Biodale – Biotech Research Services.** The University of Minnesota's Biotechnology Resource Center has significant capacity for working with industrial microbes, and provides capabilities to grow a wide range of microorganisms from shake-flask to 240L fermenter scale and to recover the cells and/or metabolites. A particular area of expertise is the expression and purification of recombinant proteins. • **Materials Research, Science and Engineering Center** – This U of M Center has broad expertise in a wide-range of materials science research and translational sciences, including work in renewable products and fuels. • **Initiative for Renewable Energy and the Environment** – This is a program contained under the Institute on the Environment. The program, which has recently been sunsetted, evaluated promising renewable energy areas and distributed funding from Xcel Energy's Renewable Development Fund to spur further R&D and development. U of M **Department of Bioproducts and Biosystems Engineering** is the home for much of the major

[69] http://biorefining.cfans.umn.edu/about-the-center/
[70] http://www.chem.umn.edu/csp/
[71] http://www.bti.umn.edu/introduction.html

	activity taking place at the university in biofuels and biobased products. The common unifying mission of the Department is "to integrate engineering, science, technology and management for sustainable use of renewable resources and enhancement of the environment."[72] It should be noted that the University of Minnesota ranks among the premiere global institutions in the discipline of **Chemical Engineering**. The Department is very good at molecular design and on the applied side is focused in materials science. Work in biochemicals is quite focused on biomedical related applications because of the availability of significant NIH funds. Faculty at the University of Minnesota are engaged in some notable projects focused on distributed systems of agri-chemical production, seeking development of anhydrous ammonia for fertilizer applications via on-farm or small regional production plants (as opposed to the current large-scale petrochemical model). **St. Cloud State University's Algae Research Program** is a unique academic/industrial partnership that focuses on the bioindustrial applications of algae. The algae program, as well as other biomass and biomaterial programs, is expected to continue to grow when the Integrated Science and Engineering Laboratory Facility (ISELF), a 100,000 square-foot structure dedicated to fostering faculty/industry research partnerships, opens in 2013. Bemidji State University also has focused efforts through its **Center for Environmental, Earth and Space Studies** on studying the potential bioindustrial applications from agricultural waste streams.
Supporting Data	**OmniViz √√** 438 records, 2 OmniViz clusters 363 in "corn biomass and biofuels" and 75 in "plant oils, biofuels and processes." **USI Publications and Citations Indices √√** Agriculture – Energy and Fuels 86 (0.75), Engineering – Chemical 213 (1.27), Biotechnology and Applied Microbiology 553 (1.0)
Potential Development Opportunities	• Biofuels • Biobased bulk and specialty chemicals • Biobased polymers • Biobased materials

[72] http://www.bbe.umn.edu/AboutUs/index.htm

Table A-9: Nutrition and Health Impacts

Description	Nutrition involves the study of the food and liquid requirements of humans or animals, consisting of the taking in and metabolism of food materials whereby tissue is built up and energy liberated.
Key Assets and Capabilities	It was noted that the U of M has strengths in livestock nutrition, particularly in the areas of swine nutrition, turkey/poultry nutrition, and the study of ruminant digestions. Among the key R&D resources present in the state are: • Hormel Institute is a major cancer research unit, conduct research across a wide range of biological sciences with applications in medicine and agriculture • Minnesota Obesity Center incorporates research across a wide range of causes and treatments of obesity • Obesity Prevention Center fosters an interdisciplinary approach to combating the obesity epidemic by focusing primarily on prevention strategies research • Nutrition Coordinating Center provides databases, software, training, and services for the collection and analysis of dietary data • Healthy Foods, Healthy Lives Institute works to increase and sustain the University's impact in the interdisciplinary arena of food, agriculture and health by building the University's capacity in research, learning and community engagement. The priority areas for focus are food safety, prevention of obesity and chronic disease, and food policy. Within these priority areas, of special importance is the integration of agriculture and medicine.
Supporting Data	**OmniViz √√** 247 records, 6 OmniViz clusters[73] 121 in "adolescent human nutrition," 52 in "soy isoflavones/fat and nutrition," 38 in "flavors," 31 in "breakfast cereal nutrition," 21 in "food minerals and human child development," and 12 in "fish fatty acids and nutrition." **USI Publications and Citations Indices √√** Food Science and Technology 283 (1.11), Nutrition and Dietetics 418 (1.18)
Potential Development Opportunities	• Molecules identified from natural sources for later synthesis into drugs • Products having functionality for improving health or nutrition, human or livestock, such as dietary supplements or nutraceuticals

[73] 247 records: 121 in "adolescent human nutrition," 52 in "soy isoflavones/fat and nutrition," 38 in "flavors," 31 in "breakfast cereal nutrition," 21 in "food minerals and human child development," and 12 in "fish fatty acids and nutrition."

Table A-10: Basic Animal Sciences

Description	Animal sciences involve the study of animal species that are largely under the control of humans (e.g., agricultural livestock and domesticated species). Animal science particularly focuses on biology, production and care of domestic animals.
Key Assets and Capabilities	The U of M is particularly well-known for its research work in three main areas: nutrition, physiology and growth biology, and production systems. This work is primarily concentrated on five animal categories (beef, dairy, equine, poultry, and swine) that are of economic importance to Minnesota. There is also a cluster of researchers working in basic animal physiology/muscle biology. Key areas of research currently include: • Molecular, Cellular, Developmental, and Growth Biology • Genetics (quantitative, molecular and functional) • Physiology and Cell Signaling • Reproduction • Nutrition (ruminant and non-ruminant) • Production Systems Because of the growth of the biofuels industry in Minnesota and the North Central region, animal scientists at U of M have undertaken important work evaluating biofuel production coproducts (such as distiller grains) as feedstocks for livestock and poultry.
Supporting Data	**OmniViz √√** 232 records, 3 OmniViz clusters 119 in "animal muscle biology", 79 in "poultry genomics" and 34 in "ruminant digestion" **USI Publications and Citations Indices √√** Agricultural Dairy and Animal Science 188 (1.15), Genetics and Heredity 643 (1.04)
Potential Development Opportunities	• Improved, higher-value animal breeds (faster growth, leaner meat, enhanced marbling and flavor, etc.) • Healthier food animals with enhanced physiologic characteristics (such as increased bone density to support higher meat yield) • Production of transgenic or chimeric animals for research and commercial applications such as xenotransplantation • Production of transgenic animals for the expression of desirable proteins, biochemicals, drugs, and biologics

Table A-11: Dairy Production and Reproductive Biology

Description	The dairy industry uses large animals (primarily cows, but also goats and other livestock species) for the production of fluid milk which is then processed into pasteurized milk and value-added dairy products (e.g., chesses, yogurts, whey protein, etc.). Milk production requires management of dairy herd reproduction and associated lactation, thus reproductive biology is a key area of scientific study, together with livestock nutrition and health.
Key Assets and Capabilities	It was noted that the U of M has strengths in dairy production and reproductive biology. Among the key R&D resources present in the state are: • Center for Dairy Health Management and Food Quality conducts research in cow health and management to advance knowledge as it relates to veterinary medicine and dairy production
Supporting Data	**OmniViz √√** 335 records, 2 OmniViz cluster 274 in "dairy cattle and milk production" and 61 in "cattle fertility and reproductive cycles." **USI Publications and Citations Indices √** Agricultural Dairy and Animal Science 188 (1.15)
Potential Development Opportunities	• Healthier animals for the dairy industry with enhanced economic results • Reduced disease losses among herds • Commercial diagnostic tests and kits • Vaccines • Disease treatments • Improved food products • New food products