



The BioBusiness Alliance
of Minnesota

Biobusiness: Minnesota's Present Position and Future Prospects

Report of the
Statewide Biobusiness Assessment Project
of the BioBusiness Alliance of Minnesota

Principal Author:

Kelvin W. Willoughby, Ph.D.

Project Co-chairs: Kelvin Willoughby, Vincent Ruane

Chairman of the Board: Dale Wahlstrom

Project Executive: Jeremy Lenz



Foreword



The BioBusiness Alliance of Minnesota (“BioBusiness Alliance”) is an industry-led, 501(c)(3) not-for-profit organization dedicated to the advancement of bioscience-based industries to create jobs for the citizens of Minnesota. The participants consist of experienced people from industry, academia, and state and local government. Those involved share the following common characteristics and beliefs.

1. First, we all believe that the biosciences will have a profound impact on the lives of the global community in the future. We believe the impact of the biosciences over the coming 20 years will be similar to the impact that computers have had on our lives over the past 20 years. These dramatic impacts are already happening.
2. Second, because we all work in the industry in some manner, we are exposed to what is happening around the world in bioscience and biobusiness. We share a belief that Minnesota needs to be at the forefront in the areas in which we choose to participate, or we will lose an important portion of our economy. We also share a concern that Minnesota will have to do more than is currently being done in order to keep up. Biobusiness is an industry that has become the platform for growth of many global communities.
3. Third, we are all willing to donate our time, knowledge and skills to help understand what needs to be done to ensure our future. We are also willing to donate the same to help implement the changes that are identified.

The Board of Directors of the BioBusiness Alliance was assembled for the first time in February 2005. We agreed on the following three strategies as most critical to retaining and growing biobusiness jobs in Minnesota:

1. Conduct a **Statewide Assessment** of our knowledge and business generation capability. This is our first deliverable.
2. Develop a short-, medium- and long-term plan for growth in the biobusiness industry. This is called **Destination 2025**.
3. Create a support mechanism to help start-up companies, entrepreneurs and existing companies to expand in or move to Minnesota. This is called the **BioBusiness Resource Network**.

The BioBusiness Alliance will be publishing information and results on a periodic basis. If you would like to learn more about the BioBusiness Alliance, or what you can do to participate, please check our website at www.biobusinessalliance.org or contact the organization at 952.746.3812.





Preface



As the Chairman of the Board of Directors for the BioBusiness Alliance of Minnesota, it is my great pleasure to present to the citizens of Minnesota the final report of the BioBusiness Alliance's Statewide Assessment. This report was conducted by the Statewide Assessment team under the guidance of the BioBusiness Alliance of Minnesota's Board of Directors. Its purpose is to present objective data that will yield the reader a sense of where Minnesota stands in the rapidly growing areas of bioscience and biobusiness. In addition, the Board of Directors offers the reader its perspective of what it means, and some preliminary thoughts on where we need to focus our efforts to ensure that our state's future continues to be bright. It is also important to understand that this report is not the end of our work. It represents a moment in time and a place where we can start work on Destination 2025, our long-term planning process. The report truly represents **the very beginning**.

Background

When the BioBusiness Alliance Board of Directors initiated the assessment process, we made some promises to the people of Minnesota and our funding partners. The promises included:

- The assessment would take a grassroots approach and would look at large, mid-size, small, and start-up companies.
- It would include knowledge generation (basic and applied research, mostly in the not-for-profit sector), and private-sector commercialization capability and focus.
- We would study the major categories of biobusiness that are important to Minnesota: agri-bio technology, bio-industrial technology, human health technology and biotechnology.
- We would reach out to the four corners of the state.
- We would investigate markets and products, but focus the assessment on technologies. We chose this focus to develop a clear understanding of what Minnesota's technological "pillars of strength" really are so we can build on them for the future.
- Finally, we would provide an analysis of the work that would give context to Minnesota's competitiveness in the national and global economy.

To accomplish the assessment and deliver on our promises, we commissioned two independent studies. The first was a **comparative study** conducted by Willoughby International, LLC. This study used **public information** to assess the **private sectors** of Minnesota compared to 10 other states with similar goals for their economic growth in biobusiness-related fields. The academic sector was not part of that study. The study yielded a clear picture of where Minnesota stands compared with these other states.



The second commissioned study was conducted by the ANGLE Technology Group. This study followed a **grassroots** approach that included **both for-profit and not-for-profit organizations, in both the academic and industry sectors**. There were two primary deliverables for this study. The first was to develop a census of both for-profit and not-for-profit enterprises (operating independently or as a unit of a larger corporation or organization) in Minnesota that develops biobusiness-related technology. We refer to these as biobusiness technology enterprises (BTEs). The second was to produce an understanding of the markets, products and technologies these enterprises employ to meet their organizational objectives. ANGLE looked at both current capacity and future directions. The research was conducted using questionnaires, telephone conversations and face-to-face interviews. To protect confidential information provided by respondents, most of the data reported in this study is presented in aggregate form only.

The final report presented here is a consolidated analysis that combines the content of the two studies into one report. This was done to reduce the complexity of documents for the reader, and to help build context for a more comprehensive understanding of biobusiness in Minnesota.

A Teaser To Encourage the Reader To Read On

We are very pleased with the final product, and feel very positive about the content of the report. We have met the commitments we made. Some commitments were met more completely than others. For example, even though the census of BTEs identified 425 entities, a significantly larger number of Minnesota BTEs than we previously were aware of, we know it is still not complete. We will find more BTEs as we take the research to the next level of detail. We also found it very difficult to find “good” publicly available data on the bio-industrial and agri-bio technology sectors. These sectors are relatively new, and good measures are not readily available. We are already working to resolve this issue with the Minnesota Department of Agriculture and the Agricultural Utilization Research Institute (AURI). We now know this is a problem shared by all U.S. communities involved in agri-bio and bio-industrial economic activity.

We found information to validate some previously held opinions. Certainly, Minnesota remains a **dominant player in medical devices**. We rank near the top of nearly all indicators measured in this area. We also are a **dominant player in renewable fuels**, an area where the world is watching Minnesota.

We also found some areas of strength that were not so well known. For example, Minnesota is a **dominant player in materials science**. This is true for both renewable and non-renewable materials. It also may represent a crossover opportunity between our industrial, agricultural and medical device sectors. We are also heavily focused and very strong in **delivery systems** (e.g., drug delivery or therapeutic device delivery) for animal and human health applications. As with the life sciences, the animal and human health sectors continue to “converge.” We know and understand advanced materials and delivery technologies, and these skills will serve us well in the future and are critical in facilitating the aforementioned convergence (convergence of technologies within



existing industries, and convergence of previously separated markets and product categories around emerging technologies). They offer great value to us when building our future economy.

Areas of weakness and concern were also identified. Even though we are dominant in renewable fuels, medical devices and a few other areas, we lost ground from 1997 to 2002 in total biobusiness technology employment and in key sectors within biobusiness technology where we historically have had clear dominance. We turned the trend around between 2002 and 2005, but we know that our competition is also improving.

Our initial analysis would indicate that most of our large companies are still hiring and growing. Since 2002, some of Minnesota's larger biobusiness companies have hired significant numbers of new employees. However, for some reason total hiring across the whole of biobusiness technology in Minnesota does not reflect this growth as much as we might have expected. The measures of the study indicate to us that our small, medium-sized and start-up companies may be struggling disproportionately. We will be conducting an in-depth study to analyze this issue. For now, we are confident that we need to continue to support our large companies, but we also need to put more focus on helping the smaller companies and on catalyzing start-up activity. These efforts cannot wait for Destination 2025. We are, therefore, starting this work immediately.

Another area of concern to the Board of Directors is the category of jobs called "R&D in the life sciences." These jobs represent the core skills that are required for development of products such as catalysts for fuels or biopharmaceuticals. In effect, it is the study of the function of organisms, and their interactions between each other and their environment, that may lead to commercial products or applications. This is one of the pillars of knowledge for the new economy that is evolving. It turns out that Minnesota is **not a strong competitor** in commercialization of R&D in the life sciences. We do have a strong educational and research capability, but the commercial side of employment in this area is only slightly bigger than it is in Iowa and Utah, and smaller than in all other states studied. Most significantly, all of the other states studied, including Iowa and Utah, are growing this sector faster than Minnesota.

The lack of competitive strength in commercialization (translating invention into new start-up companies and enterprises within Minnesota) may be our most disturbing finding. To compete long term, in addition to a strong academic sector, Minnesota needs to have a base of private-sector employment in life sciences devoted to R&D that is at least commensurate with a state of our size. To accomplish this goal, we would need approximately 5,000 high-tech employees involved in commercial life sciences R&D compared to the 2,200 we have today.

We feel this is important for two reasons. First, by itself R&D in the life sciences will provide an opportunity for economic and job growth in the future. Second, it is the knowledge base that will support the convergence of life sciences with medical devices. Since nearly 80 percent of the private-sector biobusiness technology jobs in Minnesota today are involved in medical devices, we cannot allow that sector to erode. In the future, the human health skill base will need the life science skill



base. As you can imagine, understanding the implications of the data is our highest priority. We are already implementing strategies to address this issue. The need is obvious.

About the Process

Our first goal was to agree on a few definitions and begin the process of creating a language for our work. As you begin to read this report, I would recommend that you at least become familiar with the definitions. They are the beginnings of a language that we will develop further over time.

I would also recommend that you spend some time becoming familiar with the measurements contained in the comparative study section of the report. These are the measurements that you will see again and again. They will be the basis of measurements used as we monitor the impact of our projects, and the impact that Destination 2025 will have on our state.

The area of the report that may seem the most confusing to you is the section on the grassroots assessment and the discussion on technologies. As stated before, our skills, represented by the technologies that we have mastered, are important. They are the “gold in our treasure chest” as we build our future. Our skills represent our strengths, and our lack of skill in a given area represents our weaknesses. Yet, it is hard to discuss this topic and create shared understanding. It is even harder to measure and quantify.

The world needs a standard method and language to allow meaningful dialogue on this topic of biobusiness skills. To address this issue, we have incorporated a color-coded classification system initially introduced by the trade group EuropaBio. We have added a couple of dimensions to this (hopefully) simple-to-understand system, and hope to build on the approach working in collaboration with our European colleagues. They have initiated an important concept, and we would like to see it evolved further to create a global biobusiness language. I would encourage you to take a close look at this section of the report. The concept is young and is under construction. Failure to create a language for applied biotechnology is not an option, however.

We already have enough clarity, as a result of our initial work, to allow us to initiate Destination 2025 and are confident we will be able to communicate our results to you effectively in future reports.

Acknowledgements From the Chair

I want to take a moment to specifically call attention to the contributions of a few people who played key roles in achieving the monumental task of this project. The first is Jeremy Lenz. Jeremy has functioned as the Project Executive and has been invaluable in keeping the process moving and the volunteers on task. Vincent Ruane, the Statewide Assessment team Co-Chair, has repeatedly demonstrated his leadership skills by pulling us back to the key issues and messages when we began to get lost in the mountain of details. Gail O’Kane repeatedly applied her analytical capabilities to



uncover key points that are important to the story. Some of our key takeaways would have been missed without her contributions.

Finally, we want to express our deepest gratitude to Dr. Kelvin Willoughby. During the past year Dr. Willoughby has worn many hats in the Statewide Assessment project. As the Statewide Assessment Lead Chair, Dr. Willoughby was the architect of the process that we collectively subscribed to and wholeheartedly implemented. His leadership was evident from framing the request for proposals, to providing a framework to capture Minnesota's global areas of technological excellence, to conducting the comparative study. Drawing on his considerable experience in performing assessments, Dr. Willoughby completed the analysis of the two commissioned studies and published this consolidated report, which helps us to connect the dots and draw valuable meaning out of all of the data. We wish to express our deepest appreciation to Kelvin, without whom we could not have completed this enormously challenging task.

Summary

The Board of Directors of the BioBusiness Alliance of Minnesota is proud of the document you are about to read. Not all of the news is good news, but neither is it all bad news. The data would indicate there are reasons for us to stop and take a good, hard look at what we are doing. We believe the direction of the wind is shifting, and Minnesota does need to adjust the “tack in our sails.”

We are not concerned about our ability to make the needed changes. We have a great educational system, educated and informed employees with tremendous skills, and an unquestioned work ethic. We are blessed with industries that are truly world class, and have the ability to attract global talent. We start this improvement process in an enviable position.

We think that our success in preparation for the future is dependent on three things: collaboration, vision and personal commitment. With these three things, combined with appropriate leadership, we can create the momentum that we need to compete wherever we choose.

We look forward to working with you to create Minnesota's biobusiness future.

Respectfully,

Dale Wahlstrom
Chairman of the Board
The BioBusiness Alliance of Minnesota

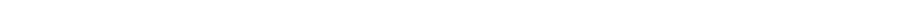




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Executive Summary



By late 2002, the most recent year for which detailed national data from the U.S. Economic Census is available, the biobusiness technology sector in the United States consisted of over 55,000 establishments, about 1.2 million paid employees, an aggregate annual payroll of over \$60 billion and aggregate annual revenues of over \$330 billion.* In addition, according to data from Battelle, average wages in the bioscience sector (at \$65,775 in 2004) were over \$26,000 greater than the average private-sector wage. With statistics for a “young industry” outlined above, Minnesota has motivation to understand its position in this increasingly competitive and global industry.

This report represents the first-ever comprehensive assessment of Minnesota’s statewide biobusiness technology industry and provides Minnesota’s leadership with a “line in the sand” against which to benchmark this industry. The project was designed to confirm Minnesota’s technological capabilities and to uncover emerging technology-related opportunities in the human health and agri-bio/bio-industrial sectors of the economy.

The specific goals of the assessment were to:

- Provide a baseline assessment of biobusiness technology in Minnesota against which the state may be benchmarked.
- Provide thoughtful, well-researched recommendations to help guide the state in becoming more competitive in specific areas of biobusiness. These recommendations will reflect the convergence of technologies, products and markets that exist within Minnesota.

Through focusing on specific and distinctive biobusiness technology categories in which Minnesota can compete as one of the top few global centers of excellence, we are confident that Minnesota will continue to find future areas in which to excel and thus create and retain biobusiness jobs in Minnesota.

The success of the Assessment was directly linked to the process covering every scale of technology enterprise from start-ups and small organizations to medium-sized and large organizations, whether they were located in the private or the public (academic research) sectors. Additionally, the Assessment was statewide and incorporated Minnesota enterprises from corner to corner, across the state.

* Battelle Technology Partnership Practice and SSTI, Growing the Nation’s Bioscience Sector: State Bioscience Initiatives 2006 (Columbus, OH: Battelle Memorial Institute, April 2006.) Note: Battelle’s term “bioscience” covers a slightly different, although closely related, business territory than our term “biobusiness” (see Appendix 3 of this report for a detailed explanation).



Overview of Components of the Assessment Project

We followed two parallel assessment pathways in order to develop a comprehensive picture of Minnesota's position in biobusiness. The two pathways were a comparative study of Minnesota with 10 other states, and a grassroots study of Minnesota's distinctive biobusiness technology capabilities.

Comparative Study

The first pathway was a comparative study of Minnesota against 10 other states. The objective of this study was to compare Minnesota's biobusiness performance measures to those key states that are targeting areas of economic development similar to Minnesota. This approach was designed to reveal how Minnesota is doing in relation to our competitors, where our relative position is strengthening or weakening, and how serious the threat of competition from other states might be.

The primary sources of data used in this study were the U.S. Census Bureau and the Minnesota Department of Employment and Economic Development. It is important to note that, because the U.S. Census Bureau does not include academic facilities in their data on biobusiness-related fields, the comparative study did not include the biobusiness technology capabilities of the state contained in the academic and not-for-profit organizations. It focused only on private-sector industry organizations. The academic and not-for-profit organizations were covered in the grassroots study.

Findings of the Comparative Study

Utilizing the most recent Economic Census data from the U.S. Bureau of the Census for the two most recent surveys, 1997 and 2002, we assessed three areas: Minnesota's overall biobusiness technology industry and two subcategories of the biobusiness technology industry: medical devices and R&D in the life sciences.

Since the Economic Census data are published only every five years, we also produced estimates of Minnesota's biobusiness technology industry from 2002 to 2005, using data from the Quarterly Census of Employment and Wages (QCEW) provided by the U.S. Department of Labor (these data are sometimes also called the "ES-202 series" data). Because the QCEW data are not categorized in sufficiently fine detail to properly represent all the biobusiness technology sectors, we relied primarily upon the U.S. Economic Census data (which use finer categories) for the majority of our analysis.

Overview of the Biobusiness Technology Industry

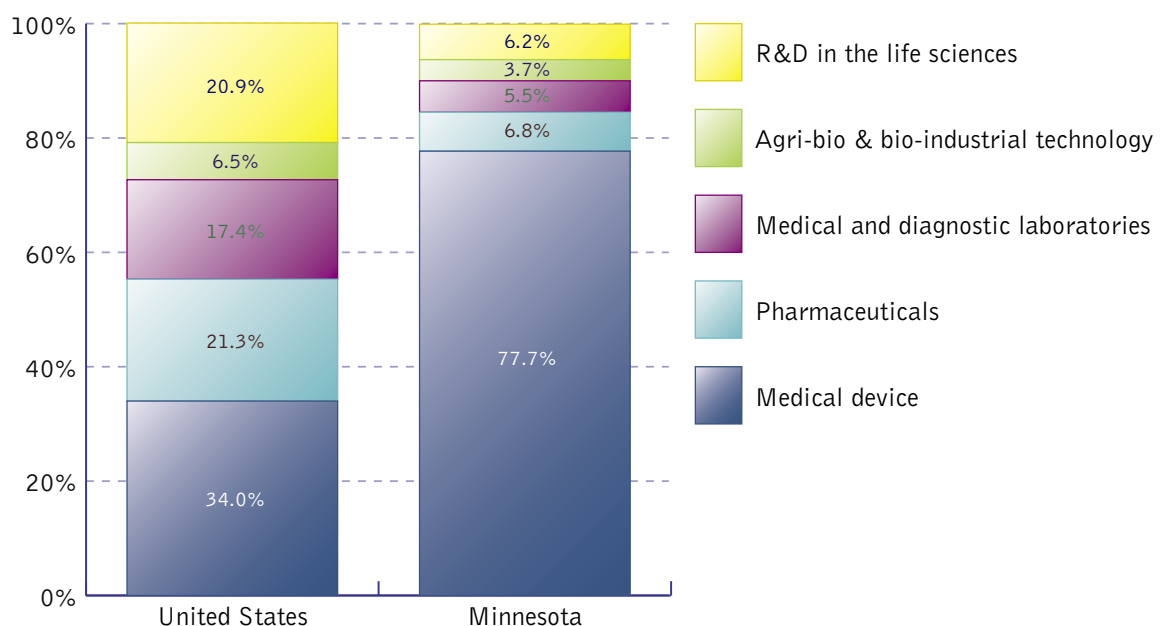
Biobusiness technology is the "macro" biobusiness technology industry category. It incorporates all five subcategories, including the two already mentioned (medical devices and R&D in the life



sciences). The other categories that we did not analyze in-depth — due to restrictions of time and space or due to problems with the quality of available data — include pharmaceuticals, agri-bio & bio-industrial technology and medical & diagnostic laboratories. We hope that these additional areas may be analyzed in the future.

Minnesota's biobusiness industry is competitive in the macro biobusiness technology category. However, there are areas of concern. For example, Minnesota's national share of paid biobusiness technology employees dropped 1 percentage point between 1997 and 2002 (from 3.43 percent to 2.41 percent, respectively).

Executive Summary: Figure 1. Percentage of Employment in Each Field of Biobusiness Technology, 2002

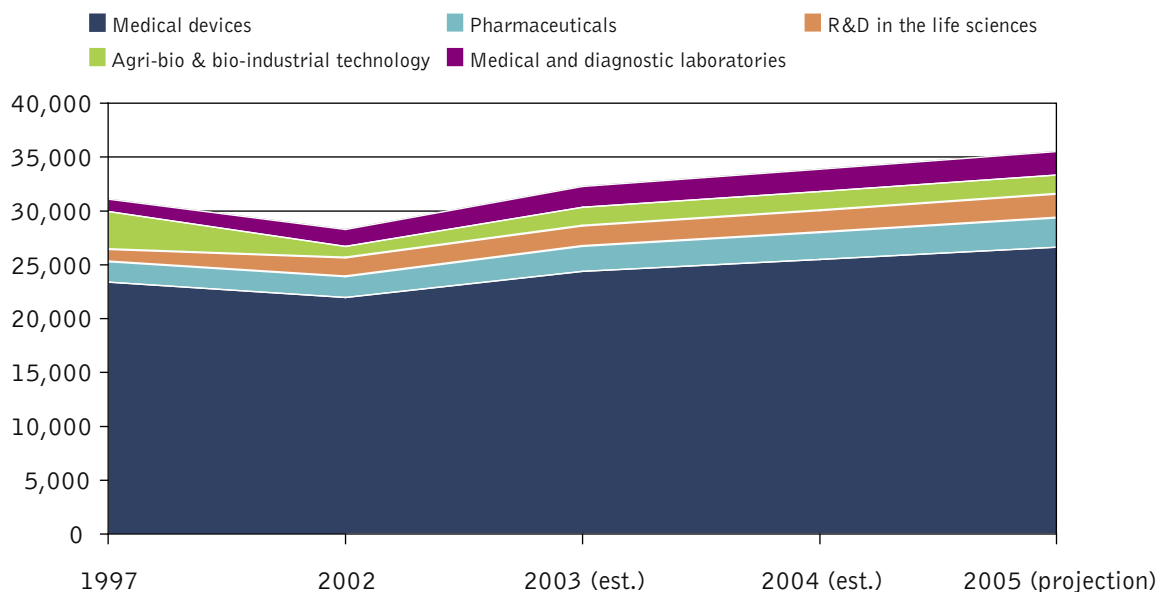


Minnesota's economy is more heavily oriented toward biobusiness technology employment than is the economy of the country as a whole, with 1.33 percent of our workforce employed in biobusiness technology, compared with 1.07 percent for the nation as a whole. Our state's future employment prospects are, therefore, more dependent than other states on what happens to its biobusiness sector. As the above chart (Executive Summary: Figure 1) demonstrates, the portion of biobusiness technology workers employed in the medical device industry is about twice as large in Minnesota as in the nation as a whole.

As illustrated in the following chart (Executive Summary: Figure 2), which depicts Minnesota's biobusiness technology employment over the eight years from 1997 to 2005, the heavy emphasis on medical devices here has remained resilient over time.



Executive Summary: Figure 2. Biobusiness Technology Industries in Minnesota, Total Number of Employed People, 1997-2005



For the biobusiness technology industry as a whole, when compared with other states, Minnesota holds a respectable, but not stellar, position. The state is slightly stronger than average in generating employment, revenue and payroll, and slightly weaker than average in generating enterprises. Thus, Minnesota is less entrepreneurial in biobusiness technology than other states, even if its overall economic performance in the industry is competitive. Overall, our findings show that when the figures are weighted to take into account the relative size of the economy of each state, and the overall level of the biobusiness technology industry at the national level, Minnesota performs only slightly better than one would expect.

Overview of Medical Devices

Minnesota is a major international player in the medical device industry. Within the United States, Minnesota and Massachusetts were roughly equal in employment numbers, second only to California. In 2002, almost 22,000 employees, or 78 percent of Minnesota's biobusiness technology employees, worked in the medical device industry.

When it comes to creating business activity based on medical devices, Minnesota is solid, being home in 2002 to 2.6 percent of the nation's medical device establishments and 5.5 percent of the nation's medical device employees. Minnesota shines even more brightly as a very competitive location when the data on the medical device industry are weighted to take into account the relative sizes of the economies of each state.

Although still a leader in the medical device sector, not all of the news is good. Minnesota lost jobs in the medical device industry from 1997 to 2002, during a period when most of its competitors



were gaining jobs in the field. Our share of medical device jobs dropped almost 1 percentage point, down from 6.45 percent in 1997. During this same period, our state's relative strength in generating jobs and enterprises in medical devices declined. Additionally, we are lagging in medical device entrepreneurship (density of company generation) in comparison to many of the other states studied.

Overview of R&D in the Life Sciences

Taking some liberty to simplify the definition, this industry category is most easily defined as “core biotechnology R&D,” including enterprises “primarily engaged in conducting research and experimental development in medicine, health, biology, botany, biotechnology, agriculture, fisheries, forests, pharmacy, and other life sciences including veterinary sciences” (U.S. Census Bureau, North American Industrial Classification definition). Because this category represents core knowledge and technology, we consider this to be a foundational category for future high growth itself and a core area of convergence with medical devices. Due to the way that industry data is classified by the U.S. government (the NAICS system), this industry category includes only companies that engage primarily in R&D activities, not those engaged primarily in manufacturing activities.

In contrast with its historical leadership role in the medical device industry, Minnesota is not a leading employer in this category. Of the 11 comparison states (chosen because of their peer status in terms of economic development ambitions vis-à-vis biobusiness), only Iowa and Utah exhibit smaller absolute employment levels than Minnesota. While Minnesota did increase its employment in this field between 1997 and 2002, both Iowa and Utah showed significantly larger growth rates than Minnesota. Simply put, Minnesota is improving, but is starting from a small base, and is growing more slowly than the competition. Since start-up companies tend to remain and grow in the place where they are founded, this is a salient indicator of the future biobusiness technology sector in Minnesota.

Overview of Agri-bio and Bio-industrial Technology

Agri-bio and bio-industrial technology is technology directed primarily toward applications of biological systems outside the human body. Agri-bio and bio-industrial technology may incorporate technical means from any field of technology, including biotechnology, but it must be directed toward applications in living systems or biology-related contexts. Examples would include controlled fermentation systems for the food or energy industries, or advanced biomaterials production systems.

There is no standard industrial classification that the U.S. Census Bureau has adopted for this general domain of biobusiness. The quality and comprehensiveness of the data published on agri-bio and bio-industrial technology as part of the U.S. Economic Census — which are drawn from a disparate set of subcategories — are uneven; so while they have been included as part of the



aggregated data for the whole biobusiness technology sector, they are not separately presented here.

Ethanol production is the one area of these industries where strong, comparative data were available. For farmer-owned ethanol production, Minnesota is an extraordinarily strong performer, second only to Iowa. Our state's annual production value now approaches an estimated \$1 billion.

Many interesting conclusions were drawn from the grassroots assessment regarding these sectors, and the BioBusiness Alliance of Minnesota has identified this area as a target for future work. Because of the challenges outlined, the BioBusiness Alliance is actively working to ensure that future comparative studies will have access to better developed data sets for this critical industry area.

Grassroots Study

The second pathway we followed in our assessment project was a grassroots study that aimed to identify the technological strengths and weaknesses of the state. We believe that understanding the skills and capabilities of the technologies our biobusiness technology enterprises (BTEs) have mastered today, or are developing for the future, will give us a picture of where Minnesota is heading in biobusiness. This information will help us to understand where we are investing and will allow a comparison to the picture of where we believe the future of our industries lies. The fundamental goal of this exercise is to give our state the strongest foundation to be able to retain and create biobusiness enterprises and biobusiness jobs.

To accomplish this task, we conducted a comprehensive census of all biobusiness technology enterprises and a detailed study that involved contacting each enterprise identified in the census. This detailed study identified the core technologies and products which Minnesota companies are involved in producing, the markets in which they are selling and where the academic sector is focusing its research. Unlike the comparative study, the grassroots study focused on **both for-profit and not-for-profit organizations, in both the academic and industry sectors**. The source of this information was direct contact with companies, academic institutions and other organizations, using questionnaires, telephone interviews, and face-to-face interviews. Due to their nature, much of these data are confidential and are presented in an aggregated format to protect the identity of participants.

To categorize the results of the census and detailed study, we adopted and modified the color biotechnology classification system originally developed by EuropaBio. The modified EuropaBio and Minnesota combined approach defines the following classifications of technologies in the form of biobusiness categories:

- **White biobusiness technology** is biobusiness focused on the application of biological technology in industrial fields such as biomaterials, bioprocessing, bioenergy, bio-based chemicals, food ingredients and bioremediation. This field of biobusiness is sometimes called “bio-industrial technology.”



- **Green biobusiness technology** is biobusiness focused on the application of biological technology in the field of plants and agriculture. This field of biobusiness is sometimes called “agri-bio technology.”
- **Red biobusiness technology** is biobusiness focused on the application of technology in the biological domains of human health and veterinary medicine. It includes medical devices, pharmaceuticals and complex medical technology systems. This field of biobusiness is sometimes called “medical technology” or “human health technology” (as shorthand for both human and animal medical technology).
- **Blue biobusiness technology** is biobusiness focused on the application of biological technology in aquatic contexts. It includes aquaculture, biotechnology-enhanced environmental remediation in both freshwater and oceanic settings, and other water-related bioscience-based economic activities.

Census

The census identified 425 Minnesota biobusiness technology enterprises (BTEs), which are enterprises devoted to the development and/or commercialization of bioscience or bioscience-related technologies, products, or services. A critical outcome of this phase was generation of the most comprehensive list of Minnesota’s biobusiness technology industry to date.

The BioBusiness Alliance of Minnesota has developed a database of this information that will be maintained to track the industry. This database has basic descriptors about each BTE, including organization name, location, contact detail, enterprise description and activities, primary field of technology and primary mode of activity.

Detailed Study

Once the census was completed, a questionnaire was mailed to all BTEs, and many organizations were also contacted directly by telephone, face-to-face interview and other means. The questionnaire was focused on understanding the core technologies, products and markets in which the BTE is currently active, and also where it expects its future focus to be. Through this direct interaction with BTEs, we were able to collect data to develop a macro view of Minnesota’s technological strengths.

As a result of this survey, three fascinating features of Minnesota’s biobusiness sector were revealed. First, the vast majority (about 93 percent) of Minnesota’s biobusiness technology enterprises are oriented in one way or another toward red biobusiness (i.e., health care technology/medicine); and a significant majority (almost two-thirds) are oriented exclusively toward red biobusiness. Second, over a quarter of the enterprises in the sample (about 27 percent) are active in multiple fields of biobusiness. In other words, over a quarter are involved in some kind of biobusiness industry



convergence. Third, of the enterprises active in white biobusiness and green biobusiness (just over one third of the sample), 78 percent are also active in red biobusiness. The implications of this third discovery are profound. In short, it appears that the future prospects of non-medical biobusiness and medical biobusiness in Minnesota are interlinked.

This last topic — **the interconnectedness of different fields of biobusiness in Minnesota** — will be a pivotal theme for subsequent work of the BioBusiness Alliance of Minnesota. In coming months, further analysis of the data produced in this project will be conducted to identify important sectors in which Minnesota can best focus resources to succeed.

Conclusions

Our two parallel, yet distinctly different, analyses of Minnesota's biobusiness economy yielded some results that we fully expected to affirm and others that could only have been revealed through the process of conducting the assessment. This assessment is prompting immediate action steps based on the findings of the report. We anticipate that ongoing action steps will be suggested as the data continues to be analyzed. Based on our understanding of the data today, our key conclusions include:

Minnesota's economy is more dependent upon biobusiness than other states. Minnesota's economy is 24 percent more dependent upon biobusiness technology, vis-à-vis employment, than is the norm for the whole of the United States. There is more at stake for Minnesota, as the emerging biobusiness economy unfolds, than is the case for the rest of the country. What we do to nurture this sector of employment and to strengthen it against competition matters for the citizens of our state.

Minnesota's biobusiness sector is distinctive. Biobusiness in Minnesota is not merely a microcosm of the biobusiness sector of the United States. It has unique characteristics that need to be cultivated for distinctive and sustainable competitive advantage. For example, medical devices account for a greater share of biobusiness technology in Minnesota than they do for the United States as a whole. In addition, Minnesota's biobusiness technology sector is much more prominent in bioenergy than is the case for other states. Minnesota needs strategies and policies designed to enhance our state's distinctive biobusiness technology profile.

Minnesota's emerging biobusiness sectors exhibit high levels of convergence with established biobusiness sectors. Organizations in Minnesota engaged in biobusiness — whether for-profit companies, not-for-profit institutes or units of universities, hospitals or for-profit companies — are often active in multiple fields simultaneously, stretching across conventional market and product categories. The proportion of Minnesota's enterprises engaged in the application of biological technology in the fields of plants and agriculture, or in industrial fields such as biomaterials, bioprocessing, bio-based chemicals, food ingredients, or bioremediation, that are also engaged in the general area of medical technology, or human health technology, is substantial.



The future of Minnesota's health care (red) biobusiness sector is interdependent with the future health of Minnesota's agri-bio (green) and bio-industrial (white) biobusiness sectors. The future competitiveness of biobusiness in Minnesota requires cooperation between stakeholders in the different biobusiness sectors. The fact that there are underlying technologies and fields of science that transcend multiple biobusiness fields is one of the reasons for the interdependence of Minnesota's biobusiness sectors.

Minnesota's biobusiness sector is growing. Despite problems faced by the state between 1997 and 2002, in the face of competition from elsewhere, the overall biobusiness sector is growing. Over 7,000 new biobusiness jobs are estimated to appear to have been created in Minnesota since 2002. This growth generates opportunities to capitalize on the interplay that already appears to have emerged between the various fields of biobusiness in the state. It also provides hope that the unusually high contribution of biobusiness to the economy of Minnesota (compared with the economies of other states) may be sustained, as long as the threats posed by the growth of biobusiness elsewhere are addressed.

Minnesota's competitive position is under threat due to heavy biobusiness investment and growth in other states. Despite growth in biobusiness overall in recent years, Minnesota's current competitiveness is under threat as other states invest heavily, aggressively and creatively in developing their own biobusiness industries. Our state needs to act strategically and decisively to maintain a competitive position in biobusiness in future years

The health of Minnesota's economy will be affected by whether or not the competitiveness of the state's biobusiness sector can be strengthened. Minnesota's economy is more dependent on biobusiness than are the economies of most other states in the United States, and biobusiness in Minnesota is facing serious competitive threats from elsewhere. This means that strengthening the biobusiness sector matters for the citizens of our state. Given that the average wage in the biobusiness / biosciences sector is about 165 percent of the average private sector wage in the United States, and every new bioscience job results in the creation of an additional 5.7 jobs, the positive benefits to the citizens of Minnesota from strengthening biobusiness will be amplified disproportionately throughout the state's economy.¹

We are optimistic. The dynamism, uniqueness and recent continued growth of the employment and business activity in our state's biobusiness technology sector provides solid grounds for hope that the necessary steps can be taken to sustain Minnesota as a global player in a handful of biobusiness fields where we can truly be among the best of the best.

¹These two items of economic data are taken from the following source: Battelle Technology Partnership Practice and SSTI, Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006 (Columbus, OH: Battelle Memorial Institute, April 2006).





Acknowledgements



First, and foremost, we wish to extend a special thank you to funders with the foresight and commitment to make this assessment happen: the University of Minnesota (Office of the President, Academic Health Center and Office of the Vice President for Research), the Minnesota Department of Employment and Economic Development and the Minnesota Department of Agriculture.

We also would like to express our most sincere gratitude to the dedicated team of people who worked so long and hard over the last year to assess the state of biobusiness technology in Minnesota. This assessment could not have been completed without the leadership and participation of volunteers throughout the process.

We wish to extend our appreciation to the entire BioBusiness Alliance Board of Directors:

Doug Cameron	Dave Melin
Mitch Davis	Tim Mulcahy
Mark DuVal	Gail O’Kane
Ray Frost	Lynne Osterman
Donald Gerhardt	J. David Prince
Gene Goddard	Christopher Puto
Jennifer Kuzma	Ken Stabler
Tim Laske	Dale Wahlstrom, Chair
Kurt Markham	Eric Wieben

We also wish to extend our appreciation to a team of volunteers who participated in numerous different ways during the Assessment:

Bonnie Holte Bennett	Ruth Lane
Pete Bianco	William McGinnis
Kit Borgman	Patricia Neuman
Kathleen Crandall	Douglas Petty
Jessica Deegan	Sara Thurin Rollin
Bob Elde	Dick Sommerstad
William Hoffman	Marc von Keitz
Bob Isaacson	Jill Zullo
Jennifer Kocs	



Additionally, we would like to thank Robert Butterbrodt for staffing assistance during a key part of the project.

Last, it is with great appreciation that we call attention to the three people without whose support, insights and leadership this project would not have happened:

Dale Wahlstrom – for his leadership as Chairman in the creation of the BioBusiness Alliance, and his strong support and involvement throughout the Statewide Assessment process.

Jeremy Lenz – as the staff person for the Statewide Assessment project, who was intricately involved from pre-inception through completion.

Gail O’Kane – whose insights and participation have greatly enriched the outcomes of this report.

Vincent Ruane and Kelvin Willoughby



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Introduction

This report summarizes the results of a yearlong project conducted by the BioBusiness Alliance of Minnesota to provide a baseline assessment of the technology-related capabilities of Minnesota in biobusiness. It will form the basis for developing a future strategy to help Minnesota remain or become a globally competitive leader in several fields of biobusiness. Additionally, the report will outline steps for developing a robust engine for state economic development across the whole biobusiness sector. This is the first known statewide, comprehensive assessment of Minnesota's biobusiness technology industry and provides Minnesota's leadership with a "line in the sand" against which to benchmark this tremendously important industry.

The project was directed by the Board of Directors of the BioBusiness Alliance of Minnesota, chaired by Dale Wahlstrom. The assessment project was co-chaired by Kelvin W. Willoughby, W. R. Sweatt, chair in the Management of Technology, at the University of Minnesota, and Vincent Ruane, retired vice president of 3M. Jeremy Lenz carried the responsibilities of project executive throughout the whole process. The assessment project team included a wide variety of citizens of Minnesota who gave generously of their time, knowledge and wisdom throughout the project. They are recognized individually in the acknowledgements section of the report.

The report begins by putting our work within the context of the broad goals with which we commenced the project, followed by a description of the philosophy we followed as we developed a methodology for the project execution consistent with those goals. We also devoted significant effort toward carefully defining the various technological, business and organizational dimensions of biobusiness on which our inquiries have been centered. The report includes a section devoted to articulating these definitions.

Following the above introductory material, the report then provides a basic profile of the size and scope of the biobusiness technology sector in Minnesota. This profile is followed by presentation of the results of two separate detailed assessment exercises. The first was a comparative analysis of the competitiveness of Minnesota and 10 other U.S. states known to be active in various technological fields of biobusiness. The analysis was conducted using standardized data produced by the U.S. Census Bureau from its periodic economic surveys and from related surveys of non-employer establishments in the United States.

The second exercise consisted of an original grassroots census aimed at identifying the biobusiness technology enterprises in Minnesota, and then conducting a detailed original survey of the enterprises in an attempt to map the underlying technological capabilities of the state in biobusiness.



After presenting the results of the two separate assessment exercises, the report concludes by arguing that while Minnesota's biobusiness sector is substantial, dynamic, distinctive and strong, it faces significant competition from other communities, both in the United States and elsewhere, that threatens to undermine our state's position in biobusiness. To thrive economically in this environment, Minnesota must immediately begin to develop and implement new strategies that promote growth of the biobusiness technology sector.

The general conclusions of the report are followed by an outline of some of the practical initiatives being undertaken by the BioBusiness Alliance to develop a robust strategy for Minnesota's competitive future in biobusiness.



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Goals of the Project

The objectives of the BioBusiness Alliance of Minnesota are to provide clarity to help our research institutions target research, our legislators target investments and policy needs, our educators to develop curriculum, our investment community increase its confidence in Minnesota's business development capability, and our businesses grow and create jobs for the citizens of the state. Our efforts to pursue these objectives began with accurately assessing the capabilities of biobusiness in Minnesota through this Statewide Assessment project.

The project was designed to assess Minnesota's capabilities and uncover the emerging technology-related opportunities of the state in the human health, agri-bio and bio-industrial sectors. The ultimate goal of the project was to identify specific and distinctive biobusiness categories in which Minnesota could compete as one of three to five global centers of excellence. This goal required a dual approach of looking inward, to discern the truth about Minnesota's biobusiness capabilities, and looking outward, to discern the position of the state compared with the rest of the United States, and eventually, the rest of the world.

The project also was designed to engage a wide range of players and stakeholders concerned with Minnesota's biobusiness sector, including those from small firms, large corporations, not-for-profit organizations, universities, hospitals and government. In addition, the project sought to be comprehensive in its scope, covering all regions of the state (both rural and metropolitan), and all industry groups (including agriculture, food, bioprocessing, biomaterials, biotechnology research, medical devices, pharmaceuticals and health-care technology more generally). The intention was not only to generate knowledge to assist Minnesota in developing successful strategies for the future, but also to engage stakeholders in a conversation that would help build and strengthen the state's biobusiness community for action.





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Our Philosophy

Our overall approach to this project has been guided by our conviction that a “me too” strategy for Minnesota, driven by a desire to emulate other leading bioscience states, will not serve our fellow citizens or our state’s economy well. Rather, we have been inspired by empirical and anecdotal evidence that Minnesota companies and institutions have extraordinary technological strengths that, when used in combination, can form new, distinctive, leading technologies that can be commercialized worldwide. We have been guided in our work by the idea that Minnesota should find a way to build on our strengths in agricultural technology and medical devices to stand apart from the crowd, in the world of biobusiness, both nationally and internationally.

Some believe Minnesota has waited too long to invest heavily in the life sciences, or in biobusiness more generally, and that the state can no longer hope to compete with California or Massachusetts or North Carolina or Washington ... or Japan or Singapore or India. In other words, some say the “biobusiness train” has already left the station.”

We have two thoughts about this notion. First, there are areas of biobusiness in which it would not make sense for us to compete. We have some distinctive strengths that will enable us to compete in areas where we choose to focus. We are already a mega cluster in medical devices. We are a recognized global leader in renewable fuels, and for that matter, agriculture and food production in general. We also have a strong high-technology sector to provide a base for competition. Minnesota does not need to compete with every biobusiness cluster in the world. If Minnesota’s biobusiness leaders develop and adhere to a plan of relentlessly pursuing *distinctive* technologies individually, or in combination, the state can define the areas where it can compete with the best of the best. We can develop our own “railroad tracks.” In other words, we can dominate the areas in which we choose to focus!

Second, we suggest that it is a deeply flawed assumption to believe that the life sciences related industries are on a clearly defined “right of way.” In many biobusiness segments (particularly at points of convergence between traditionally independent technologies) we are at the “identification and definition” stage ... there are no railroad tracks, no stations and no predetermined rights-of-way. Now we must determine what the emerging bioscience/biotech-based biobusinesses will mean to our existing capabilities. We will need to define, plan and finance our own rail lines, lay our own tracks, build our own stations and transport our own goods to market. Nobody else will do it for us, and we cannot rely upon our competitors’ established rail lines for our own access to global biobusiness markets.

Our approach involves seeking to deliver true meaning to the term “converging technologies.” As we look across all segments of the biobusiness sector we find tangible examples of the need



to combine the best in the biological sciences, materials sciences, information technology and engineering. However, the needed collaboration to accomplish such convergence requires nurturing. Examples of emerging fields of convergence that may form the basis of Minnesota standing apart in global biobusiness include: the convergence of genomics and cardiovascular disease management to produce new cardiac disease management capabilities; the convergence of advanced computing with genetics and proteomics to produce new forms of individualized medicine; the convergence of agriculture and sophisticated bioprocessing techniques to produce new biofuels and bio-packaging materials; or, the convergence of pharmaceuticals with medical device capabilities and advanced materials to produce advanced combination devices. With the perspective of convergence in mind we have employed a somewhat distinctive dual methodology, explained below, for assessing the state's biobusiness capabilities.

Our study recognizes that Minnesota's biobusiness capabilities are distributed across a wide variety of enterprises that include R&D units inside universities, hospitals, and public-sector organizations, together with private-sector corporations and various other not-for-profit entities. Together these organizations form a community of biobusiness technology enterprises. In order to fully capitalize upon Minnesota's emerging biobusiness strengths it is necessary to identify and recognize the whole array of organizations in the state that make up the biobusiness "industry."



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Two Parallel and Complementary Assessment Pathways

We chose to pursue our goals for the statewide biobusiness technology assessment by following two complementary and parallel assessment pathways. The first is a comprehensive study that aims to “benchmark” Minnesota against 10 other states. The second aims to identify and understand the state’s local technological capabilities from the ground up. In effect, it aims to identify what “tools” (i.e., skills) we have in our toolbox, and then determine how these capabilities might be cultivated to create value to help Minnesota compete in the evolving global environment.

Comparative Assessment of Competitiveness

The first assessment pathway, the “benchmarking approach,” involves systematically comparing Minnesota with 10 other U.S. states to find out how competitive this state is nationwide in biobusiness. This comparative study can tell us how well we are doing vis-à-vis our competitors, whether our position is strengthening or weakening, and how serious the threat of competition from other states may or may not be. It tells us whether we can afford to continue with our current biobusiness strategies, or whether we need to reassess these strategies in the face of competitive threats from other states.

The benchmarking approach requires the use of standardized data sets based upon standardized industry categories and orthodox industry definitions. Without this, it is not possible to conduct reliable comparisons across regions or states. Uniformity of definitions, categories and data collection methodologies is a prerequisite for this kind of work. Typically, these conditions can only be met by using established publicly available industry databases that, for the most part, are assembled and maintained by public sector agencies such as the U.S. Census Bureau or the U.S. Bureau of Labor Statistics.

The vast majority of industry studies conducted for state governments, regional economic development organizations or industry associations are of this type. They have the advantage that they are replicable, easily understood, relatively simple to conduct and (in principle) comparable across regional and state boundaries.

Grassroots Assessment of Capabilities

While the benchmarking — or comparative competitiveness — approach to assessing biobusiness in a state has several advantages, it also has a number of disadvantages. To begin with, the



standardized data categories that are the hallmark of this approach reflect established and orthodox industry concepts and not the emerging industries and emerging technologies that typically form the foundation of future competition. They are well suited to documenting established competition, but they are not so well suited to predicting future competition. The standardized industry categories and industry databases typically enable abstract and high-level portrayals of regional economies, but do not allow for rich and deep characterizations of underlying technological capabilities and as-yet-poorly-defined emerging products and markets. In addition, part of the price of compiling relatively reliable standardized and nationwide industry databases is that by the time they are ready for public use they are typically already somewhat out of date.

The most important limitation of the standardized industry databases, however, is that they provide very little help in aiding states, such as Minnesota, to identify how to build a distinctive technological base for future economic development. The fulfillment of that goal requires a different approach — what we call the grassroots approach to industry analysis. It is an approach that focuses on understanding the technologies that underlie products and markets using freshly generated knowledge. It requires a rigorous grassroots approach to collecting data from local people and organizations that makes identifying linkages and areas of convergence between underlying technologies, and across industries, feasible.

Finally, the grassroots approach to assessing biobusiness technology capabilities in a state requires using a common language. It is critically important to employ nomenclature for industries and technologies that reveals, rather than obscures, the essential underlying truth about a region's emerging distinctive capabilities. The terminology employed in the standardized industry databases used in benchmarking studies reflects technologies that originated in a previous industrial era, not in the contemporary era of biobusiness.

We therefore decided to be very careful in our language and definitions as we approached our work. We wanted to ensure that we talked, and labeled what we discovered in a way that would highlight our state's distinctive strengths and allow us to properly articulate the specific and distinctive biobusiness categories in which Minnesota may compete as one of a handful of global centers of excellence. Our report therefore devotes some attention to outlining our guiding definitions and nomenclature.

In summary, our work in assessing Minnesota's biobusiness sector involves artfully balancing both a standardized comparative interstate industry assessment and a fresh grassroots assessment of our state's distinctive biobusiness capabilities.



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Basic Profile of Minnesota's Biobusiness Economy

Before providing key results from each of our two parallel biobusiness assessment exercises, it will be useful to provide an overall picture of Minnesota's biobusiness economy. However, let's begin with some definitions of the basic concepts that have undergirded our work. A full list of definitions and accompanying explanations is provided in Appendix 1.

Biobusiness is economic activity devoted to the development or commercialization of bioscience or bioscience-related technologies, products or services. In other words, biobusiness is technology-based economic activity that utilizes or is informed by biology.

Biobusiness deals with the spectrum of enterprises from start-ups to established firms, together with associated infrastructure and support services. In this project, however, we have left analysis of the associated infrastructure and support services (such as those provided by legal service firms, management consultants, marketing organizations, accountants, lobbyists, investors, regulatory affairs specialists, or specialized property developers) to another occasion. We have instead focused our analysis on a narrower set of enterprises: those whose primary business is the development or commercialization of what we have labeled as “biobusiness technology.”

Biobusiness technology is technology devoted to the biological domain, as either a system of tools or as a field of application.

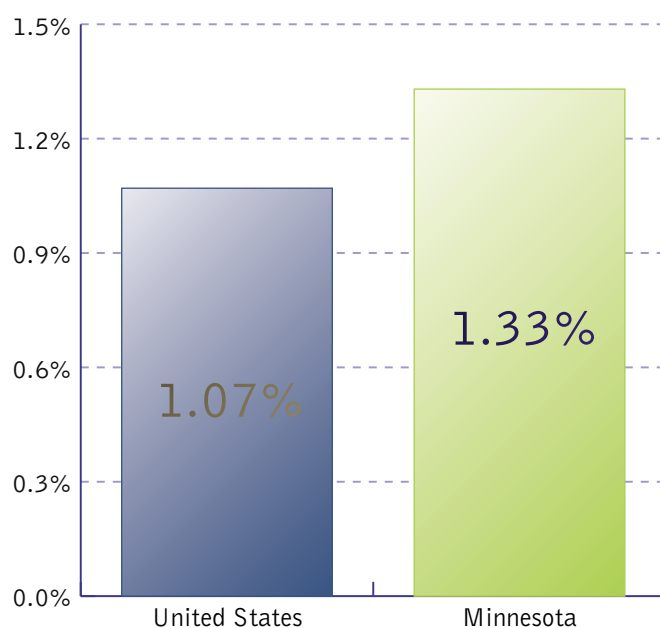
Put simply, biobusiness technology is technology focused on biology. It is the technological foundation of biobusiness. As explained further in Appendix 1, we group biobusiness technology into three broad and overlapping technological subdomains: biotechnology; human health technology; and agri-bio & bio-industrial technology. We call an organization whose business is based on any of these three domains a “biobusiness technology enterprise” (BTE).



By late 2002, the most recent year for which national data from the U.S. Economic Census is available, the biobusiness technology sector in the United States consisted of over 55,000 establishments, about 1.2 million paid employees, an aggregate annual payroll of over \$60 billion, and aggregate annual revenues of over \$330 billion.² The biobusiness technology sector in the U.S. is substantial. In addition, according to data from Battelle, average wages in the bioscience sector (at \$65,775 in 2004) were over \$26,000 greater than the average private-sector wage.³ Biobusiness technology is an important field of industry from the point of view of economic development.

As shown in Figure 1, Minnesota's economy is more heavily oriented toward biobusiness technology employment than is the economy of the whole country. This means that Minnesota's future employment prospects are more dependent than most other states on what happens to its biobusiness sector. In short, more is at stake for Minnesota in biobusiness than is the case for most other states.

Figure 1. Biobusiness Technology Employment as a Percentage of Employment in All Industries, 2002



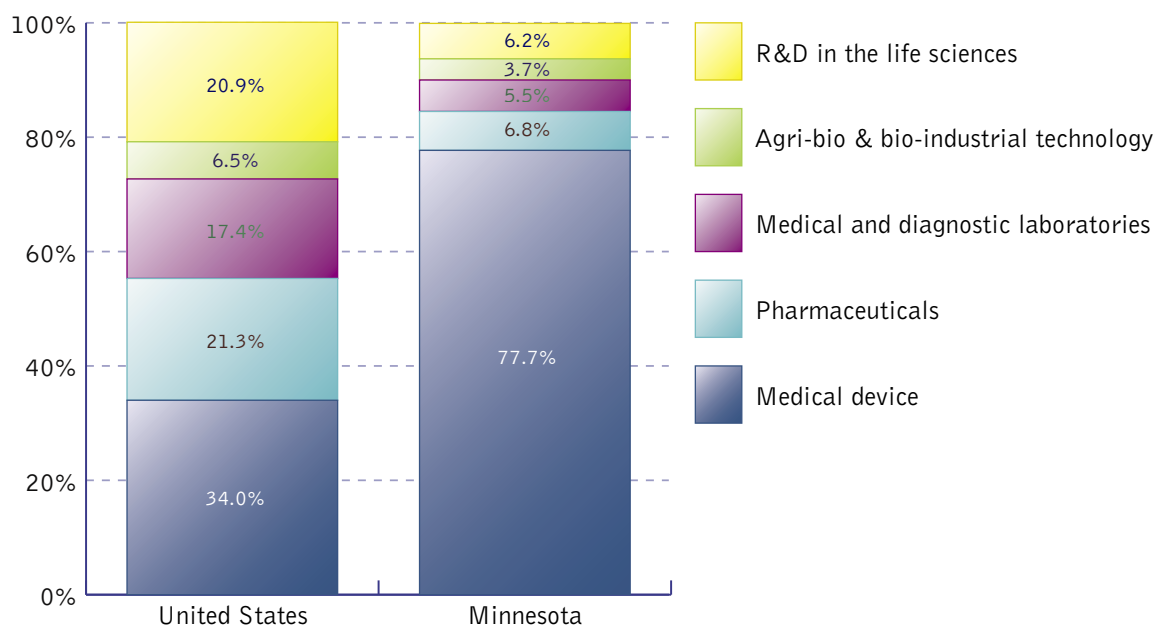
²These numbers were calculated by Dr. Kelvin Willoughby using data from the 2002 U.S. Economic Census of the U.S. Bureau of the Census, using a selection of industry categories listed in Appendix 2. The data used to construct Figures 1 and 2 were also drawn from that source. These data exclude employment inside universities, hospitals and other not-for-profit organizations involved in biobusiness. The grassroots assessment summarized later in this report includes those organizations.

³Battelle Technology Partnership Practice and SSTI, Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006 (Columbus, OH: Battelle Memorial Institute, April 2006).



As shown in Figure 2, Minnesota also has a distinctive biobusiness technology profile. Compared with the rest of the country, our state's biobusiness sector is heavily dependent upon the medical device segment. In fact, the percentage of biobusiness technology employment accounted for by the medical device segment is about twice as large in Minnesota as in the nation as a whole. The relationship (especially in areas of technological convergence) between the devices segment and other segments therefore seems to be salient for Minnesota, compared with other states.

Figure 2. Percentage of Employment in Each Field of Biobusiness Technology, 2002

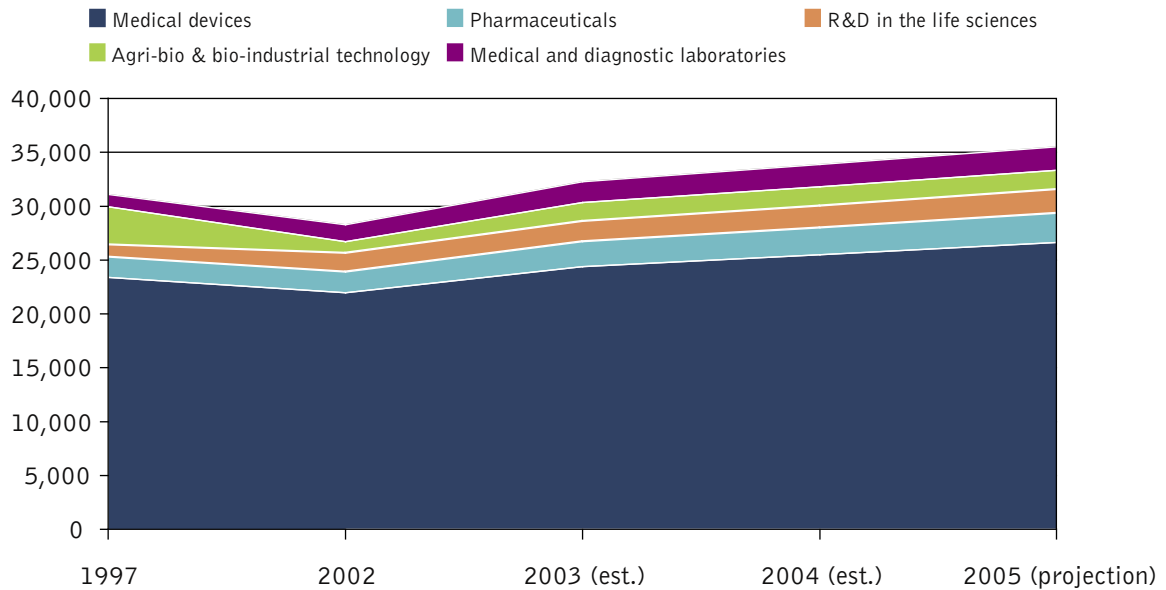


What about the absolute size of Minnesota's biobusiness technology sector? We have estimated that by the end of 2005 (see Figure 3) the state was home to more than 35,000 biobusiness technology employees, and that employment growth had taken place during each of the three preceding years. The state experienced a decline in biobusiness technology employment from 1997 to 2002 (the dates of the two most recent U.S. economic surveys). It also is estimated that those 35,000 biobusiness jobs were associated with over \$2.8 billion in payroll, spread over more than 500 enterprises in the state.⁴ It is worth noting that economic impact would be even greater if all biobusiness enterprises were taken into account, as opposed to solely including biobusiness technology enterprises, as we have done here for the purposes of the assessment.

⁴The numbers in Figure 3 for 2003 and 2004 are estimates produced by Dr. Kelvin Willoughby, based upon analysis of data from the Quarterly Census of Employment and Wages ("ES-202 series") produced by the Bureau of Labor Statistics in the U.S. Department of Labor, together with data from the 2002 U.S. Economic Census. Numbers for 2005 are projections based upon the estimates for 2003 and 2004.



Figure 3. Biobusiness Technology Industries in Minnesota, Total Number of Employed People, 1997-2005



Minnesota has a significant presence in biobusiness technology; and biobusiness technology plays a significant role in Minnesota's economy.



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Minnesota's Competitive Position in Biobusiness

Overview of Methodology and Data Sources

The publicly available data sources that are useful for conducting comparative industry competitiveness studies across the United States do not lend themselves very neatly to the analysis of biobusiness or, more particularly, biobusiness technology. The best that can be done is to select a group of industry categories that may act as an indirect proxy for biobusiness technology as defined and illustrated in Appendix 1.⁵

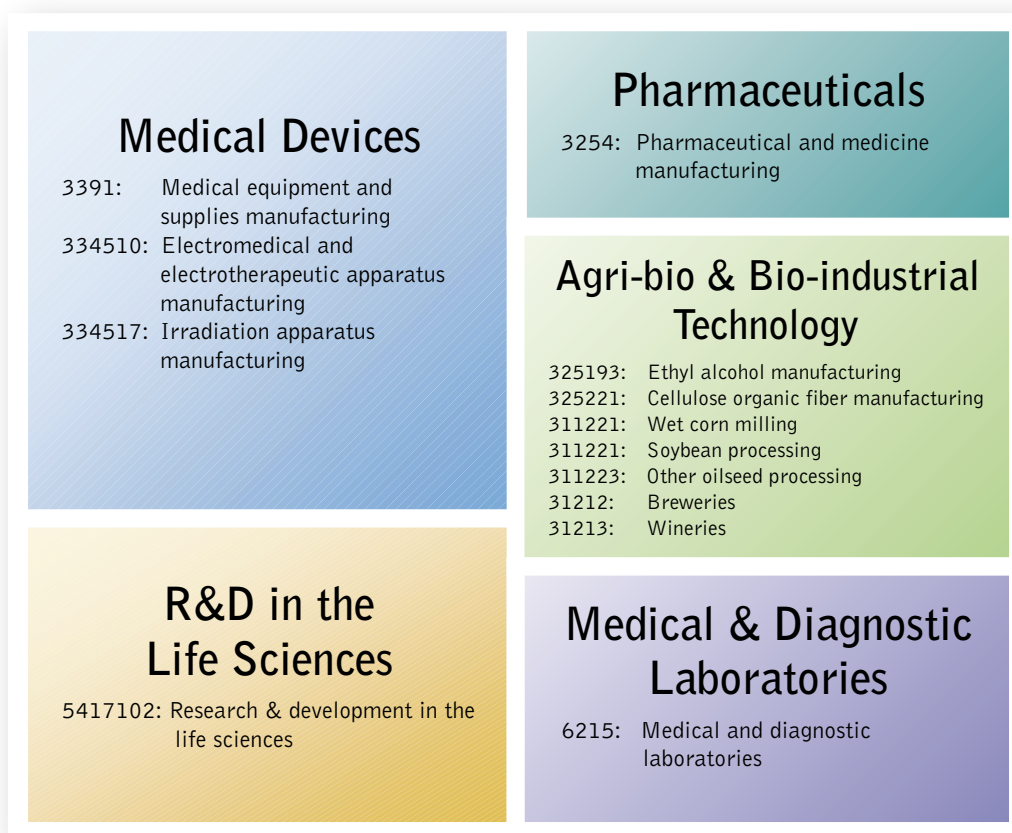
The primary data source that we have drawn upon for analysis of Minnesota's competitive position is the periodic Economic Census conducted by the U.S. Census Bureau, together with data from the various surveys of non-employers associated with the Economic Census. The Economic Census profiles American business every 5 years, from the national to the local level. The Economic Census is based on a new standard industrial classification system (the North American Industrial Classification System, NAICS), which was implemented for the first time in 1997. The most recent Economic Census data were generated in 2002.

The new NAICS categories are more suitable for mapping new science- and technology-based industries than were the old categories (based on Standard Industrial Classification, SIC, codes). Despite these much welcomed advances, the industry categories employed by the U.S. Census Bureau every five years in its economic surveys (formalized as the NAICS codes) do not fit neatly with the concept of a biobusiness technology industry. The NAICS codes tend, on the whole, to be based on product or market concepts; whereas the concept of the biobusiness technology industry (or industries) is based primarily on underlying technology concepts rather than product or market concepts. As a consequence, it is impossible to find a set of NAICS codes that corresponds exactly to the group of biological technology industries that we have labeled collectively as biobusiness technology industries.

⁵The research that provided the basis for this section of the report was conducted by Dr. Kelvin Willoughby during the spring of 2006.



Figure 4. Biobusiness Technology Industries (Map of NAICS-based categories)



Nevertheless, after careful study of the North American Industrial Classification System, we selected a group of NAICS codes to act as a rough approximation for the set of enterprises that together constitute the biobusiness technology sector. The results of our efforts are summarized in Figure 4. The categories shown here may be seen as a practical but inexact substitute for the biobusiness technology categories portrayed in Appendix 1. Data were collected and analyzed for each of the NAICS industry categories listed in Figure 4, covering both enterprises with paid employees and enterprises without paid employees, for both 1997 and 2002. Precise definitions of each industry group included in Figure 4 are provided in Appendix 2 at the end of this report. A systematic comparison between the NAICS categories employed in this report versus NAICS categories employed by analysts elsewhere is provided in Appendix 3.

In an effort to fit in as much as possible with assumptions and concepts embedded in the NAICS categories, biobusiness technology was subdivided into five sub-categories: medical devices, pharmaceuticals, R&D in the life sciences, agri-bio & bio-industrial technology, and medical & diagnostic laboratories.

The three combined categories of medical devices, pharmaceuticals and medical & diagnostic



laboratories illustrated in Figure 4 (themselves being aggregations of sub-collections of NAICS categories) are treated as a rough proxy for what is labeled as “human health technology” in Figure 34 in Appendix 1. The aggregated collection of NAICS categories labeled in Figure 4 as “agri-bio & bio-industrial technology” is treated as a rough proxy for the biobusiness technology category of the same name in Appendix 1 (Figure 34). The NAICS category in Figure 4 labeled as “R&D in the life sciences” is treated here as a rough proxy for the biobusiness technology category labeled in Appendix 1 (Figure 34) as “biotechnology.” The NAICS category called “R&D in the life sciences” actually includes a broader range of biology-related fields of R&D than biotechnology (strictly defined), some of which perhaps really belong in the category labeled as “agri-bio & bio-industrial technology” in Appendix 1 (Figure 34). However, given the limitations of the NAICS data sets, treating “R&D in the life sciences” as roughly equivalent to what most people think of as “biotechnology” is a reasonable compromise to help us deal with the realities of publicly available data sets.

The R&D in the life sciences category includes only R&D activities and not manufacturing activities. The official NAICS definition is: “Establishments primarily engaged in conducting research and experimental development in medicine, health, biology, botany, biotechnology, agriculture, fisheries, forests, pharmacy, and other life sciences including veterinary sciences.”⁶

The manufacturing components of biobusiness technology belong in a number of places. The medical device category and the pharmaceutical category are both manufacturing categories. In addition, the generic category labeled as “agri-bio & bio-industrial technology” is a manufacturing category. Enterprises devoted primarily to R&D activities in agri-bio and bio-industrial technology (vis-à-vis Figure 34) are included within the R&D in the life sciences category (in Figure 4). Food technology companies come mostly under the broad category of agri-bio & bio-industrial technology. In the cases where food firms are devoted primarily to research and development activities, they are classified within the R&D in the life sciences category (in Figure 4).⁷

⁶Of the two available official US federal data sources that employ NAICS categories — the Economic Census of the U.S. Bureau of the Census and the Quarterly Census of Employment and Wages (QCEW) of the U.S. Bureau of Labor Statistics — only the Economic Census drills down deep enough to identify establishments belonging to the NAICS “research & development in the life sciences” category. The QCEW data set does not differentiate between R&D in the life sciences and R&D in engineering and the physical sciences. Hence, the QCEW data source is not adequate for a thorough treatment of biobusiness technology industries.

⁷Note: The second phase of the Assessment Project (the grassroots phase) placed more emphasis on R&D-intensive enterprises than is the norm for enterprises included in the NAICS-based data from the Economic Census and from the QCEW data set.

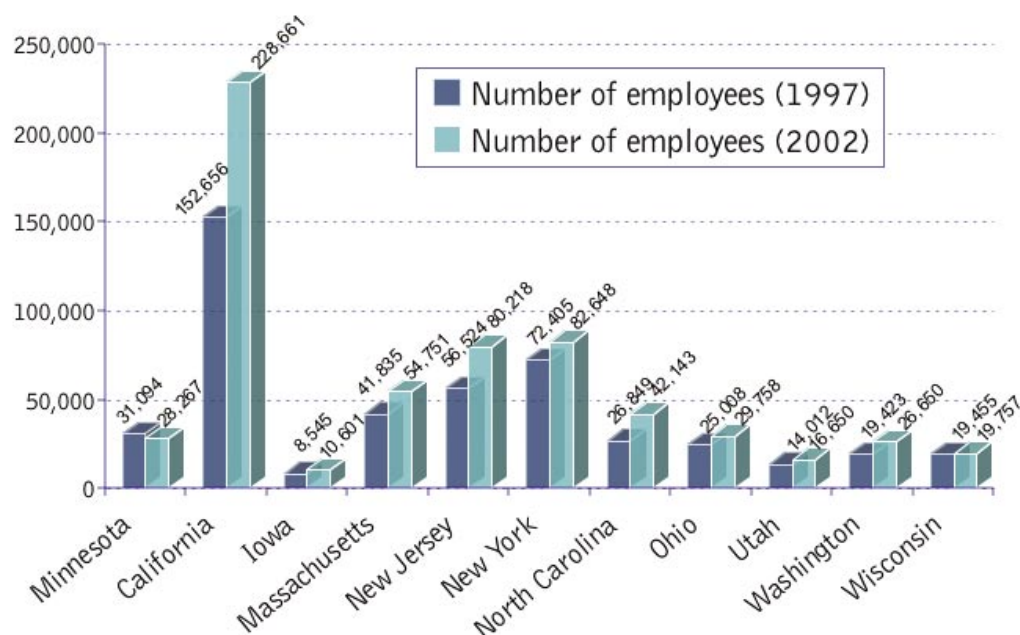


Having defined and illustrated what we mean by biobusiness technology (primarily business centered on biological technology), and having provided a basic profile of the biobusiness technology sector in Minnesota, it is appropriate now to review our state's competitive position alongside other important biobusiness states. The following sections of this report compare Minnesota with 10 other U.S. states that are widely regarded as prominent players in biobusiness technology, which are of interest because of similarities or differences they exhibit vis-à-vis biobusiness in Minnesota, or which are often considered by policy analysts and industry observers to be peer states of Minnesota. These 10 states are California, Iowa, Massachusetts, New Jersey, New York, North Carolina, Ohio, Utah, Washington and Wisconsin. This list is not meant to be exhaustive; it is intended to be useful for competitive analysis. The list also provides a wide spectrum of states, large and small, urban and rural, coastal and heartland, proximate to Minnesota and distant.⁸

Biobusiness Technology

Figure 5 plots the total employment level for biobusiness technology enterprises (defined using the NAICS codes as proxies) in Minnesota and the 10 other selected states. California clearly leads the nation in biobusiness technology, approaching a quarter of a million employees in biobusiness technology enterprises by 2002! Over 76,000 of these jobs were added during the preceding five years.

Figure 5. Employment, Biobusiness Technology Industries



⁸All of the calculations and figures reported in this section of the report dealing with Minnesota's competitive position were produced by Dr. Kelvin Willoughby drawing upon data from the 1997 and 2002 U.S. Economic Censuses.



California is followed in the distance by three states that are positioned in the second tier vis-à-vis biobusiness technology employment: New York, New Jersey and Massachusetts. Interestingly, these are the same states that dominate the second tier for employment in life sciences R&D, and also the second tier for employment in the medical device industry, with the exception of Minnesota. Minnesota is a dominant second-tier player in medical devices but currently a non-player in life sciences R&D.

A sobering observation for Minnesota is that Minnesota was the only state out of 11 that appeared to lose biobusiness technology industry employment during the five years from 1997 to 2002 (a decline from over 31,000 employees in 1997 to just over 28,000 employees by 2002). Fortunately for Minnesota, however, the state does appear to have recently reversed this negative trend (as suggested by the data presented in Figure 3). Nevertheless, by 2002 Ohio and North Carolina — which shared the third tier with Minnesota — were both ahead of Minnesota in total biobusiness technology industry employment ... and Washington was very close behind (and catching up).

Figure 6. Percentage of Total National Employment in Biobusiness Technology Industries

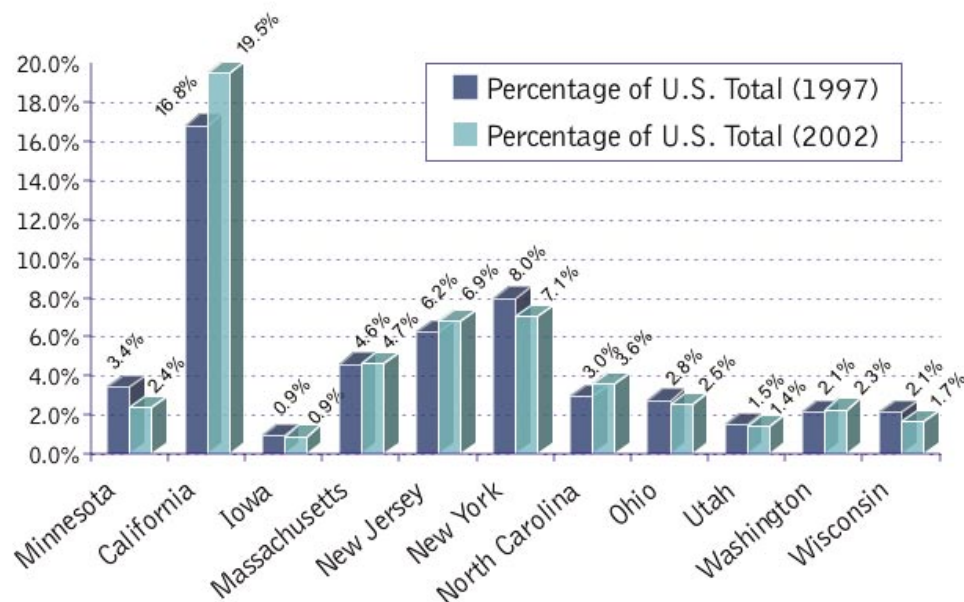


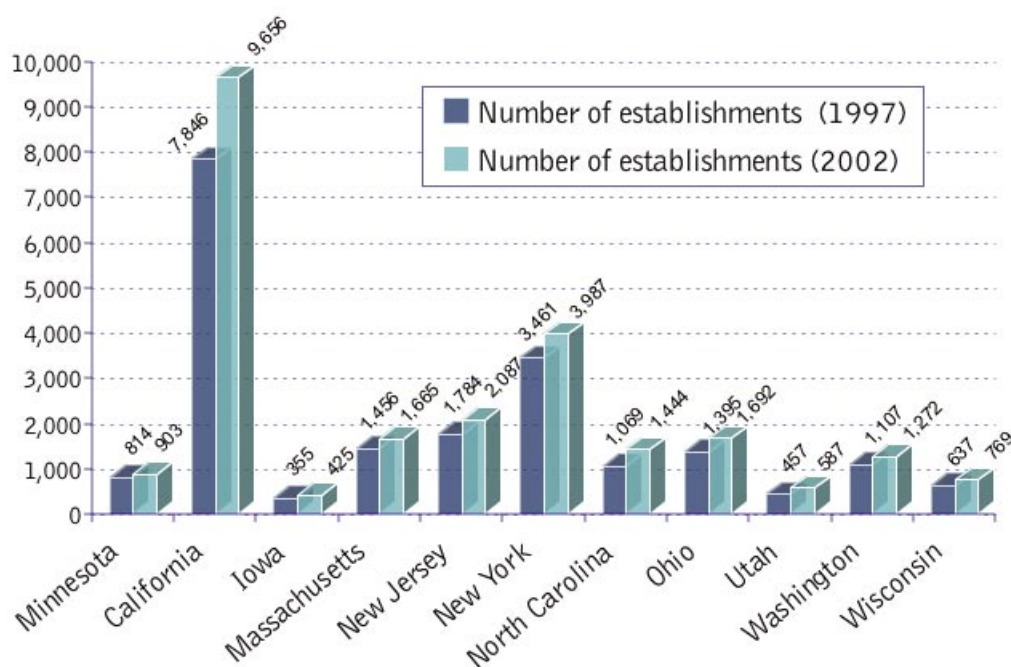
Figure 6 takes the same data that were used to construct Figure 5 but expresses them as a percentage of the national total, rather than as absolute employment numbers. The “national total” here refers to the total of the whole of the United States, not just the 11 comparison states that are the focus for our analysis. California once again is the overwhelming leader, and its employment share actually increased over five years, despite stiff competition from other states. Minnesota’s share of the national total dropped from 3.4 percent to 2.4 percent. Of the strong second-tier states, New Jersey managed to slightly increase its share of the national employment total. California managed to advance its relative position nationally despite its widely touted



“inhospitable business climate” (due to high real estate prices and high wages).

It also is important to examine the relative position of states in generating new biobusiness technology *companies*, in addition to total biobusiness technology *employment* — in other words, to analyze the relative *entrepreneurial propensities* of the states in biobusiness technology. Figure 7, which was produced for this purpose, reveals that Minnesota has performed better in the generation of biobusiness technology enterprises than it has for the generation of biobusiness technology employment. The number of biobusiness technology enterprises in Minnesota increased by almost 90 during the five years from 1997 to 2002; but unfortunately it remains fairly low on the list of competitor states. Out of the 11 comparison states, only Wisconsin, Utah and Iowa were home to fewer biobusiness technology enterprises than Minnesota by 2002.

Figure 7. Enterprises, Biobusiness Technology Industries



California led the pack yet again as the sole first-tier state, with almost 10,000 biobusiness technology enterprises by 2002, compared with 903 in Minnesota. New York stood apart as the sole second-tier state with almost 4,000 biobusiness technology enterprises in 2002. The third tier is more evenly spread out, with New Jersey, Massachusetts and Ohio appearing strong; and with Washington and North Carolina (each exhibiting significantly more than a thousand biobusiness technology enterprises) positioned not too far behind their peer third-tier states.

Besides these observations about the relative rankings of the 11 states, it is appropriate to observe that none of those states actually reduced their number of biobusiness technology enterprises during the five years ending 2002. All continued to create new enterprises, even if the increases



were marginal in some cases. **Biobusiness technology, as a broad domain, appears to be an area in which entrepreneurship continues steadily in all the states reviewed here.**

In the minds of some observers, California's extraordinary performance should be discounted because California is simply so large. It is therefore appropriate to conduct deeper analyses that take into account the relative size of the whole economy in each state, and that weights each state's contribution accordingly.

One way to do this is through what may be labeled generically as an "industry density index." An industry density index may be used as an indicator of the relative capacity of regions to generate a particular kind of industry. Each index tells you something about the regional strength of an industry, standardizing the figures to take into account differences in the scale of the economies in the regions (e.g., states) under consideration, the state of the industry in the larger region (e.g., nation, as the case may be), and the current state of the whole economy throughout the nation (or whatever reference region is used).

The indices take into account that, with all other things being equal, one would expect to find a large-scale industry (of a specified kind) in a large community, and a corresponding small-scale industry (of the same specified kind) in a small community. For example, you would expect to find more restaurants in Minneapolis-St. Paul than in Rochester, simply because of the larger population in the metropolitan area, but the fact that this was the case would not tell you if the restaurant industry was any more dominant or *strong* in the Twin Cities than in Rochester. Industry density indices enable fair comparisons between regions, standardizing for differences in the size of the regional economies.

The industry density indices are designed so that they always compute to 1.0 for the reference region. A region with an industry density index of less than 1.0 is less productive than would be expected as normal for generating activity in that particular industry; whereas a region with a score of above 1.0 has above-average strength in generating a local presence of the respective industry. Under certain assumptions, the indices may be used to suggest differences in the competitiveness of the regions under study.⁹

⁹In some academic disciplines, the particular kind of industry density index labeled in this Report as an "employment density index" is known as a "location quotient."



Industry density indices can be calculated for any industry, and may be based upon any standardized factor that is a reasonable indicator of the level of activity of a particular industry that occurs in multiple local regions within a larger reference region. Such standard factors may include employment, number of firms, level of revenue, payroll levels, the financial capital base of enterprises, or the size of intellectual property assets, among other things. A key requirement for calculating these indices is that uniform, standardized data must be available across the local regions of interest. Employment is typically the most useful, and robust, industry factor to be included in the calculations for these indices. Appendix 4 provides a detailed explanation of industry density indices.

The data assembled every five years by the U.S. Census Bureau, as part of its Economic Census, lend themselves extremely well to the calculation of industry density indices for industries located in the United States.

Figure 8. Employment Density Indices, Biobusiness Technology Industries

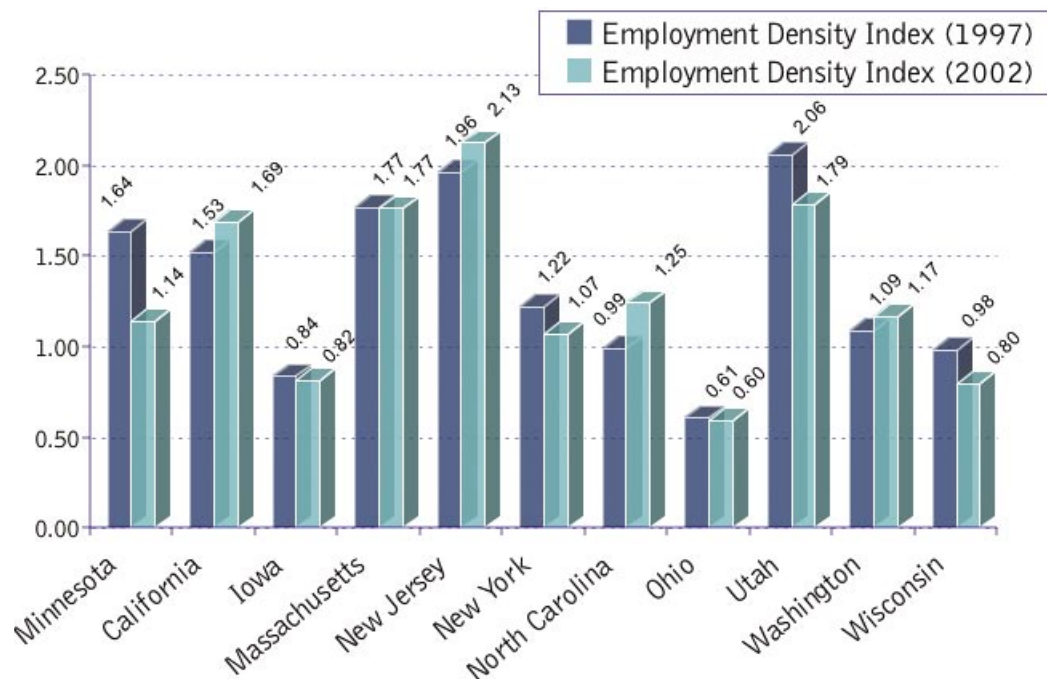


Figure 8 plots the biobusiness technology employment density indices for Minnesota and the 10 comparison states. **The good news for Minnesota is that, from the point of view of employment generation, it is one of the states exhibiting above-average levels of competitiveness (i.e., it scored an employment density index of greater than 1.0).** The competitive states, in descending order of strength in generating biobusiness technology jobs in 2002, are: New Jersey, Utah, Massachusetts, California, North Carolina, Washington, Minnesota, and New York. **The unsettling news for**



Minnesota, however, is that Minnesota's biobusiness technology employment density index actually dropped significantly, from 1.64 in 1997 to 1.14 in 2002, during a time when the majority of the 11 states increased their biobusiness technology employment density indices or remained steady. Minnesota's employment density index dropped more sharply than that of any other state.

We know from the estimates presented in Figure 3 that biobusiness technology employment levels in Minnesota have improved since 2002, and we anticipate that future research may also reveal an improvement in the corresponding employment density indices. The results presented here nevertheless point to the need for concerted effort by Minnesotans to improve the state's future competitiveness in the biobusiness technology industry.

Figure 9. Biobusiness Technology Industry Density Indices 2002

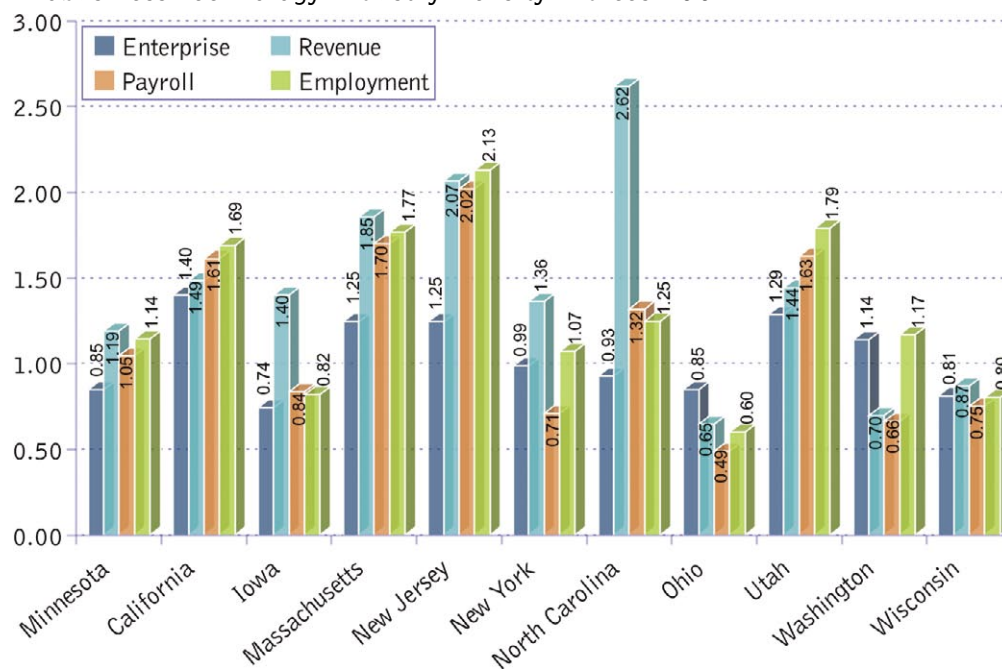


Figure 9 plots four different types of density indices for biobusiness technology enterprises for the 11 competitor states. The graph shows that not only does California lead in the absolute level of biobusiness technology entrepreneurship, but it also leads on a density basis, with an enterprise density index (i.e., industry density indices using enterprises rather than employment as the industry factor) of 1.4 in 2002. California has apparently earned its position, with above-average performance. The other competitive states (i.e., the states exhibiting biobusiness technology industry density indices greater than 1.0) are, in descending levels of competitiveness: Utah, New Jersey and Massachusetts (equal, 1.25), and Washington. Despite its commanding lead over other states (with the exception of California) in its total number of biobusiness technology jobs, New York's strength in generating biobusiness technology enterprises is about what one would expect, all things being equal. In other words, New York is about average, nationwide, in the generation of enterprises in this combined set of fields.



Minnesota's position as a generator of biobusiness technology enterprises is, according to Figure 9, below average (enterprise density index for 2002 = 0.85). Unfortunately, this lackluster performance has a further shadow cast over it by the fact that Minnesota's enterprise density index actually dropped over five years from its previous level of 0.91. This is not a precipitous decline, by any means, but it is a cause for concern.

Minnesota is competitive (i.e., exhibits above-average strength in generating activity in the biobusiness technology industry) from the point of view of employment, revenue and payroll, but has fallen behind in its strength in generating biobusiness technology enterprises.

When all four industry factors are used to calculate industry density indices for the whole biobusiness technology sector, some interesting results emerge. North Carolina is extraordinarily strong in generating revenue from biobusiness technology activities. New Jersey and Massachusetts follow next with aggregate financial performance that is, despite being lower than that of North Carolina (adjusted for the size of the economy), very impressive indeed. This evokes the question of whether the relatively high biobusiness technology competitiveness of these states might be amplified over time through internal reinvestment of their relatively high financial returns. An early lead, as expressed in high industry density indices, may become self-reinforcing over time. **This may be a challenge for Minnesota to address in the near future.**

Figure 9 reveals that only four out of 11 states (New Jersey, Utah, Massachusetts and California) have managed to achieve nationally competitive positions (i.e., industry density index scores of above 1.0) for all four industry factors (employment, enterprise, revenue, and payroll). These four states appear to exhibit relatively robust biobusiness technology competitiveness profiles.

Figure 9 also reveals that while Minnesota's competitiveness performance overall in the biobusiness technology is generally respectable (i.e., mixed, depending upon the factor, but about average overall, when all factors are taken into account), it is nevertheless one of the two states that managed to score three out of four industry density indices above 1.0 during 2002. The other was North Carolina. **This may be taken to imply that Minnesota has sufficient basic strength in biobusiness technology that, if it manages to develop and implement powerful and sophisticated strategies in the near future, it might be able to lift itself from a middling position to one of national prominence in the industry.**

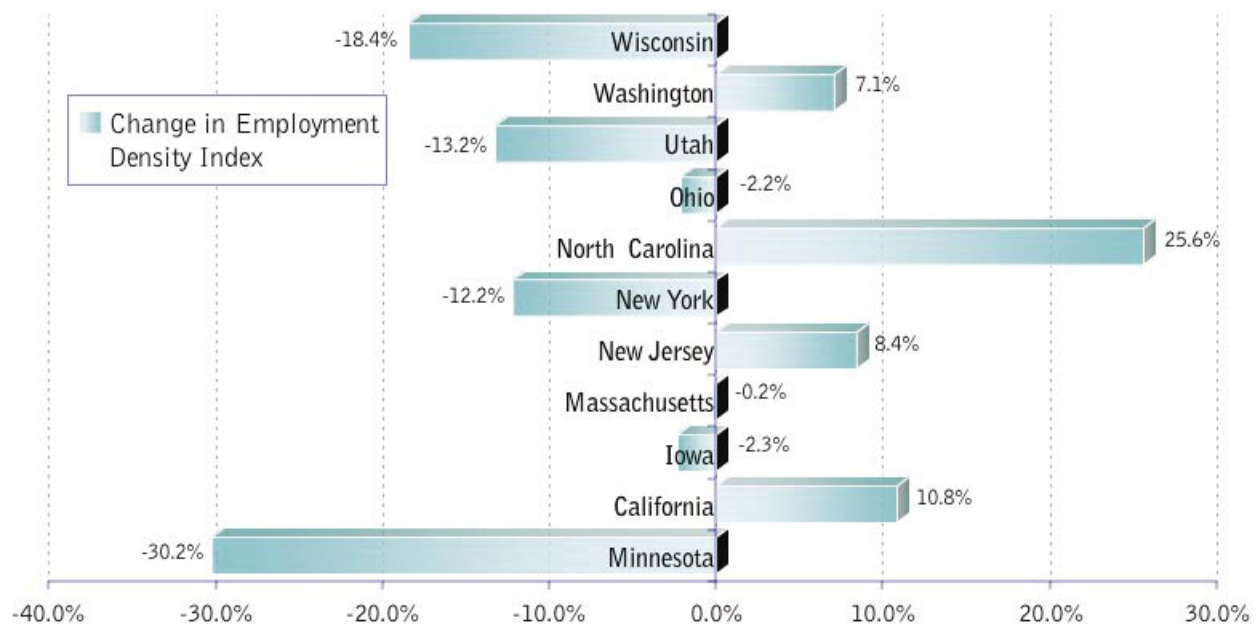
An even more obvious way to evaluate the competitive position of a state, in a particular industry, is to examine changes in its industry density indices over time, compared with other states. Figure 10 does this for employment density indices for the 11 states for the five years between 1997 and 2002. Figure 10 takes the same data that were used to calculate the employment density indices in Figure 8 but expresses each shift as percentage change over five years from the base position of each state in 1997.

This graph may be useful for helping state leaders to identify which states might be doing "something right" to improve their competitive position in biobusiness technology, and which



states might be “getting behind in the game.” The states positioned on the right-hand side of the graph are improving their game, while the states positioned on the left-hand side of the graph may need to readjust their game plans.

Figure 10. Percentage Change in Employment Density Indices, 1997-2002, Biobusiness Technology Industries



We can see from Figure 10 that, of the 11 states examined in this study, North Carolina exhibits the most dramatic underlying shift in its competitive position in the biobusiness technology industry in the United States over the five years from 1997 to 2002. California, New Jersey and Washington also appear on the right-hand side of the graph, suggesting that there are positive strategic lessons to be learned from examining their situations.

Conversely, although Minnesota is not alone in experiencing a drop in its competitive position in biobusiness technology employment during the five years to 2002, the scale of Minnesota's decline (measured as a rate of change from the 1997 level) is the most noticeable of all the states.

Medical Devices

The medical device sector, as shown by Figure 3, is the most prominent part of Minnesota's biobusiness industry. It is therefore important to explore the competitiveness of this sector in its own right.



Figure 11. Employment, Medical Device Industry

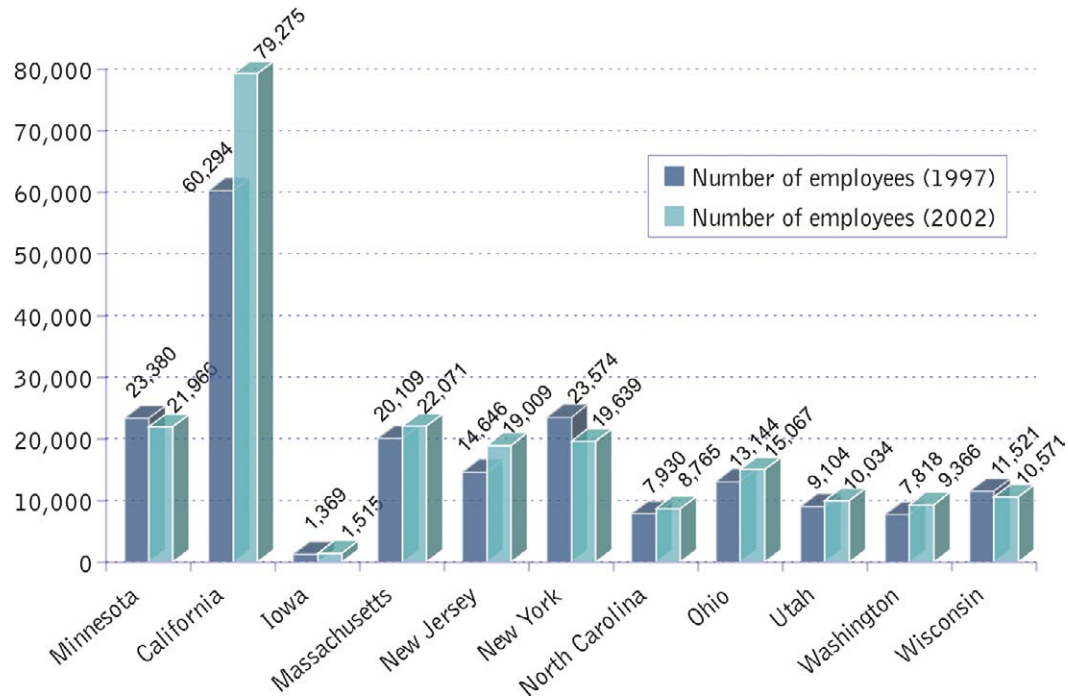


Figure 11 compares Minnesota with the 10 comparison states in medical device industry employment at two points in time, 1997 and 2002. During that five-year period, both California and Massachusetts expanded their total medical device industry employment, whereas Minnesota's employment actually contracted marginally. By 2002, both New York and New Jersey were close competitors of Minnesota in medical device employment, with New Jersey in particular having shown impressive growth over the previous five years. These numbers suggest that Minnesota's general leadership position as a medical device employer may be eroding.



Figure 12. Enterprises, Medical Device Industry

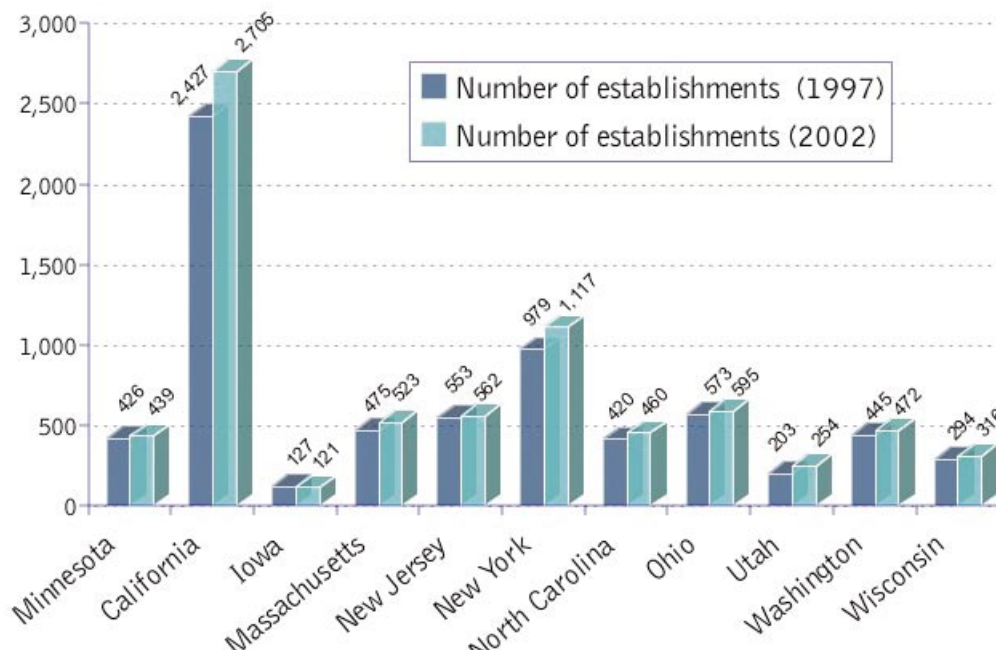
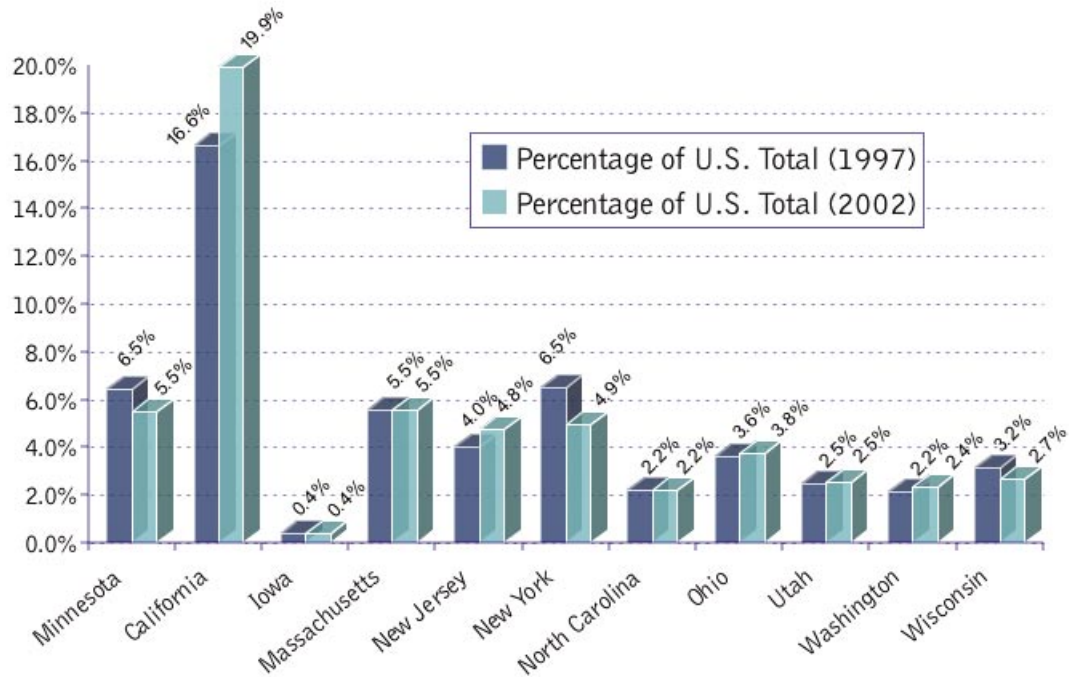


Figure 12 contains the same type of information as Figure 11, except that it compares the number of medical device enterprises in each of the 11 selected states, rather than the total number of employed persons. **Minnesota increased its number of medical device enterprises marginally over the five years to 2002**, but so did most of the other 10 states. By the end of 2002, California was home to more than six times as many medical device enterprises as Minnesota. The fact that the ratio of California over Minnesota is significantly larger for enterprises than it is for employment must suggest that California exhibits a more entrepreneurial structure to its medical device sector than does Minnesota. The average size of Minnesota's medical device firms (about 50 people per firm) is greater than that of California (about 29 people per firm). Minnesota's medical device enterprises typically appear to be more mature than those of California. The average size of enterprises in Massachusetts is roughly similar to that of Minnesota (suggesting that the maturity/entrepreneurship balance of those two states is similar).

Interestingly, while New York also lost some ground in total medical device employment from 1997 to 2002, that state appears to have shifted slightly toward a more small-business or entrepreneurial structure for its industry. Like California, New York exhibits a more entrepreneurial structure to its industry than does Minnesota. The growth in the number of new enterprises in New York in recent years, combined with its relatively large existing base of medical device enterprises, suggests that it may be a competitor for Minnesota to watch in the near future (despite New York's recent decline in the total number of medical device jobs).



Figure 13. Percentage of Total National Employment in Medical Device Industry



The fact that California has many more medical device jobs than Minnesota, and that a number of other states now have more medical device enterprises than Minnesota is not, in itself, a cause for concern. These states have much larger populations than Minnesota (California's population, in particular, is an order of magnitude larger than that of Minnesota) so, with all things being equal, we would expect those states to generate larger industries than Minnesota. Figure 13 was produced to try to put these factors into perspective, by expressing each state's medical device employment as a percentage of the U.S. national total, rather than as an absolute number.

California is home to about one fifth of all medical device industry workers in America; Minnesota and Massachusetts share second place with 5.5 percent each. Another sobering fact is revealed in Figure 13, however: While Massachusetts has held steady at 5.5 percent of the national share, Minnesota actually dropped by 1 percentage point over the five-year period from 1997 to 2002. California, on the other hand, despite its widely touted "inhospitable business climate" (due to high real estate prices and high wages), actually increased its national share by over 3 percentage points during the same period. **Is this rise in California's prominence in the national medical device sector, both in relative share and absolute numbers, really an issue about which Minnesota ought to be concerned?**

Figure 14 addresses this question by plotting four different kinds of industry density indices for the medical device sector in the 11 states. It reveals that, when the relative size of their two economies is taken into account, and when the size of the whole medical device industry nationwide is taken into account, **Minnesota is significantly more productive than California in generating**



medical device industry employment. Minnesota's relative strength over California in generating revenue for medical device enterprises is even greater than its lead in the area of employment. The exception to this pattern, as also shown in Figure 14, lies in the area of new enterprise creation (i.e., entrepreneurship in medical devices). California and Minnesota both appear to be roughly similar in this area, with enterprise density indices in the vicinity of 1.3 (both exhibit above-average levels of medical device industry competitiveness).

According to the calculations graphed in Figure 14, the following states are "competitive" in the medical device industry (i.e., they have industry density indices greater than 1.0): Utah, Minnesota, Massachusetts, California, New Jersey, Wisconsin and Washington. The following states, by the same logic, are less than competitive, overall, in the medical device industry: Iowa, New York, North Carolina and Ohio. Given the size of their respective economies, we would expect these four states to have done better. The good news for Minnesota is that it is strong (from the point of view of **industry density** in the medical device sector). While Minnesota is definitely in the leading group, it is not unique. In fact, Utah (a much smaller state than Minnesota) does better, overall, than Minnesota in generating medical device industry activities, given the size of its economy.

Figure 14. Medical Device Industry Density Indices, 2002

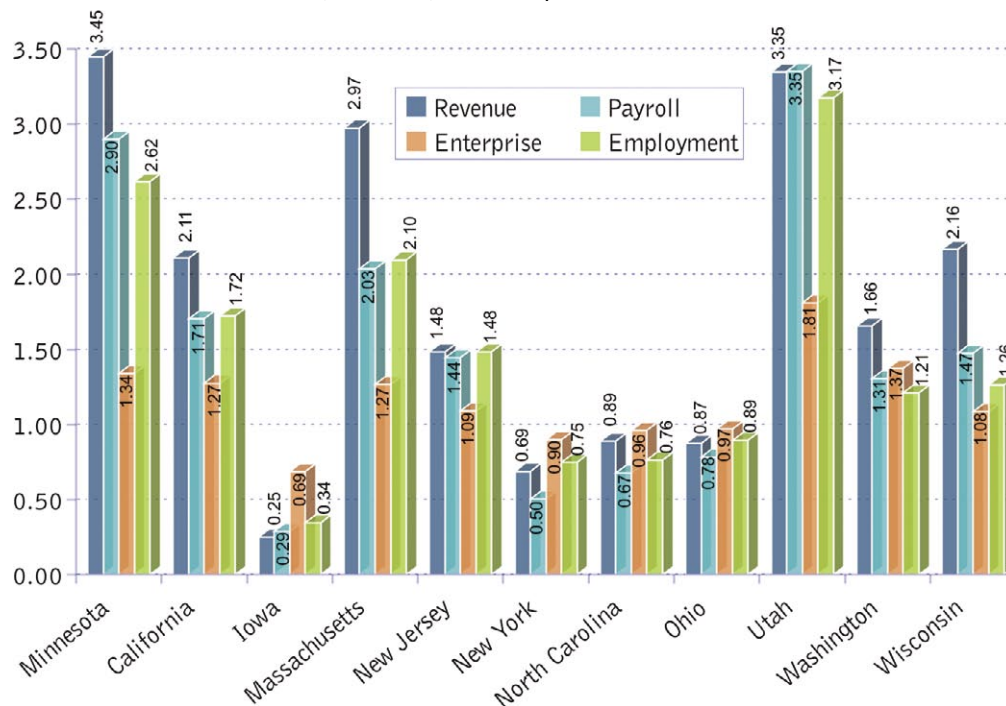
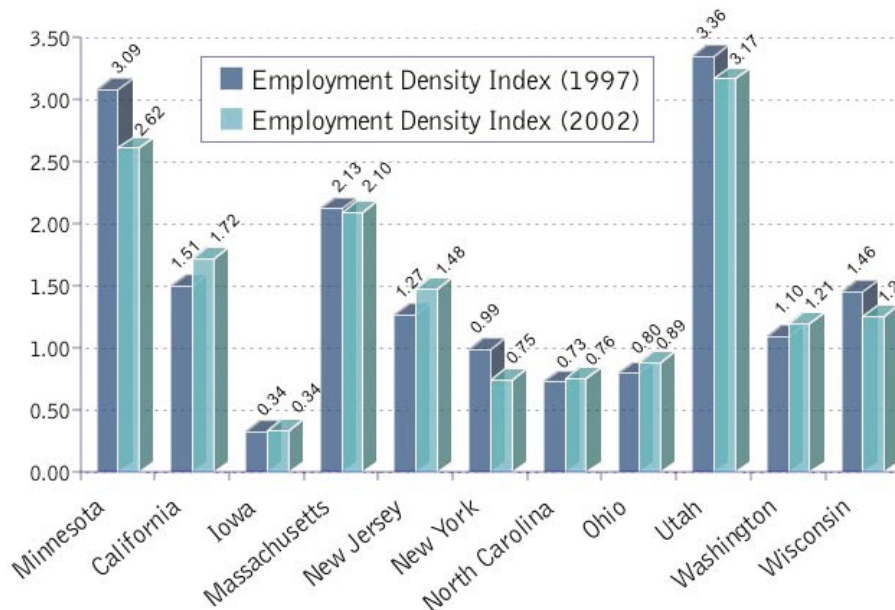




Figure 15 represents an attempt to evaluate changes in the competitive position of the 11 states for the five years ending 2002. Of the eleven states compared, Minnesota is the second most competitive (i.e., efficient at generating jobs) in the medical device sector (behind Utah) for both 1997 and 2002.

Figure 15. Employment Density Indices, Medical Device Industry

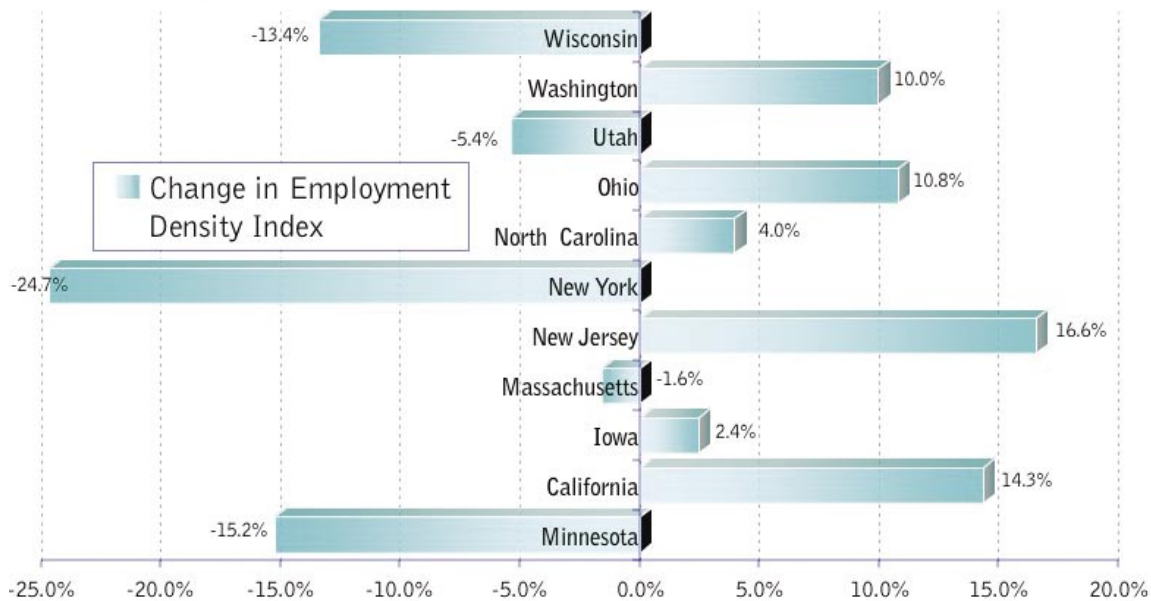


However, the decline in Minnesota's employment density index from 3.09 to 2.62 over five years may be an early-warning sign that its competitiveness is under threat. Minnesota was not the only state whose employment-generating strength in medical devices weakened during that period: Wisconsin and New York also declined. California, in contrast, demonstrated an actual increase in employment-generating strength during that period — despite (or perhaps because of?) its already strong absolute position in medical devices. New Jersey, Washington and Ohio also exhibited advances.

Figure 16 takes the same data that were used to calculate Figure 15 but expresses each shift as a percentage change over five years from the base position of each state in 1997. The states positioned on the right-hand side of the graph (New Jersey, California, Ohio and Washington) are improving, while the states positioned on the left-hand side of the graph (New York, Minnesota and Wisconsin) may need to readjust their strategies. Meanwhile, perhaps Utah's winning strategies from the past for medical devices may be nearing the end of their utility.



Figure 16. Percentage Change in Employment Density Index, 1997-2002, Medical Device Industry



It appears from the scores in Figure 16 that **Minnesota may find some helpful positive lessons for its own future strategy by studying what has been going on during recent years in the medical device industry, and its context in New Jersey, California, Ohio and Washington (and perhaps also North Carolina and Iowa).** Even though California is so much larger than Minnesota, the industry density measures reveal that there may still be some useful lessons to be learned. In that same vein of logic, by studying New York and Wisconsin (and perhaps also Utah), Minnesota may learn some valuable lessons about what not to do as it seeks to grow its biobusiness sector.



Figure 17. Enterprise Density Indices, Medical Device Industry

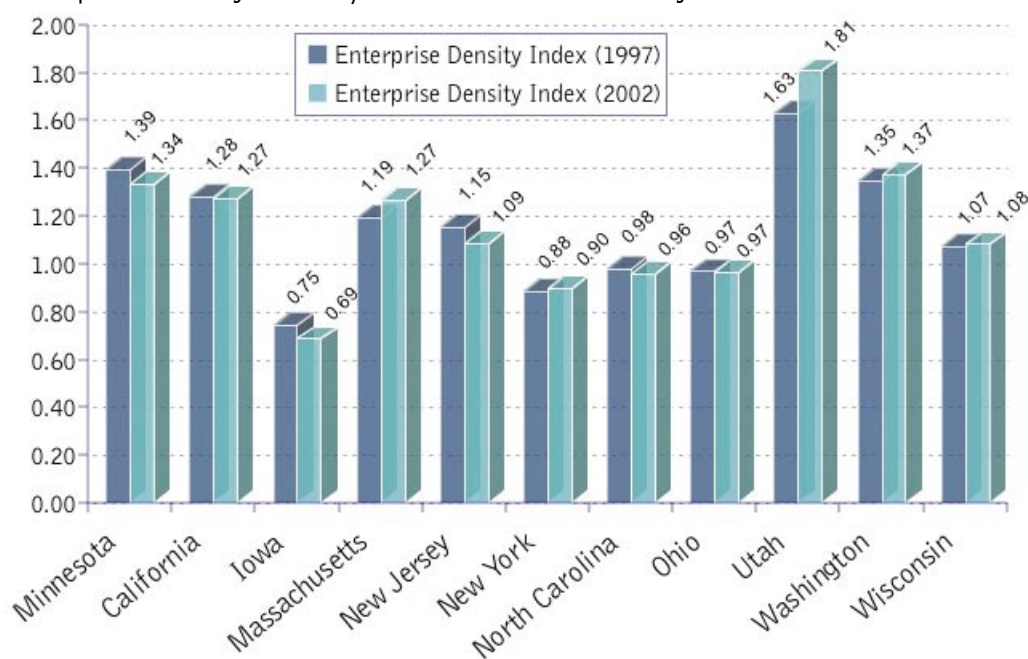


Figure 17 plots enterprise density indices for all 11 states for 1997 and 2002. In effect, this graph reveals the relative strength of each state in generating enterprises in medical devices, and how their performance (i.e., entrepreneurial strength) may have shifted over five years.

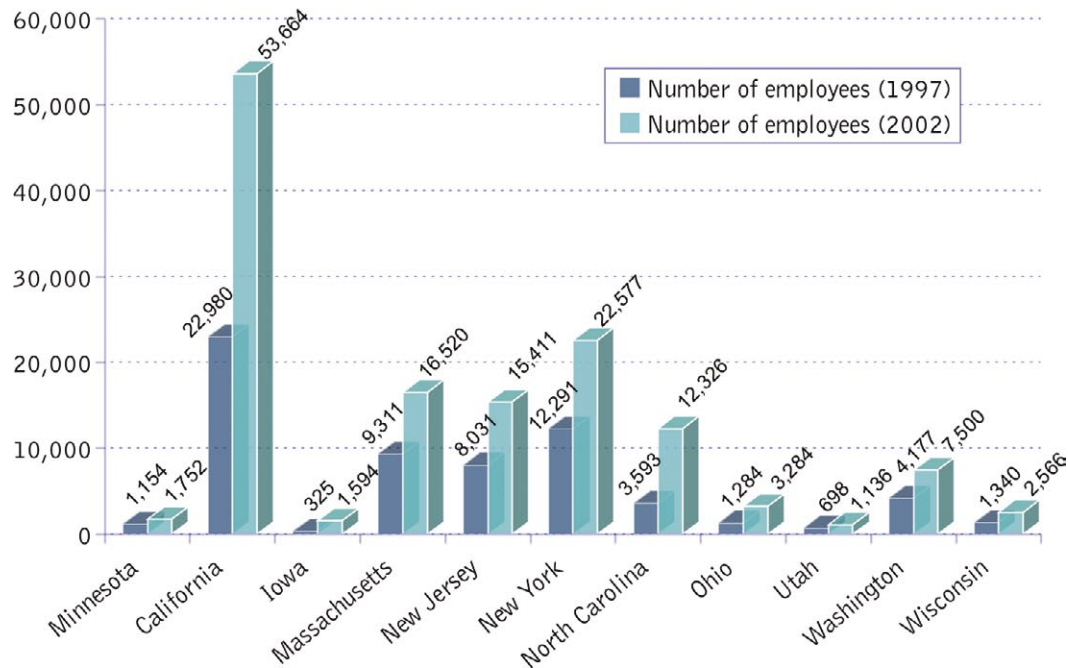
The contrasts between states in their strength in generating and sustaining medical device enterprises are not as extreme as they are for employment generation in medical devices. Minnesota is also among the leading states by this measure, with only a marginal (and perhaps not very significant) decline over five years. Utah, it appears, has actually improved its strength in generating new medical device enterprises, despite a minor decline in its strength of generating new jobs (remember, in contrast with Minnesota, Utah still actually increased its total medical device employment from 1997 to 2002, even though its strength of doing so decreased slightly). In short, the states that are both unusually productive in generating new medical device enterprises and that improved their strength in doing so over half a decade, are Utah and Massachusetts (with Washington also showing slight improvement). These were the leading new “entrepreneurial” medical device states.

R&D in the Life Sciences

During the last three decades a new set of industries, based around new knowledge and new techniques emanating from the life sciences, has captured the attention of investors, policy makers, entrepreneurs, community development professionals and the public at large. Figure 18, using data taken from the U.S. Economic Census, graphs employment levels in this new industry domain across the 11 comparison states.



Figure 18. Employment, R&D in the Life Sciences



In contrast with its historical leadership role in the medical device industry, Minnesota is not a leading employer in the new life sciences industries. Of the 11 comparison states, only Iowa and Utah exhibit smaller absolute employment levels than Minnesota in R&D in the life sciences. Both of those states show significantly larger growth rates in life sciences R&D employment than Minnesota. In the five years ending in 2002, Minnesota's employment in the life sciences R&D industry grew by 52 percent, whereas Utah's grew by 63 percent and Iowa's grew by an astounding 390 percent from its relatively low starting point. It appears that, not only is Minnesota not a major player in life sciences R&D, its position may even be declining compared with other minor players.

California, as was the case with medical devices, is also the overwhelming leader in life sciences R&D employment. The number of new jobs (over 30,000 employees) that California created in this field over the five years ending in 2002 is significantly greater than the total 2002 employment levels of any other state. California's life sciences R&D enterprises ended the five-year growth period with almost 54,000 employees. Other prominent, and leading, states include: New York, Massachusetts, New Jersey, North Carolina and Washington. Of the prominent competitor states, North Carolina in particular has exhibited especially impressive growth, with an increase in life sciences R&D employment of over 240 percent in five years. Minnesota's neighbor, Wisconsin, managed to widen its lead over Minnesota during the period covered by Figure 18 from a 16 percent edge to a 46 percent edge. Minnesota did increase its employment in this field during that period, but not as much as its competitor states.



Figure 19. Percentage of National Employment in R&D in the Life Sciences

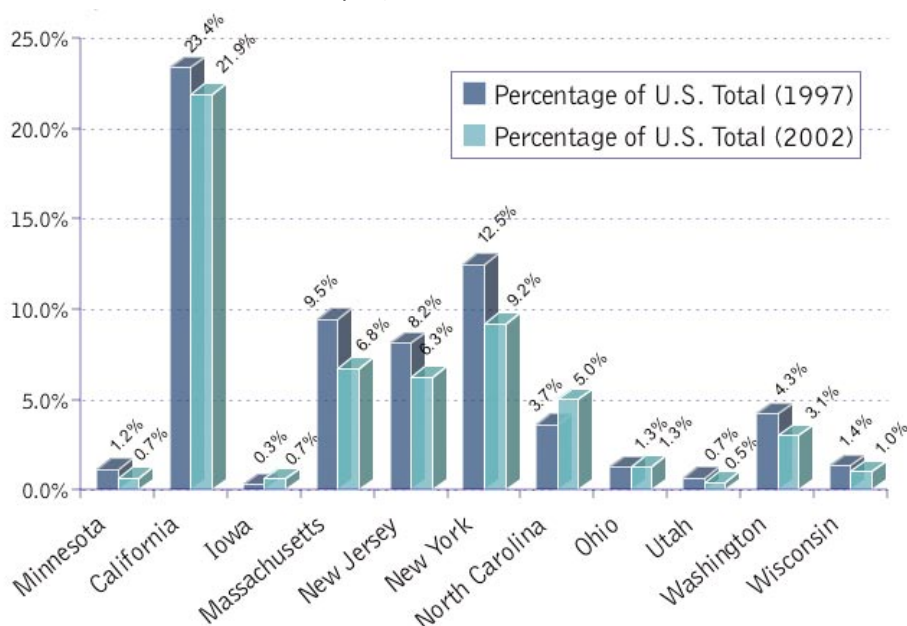


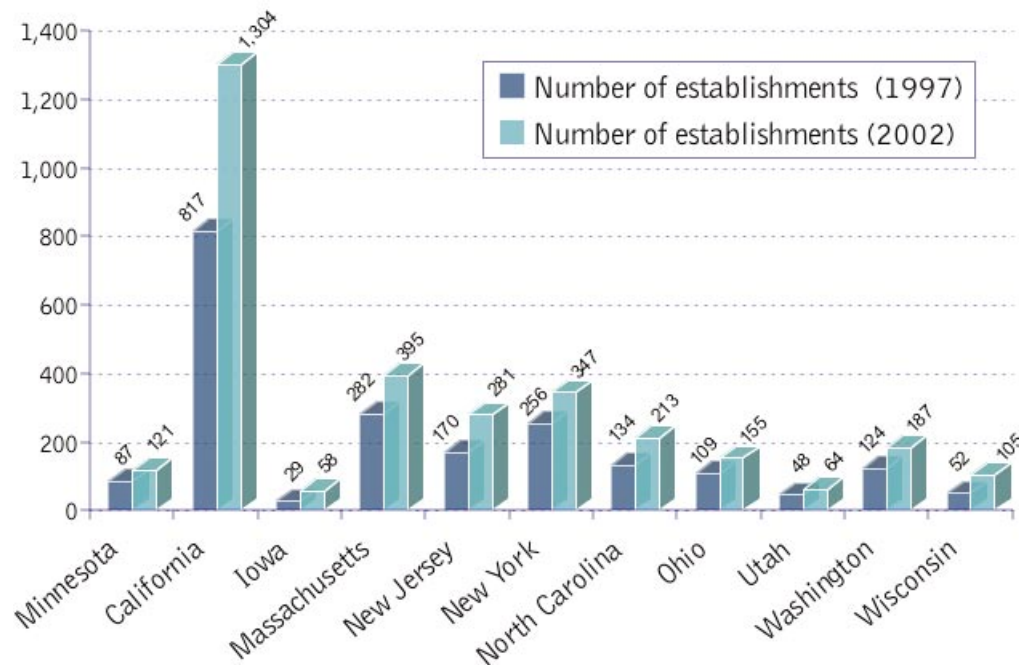
Figure 19 takes the same data that were used to construct Figure 18 but expresses them as percentages of the national total, rather than as absolute employment numbers. California still appears as the overwhelming leader, even though its share of the national total dropped slightly over five years as other states invested heavily in the biosciences. Minnesota's share of the national total dropped from 1.2 percent to 0.7 percent. The two particularly interesting states illustrated in Figure 19 are North Carolina and Iowa, the only two states out of 11 that actually increased their share of the national total. Iowa started the period with one-quarter of Minnesota's share of the national total but ended the period equal with Minnesota. North Carolina increased its share of the national total by 1.3 percent (which was a 35 percent growth over its share in 1997).

There are 39 states not explicitly addressed in the figures (plus Washington, D.C., and Puerto Rico). The total number of people employed in R&D in the life sciences throughout the U.S. in the other states increased sufficiently from 1997 to 2002 that the percentages in Figure 19 could drop, even though the absolute numbers (in Figure 18) increased.

The density indices take into account what is happening in all U.S. states, not just what is happening in the 11 selected states. Interestingly, the same rough pattern that appears in Figure 19 also appears in Figure 21 (below). Hence, we can conclude that there has indeed been a substantial overall increase in nationwide employment in R&D in the life sciences, including states other than the 11 that are the focus for this study. This is confirmed by the fact that the 2002 level of U.S. national employment in R&D in the life sciences is about 250 percent of the 1997 level; whereas, in contrast, the 2002 level of employment in Minnesota R&D in the life sciences is only about 150 percent of the 1997 level. **Minnesota is growing more slowly than the nation as a whole in R&D in the life sciences employment.**



Figure 20. Enterprises, R&D in the Life Sciences



It is also important to examine the relative position of states in generating new life sciences R&D companies, in addition to total *employment* — in other words, to analyze the relative entrepreneurial propensities of the states. Figure 20 was produced for this purpose. Figure 20 reveals that Minnesota fares slightly better in the generation of life sciences R&D enterprises than it does in the generation of employment in that field. However, it is still fairly low on the list of competitor states. Furthermore, of the several states in the list of 11 that may be considered as Minnesota's third-tier peers — Ohio, Wisconsin, Utah and Iowa — the majority grew more strongly than Minnesota from 1997 to 2002. Only Utah increased by a smaller percentage than Minnesota.

California, once again, appears as the front-runner, with over 1,300 life sciences R&D enterprises by 2002, compared with 121 in Minnesota. Massachusetts, New York, New Jersey and North Carolina — and also, running close behind, Washington — have emerged as strong entrepreneurial states behind California. New York appears as a strong entrepreneurial state (again, behind California) in *both* the medical device industry (Figure 12) *and* the life sciences R&D industry (Figure 20). In addition, New York, New Jersey and Massachusetts all occupy strong second-tier positions behind California in employment generation for *both* the medical device industry (Figure 11) *and* the life sciences R&D industry (Figure 18). **The leading (and apparently strengthening) positions of California, New York, Massachusetts and New Jersey in both industry domains — medical devices and life sciences R&D — prompts the question of whether there is some kind of technological synergy (or even convergence) at work here that these states are able to harness for both entrepreneurship and employment generation.**

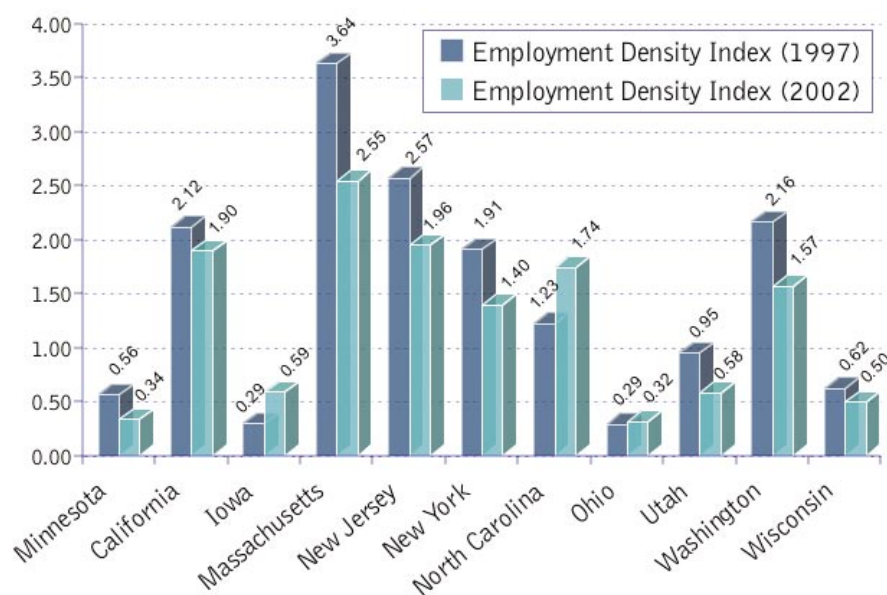


These several leading states all have much larger populations and economies than Minnesota so, if there was a level playing field, we would expect these states to outperform Minnesota in terms of the absolute numbers of jobs and enterprises in life sciences R&D. It is therefore appropriate to weight the data in Figures 18, 19 and 20 to take into account the relative sizes of each state vis-à-vis each state's economy and the national economy. Figures 21 and 22 accomplish this by representing the industry density indices of each state, for employment and enterprises, respectively.

The employment density indices for the life sciences R&D industry (see Figure 21) reveal that, of the 11 states analyzed, the following are competitive on a national scale (in descending order of competitiveness): Massachusetts, New Jersey, California, North Carolina, Washington and New York. Each of these states scores an employment density index of 1.0 or greater. Of these, North Carolina is the most intriguing, because it is the only one among the six competitive states that managed to increase its employment density in life sciences R&D during the five years to 2002.

Minnesota finished the five-year period near the bottom of the list of 11 with an employment density index of 0.34, marginally above Ohio. Even though Ohio (0.32) scored the lowest employment density index out of the 11 states, it outperformed Minnesota in one sense: Its employment density index grew slightly from 1997 to 2002, whereas Minnesota's index actually shrunk. In short, Figure 21 shows that even when the figures are weighted to take into account the relative sizes of the economies in each state, Minnesota still appears to be a low-performing state compared with its peers. California, while not as strong as Massachusetts when the employment numbers are expressed as density indices rather than as absolute values, is still very competitive. In other words, California (with an employment density index of 1.9) still generates much higher levels of employment than one would expect, all things being equal, in the life sciences R&D industry.

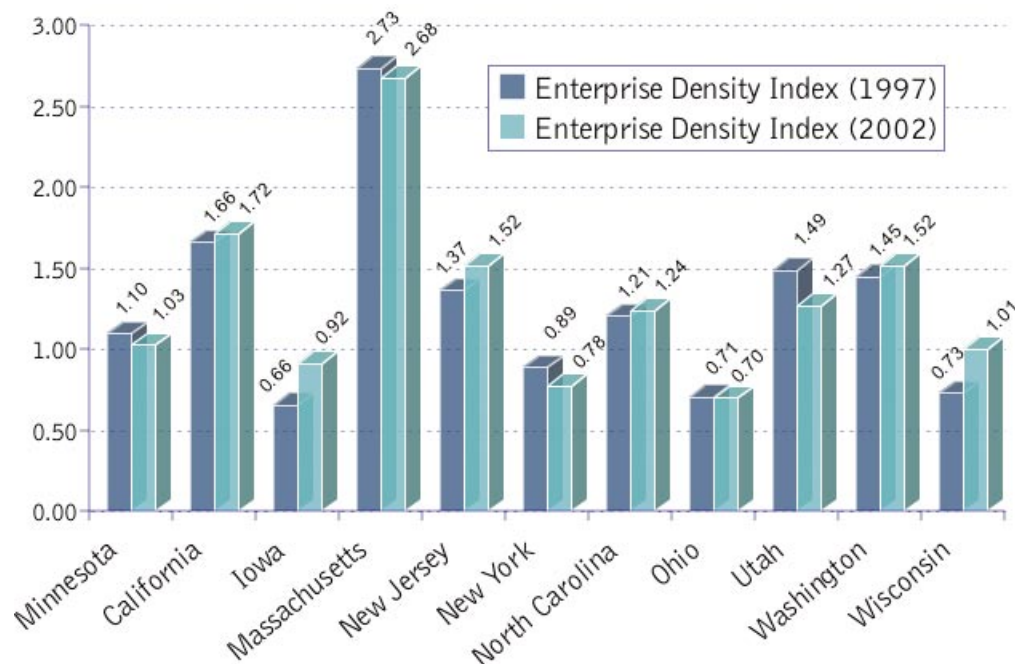
Figure 21. Employment Density Indices, R&D in the Life Sciences





What about the competitiveness of each state in generating enterprises in the life sciences industry, weighted to adjust for the size of each state's economy? The enterprise density indices (what we might informally call the “entrepreneurship quotients”) in Figure 22 help us to address this question. Figure 22 shows that, by this measure, Minnesota actually performs reasonably well. **In 2002 Minnesota scored an enterprise density index for R&D in the life sciences of 1.03, which means that Minnesota performs at about the level one would expect, all things being equal.** It seems that in the field of life sciences R&D entrepreneurship, Minnesota is about average.

Figure 22. Enterprise Density Indices, R&D in the Life Sciences



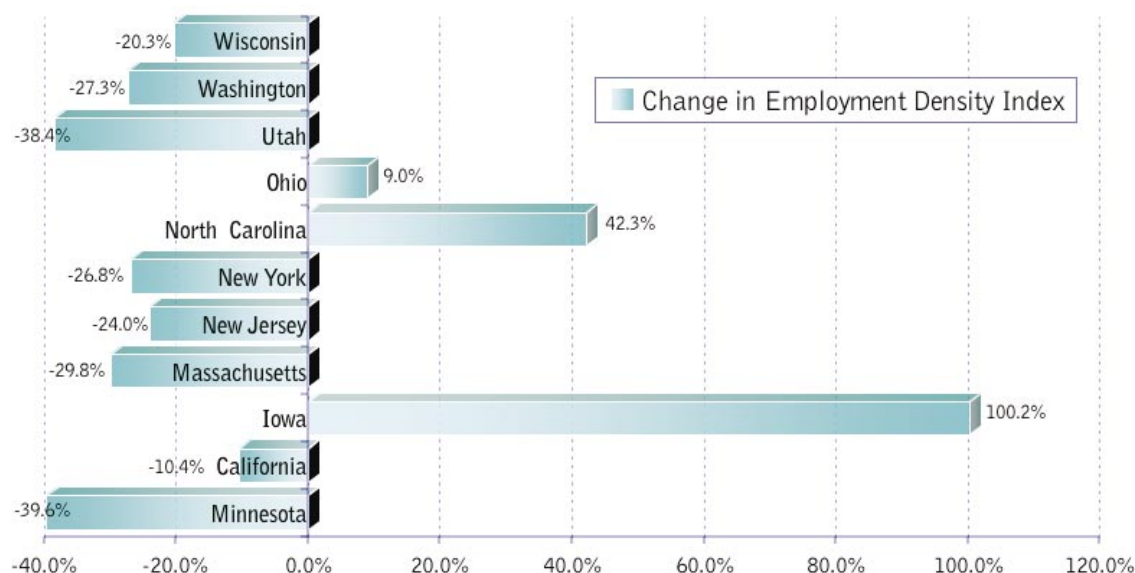
The competitive states, in terms of life sciences R&D entrepreneurship in 2002, are (in descending order of competitiveness): Massachusetts, California, New Jersey, Washington, Utah, North Carolina, Minnesota and Wisconsin. Of these eight states, only five (California, New Jersey, Washington, North Carolina and Wisconsin) actually improved their entrepreneurial competitiveness over the five years to 2002. The biggest jump occurred with Wisconsin, which managed to achieve a 38 percent growth rate (calculated over five years) in its index from its 1997 level. In contrast with Minnesota, Wisconsin managed to switch from being a member of the “less than competitive” group to the “competitive” group during that time.

Iowa is another interesting state, in terms of entrepreneurship in life sciences R&D. Iowa, which by 2002 was still in the “less than competitive” group, managed to experience a 39 percent growth rate in its enterprise density index from 1997 through the following five years. It appears that Iowa may be a state to watch in coming years vis-à-vis life science R&D entrepreneurship.



As we saw in the case of the medical device industry, changes in the level of a state's industry density indices over time may provide a very powerful tool for differentiating between states that are "doing something right" versus those that may be "underplaying their game." Careful analysis of these indicators can provide a kind of early-warning system of either impending "sleeper" problems or even of unexpected future success, as the case may be. Figure 23 was designed to play that role for the life sciences R&D industry.

Figure 23. Percentage Change in Employment Density Indices, 1997–2002, R&D in the Life Sciences



Of the six states we previously classified as being competitive in the generation of life sciences R&D employment (Massachusetts, New Jersey, California, North Carolina, Washington and New York) only one (North Carolina) appears on the right-hand side of the chart. This does not mean that the other five are no longer competitive. Rather, it means that their level of strength in generating life sciences R&D jobs actually declined, even if the number of life sciences R&D jobs increased during that time period. Figure 23 tells us that **North Carolina is probably doing something especially effective in creating the right conditions for future life sciences R&D employment growth.**

Iowa and Ohio, even though they were part of the "less than competitive" group at the time the data were collected, were almost certainly doing something very effective to improve their relative position as locations for the life sciences R&D industry. Figure 23 suggests that Minnesota may do well to study the strategies of Iowa, North Carolina and Ohio should it wish to gain insights about effective ways to improve its competitive position in the generation of employment in the emerging life sciences R&D industry. Given that these three states also appeared on the right-hand side of the equivalent graph for the medical device industry (Figure 16), the chances that Minnesota may gain valuable policy insights by studying the strategies and conditions of North Carolina, Iowa and Ohio are quite high.



What about Minnesota? It appears that while Minnesota is performing as well as might be expected under the circumstances, in the generation of life sciences R&D *enterprises* (i.e., Minnesota is a respectable state vis-à-vis life sciences R&D entrepreneurship), it is underperforming in the generation of *jobs* within this industry. In addition, Minnesota's overall level of *strength* in generating both employment and enterprises in the life sciences R&D industry showed signs of weakening over the five years to 2002. **Minnesota has no grounds for being complacent regarding its future position in research and development within the life sciences.** In fact, as we have seen from the data in the above figures, there are reasons to be concerned.

Agri-bio and Bio-industrial Technology

Agri-bio and bio-industrial technology is technology directed primarily towards applications in biological systems outside the human body.

Agri-bio and bio-industrial technology may incorporate technical means from any field of technology, including biotechnology, but those means must be directed toward applications in living systems or biology-related contexts. Using the terminology first introduced by the trade group EuropaBio, agri-bio technology is “green biobusiness technology” (biobusiness focused on the application of biological technology in the field of plants and agriculture), and bio-industrial technology is “white biobusiness technology” (biobusiness focused on the application of biological technology in industrial fields such as biomaterials, bioprocessing, bioenergy, bio-based chemicals, food ingredients, and bioremediation). The concepts of green biobusiness technology and white biobusiness technology will be elaborated upon later and are illustrated in the grassroots assessment section of this report (see Figure 30 and also Appendix 1).

There is no standard industrial classification for this general domain of biobusiness so, as explained earlier in this report, we selected the following NAICS categories as rough proxies, when combined together, for agri-bio and bio-industrial technology:

NAICS 325193: Ethyl alcohol manufacturing

NAICS 325221: Cellulose organic fiber manufacturing

NAICS 311221: Wet corn milling

NAICS 311222: Soybean processing

NAICS 311223: Other oilseed processing

NAICS 31212: Breweries

NAICS 31213: Wineries

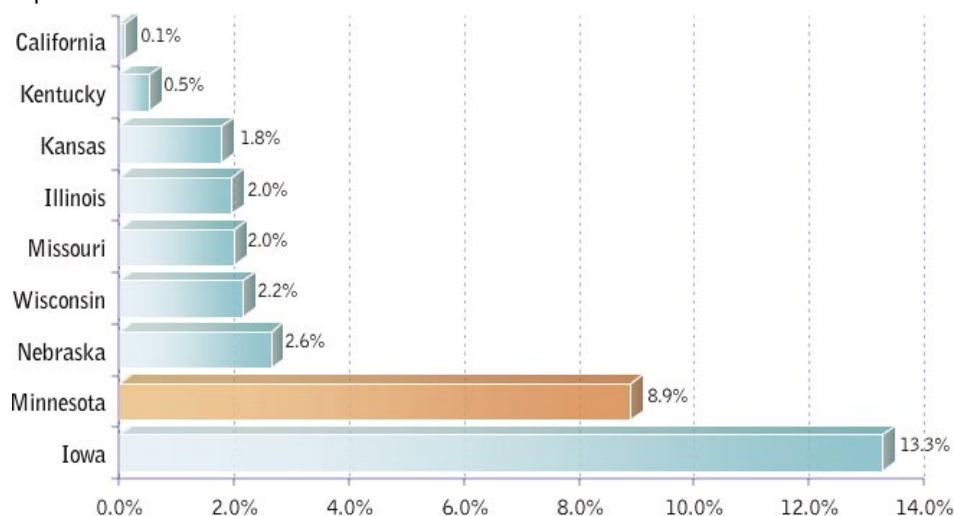
As stated earlier, one of the primary purposes of this assessment was to characterize the biobusiness R&D capacity of the state. Unfortunately, the above NAICS codes are designed to capture



manufacturing operations. Although many of these manufacturing operations may engage in R&D activities, it is impossible to isolate these activities using the existing codes. Moreover, the quality and comprehensiveness of the data published on agri-bio and bio-industrial technology as part of the U.S. Economic Census are very inconsistent. The primary reason for this is that in cases when there are a small number of facilities in a particular NAICS category in a particular region, the U.S. Census Bureau withholds the data so as to ensure that the identity of individual enterprises cannot be deduced. In addition, as this whole area of biobusiness is emerging and may be considered to be a set of immature industries, the rigor and clarity with which individual enterprises are classified, and by which data are collected, are not yet very stable. It is therefore not appropriate to produce standard calculations for this amorphous sector using U.S. Economic Census data, as has been done for medical devices and R&D in the life sciences. The U.S. Economic Census data that are available for agri-bio and bio-industrial technology sector have been included as part of the aggregated data for the whole biobusiness technology sector described earlier in the report, but they are not separately presented here.

The BioBusiness Alliance of Minnesota has identified this problem area as a target for future work. We believe that it is important to develop more precise and useful categories and labels for describing business activity in agri-bio and bio-industrial technology, and for standardized approaches to data collection in these fields, across state boundaries, to be put in place. For now, however, the best we can do is to provide a fragmented snapshot of the general domain, based upon limited data to which we have access.

Figure 24. State Share of Total U.S. Annual Farmer-Owned Ethanol Production Capacity, April 2006



We have managed to assemble some inter-state comparative data for one segment of the agri-bio and bio-industrial technology sector, namely, production of the biofuel ethanol (equivalent to NAICS 325193).¹⁰ While these data pertain to one segment only, we hope that, in lieu of better

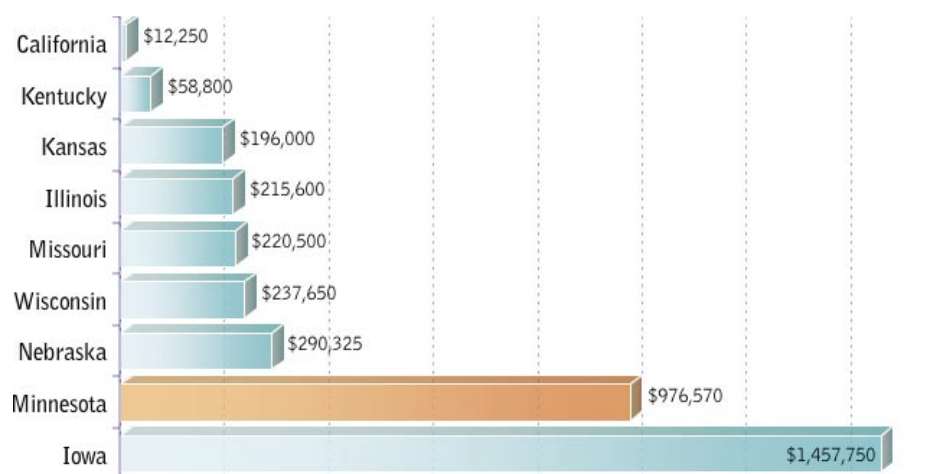


data to be produced by future research, they will provide a useful and interesting indicator of inter-state competitiveness across the broader group of industries that make up this sector.

Figure 24 compares the share of total U.S. farmer-owned production capacity in ethanol across a selection of nine leading states. These are not the same states that were used for comparison purposes earlier in this report. Rather, they are a selection of leading states in farmer-owned ethanol production for which we could get access to data. Reliable data on corporate-owned ethanol production plants were not available to us at the time this research was conducted. Figure 24 shows that Minnesota is a strong performer in ethanol production, second only to Iowa.

It should be noted that ethanol capacity follows corn production, the current primary feedstock for ethanol production in the United States. Given that Iowa is the leading corn-producing state, it is logical that the majority of ethanol production would be found there as well.¹¹

Figure 25. Estimated Annual Value of Farmer-Owned Ethanol Production Capacity (in thousands), April 2006



¹⁰The data on ethanol production capacity used in the charts in this section were not provided by the U.S. Census Bureau. They were produced independently by the Renewable Fuels Association, and were provided to the BioBusiness Alliance of Minnesota courtesy of the Minnesota Department of Agriculture in April 2006. The data source for ethanol prices was the consulting company Informa Economics Inc., April 2006. The source for data on all industries (the macro economies of all nine comparison states) was the U.S. Department of Labor's Bureau of Labor Statistics, April 2005. All calculations were conducted by Dr. Kelvin W. Willoughby, April 2006.

¹¹Thanks are due to Dr. Jill Zullo, of Cargill Inc., for this observation.



Figure 25 graphs the estimated financial value of farmer-owner U.S. production capacity in ethanol across the same nine leading states, using average prices at source.¹² Minnesota's annual production value now approaches an estimated \$1 billion.

Figure 26. Farmer-Owned Ethanol Production, Industry Density Indices, April 2006

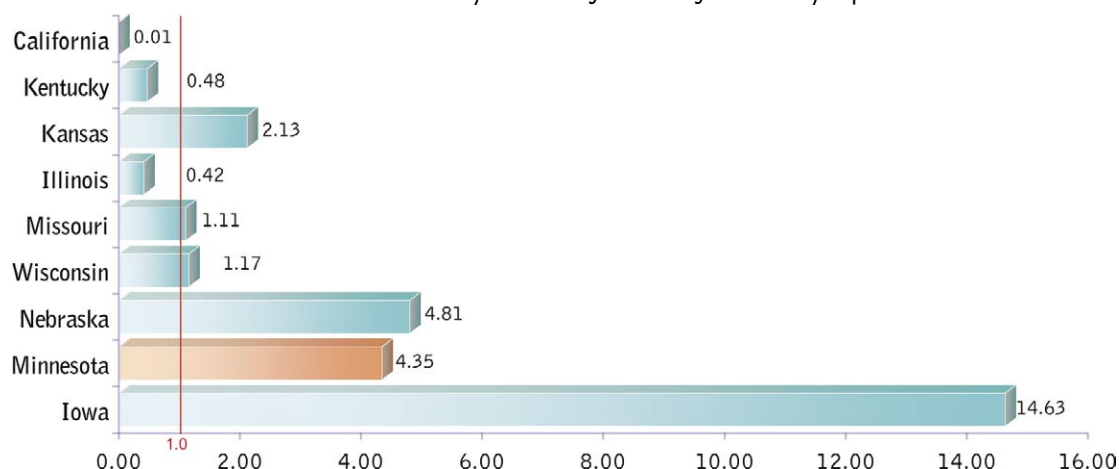


Figure 26 takes the same data that were used to produce Figure 25, together with aggregate data on the macro economy of each of the selected states and the whole of the United States, and expresses them as industry density indices.¹³ We can see from Figure 26 that, with an industry density index of 4.35, Minnesota is extraordinarily strong in farmer-owned ethanol production.

Conclusions: Competitiveness

The analysis of standardized national economic data from the U.S. Census Bureau presented in this report confirms that Minnesota is indeed a major national player in the U.S. medical device industry. Minnesota and Massachusetts stood roughly equal as locations for medical device industry jobs in 2002, tying for second place behind California.

¹² The Emerging Biobased Economy, a multi-client study assessing the opportunities and potential of the emerging bio-based economy, developed by Informa Economics Inc. in participation with MBI International and The Windmill Group, April 2006, page 128 (approximately \$2.40-\$2.50 / gallon, in origin markets).

¹³ The formula used for calculating this ethanol production industry density index is as follows: $\frac{\text{(annual value of ethanol production in individual state)} / \text{(annual value of ethanol production in the U.S.)}}{\text{(annual payroll in all industries in individual state)} / \text{(annual payroll in all industries in the U.S.)}}$. This formula computes to 1.0 for the whole country.



When it comes to creating medical device companies, rather than jobs, Minnesota is solid, being home in 2002 to 2.6 percent of the nation's medical device establishments. However, it lags behind quite a few other states in medical device entrepreneurship (creation of new enterprises based on medical devices).

When the data on the medical device industry are weighted to take into account the relative sizes of the economies of each state, using density indices rather than absolute numbers as indicators, Minnesota shines as a very competitive location; it is significantly more productive than California in generating medical device jobs, given the relative size of the resource base of each state.

Unfortunately, several shadows hang over Minnesota's historical strength in medical devices. First, the state actually lost jobs in the medical device industry from 1997 to 2002, during a period when most of its competitors were gaining jobs in the field. Second, Minnesota's overall competitiveness in medical devices — meaning its relative strength in generating jobs and enterprises in medical devices, taking into account both the size of the medical device industry nationwide, and the size of Minnesota's economy compared to the economy of the nation as a whole — actually declined during the most recent five years for which data are available. This decline is indicated by a downward shift in Minnesota's medical device industry density indices.

In short, while Minnesota remains strong in the medical device industry, the state appears to have lost ground during the most recent census period from the point of total medical device employment: both its overall leadership position and its competitiveness compared with other U.S. states appear to have eroded somewhat.

Ample opportunity exists for Minnesota to capitalize on its many strengths in biobusiness technology. The state remains very competitive in medical devices. The economic indicators reviewed in this report should be interpreted as a call for action. It would not be wise for Minnesota to rest on its medical device laurels. The state needs to identify its strengths and vigorously cultivate them in the face of stiff interstate competition if it is to maintain its "golden apple" industry — medical devices — as a mainstay for the future.

Has Minnesota done better in the development of new science-based, bio-related R&D industries, to compensate for its eroding competitiveness in medical devices? Our analysis of the emerging industries based around R&D in the life sciences revealed that Minnesota is a rather minor player in these new fields, at least in the private-sector enterprises, which were the subject of this analysis. Minnesota falls near the bottom of the list of the 11 states compared in this study as a location for the NAICS industry sector R&D in the life sciences. This pattern holds true no matter whether the figures are expressed as absolute numbers or are weighted to take into account the relative size of each state's economy.

An even more unsettling fact for Minnesota emerged through the foregoing analysis: The state's competitive position in R&D in the life sciences actually declined during the period covered by this study; and this happened during a period when total employment in the field nationwide



increased by about 150 percent.¹⁴ Unlike the historical role the state has played in the medical device industry, Minnesota is in a weak position in the new science-based biology-related research industries.

In the wider biobusiness technology industry analyzed in this study Minnesota has performed much better than it has in the new life sciences R&D industry fields. It appears that Minnesota has managed to leverage its underlying capabilities in medical devices and various fields of agri-bio and bio-industrial technology — in both the medical and non-medical domains — to stake out a credible position in the technology-intensive fields of biobusiness. With over 900 enterprises, over 28,000 employees, over \$6.6 billion in annual revenues, and dispensing over \$1.3 billion in payroll to Minnesota's citizens annually (in 2002), the biobusiness technology industry is a significant player in the state's economy. By 2005, total employment in biobusiness technology enterprises (excluding those in universities, not-for-profit entities or government agencies, or embedded as units inside corporations) had reached an estimated level of over 35,000 people (see Figure 3).

Figure 27. Overall Economic Trends, Biobusiness Technology Industries (and the Macro-economy), Minnesota, 1997-2002

Economic variable	Medical Devices	R&D in the life sciences (excluding the academic sector)	Total biobusiness technology	All industries (in the macro-economy)
Number of employed people (in Minnesota)	Down slightly	Up	Down	Up
Percentage of U.S. workforce	Down	Down	Down	Up
Number of enterprises (in Minnesota)	Up slightly	Up	Up	Up
Percentage of U.S. enterprises	Down slightly	Down	Down	Down slightly
Competitiveness	Down	Down	Down	Stable/up slightly

¹⁴This refers to life sciences R&D in business enterprises, not in academic organizations such as the state's universities and the Mayo Clinic.



Compared with other states, Minnesota holds a very respectable, but not stellar, position. Minnesota is competitive in biobusiness technology. The state exhibits slightly above-average strength in generating employment, revenue and payroll, and slightly below-average strength in generating enterprises, in the biobusiness technology sector. Minnesota is less entrepreneurial in biobusiness technology than other states, even if its overall economic performance in the industry is competitive. Overall, when the figures are weighted to take into account the relative size of the economy of each state and the overall level of the biobusiness technology industry at the national level, Minnesota performs slightly better than one would expect. Minnesota is performing reasonably well at the aggregate level.

Minnesota's respectable performance in building a broad-based biobusiness technology industry is mitigated by the fact that its relative competitiveness (measured by industry density indices) actually fell during the five-year time period covered by this study. In other words, Minnesota's strength at generating biobusiness technology industry activity compared with other states, and with the nation as a whole, showed signs of erosion. If this trend continues, it is highly doubtful that Minnesota will be able to command a leadership position in the vital new domain of biobusiness. The overall competitive situation of Minnesota's biobusiness technology sector, in comparison with the overall macroeconomic situation in the state, is summarized in Figure 27.

For now, Minnesota is competitive, overall, in biobusiness. However, in order to ensure a viable future for itself in biobusiness, Minnesota will need to activate all its available resources and creativity, and build upon its existing distinctive capabilities in biobusiness technology across a wide range of fields, at an accelerated level above what it has been doing in recent years.

What can be done to ensure a competitive future for Minnesota in biobusiness? Making comparisons with other states, using aggregate industry categories like "medical devices," "pharmaceuticals," "life sciences" or "biobusiness" will only go so far. Analysis of these generalities produces little more than indicators that suggest how well the state is doing and in which general areas it needs to improve its performance. These indicators do not reveal **what** needs to be done and **how** it should be done. Getting answers to those kinds of questions would require a different kind of analysis — one that is more fine-grained and attuned to the distinctive technological capabilities of the state and that would allow it to stand apart from the crowd rather than try to play catch-up.

Unless Minnesota can quickly identify several fields of biobusiness technology in which it has a reasonable chance of being the best, or among the best, in the world, its chances of ensuring a long-term internationally competitive position for itself in the biobusiness technology industry will be slim. The relevant information cannot be found in standardized national databases, and through high-level national comparative analyses. It can only be generated by carefully identifying all of the organizational players in the industry — whether they are profit-oriented corporations, service units of larger for-profit corporations, units of larger not-for-profit organizations or not-for-profit organizations in their own right — followed by a careful mapping exercise using technological



information generated directly from leaders in those organizations themselves. Would that kind of work be difficult to do? Perhaps. It certainly would involve walking along the road less traveled.

The citizens of Minnesota ought to start the challenging journey along this road earlier rather than later — despite lacking adequate maps for guidance. New maps need to be drawn and that can only be achieved by studying the local technological geography. Reading a national industry atlas may be instructive or inspirational, but it cannot lead to a better understanding of the local technological terrain and it cannot provide guidance about where one should place one's feet while walking.

What does all this mean in practice? It means that in addition to high-level comparative analysis between Minnesota and other biobusiness states and regions, it is also necessary to conduct a grassroots analysis of Minnesota's established and emerging biobusiness technology capabilities. It also means that future policies should be based upon the knowledge produced by such analysis.



– 7 –



Grassroots Assessment of Minnesota's Distinctive Capabilities

Overview and Methodology

As was discussed earlier, the most important limitation of the standardized industry databases is that they provide very little help for states, such as Minnesota, that want to identify how to build a distinctive technological base for future economic development. The fulfillment of this goal requires a different approach — a grassroots approach — targeting the technological strengths and weaknesses of the state through analysis of data collected directly from local biobusiness organizations (i.e., collecting information from the grassroots, rather than from top-level national sources). This is the approach that we chose to follow for the second part of our statewide biobusiness assessment project.

This grassroots part of the project focused on identifying the technologies that underlie the products and markets of biobusiness technology enterprises. It identified core technologies and products that Minnesota companies are involved in producing, the markets in which they are selling and upon which the academic sector is focusing its research. A fundamental objective of this approach was to make feasible the identification of linkages and areas of convergence between underlying technologies and across industries.

Unlike the comparative study, the grassroots analysis included **both for-profit and not-for-profit organizations, in both the academic and industry sectors**. Another significant difference between the two studies was that, while both attempted to focus on biobusiness entities that produce technology, the grassroots study was able to be more selective in the data it gathered. As such, the entities studied during the grassroots analysis were exclusively biobusiness enterprises devoted to the goal of developing or commercializing bioscience or bioscience-related technologies, products or services.

This grassroots approach was implemented in two phases. First, the approach required the generation of a comprehensive census of Minnesota's academic and private-sector technology enterprises (corresponding to the concepts and definitions outlined earlier in this report and as illustrated in Appendix 1, Figure 34.) Second, it required conducting a detailed study by gathering data directly from each enterprise identified in the census.



The grassroots approach to assessing biobusiness capabilities required using language in a fresh way, unencumbered by the outdated industry categories of standardized national databases. It also required recognizing the biobusiness technology activities of organizations not included in the pertinent NAICS categories of the economic census. It is critically important to employ nomenclature for industries and technologies that reveals, rather than obscures, the essential underlying truth about a region's emerging distinctive capabilities.

Accordingly, two key definitions were adopted to guide our work during the grassroots study: “biobusiness technology enterprises” (BTE) and “nascent biobusiness technology enterprise” (Nascent BTE).

*A **Biobusiness Technology Enterprise (BTE)** is a technology-based business focused on biology.*

In order to qualify in our study as a BTE, an organization had to be devoted to the goal of developing or commercializing bioscience or bioscience-related technologies, products or services. It did not necessarily need to have a successful end product on the market but, to qualify as a bona fide BTE, an organization's activities needed to be directed toward the development of biobusiness technology. In addition, because much of the research activity within universities and not-for-profit research institutes within the state is basic research, a more expansive criterion was applied to these entities. Academic BTEs were those that conduct basic or applied research with **potential** to commercialize the ensuing technology. A BTE may be an R&D unit inside a university, hospital or public-sector organization. It also may be a for-profit corporation or not-for-profit entity devoted to the development and/or commercialization of biobusiness technology, or a division within such an enterprise.

*A **Nascent Biobusiness Technology Enterprise (Nascent BTE)** is an organization with only a small proportion of its activities devoted to biobusiness, but with the potential to develop into a full BTE.*

To implement both phases of the grassroots analysis, the BioBusiness Alliance hired the ANGLE Technology Group as a consultant to identify Minnesota's assets in biobusiness technology. The ANGLE Technology Group conducted work on the census and detailed study during the second half of 2005, producing a confidential data set containing information about the technological capabilities of a sample of enterprises in Minnesota's biobusiness sector.

Results from the Census

The first phase of the grassroots study required the generation of a comprehensive census of Minnesota's academic, not-for-profit and private-sector BTEs. Screening criteria were developed based on our BTE and Nascent BTE definitions. These criteria were used as a filter to determine if an enterprise was a BTE, a Nascent BTE or neither. The census itself was conducted through utilizing desktop research, industry and regional directories, industry expert inputs and the institutional knowledge of the consultants.



The census resulted in the identification of 425 BTEs (417 private-sector companies or units within private-sector companies and eight academic R&D organizations) and the most comprehensive list of biobusinesses yet produced in Minnesota. The BTEs identified through the census included 150 private-sector enterprises not previously known to informed observers in the state. Even with this number, we are confident we have not yet found all of the BTEs that exist in Minnesota. The census also produced a list of 31 Nascent BTEs.

Figure 28. Map of Geographical Distribution of the 425 Biobusiness Technology Enterprises in Minnesota Identified in the Census, Fall 2005

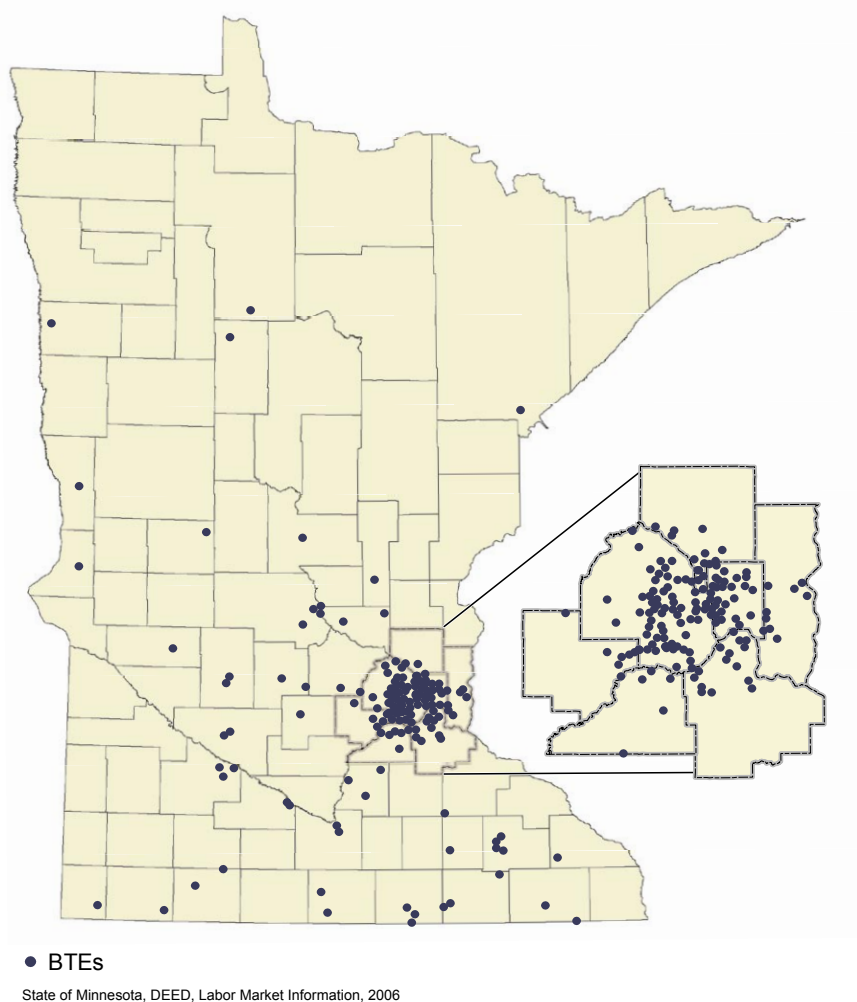
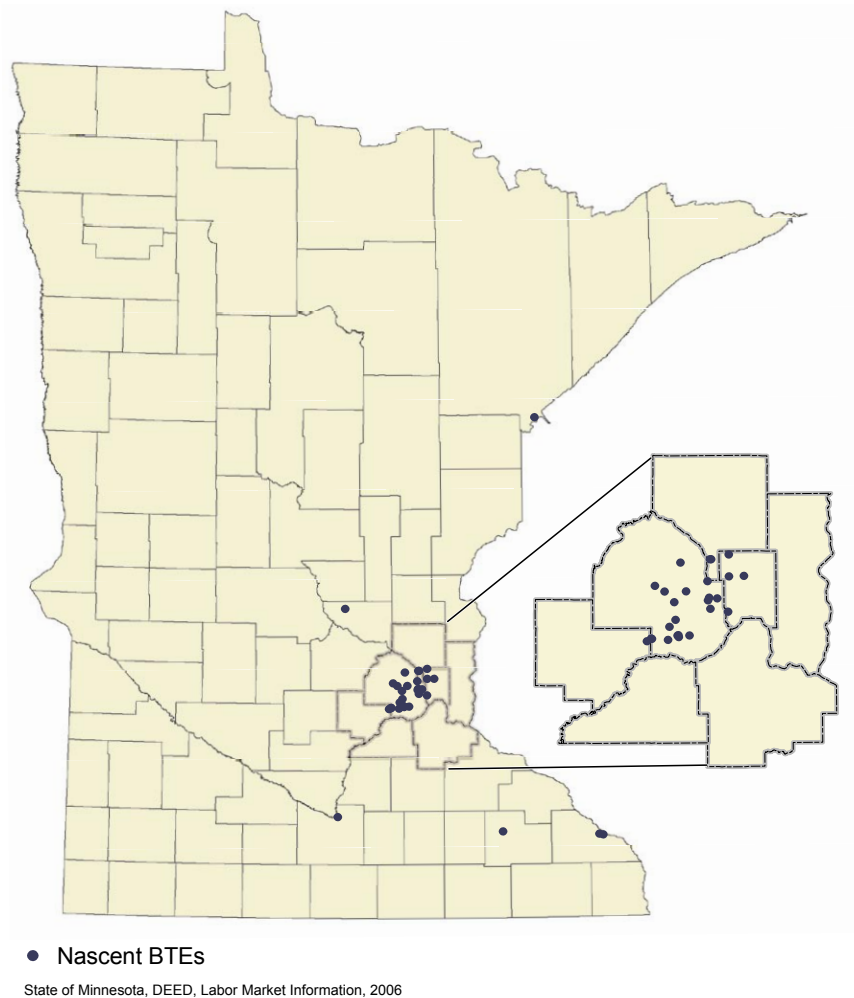


Figure 28 maps the geographical distribution of Minnesota's biobusiness technology enterprises identified during the census. While the majority of biobusiness technology enterprises are located in the Twin Cities metropolitan area, the industry is also widely distributed across rural areas of the state, with a somewhat higher concentration of enterprises in southern counties than in northern ones. A similar geographical distribution was found for the Nascent BTEs, shown in Figure 29.



Figure 29. Map of Geographical Distribution of the 31 Nascent Biobusiness Technology Enterprises in Minnesota Identified in the Census, Fall 2005



To aid in both the detailed study and in future analysis by the BioBusiness Alliance, a BTE database was developed with basic descriptors about each BTE. The database includes organization name, location, contact detail, enterprise description/ activities, primary field of technology and primary mode of activity. These data will be made public in the future. All confidential information collected during the grassroots assessment will be omitted.

Results from the Detailed Study

Once completed, the information generated during the census phase was used as the foundation for the second phase, the detailed study.

The detailed study was designed to identify the technological capabilities of the state's BTEs. The purpose of this exercise was to identify the foundation upon which future industries may be built.



In effect, our purpose was to clearly identify our strengths so that they may be used as “tools” to build Minnesota’s future economic engine.

To accomplish this, a detailed questionnaire was mailed to all BTEs, and many were then directly contacted (e-mail, telephone or face-to-face) by the consultants. The questionnaire asked participants to identify not only general enterprise information, but also their primary technologies, products and markets in four categories: current capabilities, key strengths, global leader and future focus.

Through the active support of volunteers of the BioBusiness Alliance, detailed survey data were collected from 35 percent of the 425 enterprises. Detailed coherent information on technology, product and market profiles were produced for about 25 percent of the 425 enterprises. During coming months, the BioBusiness Alliance of Minnesota will further analyze the data gathered during the survey in an effort to identify important opportunities for our state’s goal to be among the very best in the world in several fields of biobusiness. Highlights of the work conducted so far are summarized here.

To present the key results of the detailed study in an accessible and easy-to-interpret form, we decided to build upon the convention for classifying biotechnology that was developed and adopted by EuropaBio. We have extended and adapted EuropaBio’s color-coded system from biotechnology to a system that is applicable to the broader array of biobusiness technologies. These categories are based largely upon the fields of applications served by technologies. They represent the areas where our skill bases and our investments in infrastructure — or what could be called our “biobusiness toolbox” — exist or need to be developed. Our definitions are summarized below.

White biobusiness technology is *biobusiness focused on the application of biological technology in industrial fields such as biomaterials, bioprocessing, bioenergy, bio-based chemicals, food ingredients and bioremediation*. This field of biobusiness is synonymous with what we labeled as “bio-industrial technology” during the research for our census and the detailed study (see Appendix 1, Figure 34).

Green biobusiness technology is *biobusiness focused on the application of biological technology in the field of plants and agriculture*. This field of biobusiness is synonymous with what we labeled as “agri-bio technology” during the research for our census and the detailed study (see Appendix 1, Figure 34).

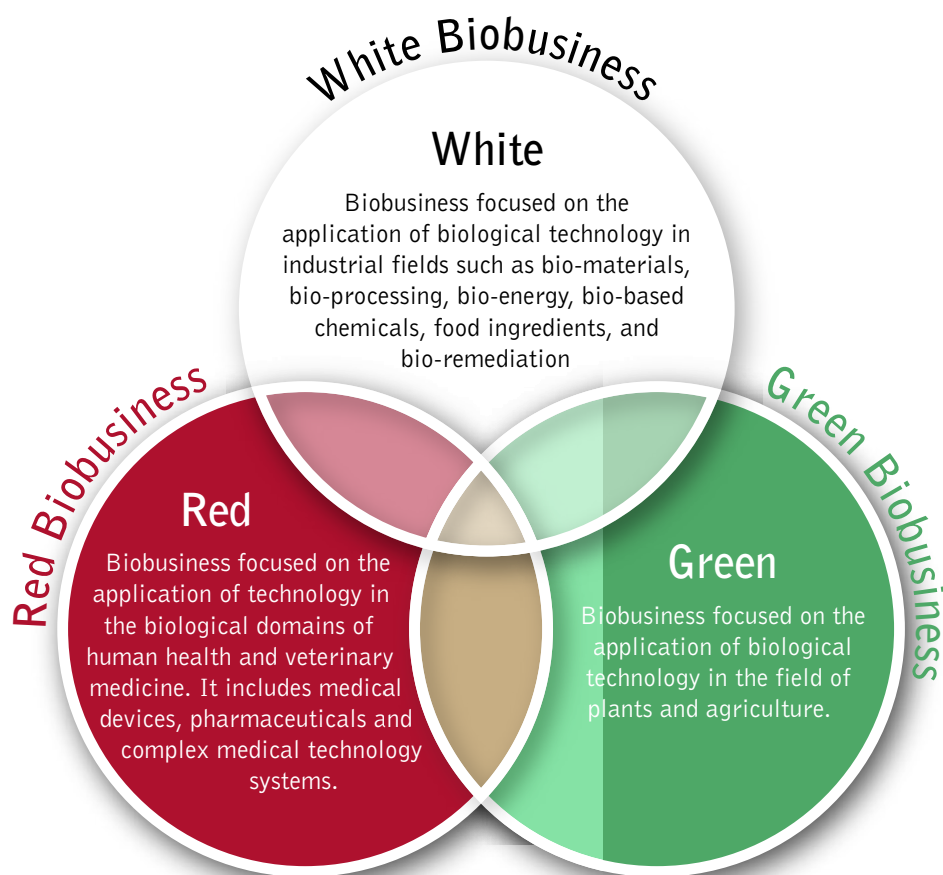
Red biobusiness technology is *biobusiness focused on the application of technology in the biological domains of human health and veterinary medicine*. It includes medical devices, pharmaceuticals and complex medical technology systems. This field of biobusiness is sometimes also called “medical technology” or “human health technology” (as shorthand for both human and animal medical technology).



Other Categories of Biobusiness Technology: Other color-coded biobusiness technology classifications may also be employed, such as blue biobusiness technology, which is biobusiness focused on the application of biological technology in aquatic contexts. It includes aquaculture, biotechnology-enhanced environmental remediation in both freshwater and oceanic settings, and other water-related bioscience-based economic activities.

In our project, we have restricted our analysis of enterprises to the dominant three categories of white, green and red biobusiness technology. These are illustrated in Figure 30. As suggested by the areas where the circles overlap in the Venn diagram, a biobusiness technology enterprise can simultaneously be active in more than one color category.

Figure 30. Fields of Application of Biobusiness



Using data from the detailed survey of respondents, we classified each enterprise for which we had data into each of the three color-coded biobusiness categories described in Figure 30. We took care to identify all cases in which an enterprise was simultaneously active in more than one field of biobusiness. The results of our analysis are summarized in Figure 31.



Figure 31. Minnesota Biobusiness Technology Enterprises
Percentage of BTEs Active in Each Biobusiness Field

Total BTEs in census = 425

BTEs in survey sample providing biobusiness field data = 108

BTEs in survey sample = 149

**Multiple Fields
of Biobusiness**

26.9% of industry

(estimated 114 BTEs)

**Red
Biobusiness**

92.6% of industry

(estimated 393 BTEs)

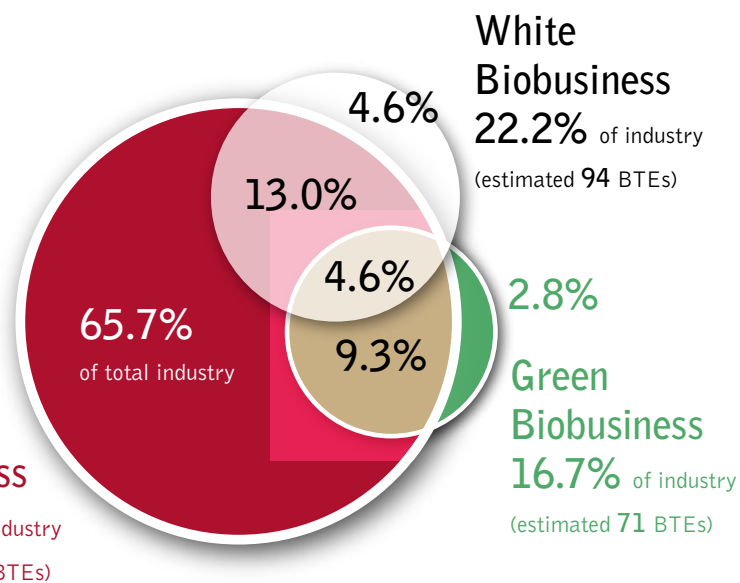


Figure 31 reveals three fascinating features of Minnesota's biobusiness technology sector. First, a significant majority (almost two-thirds) of Minnesota's biobusiness technology enterprises apply their technologies exclusively toward red biobusiness (i.e., health care technology / medicine). The vast majority (about 93 percent), furthermore, apply their technologies in one way or another toward red biobusiness.

Second, over a quarter of the enterprises in the sample (about 27 percent) are active in multiple fields of biobusiness. In other words, over a quarter are involved in some kind of biobusiness industry convergence and have skills and capabilities that cross over fields of application.

Third, of the enterprises active in white biobusiness and green biobusiness (just over one third of the sample), 78 percent are also active in red biobusiness. The implications of this fact are quite profound. It appears that Minnesota's technology enterprises active in white biobusiness and/or green biobusiness are contributors to what is going on in the wider domain of red biobusiness. In short, the skills needed to support the future prospects of medical biobusiness in Minnesota may be influenced, in some important ways, by the skills, technological innovation and business practices of enterprises based primarily in non-medical biobusiness fields. Medical biobusiness (red) appears to be interlinked with agri-bio (green) and bio-industrial (white) biobusiness.

This last topic — **the interconnectedness of different fields of biobusiness in Minnesota** — will be a pivotal theme for the subsequent work of the BioBusiness Alliance of Minnesota.



Figure 32. Top 20 Fields of Technological Capability for Minnesota’s BTEs in Each Biobusiness Market Category, in Descending Order (un-weighted for size of BTE)

Red Biobusiness	Green Biobusiness	White Biobusiness	Multiple Fields of Business
biomaterials	plant sciences	bioenergy	biomaterials
biocompatibility	genomics	microbiology	microbiology
plastics/polymer processing	biomaterials	biomaterials	chemical synthesis
drug delivery	cell culture	chemical synthesis	plastics/polymer processing
chemical synthesis	microbiology	fermentation	drug delivery
microbiology	biomarkers	genomics	device coating
cell culture	bioreactors	bioprocessing	genomics
biomechanics	fermentaion	plastics/polymer processing	biocompatibility
device coating	gene sequencing	biocompatibility	cell culture
mathematical modeling	data mining	fluid filtration	mathematical modeling
bioreactors	immunology	bioreactors	bioreactors
tissue engineering	bioinformatics	food processing	fermentation
genomics	food processing	drug delivery	fluid filtration
electrophysiology	plastics/polymer processing	cell culture	implantable electronics & sensors
fluid filtration	drug delivery	device coating	electrophysiology
immunology	chemical synthesis	mathmatical modeling	data mining
information processing	device coating	immunology	immunology
bioprocessing	biocompatibility	plant sciences	gene sequencing
fermentation	fluid filtration	data mining	information processing
implantable electronics & sensors	mathematical modeling	biomarkers	bioprocessing

To produce Figure 32 we counted the frequency with which biobusiness technology enterprises (BTEs) from the survey sample indicated they possessed significant internal capability in 46 different broadly defined fields of technology. The top 20 fields of technological capability, based on BTE self-reports, were then listed for each of the three basic color-coded fields of application



for biobusiness. We also repeated this exercise for all enterprises in the sample that were active in more than one field of application. The results of that exercise are shown in the fourth column of Figure 32.

A quick review of the top six fields in each of the four columns reveals that the technological and scientific field (broadly defined) that appears to be most prominent across all of the fields of application of biobusiness in Minnesota is biomaterials, followed by microbiology. The next most widespread field appears to be chemical synthesis technology. This is followed by plastics and polymer processing, drug delivery and genomics.

The 20 broad fields of technology identified for BTEs active in multiple fields of application (i.e., multiple biobusiness markets) represent potentially fruitful domains for further analysis. By digging more deeply within these areas, using finer categories of science and technology, we may hopefully make progress in providing clarity to the BioBusiness Alliance and interested parties within Minnesota regarding the handful of technological fields in which our state may truly stand apart from the global biobusiness crowd.

As discussed earlier in this report, the U.S. Economic Census does not include data from the universities and not-for-profit academic organizations as part of the official “R&D in the Life Sciences” NAICS category. A number of informed observers of life sciences research in Minnesota have also noted that biotechnology and other life sciences research in Minnesota is concentrated primarily in the academic sector, rather than elsewhere, and hence that the U.S. Census data need to be complemented by other data to provide a true picture of what is happening in the state. Our detailed grassroots study has sought to address these challenges for Minnesota by collecting information about that topic directly from the state’s academic organizations. The key results are summarized in Figure 33.

Figure 33. Biobusiness Technology Employment in Minnesota’s Academic Sector, 2006

Organization	Total # workers	Total Salary
University of Minnesota	1,877	\$102 million
Mayo Clinic	2,870	\$154 million
Minnesota State Colleges & Universities	180	\$12.0 million
Total	4,822	\$261 million (approx)

The numbers reported in Figure 33 are estimates only and should be treated simply as rough



indicators of the overall life sciences R&D capacity found in Minnesota’s academic organizations. Each academic institution has employed slightly different definitions of what constitutes R&D related to the life sciences, and of what constitutes an actual bioscience technology research unit within their respective institution. In addition, there are slight differences between each institution in the way that a person or a “full time equivalent person” is counted. Furthermore, as mentioned earlier, we know that there are BTEs in the state that have not been captured yet in the current analysis. In the area of not-for-profit organizations, for example, there are a number of medical centers in addition to the Mayo Clinic that also conduct vital biosciences research. We will continue to study the R&D capacity of the already identified academic BTEs and conduct research to characterize other not-for-profit BTEs not yet identified. For now, the numbers in Figure 33 provide a reasonably good indication of the overall situation for R&D related to the life sciences in Minnesota’s academic organizations.

In order to make full use of this information we need to recognize that life sciences related research activities (as opposed to manufacturing activities related to the life sciences) are distributed across three types of organizations, as follows:

$$\begin{aligned}
 &\textbf{Total Life Sciences related R\&D} \\
 &= \\
 &\quad \text{“R\&D in the life sciences” (NAICS 5417102) — in dedicated R\&D firms [Type 1]} \\
 &\quad + \\
 &\quad \text{R\&D related to the life sciences — in academic organizations [Type 2]} \\
 &\quad + \\
 &\quad \text{R\&D related to the life sciences — inside manufacturing firms [Type 3]}
 \end{aligned}$$

The information presented earlier in this report, in our multi-state comparative study of competitiveness in biobusiness technology, only included data from *Type 1* organizations (R&D in the life sciences in dedicated R&D firms—in other words, NAICS 5417102 data). For interstate comparison purposes this is the most reliable and standardized type of data that may be obtained without doing a separate major study. For the purposes of a comprehensive grassroots analysis, however, we also need to include data from *Type 2* organizations and *Type 3* organizations.

Because of the minor inconsistencies and approximations in the way that the data in Figure 33 were assembled, the terms “R&D in the life sciences” or “R&D related to the life sciences,” are being used with the same meaning as “R&D in bioscience technology.” In short, until such time as more fine-tuned research may be conducted in this area we have adopted fairly loose inclusion criteria for life sciences related R&D employment.

The information in Figure 33 reveals that the total number of full-time-equivalent persons



employed in biobusiness technology research activities in the University of Minnesota, the Mayo Clinic and the Minnesota State Colleges and Universities combined (i.e., in Minnesota's dominant *Type 2* organizations) is about 4,800 persons. Thus *Type 2* organizations account for over twice the number of people employed in R&D in the life sciences as do *Type 1* organizations (which, according to estimates provided in Figure 3, had reached about 2,200 by 2005). We can therefore estimate that there are probably about 7,000 people in Minnesota employed in establishments that are ostensibly devoted to research and development (as opposed to manufacturing) in fields of the life sciences. In other words, there are about 7,000 people in Minnesota's *Type 1* and *Type 2* organizations combined who are engaged primarily in life sciences research and development.

What about *Type 3* organizations? We can guess (from informal knowledge of the industry) that about 10 percent of the employees inside biobusiness technology enterprises classified by the Census Bureau as manufacturing establishments actually conduct life sciences R&D as their primary work. Hence, extrapolating from the data in Figure 3, we can estimate there are probably about 3,000 people in Minnesota employed in manufacturing establishments (*Type 3* organizations) who actually conduct R&D in the life sciences.

The above data and estimates can be combined together as follows: total employment in R&D in the life sciences in Minnesota = *Type 1* employment + *Type 2* employment + *Type 3* employment = 2,200 + 4,800 + 3,000 = 10,000. In short, we can estimate that currently there may be something in the order of 10,000 full-time-equivalent persons in Minnesota conducting research and development in the life sciences, spread across a variety of organizations in academia, manufacturing firms and R&D firms.

Having some sense of the total scale of life sciences R&D employment in Minnesota is a key to understanding whether or not the state will have sufficient life sciences R&D capability to meet the global challenges of biobusiness industry convergence. The results just summarized also point to the importance of cultivating strong interactions between the academic sector and the commercial technology sector for the purpose of bolstering Minnesota's biobusiness technology competitiveness.

An Industry Perspective on the Grassroots Assessment¹⁵

There is an old saying in industry that goes something like this: "*When making an investment, people and capital are for life, so make those decisions carefully.*" Obviously a company can sell its physical facilities and, with some restrictions, change its employees. However, the skills you hire and the capital equipment you buy, reflects what you think your business is now or will be in

¹⁵Thanks are due to Dale Wahlstrom for valuable insights that contributed to this section.



the future. The outcomes of these investments determine, to a large part, the technology base of a company. A company's level of technological competence determines to a large degree its ability to compete. Understanding all of this gives observers a picture of what those in charge of a company are thinking. This old saying arguably applies to communities, such as Minnesota, as well as to individual companies.

Companies, universities and legislators typically resist making new investments as long as they can. They are expensive, and there needs to be a justifiable reason. The trick is to make the investment neither too early nor too late. Often times, the decision to invest is postponed so long that a company, or state, misses the mark entirely and loses the ability to compete. Some argue that this happened 20 years ago in Minnesota in the computer industry. Most of those companies are gone. Sometimes investments are made too early and the market is not ready. These companies also frequently disappear.

Why does this happen? One explanation is clear. Once an investment is made that commits significant resources, the investor has to regain that money before they will upgrade to the newest technology. A great example where the United States made an initial investment in technology that has become outdated is that of wireless telecommunications. The United States was among the first countries where cell phone technology was made broadly available. We had state-of-the-art technology. We invested heavily in infrastructure. Today, we still have most of that first-generation infrastructure. China, Africa and South America invested in second-generation technology. Today, when this author drives from his home in one part of the Twin Cities metro area to his office in another part of the Twin Cities metro area, he will be "dropped" three times. Using the same telephone, he has traveled much of China, South America and Europe, but has never been dropped ... even in the most rural parts of northern China. Early investments in technological infrastructure have put Americans at a disadvantage in terms of mobile wireless communications compared with people in the rest of the world, including the Third World. It is important that a similar story to the one about U.S. cell phone technology is not repeated for biobusiness in Minnesota. It is important for us to use foresight when making key technological investments for biobusiness.

We believe that understanding the skills and capabilities of the technologies Minnesota's BTEs have mastered today, or are developing for the future, will give us the above-mentioned picture of where the leadership of our universities and companies think our world is headed. We wanted to create a baseline of what our skills and technological infrastructure are within the state. We think it will be very important as we begin our Destination 2025 journey. This information will help us to understand where we are investing, and why we are investing, so we can compare that against the picture of the direction in which we believe our key industries (worldwide) will head in the future. By comparing the perspectives these two sets of information will give us, we should be able to define what we need to do to "adjust our tack to put the wind squarely in our sails for the future."

Over time, we will assess which technologies will transfer to the evolving biobusiness economy, and which will not. Based on these findings we will give recommendations to our academic and



research institutions for curriculum and research needs. We will also be able to give context to help our legislators with priorities in decision making. Finally, we will inform our private-sector organizations and leaders about what we have learned so they can target their investments more effectively.

Some examples may help illustrate what these foregoing reflections mean, at a practical level, for biobusiness in Minnesota. The information illustrated in Figure 31 and Figure 32 reveals how important it is for technological capability possessed by practitioners in one field to be recognized and learned about by practitioners in another field.

Technological innovation in white biobusiness and green biobusiness may stimulate innovation in Minnesota's red biobusiness fields. For example, new generations of biomaterials, and associated production methods, developed by white biobusinesses may be applied by red biobusinesses to create non-toxic interfaces between medical implants and natural body tissue. New applications of biotechnology in white biobusiness may lead to new biological coatings on devices that make the surfaces of those devices essentially biologically invisible to the human body or animal body.

Biomarkers developed in green biobusiness technology enterprises may have applications in red biobusiness settings. Genetically modified plants from green biobusiness may have applications for pharmaceutical production (red biobusiness). Fermentation techniques developed in white biobusiness may also be applied in pharmaceutical (red biobusiness) or nutraceutical production (red/green/white biobusiness). Biodegradable packaging systems, using new biomaterials, may be applied for cost savings and improved environmental sensitivity by red biobusiness enterprises. Data mining software solutions developed in one field of biobusiness may be modified for application in another field of biobusiness.

Minnesota has been an early mover in combination products that transcend the boundaries of biobusiness fields, and that feed off interdisciplinary technological innovation. Drug-eluting stents are a recent example, but Minnesota has been a home for this kind of crossover technology for quite some time, as illustrated by its early development of steroid-eluting leads. Individual companies may invent particular combination technologies and products that have a big market impact; but those companies, and the people who work inside those companies, draw not only upon internal company resources for their innovations, but also upon the invisible web of knowledge, expertise, technological culture and problem-solving ability that exists in the wider community of the state.

The general point to be made here is that Minnesota's future competitiveness in biobusiness will depend upon seeing our state's different bio "industries" as being part of a larger bio-related industrial network, rather than being discrete islands of business activity centered around segregated markets. In other words, the future of our medical industries (red biobusiness) is increasingly interdependent with the future of our plant-based industries (green biobusiness) and bio-industrial processing industries (white biobusiness). Minnesota's future economic health will be



significantly affected by the degree to which the different biobusiness sectors of the state can work together as part of one larger biobusiness community of enterprises. Facilitating such cooperation is one of the clear requirements for long-term success.



— 8 —



General Conclusions of the Assessment Project: Minnesota's Present Position and Future Prospects

What are the general conclusions that may be drawn from the two parallel lines of investigation we have followed in our assessment of Minnesota's biobusiness industries? There are eight key results that arise from our investigations to date and that provide the foundations for the themes that may guide our work from here on.

Minnesota's economy is more dependent upon biobusiness than average for the United States

While biobusiness is becoming a centerpiece of economic development planning throughout the United States and internationally, the biobusiness sector is more important to Minnesota's economy than it is to most other states. As revealed in Figure 1, Minnesota's economy is 24 percent more dependent upon biobusiness technology than is the norm for the whole of the United States.

As the emerging global biobusiness economy unfolds, there is more at stake for Minnesota than for the rest of the country. What we do to nurture this sector of employment and to strengthen it against competition matters for the citizens of our state.

Minnesota's biobusiness sector is distinctive

Minnesota's biobusiness sector is already "dancing to the tune of its own drum" and has been doing so for a long time. Biobusiness in Minnesota is not merely a microcosm of the biobusiness sector of the United States. It has unique characteristics that need to be recognized and cultivated as the basis for distinctive and sustainable competitive advantage, nationally and globally. As revealed in Figure 4, for example, the prominence of the medical devices component of biobusiness technology is extraordinarily high. Medical devices account for a 128 percent greater share of biobusiness technology in Minnesota than they do for the United States as a whole. In addition, as revealed by Figures 24 to 26, Minnesota's biobusiness technology sector is much more prominent in the general area of bioenergy than is the case for other states.

"Copy cat" strategies from other states will probably therefore not be optimal for Minnesota's



biobusiness development. Minnesota needs to craft strategies and adopt policies designed to celebrate and enhance our state's distinctive biobusiness technology profile.

Minnesota's emerging biobusiness sectors exhibit high levels of convergence with established biobusiness sectors

The various subsectors of biobusiness in Minnesota are not discrete and isolated sets of activities. Organizations in Minnesota engaged in biobusiness, whether for-profit companies, not-for-profit institutes or units of universities and hospitals, are often active in multiple fields simultaneously, stretching across conventional market and product categories. For example, as revealed in Figure 31, 78 percent of Minnesota's white and green biobusiness enterprises are also active in red biobusiness.

In short, the proportion of Minnesota's enterprises engaged in the application of biological technology in the fields of plants and agriculture, or in industrial fields such as biomaterials, bioprocessing, bio-based chemicals, food ingredients, or bioremediation, that are also engaged in the general area of medical technology, or human health technology, is substantial. There is already a high level of industry convergence apparent for enterprises in Minnesota's emerging white biobusiness and green biobusiness sectors.

The future of Minnesota's established biobusiness sectors (red) is interdependent with the future health of Minnesota's emerging biobusiness sectors (green and white)

The fact that there is already significant convergence between Minnesota's different fields of biobusiness suggests that the prospect for employment growth in the state's emerging biobusiness sectors is somewhat dependent on the growth of the established sectors, and vice versa. The fact that red biobusiness is dominant in Minnesota, combined with the fact that the green and white biobusiness sectors exhibit greater convergence with red biobusiness than the red biobusiness sector exhibits with the others, suggests the following: *The future competitiveness of non-medical biobusiness in Minnesota is substantially connected to the future competitiveness of medical biobusiness in Minnesota.* This is because individual enterprises in the emerging sectors are dependent for a good deal of their business upon maintaining a presence in established fields related to medicine and health. Conversely, innovations emanating from the emerging sectors may significantly feed into innovation within the established sectors.

The future competitiveness of biobusiness in Minnesota requires cooperation between stakeholders in the different biobusiness sectors. It appears from the evidence we have assembled that growth in one biobusiness sector should not be seen as taking place at the expense of growth in another sector. The sustained development of red biobusiness should be seen as one key to the sustained growth of green biobusiness and white biobusiness. **The fact that there are underlying fields of knowledge, technology and science that transcend multiple biobusiness fields is probably one of**



the reasons for the apparent dependence that we have observed of some fields of application on others.

Minnesota's biobusiness sector is growing

Biobusiness in Minnesota is dynamic. Despite problems faced by the state between 1997 and 2002, in the face of competition from elsewhere, the overall biobusiness sector is growing. As revealed in Figure 3, over 7,000 new biobusiness jobs appear to have been created in Minnesota since 2002. This growth generates opportunities to capitalize on the interplay that already appears to have emerged between the various fields of biobusiness in the state.

The biobusiness employment growth that we have witnessed in recent years also provides hope that the unusually high contribution of biobusiness to the economy of Minnesota (compared with the economies of other states) may be sustained, as long as the threats posed by the growth of biobusiness elsewhere are addressed.

Minnesota's competitive position is under threat due to heavy biobusiness investment and growth in other states

The encouraging picture painted by the information just summarized needs to be counterbalanced against one sobering fact: Despite growth in biobusiness overall in recent years, Minnesota's current competitiveness is under threat as other states invest heavily, aggressively and creatively in developing their own biobusiness industries in competition with those of Minnesota.

While Minnesota does well in many areas, the data summarized in Figures 5 through 27 present a clear message when taken as a whole: Minnesota cannot afford to rest on its past laurels. Our state needs to act strategically and decisively to maintain a competitive position in biobusiness in future years.

The health of Minnesota's economy will be affected by whether or not the competitiveness of the state's biobusiness sector can be strengthened

The fact that Minnesota's economy is more dependent on biobusiness than are the economies of most other states in the United States, combined with the fact that biobusiness in Minnesota is facing serious competitive threats from elsewhere, means that taking fresh steps to improve the competitiveness of Minnesota's biobusiness sector really matters to the wider community of our state. Making Minnesota more competitive in biobusiness matters not just for people, companies and institutions that are directly active in biobusiness, but also for the whole state.

In addition, given that the average wage in the biobusiness / biosciences sector is about 165 percent of the average private-sector wage in the United States, and that every new bioscience job added



to the economy results in the creation of 5.7 additional jobs, the positive benefits to the citizens of Minnesota from strengthening biobusiness are even greater than it might appear at first.¹⁶ In short, positive actions to improve the competitiveness of biobusiness in Minnesota will be amplified disproportionately throughout the state's economy. There is a lot at stake here for Minnesota.

The train has not yet left the station

Returning to a theme about which we have been mindful throughout our project, the biobusiness “train” has not yet left the station. However, we have discovered through our investigations that — metaphorically speaking — other states and other communities are busy investing in their own biobusiness “railway” systems, complete with tracks, stations, rights of way, new types of locomotives and new rail support services. Minnesota needs to plan and implement its next-generation “biobusiness rail system” with renewed vigor and urgency ... and in a manner that truly reflects the distinctive technological capabilities of the state. The dynamism, uniqueness and recently renewed growth of the employment and business activity in our state's biobusiness sector provides solid grounds for hope that the necessary steps can be taken to sustain Minnesota as a first-tier global player in the biobusiness fields where it can truly be among the best of the best.

¹⁶The two items of economic data are taken from the following source: Battelle Technology Partnership Practice and SSTI, Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006 (Columbus, OH: Battelle Memorial Institute, April 2006).



Appendix 1

Definitions of Basic Biobusiness Concepts

Biobusiness

Biobusiness is economic activity devoted to the development or commercialization of bioscience or bioscience-related technologies, products or services.

In other words, biobusiness is technology-based economic activity centered on biology. Biobusiness deals with the spectrum of enterprises from start-ups to established firms, together with associated infrastructure and support services. In this project, however, we have left analysis of the associated infrastructure and support services to another occasion. We have instead focused our analysis on a narrower set of enterprises: those whose primary business is the development or commercialization of biological technology. We call these organizations “biobusiness technology enterprises” (to be defined and explained below).

Bioscience

Bioscience is knowledge based on the life sciences, especially emerging molecular and cellular biology, and also science applied to human health, agriculture, and bio-related industry.

Bioscience is a key source of what may be called “biobusiness technology” or “biological technology.”

Life Sciences

The life sciences are the collection of sciences concerned with the study of living organisms, including biology, botany, zoology and the medical sciences, but also including other biology-related fields such as biochemistry or ecology that deal with the functions of organisms, and the relationships between organisms and between organisms and their environments.

Sometimes, the terms “life sciences” and “biosciences” are used interchangeably.

Biobusiness Technology

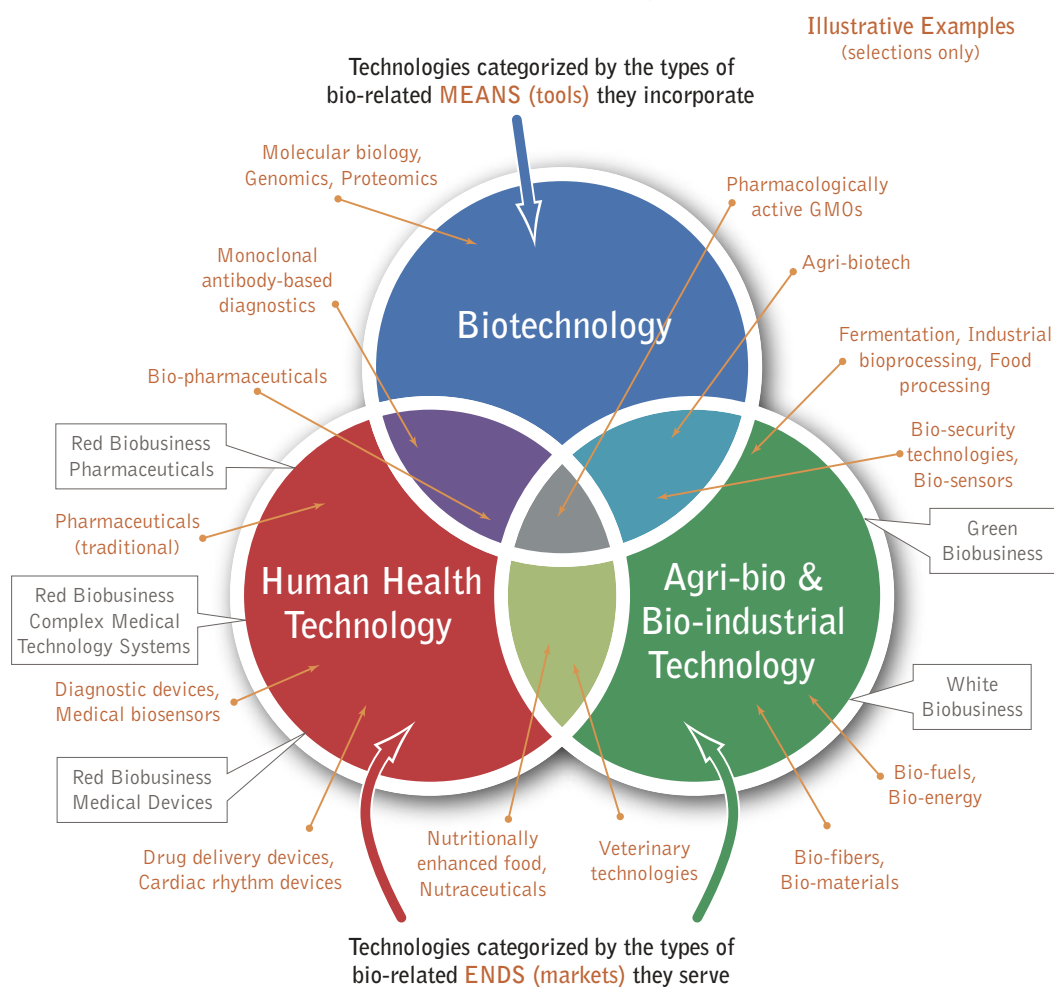
Biobusiness technology is technology devoted to the biological domain, as either a system of tools or as a field of application.

Put simply, biobusiness technology is technology focused on biology. It is the technological foundation of biobusiness. Biobusiness technology could, in principle, also be called “biological technology.”



Strictly speaking, the term “biotechnology” could be used as a label for this domain of technology. However, during the last two decades, that term has come to describe a narrower set of biological technologies, centered on the application of certain contemporary fields of science including molecular biology, cell biology, microbiology, genomics and proteomics. We have therefore been forced to coin some other terms to embrace the broad scope of technological activity focused on the biological world. We have chosen not to follow the fashion of using “bioscience” for that purpose, because we believe that science — specifically, bioscience — is just one element (albeit a critically important element) of that domain. Hence, we use the term “biobusiness technology” to cover what we would otherwise wish to label as “biotechnology.”

Figure 34. Fields of Biobusiness: Biological Technology



Biobusiness incorporates both technologies defined according to the means they employ and technologies defined according to the ends they are intended to serve. Biotechnology is a category of technologies which, properly understood, may be grouped together because of a common (or complementary) set of scientific-cum-technical means which they incorporate. In contrast, both



human health technology and agri-bio/bio-industrial technology are categories of technology which, properly understood, may be grouped together because of a common set of ends (purposes or market-applications) which they serve.

A particular technology may be simultaneously classified by both the ends that it serves and the means that it employs. For example, a diagnostic test kit based upon monoclonal antibody technology may be simultaneously classified as both a biotechnology product and a human health technology product. Likewise, a genetically engineered micro-organism for digesting oil from an aquatic ecosystem may be simultaneously classified as both a biotechnology product and as an agri-bio/bio-industrial technology product (but not as a medical technology product). Similarly, a specialized polymer for use in surgical implants may be classified as a medical technology product but not necessarily as a biotechnology product.

Biotechnology

Biotechnology is technology consisting of biological systems that are engineered at the micro level for practical applications.

More formally, biotechnology may be defined as technology in which biological systems are conceived, controlled, or influenced through the application of molecular biology, cell biology, microbiology, genomics or proteomics, and which are employed as means toward the attainment of practical ends. Biotechnology may be directed toward any practical purpose, including human health or agri-bio and bio-industrial applications, and also many other applications; but it may only incorporate means drawn from certain specified fields pertaining to the biosciences.

Human Health Technology

Human health technology is technology directed primarily toward medical applications.

It includes medical devices (both diagnostic devices and therapeutic devices), pharmaceuticals, and complex medical-technology systems (combining either chemicals or other technologies). Human health technology may incorporate technical means from any field of technology, including biotechnology.

Agri-bio and Bio-industrial Technology

Agri-bio and bio-industrial technology is technology directed primarily toward applications in biosystems (outside the human body).

It includes selected agricultural, animal husbandry, aquaculture, food-processing, food-supplement, environmental-management or life-sciences technologies. Agri-bio and bio-industrial technology may incorporate technical means from any field of technology, including biotechnology, but it must be directed toward applications in living systems or biology-related contexts.



Biobusiness Technology Enterprise

A biobusiness technology enterprise is a technology-based business focused on biology.

More particularly, a biobusiness technology enterprise (“BTE”) may be defined as a biotechnology enterprise, a human health technology enterprise, a dedicated agricultural-bio or industrial-bio technology enterprise, or a combination of any of these types of enterprises. A biobusiness technology enterprise must be devoted to the goal of developing or commercializing bioscience or bioscience-related technologies, products or services. It does not necessarily need to have a successful end product on the market, but to qualify as a bona fide biobusiness technology enterprise, an organization’s activities must be directed toward the development of biobusiness technology. A biotechnology research laboratory in a university would qualify by this criterion as much as would a free-standing biotechnology firm. A biobusiness technology enterprise could also be called a “biological technology enterprise.”

It is important to recognize that a biobusiness technology enterprise may be devoted to the goal of developing or commercializing bioscience-related services, as well as technologies and products. Research and development activities are service activities, and commercialization of R&D is therefore an example of the commercialization of services. Only certain kinds of services — those that are specifically part of bioscience or that are closely related to bioscience (e.g., technical services employed in bioscience labs) — are eligible for inclusion as the “services” to be commercialized. In short, to be included as an essential element of what qualifies a biobusiness technology enterprise as a BTE, services must be technological services and not just professional services or business services. An example of a service that could be commercialized might be a genetic testing technique based upon genomics research. A genetic testing technique is not a “thing,” even if it may require the use of “things” — rather, it is a service — but it is a special kind of service, a technological service.

Further Classification of Biobusiness by Fields of Application

Building upon the convention for the classification of biotechnology, set by the trade group EuropaBio, we have adopted a color-coded system for classifying fields of biobusiness and biological technology. These categories are based largely upon the fields of applications, or markets, served by technologies and enterprises, and not upon the underlying technologies themselves.

White Biobusiness Technology

White biobusiness technology is biobusiness focused on the application of biological technology in industrial fields such as biomaterials, bioprocessing, bioenergy, bio-based chemicals, food ingredients and bioremediation. This field of biobusiness is sometimes also called “bio-industrial technology.”



Green Biobusiness Technology

Green biobusiness technology is biobusiness focused on the application of biological technology in the field of plants and agriculture. This field of biobusiness is sometimes also called “agri-bio technology.”

Red Biobusiness Technology

Red biobusiness technology is biobusiness focused on the application of technology in the biological domains of human health and veterinary medicine. It includes medical devices, pharmaceuticals and complex medical technology systems. This field of biobusiness is sometimes also called “medical technology” or “human health technology” (as shorthand for both human and animal medical technology).

Blue Biobusiness Technology

Blue biobusiness technology is biobusiness focused on the application of biological technology in aquatic contexts. It includes aquaculture, biotechnology-enhanced environmental remediation in both freshwater and oceanic settings, and other water-related bioscience-based economic activities.

Due to the manner in which data were collected during the project, no separate analysis of blue biobusiness was conducted, although we see this as a future field to investigate and nurture.



Appendix 2

Definitions of Selected NAICS Categories Employed in Comparative Study

NAICS 3254 Pharmaceutical and medicine manufacturing

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing biological and medicinal products; (2) processing (i.e., grading, grinding, and milling) botanical drugs and herbs; (3) isolating active medicinal principals from botanical drugs and herbs; and (4) manufacturing pharmaceutical products intended for internal and external consumption in such forms as ampoules, tablets, capsules, vials, ointments, powders, solutions and suspensions.

NAICS 3391 Medical equipment and supplies manufacturing

This industry comprises establishments primarily engaged in manufacturing medical equipment and supplies. Examples of products made by these establishments are laboratory apparatus and furniture, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, dentures and orthodontic appliances.

NAICS 334510 Electromedical and electrotherapeutic apparatus manufacturing

This U.S. industry comprises establishments primarily engaged in manufacturing electromedical and electrotherapeutic apparatus, such as magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs and electromedical endoscopic equipment.

NAICS 334517 Irradiation apparatus manufacturing

This U.S. industry comprises establishments primarily engaged in manufacturing irradiation apparatus and tubes for applications, such as medical diagnostic, medical therapeutic, industrial, research and scientific evaluation. Irradiation can take the form of beta rays, gamma rays, X-rays or other ionizing radiation.

NAICS 5417102 Research and Development in the Life Sciences

Establishments primarily engaged in conducting research and experimental development in medicine, health, biology, botany, biotechnology, agriculture, fisheries, forests, pharmacy and other life sciences, including veterinary sciences.

NAICS 6215 Medical and diagnostic laboratories

This industry comprises establishments known as medical and diagnostic laboratories primarily engaged in providing analytic or diagnostic services, including body fluid analysis and diagnostic



imaging, generally to the medical profession or to the patient on referral from a health practitioner.

NAICS 325193 Ethyl alcohol manufacturing

This U.S. industry comprises establishments primarily engaged in manufacturing nonpotable ethyl alcohol.

NAICS 325221 Cellulosic organic fiber manufacturing

This U.S. industry comprises establishments primarily engaged in (1) manufacturing cellulosic (i.e., rayon and acetate) fibers and filaments in the form of monofilament, filament yarn, staple or tow or (2) manufacturing and texturizing cellulosic fibers and filaments.

NAICS 311221 Wet corn milling

This U.S. industry comprises establishments primarily engaged in wet milling corn and other vegetables (except to make ethyl alcohol). Examples of products made in these establishments are corn sweeteners, such as glucose, dextrose and fructose; corn oil; and starches (except laundry).

NAICS 311222 Soybean processing

This U.S. industry comprises establishments engaged in crushing soybeans. Examples of products produced in these establishments are soybean oil, soybean cake and meal, and soybean protein isolates and concentrates.

NAICS 311223 Other oilseed processing

This U.S. industry comprises establishments engaged in crushing oilseeds (except soybeans) and tree nuts, such as cottonseeds, linseeds, peanuts and sunflower seeds.

NAICS 31212 Breweries

This industry comprises establishments primarily engaged in brewing beer, ale, malt liquors, and nonalcoholic beer.

NAICS 31213 Wineries

This industry comprises establishments primarily engaged in one or more of the following: (1) growing grapes and manufacturing wine and brandies; (2) manufacturing wine and brandies from grapes and other fruits grown elsewhere; and (3) blending wines and brandies.

Note: All of the above definitions were extracted from the website of the U.S. Census Bureau.
Internet address: <http://www.census.gov/> Extracted: 02/16/06.



Appendix 3

Comparison of Approaches Followed by the BioBusiness Alliance of Minnesota and Battelle/SSTI in the Use of U.S. Federal Data Sources as Proxies for Biobusiness Technology Industries

On April 10, 2006 (after the research and analysis for this report was completed) the following report, which was prepared for BIO – The Biotechnology Industry Organization – was released to the public: Battelle Technology Partnership Practice and SSTI, Growing the Nation’s Bioscience Sector: State Bioscience Initiatives 2006 (Battelle Memorial Institute, April 2006). That report also used data provided by the U.S. federal government as the basis for its calculations of state performance levels in the biobusiness technology industries (labeled by Battelle/SSTI as the “bioscience” industries). In addition, the data in that report were also organized using NAICS categories. However, there are some differences in the way that data and NAICS categories have been employed in the two reports (this report and the Battelle/SSTI report). The results summarized in this report are based upon data assembled and analyzed by Kelvin W. Willoughby in: The Competitive Position of BioBusiness Technology Industries in Minnesota within the United States, Revised Version [St. Louis Park, MN: BioBusiness Alliance of Minnesota, April 19, 2006] (the “Willoughby study”).

Data Sources

The primary data source for the Willoughby study was the Economic Census conducted by the U.S. Bureau of the Census together with data from the various surveys of non-employers associated with the Economic Census. The primary data source for the Battelle/SSTI study was the Quarterly Census of Employment and Wages (QCEW) of the U.S. Department of Labor’s Bureau of Labor Statistics.

The primary disadvantage of the Economic Census data is that they are collected only every five years. The primary advantages of the Census data, however, are that they are more comprehensive and rigorous than the QCEW data, and that they drill down deeper into finer subcategories of the NAICS categories than the QCEW data. The primary advantage of the QCEW data is that they are collected every quarter, rather than every five years. The primary disadvantages of the QCEW data are that: they are less comprehensive and rigorous than the Census data; they are not disaggregated into the same level of fine subcategories as are the Census data; and they exclude information about revenue accrued by each establishment.

In addition to these basic differences generated by the choice of data sources, the two studies have one other difference. The Battelle/SSTI study includes information only from enterprises that have employees on the payroll. The Willoughby study includes information from both enterprises that have employees on the payroll and enterprises without employees (e.g., small firms in which the owners/entrepreneurs work without being placed on the payroll). About 39 percent of all biobusiness technology enterprises in the United States (in 2002) were non-employer



establishments.

Selection of NAICS Categories

As revealed by the following table, the two studies have employed different selections of NAICS industry categories to act as proxies for the bioscience/biobusiness-technology industries. The NAICS categories included by Battelle/SSTI in their study, but rejected by the Willoughby study, account for just over 25 percent of the total national “bioscience” industry employment for the U.S. (according the 2002 U.S. Economic Census data).



Figure 35. Comparison of NAICS Codes Employed in the Willoughby Study and the Battelle/SSTI Study

NAICS Code	NAICS Industry Category	Classified by Battelle/SSTI as "bioscience"	Classified by Willoughby as "biobusiness technology"	Employee, U.S. total, 2002 Economic Census (excluding non-employers)	Percentage of Willoughby's total	Percentage of Battelle/SSTI's total	Comments by Willoughby
5417101	Research and development in the physical and engineering sciences	yes	no	312,680		17.2%	Subcategory of NAICS 541710 - Research & development in the physical, engineering & life sciences
5417102	Research and development in the life sciences	yes	yes	489,474	34.6%	26.9%	Subcategory of NAICS 541710 - Research & development in the physical, engineering & life sciences
32541	Pharmaceutical and medicine manufacturing	yes	yes	248,947	17.6%	13.7%	Battelle/SSTI and Willoughby are in complete agreement about including all of these NAICS categories as part of "bioscience"/"biobusiness technology."
33911	Medical equipment and supplies manufacturing	yes	yes	326,490	23.1%	18.0%	
62151	Medical and diagnostic laboratories	yes	yes	203,261	14.4%	11.2%	
311221	Wet corn milling	yes	yes	9,546	0.7%	0.5%	
311221	Soybean processing	yes	yes	7,318	0.5%	0.4%	
311223	Other oilseed processing	yes	yes	1,533	0.1%	0.1%	
325193	Ethyl alcohol manufacturing	yes	yes	2,265	0.2%	0.1%	
325221	Cellulose organic fiber manufacturing	yes	yes	1,819	0.1%	0.1%	
334510	Electromedical and electrotherapeutic apparatus manufacturing	yes	yes	58,105	4.1%	3.2%	
334517	Irradiation apparatus manufacturing	yes	yes	13,373	0.9%	0.7%	
31212	Breweries	no	yes	28,347	2.0%		Both breweries and wineries use fermentation technology as a pivotal part of their manufacturing activities; these industries use biological technology as an integral dimension of their production systems
312113	Wineries	no	yes	24,885	1.8%		
325199	All other basic organic chemical mfg.	yes	no	77,995		4.3%	These five sub-categories of "NAICS 3253 - Pesticide, fertilizer and other agricultural chemical manufacturing" do not, on the whole, employ biological technology as part of their manufacturing systems. If these industries are included as part of "biobusiness technology" or "bioscience" just because their products are applied in agriculture, then we would also logically also need to include all other products used in agriculture, such as harvesting equipment, irrigation equipment, greenhouse control systems, dairy machinery, etc. (which Battelle/SSTI has not yet done).
325311	Nitrogenous fertilizer manufacturing	yes	no	4,760		0.3%	
325312	Phosphatic fertilizer manufacturing	yes	no	6,306		0.3%	
325314	Fertilizer, mixing only, manufacturing	yes	no	9,687		0.5%	
325320	Pesticide and other ag. chemical mfg.	yes	no	10,562		0.6%	
334516	Analytical laboratory instrument manufacturing	yes	no	34,024		1.9%	The products of this industry are mostly not specialized towards application in the life sciences.



Appendix 4

Industry Density Indices

An industry density index may be used as an indicator of the relative capacity of regions to generate particular kinds of industries. It may help you to tell whether or not the level of development of an industry in a particular region is simply a function of the overall economy of that region, within the wider economy, or whether it is a function of some special quality of that region that has a special influence on that particular industry. Each index tells you something about the regional strength of an industry, standardizing the figures to take into account differences in the scale of the economies in the regions (e.g., states, counties or cities) under consideration, the state of the industry in the larger region (e.g., nation, as the case may be), and the current state of the whole economy throughout the nation (or whatever reference region is used).

The generic formula for calculating an industry density index (IDI) for industry X in region N, using factor F as a source of data within a wider reference region (region R) is as follows:

$$\text{Industry}_x \text{ IDI}_f \text{ for region}_n = \frac{\{(\text{factor}_f \text{ for industry}_x \text{ in region}_n) / (\text{factor}_f \text{ for industry}_x \text{ in region}_r)\}}{\{(\text{factor}_f \text{ for all industries in region}_n) / (\text{factor}_f \text{ for all industries in region}_r)\}}$$

For example, if $\text{industry}_x = \text{"medical devices,"}$ if $\text{factor}_f = \text{"employment,"}$ if $\text{region}_n = \text{"Minnesota,"}$ and if $\text{region}_r = \text{"USA,"}$ then the formula for calculating Minnesota's medical devices employment density index (EDI), within the nation as a whole, is as follows:

$$\text{Medical devices EDI for MN} = \frac{\{(\text{employment in the medical device industry in Minnesota}) / (\text{employment in the medical device industry in USA})\}}{\{(\text{employment in all industries in Minnesota}) / (\text{employment in all industries in USA})\}}$$

As can be seen from this formula, changes in industry density indices over time tell you whether or not changes in the level of an industry in a region follow changes in the overall economy over time, or whether they are driven by some other more peculiar factors.

Thus, a simple increase in the level of employment for industry_x in city_n tells you nothing other than the fact that employment in that industry has changed in that city. This provides no information about the significance of that change. A change in relative percentages, however, reveals more useful information. Thus an increase in the percentage of nationwide employment in industry_x accounted for by employment for industry_x in city_n tells you that the relative position of city_n in industry_x in that country has increased. While simple percentages are perhaps much easier to grasp than density indices, they nevertheless do not tell you whether or not city_n has actually



improved as a place for employment in industry_x compared with other places, or whether the increases are simply due to increases in the aggregate size of that city's economy.

In contrast, an increase in the employment density index for industry_x in city_n tells you that city_n has become stronger for employment in industry_x — completely apart from whether or not its overall economy has lost or gained ground vis-à-vis other cities. Thus, even though industry density indices may be slightly less intuitive for many observers, compared with raw numbers or compared with percentages, they may actually be utilized as practical tools to help evaluate whether or not industry policies in a city or region (such as a state) are effective, compared with the policies employed in other cities or regions. They can also be used to evaluate the relative prowess of entrepreneurs and industry leaders in particular industries across regions.



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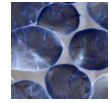
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1550 Utica Avenue South, Suite 725
Saint Louis Park, MN 55416