The BioBusiness Alliance of Minnesota™

# Biobusiness in Northeastern Minnesota: A Regional Evaluation and Implementation Plan

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# FORWARD

Biotechnology is considered the next significant area of economic growth following, and enabled by, the high technology era. For the past ten years or so, governments, universities, and industry have sought to leverage opportunities in the emerging biotechnology field. If anything, recent focus to lessen dependence on fossil fuels has only served to accentuate the importance of biotechnology.

With this basic understanding in mind, the question addressed in this report is: "What large or niche opportunities exist or can be developed for northeastern Minnesota to expand its participation in the emerging biotechnology groundswell?" In his analysis, author David Peterson recognizes that northeastern Minnesota has abundant natural resources, but a relatively small population base with limited financial and business infrastructure. Peterson considers a half dozen opportunity areas, several of which require focus on the forestry/forest products sector. To develop these opportunities, northeastern Minnesota must surely partner with other regions of Minnesota and the world.

Forestry and forest products (i.e. pulp, paper, oriented strand board, and solid and composite wood products) have long been an economic mainstay for northeastern Minnesota, along with iron ore mining and processing. Opportunities for value-added wood products, biomass energy and chemical derivatives from forest or peat resources, including industrial waste streams, may exist for northeastern Minnesota. A timely new focus on biotechnology could help support essential forest management efforts and assist in the preservation of the existing forestry/forest products industry sector. Thus, these thrusts to develop new products, co-products, or by-products could contribute to preserving the logging industry and forest management scenarios leading to an ongoing, productive healthy resource from both economic and environmental perspectives.

New value-added products need to be carefully researched, developed, and efficiently manufactured to compete with low cost, high quality products from international competitors. Chemical products may represent an attractive opportunity area if markets can be developed in the context of a highly competitive and well-developed chemicals industry based on fossil fuels, but more frequently including natural biomass feedstocks. Careful attention needs to be paid to competitive economic forces and to the development of markets for new products. The chemical industry includes a viable system of "toll" manufacturers and existing chemical plants with excess capacity. Transportation infrastructure, including an international seaport (Duluth), air transport, well developed highways and rail systems may provide important advantages in certain situations.

We may only need to look to Europe to define factors that may determine the success of a bioenergy industry based on industry waste streams, logging residues and underutilized forest species. To a large extent the opportunity will be defined by public policy that helps determine the relative economics of bioenergy to fossil fuels. Other biotechnology niches, medical technologies for example, may be possible if they are carefully selected to correspond to limited resources in the region, particularly for research and development resources.

The hurdles are substantial. A thoughtful strategic vision, coupled with collaborative efforts and adequate resources, is needed to develop biotechnology business enterprises that will contribute to the economy of northeastern Minnesota and the State of Minnesota as a whole.

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## EXECUTIVE SUMMARY

Business based on the biosciences (biobusiness) is growing nationally and globally. Many states have acknowledged the value of a strong biobusiness presence in their economies and have developed proactive strategies to attract and retain bioscience and related technologies, products or services. The BioBusiness Alliance of Minnesota (BBAM) has recognized this potential and has launched a three-step plan to help Minnesota take advantage of this rapidly growing industry. These steps are:

1) Assess Minnesota's capabilities and activities and create an understanding of where we stand as a state. This report, entitled *BioBusiness: Minnesota's Present Position and Future Prospects,* was published in August of 2006;
2) Develop a long-range strategic vision and roadmap, called *Destination 2025,* which was published by BBAM in January of 2009 in partnership with Deloitte Consulting LLP; and
3) Create an ongoing program to support regional and statewide implementation efforts through the BioBusiness Resource Network (BRN).

The purpose of this proposal is to identify the strengths, unique attributes and potential opportunities for biobusiness activity in northeastern Minnesota and to propose recommendations that will bolster the region's ability to retain existing biobusiness and grow sustainable biobusiness activities. Specifically, this proposal will:

1) Summarize the region's biobusiness activity;
2) Identify the possibilities specific to northeastern Minnesota that can support biobusiness expansion based on the strengths and assets of the region; and
3) Provide recommendations for consideration to achieve the greatest short-, medium- and long-term results.

Biobusiness includes six market sectors: **medical device**, **biologic and biopharmaceutical**, **animal health, food**, **renewable energy** and **renewable materials**. Of these markets, renewable energy and renewable materials have the most activity in the northeastern region of Minnesota. They are the most mature and expansive, relying on support from an existing and significant infrastructure. Renewable energy production centers exist throughout the region using wind, hydroelectric, and biomass sources. In addition, the region exports biomass in the form of pellets. Efforts are underway to develop more cost effective solar and biofuel technologies. The renewable materials industry is concentrated in traditional forest products applications, supported by a well-developed infrastructure and research capability. There is great potential to expand this industry into next generation products. The northeast has an additional advantage due to its international shipping port supported by strong air and highway transportation systems.

The biologic and biopharmaceutical and food market segments were found to have the next highest level of activity in terms of the range of activity and number of products produced. Food production is chiefly in the realm of functional foods, harvesting of wild rice and fish processing. Given the tremendous presence of renewable materials and renewable energy, the food, biologic and biopharmaceutical sectors are in a good position to grow by leveraging existing resources and capabilities within Minnesota.

The medical device and animal health sectors were found to have the least amount of commercial activity in the region. Although health care delivery infrastructure and research is very strong, medical device activity is either in the form of research or in the early stage of entrepreneurial activity. There is potential for attracting medical device businesses to the region, but this capability needs to be developed more thoroughly for it to be effective and sustainable. Animal health activity involves the manufacture and distribution of products such as health care products and bedding materials, and has a small regional presence.

Based on the results of this regional study, BBAM feels there is tremendous potential for biobusiness growth in the region and, as shown in Table 1, recommends the following general approach to targeting these business opportunities:

***1) INDUSTRY GROWTH***

Table 1, Regional Biobusiness Potential

| Biobusiness Industry Sector | Development Strategy |
|---|---|
| Renewable Energy | Aggressive pursuit of biomass applications |
| Renewable Materials | Aggressive pursuit of co-products to partner with existing industries (lumber) |
| Biologic and Biopharmaceutical | Aggressive pursuit of active extractible biomass components |
| Food | Maintain focus on growing existing industries |
| Medical Device/Animal Health | Develop “mini clusters” and pursue “low hanging fruit” |

To support these industry development strategies, there are four broad categories of capabilities where enhancement strategies are needed to support the development of biobusiness in northeastern Minnesota and help to ensure success.

*2)* ***FOUNDATIONAL CAPABILITIES***

Foundational components are elements that build the infrastructure and environment which help to establish a community’s ability to compete.

A. **Knowledge Access: Establish and formalize communication channels between the northeastern region and other parts of the state and world to facilitate the exchange of information, technologies and resources related to targeted bioscience based industries.** An example of how to accomplish this goal would be to incorporate a “hub and node”[1] strategy to partner with other regions of the state, country and world that can bring targeted capabilities and investments to the region. Another suggestion would be to organize an annual regional biobusiness forum to exchange ideas and to showcase regional biobusiness capabilities and achievements in an effort to attract interest and investment.
B. **Adequate Funding and Leadership**: Augment existing programs with prequalified sources of long-term funding needed to create a continuum of funding for high-growth bioscience projects. To make this functional leadership is also needed. This could be established by creating a “pool” of seasoned executive-level leaders to guide small and start-up companies.
C. **Forest Policy**: Since forest resources are so important to the region, regional and state policies need to evolve to ensure long-term access to raw materials and stabilization of biomass prices.

[1] New Economy Strategies, From Clusters of Industry to Clusters of Knowledge and Competency, Briefing Paper 1, July 2007. http://www.new-econ.com/pdf/NES-hubsnodes.pdf

This is needed to encourage healthy economic growth while being managed in a sustainable manner to ensure existing and new applications for forest resources can flourish. It is recommended that the northeastern Minnesota region participate in the development of a system dynamics-based model currently being developed in partnership with Sandia National Laboratories, the Minnesota Department of Natural Resources (DNR), the University of Minnesota and BBAM. This model is planned to help manage access to biomass to support the various industries that are developing.

D. **Local Support Systems for Biobusiness**: Aggressively seek support for local development of biobusiness through the formation of targeted champions teams, appropriate acceleration capability and other commercialization support mechanisms as they are needed.

### *3) "IDEATION-TO-COMMERCIALIZATION" CAPABILITIES*

The following strategies focus largely on activities to bring biobusiness concepts to commercial success.

A. **Develop Regional Academic and Entrepreneurial Knowledge**: Foster programs to encourage joint academic and industry projects that assist regional biobusiness formation through technology transfer and local company incubation.

**B.** **Establish NE Minneosta as a World-Class Commercialization Cluster in Biorefinery Technologies, Biosynthesis and Renewable Materials**: This is a multiyear/multiphase recommendation to establish globally recognized capability to develop, access and commercialize the knowledge and state-of-the-art technology for the extraction and biosynthesis of chemicals derived from natural materials native to the region.

C. **Technology Transfer**: Seek out and create partnerships and incentives for companies to develop local technology transfer capabilities for the production of renewable materials.

### *4) MARKET OR INDUSTRIAL SECTOR SPECIFIC CAPABILITIES*

The following strategies to develop targeted capabilities are specific to biobusiness industrial sectors since each has unique needs and are at varying degrees of maturity. Success in creating industry sectors is dependent on a collaborative and focused effort by the public, academic and private sectors.

**Renewable Energy and Renewable Materials:** To maintain or establish leadership status, increase renewable material applications and support renewable energy production mandates. It is important to increase the number of projects and organizations involved so a critical mass can be reached and the industry becomes self-sustaining and self-funding.

A. **Demonstration Projects:** Encourage regional demonstration projects to evaluate feasibility of new and existing renewable energy technologies.

B. **Large Biotechnology**: Encourage the development of business models and policies to support growth and construction of biorefinery operations. Actively pursue the construction of a biorefinery capability in the region.

**Food and Biologic/Biopharmaceutical:** Accelerate growth of these industries with a focus on bioactive materials which include food supplements and biopharmaceuticals.

A. **Academia:** Clearly identify the region's resources and add capability to enhance the region's ability to generate new knowledge in this area of study. Target this knowledge for commercialization

B. **Product Development and Technology Transfer:** Actively seek out companies that can develop local biologic and biopharmaceutical technology transfer capabilities and create local commercialization capability in partnership with the academic community.

**Medical Device and Animal Health**: Identify "low-hanging fruit" opportunities in these sectors and leverage statewide resources to grow these industries in the region. Effort should be made to identify specific communities with specific capabilities, interest and commitment to target the creation of a local industry. An example is Hibbing leveraging its excess electronic manufacturing workforce to produce medical technology products.

***5) IMPLEMENT THE BIOBUSINESS RESOURCE NETWORK***

An overarching recommendation is to implement the BioBusiness Resource Network (BRN) or comparable focused capability in northeastern Minnesota to lead regional biobusiness projects and provide support to companies. The major goal of the BRN is to complete an overall biobusiness plan for the region. This plan will be developed with local stakeholder participation and possess a clear vision with objectives and milestones for attaining the goals. The local contact and representative with the BRN will also lead projects, coordinate activities and be accountable for accomplishing specific objectives in northeastern Minnesota. Support for the BRN concept will require a dedicated and experienced private sector person and an active board of regional champions working in partnership with existing organizations and resources as well as with other national and international organizations.

# 1.0 INTRODUCTION

Biobusiness is defined as the economic activity related to the development or commercialization of bioscience or bioscience-related technologies, products or services. The global biobusiness industry is growing at an annual rate of approximately 15 percent. This growth is being driven by the expansion in the understanding of how to engineer the outcomes of biologically-based products. Many states have recognized the economic growth potential of focused strategies and programs to retain, create and recruit biobusiness.

Retaining, creating and recruiting biobusiness is good business. Approximately 5.7 jobs are created for every primary biobusiness job.[2] As a whole, biobusiness is believed to be at about the same stage of maturation the electronics industry was in the 1960s. Worldwide pressure from carbon emissions, food shortages, pollution, disease, depletion of fossil fuels, increasing energy needs and health issues will continue to push technology for sustainable solutions. Biobusiness seems to offer great hope as a source of viable long-term solutions to these significant issues through a reasonable use of sustainable resources and innovative technologies. The key ingredient to this solution, or any solution, is effective leadership.

BBAM started on a track a few years ago to bolster the presence of biobusiness in the state. This focused effort started with a benchmarking assessment comparing Minnesota to other states, followed by a multiyear process to develop long-term strategic plans for the various industry sectors. These strategic plans were released in January 2009 under the name "Destination 2025" (D2025). The BioBusiness Resource Network (BRN) was established by BBAM as ongoing support to grow biobusiness. As a part of the implementation of D2025, regional test programs have been started in the southeastern and northeastern regions of the state to expand the efforts to grow biobusiness in Minnesota. These two test areas are partially funded by grants from the Blandin Foundation and the McKnight Foundation.

[2] Battelle, 2006

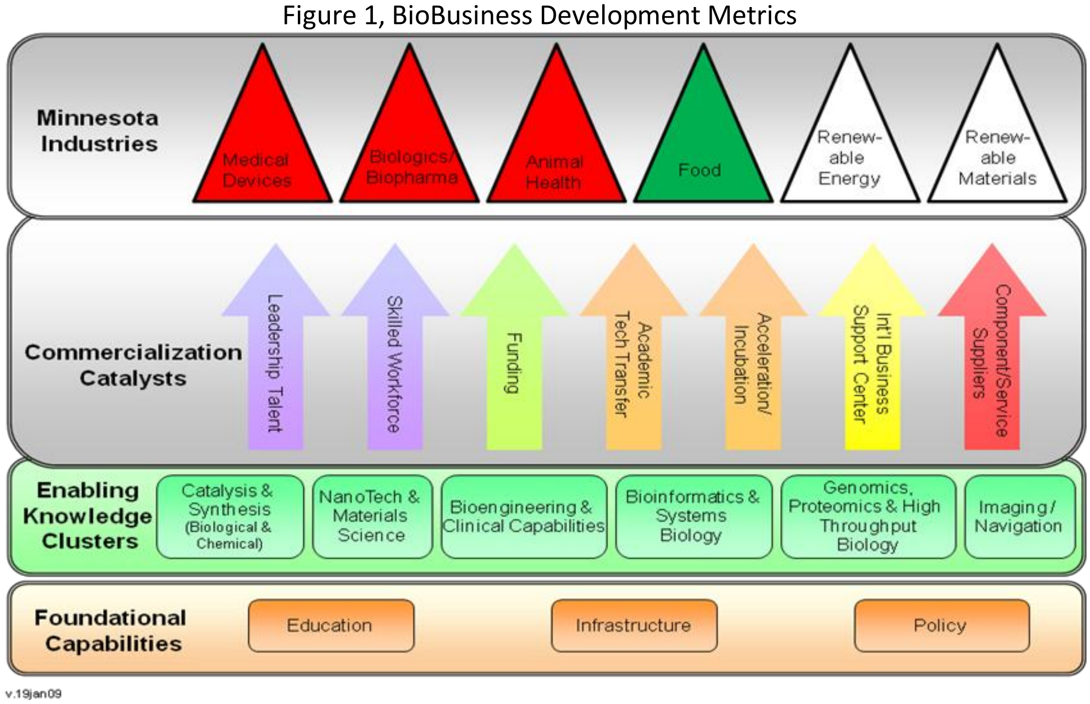
The purpose of this report is to evaluate the potential for growing biobusiness in northeastern Minnesota, which includes gaining a better appreciation for the unique assets of this region and generating recommendations for sustainable growth of its biobusiness. The more specific objectives of this proposal are to integrate the information into a coherent document to do the following:

1) Provide a summary source of biobusiness information that will be useful both now and in the future as a reference tool.
2) Provide a basis to reach logical conclusions on the priorities specific to northeastern Minnesota to support biobusiness development and allocate resources to achieve the greatest benefit.
3) Provide guidance on what strategies should be developed to achieve the greatest short-, medium- and long-term results for the citizens and economy of northeastern Minnesota.

To meet the above three objectives, this study analyzed the region's resources; access to new technology, business and technology development capabilities; funding; public support and infrastructure. An effort was made to use existing studies and information wherever possible. This accelerated the study and helps to achieve consensus on the conclusions and results.

The template for this document and pattern for the analysis will be the format developed by BBAM as shown in Figure 1. This is a logical and well-tested approach for analyzing the range of key success factors needed for viable biobusiness growth. As such, we will examine the following six market areas in order of left to right using the top line of Figure 1. As a means of analyzing the potential for northeastern Minnesota to support these industries, we will look at the key success factors that have been developed by BBAM to define a vigorous life science community. These success factors, called "community capabilities," are defined by the bottom three boxes in the Figure 1.

Figure 1, BioBusiness Development Metrics




It will be helpful for the reader to consider several items before reading this document.

1. First, this is a business-oriented document. As such, it is not a research paper, but does draw heavily upon a number of excellent studies that have been prepared and issued on an assortment of related topics. These studies are referenced in the paper.
2. Because the field of biobusiness is significant and the body of knowledge for and surrounding biobusiness is growing so rapidly, this document may use terms that are new to many readers. The appendix provides a glossary.
3. The organization of this proposal is to first give a general overview of the region, then to analyze the region using appropriate metrics, followed by more specific analysis of the six market segments. Lastly, the proposal will offer conclusions and recommendations. The market sector analyses will draw upon information presented in the introductory sections, provide new market-oriented information and draw upon data generated by BBAM to develop the documents related to the D2025 project.

# 2.0 REGIONAL DESCRIPTION

**GEOGRAPHY AND POPULATION**

Northeastern Minnesota encompasses seven counties: Aitkin, Carlton, Cook, Itasca, Lake, Koochiching, and St. Louis. The region, about the size of Denmark, accounts for 23 percent of the land area in the Minnesota, covering 18,220 square miles, but only 6.1 percent of the population, with 320,342 people using 2008 estimates (Table 2). Northeastern Minnesota is a heavily forested area that is largely rural with most of the population concentrated in a few cities. The largest city is Duluth with about 86,000 residents (2006 estimate). When added with the population of the adjacent Wisconsin city of Superior, the Duluth/Superior Metropolitan Statistical Area (MSA) population totaled 275,075 people in 2007.[3] Regional economic development activities for northeastern Minnesota may also involve business leaders and economic development professionals from Douglas County, the Wisconsin county adjacent to Duluth. Douglas County has a population of approximately 44,061 (2006)[4] with an area of 1,480 square miles. While the regional population has experienced a net decline during the past nearly 30 years as shown in Table 2, since 1990, some counties in the region have experienced modest growth.

[3] APEX Regional Economic Source, "Think Big", page 4
[4] Douglas County Estimate. 2000 census population was 43,287 http://quickfacts.census.gov/qfd/states/55/55031.html

| Table 2, NE Minnesota County Demographics and Size | | | | |
|---|---|---|---|---|
| Area | Population 2008 (1) | Population 1980 (2) | Households (3) | Land Area (square miles) |
| *Minnesota* | *5,220,393* | *4,075,970* | *1,923,495* | *79,610* |
| **Aitkin** | 15,736 | 13,404 | 6,644 | 1,819 |
| **Carlton** | 33,933 | 29,936 | 12,064 | 860 |
| **Cook** | 5,437 | 4,092 | 2,350 | 1,450 |
| **Itasca** | 44,512 | 43,069 | 17,789 | 2,665 |
| **Lake** | 10,609 | 13,043 | 4,646 | 2,099 |
| **Koochiching** | 13,251 | 17,571 | 6,040 | 3,102 |
| **St. Louis** | 196,864 | 222,229 | 82,619 | 6,225 |
| **NE MN Totals** | 320,342 | 343,344 | 132,152 | 18,220 |

Source:

(1) 2008 Minnesota population estimate (http://quickfacts.census.gov/qfd/states//27000.html) The populations for Lake, Koochiching, and S. Louis County decreased from 2001 to the 2006 estimates
(2) Census Bureau Data, http://www.demography.state.mn.us/
(3) 2000 County Population Census Data (http://quickfacts.census.gov/qfd/states//27000.html)

**ECONOMY**

The regional economy has been challenged since the major mining operations made significant employment cutbacks in the early 1980s. There have been numerous plant closings and production contractions. Occasionally, new businesses have started in the region, but have not created enough new activity to replace the losses. Yet after years of economic slowdowns and layoffs, the regional economy is seeing areas of new economic activity, such as a new $1.65 billion steel mill being built in the Iron Range[5] and strong growth in the health care and educational fields. Duluth, which is the largest city in the region, is also the regional economic, health and academic center. Virginia and Hibbing are centers of commerce for the Iron Range area. The region has many attractive characteristics that enhance the quality of life and draw people and businesses to the area. Cities such as Ely and Grand Marais are well-known scenic and tourist destinations. The same natural resources that serve as a source of commercial activity also provide abundant recreational activities and are a basis for a strong tourism industry. Among the key "quality of life" reasons for expanding into the region, as identified by the Area Partnership for Economic Expansion (APEX) and other regional agencies, are the many outdoor recreational opportunities, outstanding cultural amenities, first-rate tourism and historic attractions, access to the Boundary Waters Canoe Area, Lake Superior, and the scenic North Shore of Lake Superior, quality education activities, and many other natural attractions.[6]

**SUMMARY OF RENEWABLE RESOURCES**

The region boasts an abundance of natural renewable resources, most notably timber. By far, the region's most extensive, natural renewable resource of commercial value is its forests, followed by peat, brush and other resources.

[5] Range View, Fall 2008, an Iron Range Resources publication, A New Era in Minnesota Mining. The article features Essar Steel's new plant near Nashwauk.
[6] http://www.apexgetsbusiness.com/top10.htm Add IRR handbook

**WOODY BIOMASS**

Forest land makes up nearly 32 percent of Minnesota. The state ranks 14th nationwide in land area, 19th in forest land area, and 12th in timberland area.[7] Approximately 54 percent (7.9 million acres)[8] of Minnesota's harvestable forest land is located in the northeastern region, where three-fourths of the land is classified as harvestable forests. Minnesota, with a total of 8.4 million acres, has the highest percentage of certified forest lands in the nation under the national Sustainable Forestry Initiative Program.[9] The region's forests consist of sub-boreal hardwood and softwood species, with aspen, birch and pine being the major commercial species. Secondary species include basswood, cedar, and maple (see Appendix E). Wood, as a biomass energy source, is relatively attractive due to its very low ash content, ease of storage and well-developed harvesting infrastructure of operators, equipment and business systems.

During the past few years, there has been an annual net gain in the amount of wood available for harvesting. The sustainable harvest rate modeled by the Minnesota DNR is 5.5 million cords.[10] The average annual harvest between 2002 and 2005 was 3.7 million cords. Actual harvest levels declined in 2006 to 3.2 million cords as shown in Table E1 in Appendix E, which does not include the effect of the recent mill closures that occurred in 2007 through earlier 2009. The current annual net growth for all of Minnesota's forest is estimated to be 8.7 million cords (See Appendix E, Table E3). **This represents a significant opportunity: harvesting can be increased from current levels while remaining sustainable.** At peak commercial activity, the major commercial species are near sustainable limits, whereas the other non-commercial species have capacity for more harvesting. See Table E2 for the harvest levels by species. In addition, efforts are underway with researchers to develop methods to quantitatively characterize and enhance genetic improvements to further increase forest productivity.[11]

Potentially significant sources of biomass are brush and forest residues from other cutting operations. The DNR has estimated that 1.3 million acres within a 100-mile radius of Hibbing can be harvested on a sustained level with net environmental benefits (see Appendix G). Based on DNR data, the brush consists mainly of alder, but also includes willow and hazel and other numerous minor components.[12] The major challenge with this source of biomass is the cost of transporting the material due to its low density.[13]

**PEATLANDS**

Northeastern Minnesota is also home to extensive peat lands, 7 million acres in total (14 percent of the land area) and holds 37 percent of the stored carbon, which is the most of any state in the lower 48.[14] For years people have tried to develop uses for peat, ranging from fuel, such as the new peat-fired power station that opened in Offaly, France in 2000[15], to agricultural products where peat is well known as a soil conditioner.[16] Historical uses for peat are numerous, including tar, waxes, organic chemicals

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[7] USDA, FS, Minnesota Forests, 1999-2003, http://www.nrs.fs.fed.us/pubs/rb/rb_nrs12.pdf
[8] E-mail communication with Mimi Barzen, DNR Forestry, January 7, 2009
[9] Minnesota Forest Industries, http://www.minnesotaforests.com/resources/pdfs/2007factbook.pdf, sfiprogram.org
[10] MN DNR, GEIS
[11] Communications with Bill Berguson, NRRI
[12] E-mail correspondence with DNR officials in Grand Rapids
[13] The specific need is to have a one-pass harvest operation that cuts the brush and collects while compressing it for efficient shipping during predominantly winter conditions to minimize damage to the fragile brush ecosystem.
[14] Minnesota's peat bogs 'wild card' in Global Warming Long overlooked By Bill McAuliffe, Star Tribune, January 9, 2008
[15] http://www.peatlandsni.gov.uk/history/build.htm
[16] ttp://www.peatfarmers.ca/adp/pfo/PFOTemplate.htm?snippet=pfo/snippet/Education.htm

and disinfectants.[17] More recently, the Natural Resource Research Institute has studied current uses of peat, such as horticultural and water filtration purposes.[18]

### OTHER SOURCES OF RENEWABLE RESOURCES

Wild rice (*Zizania aquatic)* is an abundant food source located in northeastern Minnesota. Approximately 700,000 pounds of wild rice was harvested in 2006 in Minnesota,[19] predominantly in northeastern Minnesota. The Minnesota DNR estimates that more than 60 percent of the wild rice harvested in the state comes from northeastern Minnesota. The DNR identified the 10 most significant wild rice production areas in Minnesota, of which nine are located in the northeast.

In addition, grass and flowers are sources of unique chemicals[20] or can be used as factories for producing those compounds. Genetically modified duck weed, a local water plant, has been used to produce targeted proteins valuable for pharmaceutical uses.[21]

Commercial fishing is also a source of a natural renewable resource found in northeastern Minnesota. Twenty-five commercial fishermen are licensed for Lake Superior.[22] Other species of commercial fish on Lake Superior, such as whitefish, smelt, and chubs, are caught in very small numbers. Lake trout populations are recovering as populations of sea lamprey have been controlled. North Shore commercial fishermen have asked the DNR to reinstate a small commercial harvest of lake trout in the coming years. Inland commercial fishing was not found to be significant.

## FOREST PRODUCTS MARKET ANALYSIS

The forest products industry has applications in most of the biobusiness sectors and is a significant driver of the economy in northeastern Minnesota. For this reason, the forest products industry will be analyzed more closely in the following section.

### MAJOR OPERATIONS THAT UTILIZE FOREST PRODUCTS

Northeastern Minnesota has a variety of large forest product-based operations (Appendix E, Table E3 lists the larger companies, respective products and species of wood used). Relatively new entrants to the forest products landscape are pellet production plants (Appendix E, Table E5), with biomass pellets used primarily as a source of biofuels. Plans for the area include a new biomass plant to be built by Cleveland-Cliffs Inc., to produce biomass fuel for its taconite operations. The plant, to be built north of Orr in the town of Cusson, will be a $15 million project with an annual payroll of $1 million and will employ 25 people. These capital plans have been disclosed, but recent economic concerns and lower steel prices may change or delay these plans.

In an effort to increase the competitiveness of forest products companies in northeastern Minnesota, Jaako Poyry Consulting was contracted in 2002 by the Range Economic Response Strategy Team to study

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17 American Chemical Society, Chemical Abstracts, January, 1916 (Google search)
*18* www.nrri.umn.edu
19 Minnesota Natural Wild Rice Harvester Survey: A Study of Harvesters' Activities and Opinions http://files.dnr.state.mn.us/fish_wildlife/wildlife/wildrice/WildRiceHarvest-20080301.pdf
20 FLAVOUR AND FRAGRANCE JOURNAL, *Flavour Fragr. J*. 2006; 21: 225–227, Published online 16 August 2005 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/ffj.1560, Volatile organic compounds of leaves and flowers of *Montanoa tomentosa* Ramón Enrique Robles-Zepeda, et al.
21 Referenced Patent, http://www.freepatentsonline.com/6815184.html
**22** Fishing for A Living, Minnesota Volunteer *by Jason Abraham http://www.dnr.state.mn.us/volunteer/novdec04/fishing.html*

this issue and make recommendations.[23] In December 2006, the Governor's Task Force on the Competitiveness of Minnesota's Primary Forest Products Industry[24] also issued recommendations on this matter. Both of these studies concluded that the high cost of raw materials would limit growth and expansion of forest products. The reports encouraged investment to preserve key industries and jobs. The 2002 report also noted that the region has a reputation of being "anti-business" with unattractive taxes. Still today, based on discussions with experts and business leaders, it is clear that the issues identified in both the 2002 and 2006 studies continue to prevail. **In an October 2008 forum, regional economic development leaders said more access to wood fiber is still needed and is perceived to be harder to obtain and more expensive in northeastern Minnesota than in other states.**[25]

There is also a perceived need to more efficiently allocate the harvested fiber, which facilitates the highest value use. A member of the Arrowhead Growth Alliance described seeing a harvest site in Scandinavia where harvested trees were organized by parts, such as bolts, tops, stumps, and branches and sometimes by species. These components were sorted into piles and sold as such. In short, the harvesting and use of tree components represents a market opportunity for northeastern Minnesota.

**EXTRACTING VALUE-ADDED PRODUCTS FROM WOOD**

Northeast Minnesota's leading bioscience resource is its timber – an observation confirmed by our analysis. The following section provides an overview of current markets for wood-based bio-products and current methods for extracting value-added products from wood.

The markets for biomass, renewable energy and renewable construction materials are well-known in the region. Less familiar are newer industrial markets within the biologic, biopharmaceutical and renewable materials sectors, even though these products are commonly used. To aid the readers in understanding these newer markets, a quick overview of the biochemical markets are presented in Appendix C.

The biobusiness markets utilizing these materials are significant. The potential for the types of products that can be made from naturally renewable materials are limited only by current scientific and commercial constraints. As advancements in science and market applications occur, the uses of these products will expand. **Current applications include pharmaceuticals, anti-fungals, herbicides, anti-virals, biocides, plant growth regulators, insecticides, anti-feedants and anti-bacterials to name only some of the larger categories.** These markets are growing with most over $100 million and some reaching multi-billion dollar market size. Products in these markets sell for as little as dollars a pound to more than $1,000 per pound for proprietary, high-value bioactive products.[26] As we expand our understanding of biochemistry and natural processes and learn new methods of synthesizing bioactive compounds, the market potential expands with each new legitimate discovery. In the article titled, "Natural Sources for Modern Pharmaceuticals,"[27] it was reported that approximately 63 percent of all

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[23] East Range Economic Response Strategy Team, Northeast Minnesota East Iron Range Economic Adjustment Strategy, October 2, 2002, Jaako Poyry Consulting

[24] Final Report to the Governor, Governor's Task Force on the Competiveness of Minnesota's Primary Forest Primary Forest Products Industry, December 15, 2006

[25] Area Growth Alliance Board Meeting, October 2009

[26] Author's personal knowledge as President and CEO of technology start-up company NaturNorth Technologies, LLC.

[27] Natural Sources for Modern Pharmaceuticals*, Muhammad Yousaf, PhD, Organic/Purification Chemist)*, April 2008, *(http://govpe.ca/photos/original/ftc_april08news.pdf)*

approved small molecule drugs are derived from natural products or are nature-inspired semi-synthetic derivatives of natural products.

There are three primary means of producing bioactive materials from natural compounds:

1) Simple mechanical processes, such as grinding, crushing and other particle size altering methods;
2) More advanced chemical extraction and purification; and
3) Biorefinery concepts.

Organizations that conduct natural product extraction research and manufacturing are scattered around the nation and perform specialized functions based on skills sets, equipment available and business focus. Those organizations also have differing interests toward intellectual property, which are critically important to recognize when developing new technology. These organizations, especially the “toll”-based organizations can have excess capacity, specialized skills and may offer a lower cost structure due to depreciated assets.

**Market and Business Risks**

Ventures making new products based on processing technologies face immense hurdles: long product development time, long-term funding, product registration and regulatory requirements, process scale-up challenges, market barriers, competitive threats, and numerous business and technology challenges. For these reasons, the risks need to be carefully mitigated and experienced leadership is needed to guide these ventures.

***The markets for these biobusiness products are substantial, and there is room for many niche players.*** The University of Minnesota offers significant knowledge of potential products in this area of science, and is a resource which could be leveraged to help identify opportunities.

# 3.0 FOUNDATIONAL CAPABILITIES

The following is an analysis of the foundational capabilities of northeastern Minnesota.

**EDUCATION**

A highly trained and talented workforce is a requirement for developing biobusinesses and providing the “fuel” for expansion.[28] Numerous post-secondary educational institutions (technical colleges, community colleges, private colleges and universities) are available to provide degree programs, continuing education and job-related training for employees (Appendix D). Within the region there are 13 higher education institutions. The University of Minnesota at Duluth (UMD) has accredited chemistry, biology, business, and engineering programs in five disciplines along with medical and pharmacy schools and an MBA degree program. UMD offers 600 undergraduate bachelor degrees and an assortment of science-related master degree programs. The private college, St. Scholastica, also offers science-related non-engineering degrees as well as business degrees.

[28] Growing Talent: Meeting the Evolving Needs of the Massachusetts Life Sciences Industry Research Findings and Recommendations from the Life Sciences Talent Initiative Commissioned by: The Massachusetts Life Sciences Center, The Massachusetts Biotechnology Council, http://www.masslifesciences.com/docs/LSTITechnicalReport_Final111808.pdf

UMD has master-level programs in a number of science-related disciplines, with graduate-level and post-doctorate research opportunities. The region has biology and chemistry-related Ph.D. programs. The close proximity and relationship with the large research capacity of the Twin Cities campuses strengthens regional and metropolitan programs. The addition of Ph.D. programs, such as biorefinery chemical engineering, natural product extraction, biosynthesis, artificial tissues, biological systems engineering, natural medicine, and natural biology would aid the development of biobusiness.

*The region has a strong overall academic presence with good educational and training opportunities. The region's biobusiness growth can be strengthened by additional Ph.D. level research capabilities in targeted bioscience technology-related sectors.*

**INFRASTRUCTURE**

The area has well-maintained rail and highway systems in addition to an international airport, international sea port and regional airports in each county. Four national railways serve the region: Burlington Northern Santa Fe, Canadian National, Canadian Pacific, and Union Pacific. Due to limited service to various areas by just one railroad, areas of northeastern Minnesota may have rates that are noncompetitive on a national level. By rail and truck, the region ships large quantities of taconite pellets and forest products throughout the United States. The telecommunications/technology infrastructure rivals that of any rural system in the nation.[29] The port of Duluth/Superior, the western most terminus of the Great Lakes, has the capabilities to handle the large volumes of intramodal shipments, including large pieces of equipment. As an example, most wind turbines bound for wind farms in Montana, Oklahoma, Illinois, Iowa and Minnesota enter through the Duluth/Superior port. From 2005 to 2007, shipments of wind turbines through the port increased sharply from 34,080 to 307,000 freight tons.[30] The highway, rail and shipping infrastructure has the capacity to handle large and high-volume transportation needs.

The Duluth area has a regional waste treatment center, the Western Lake Superior Sanitary District (WLSSD). This facility was built in 1978 as a regional waste water treatment and solid waste disposal facility to replace antiquated treatment facilities and restore the natural beauty of the St. Louis River bay. Using state-of-the-art technology and nationally recognized operating standards, the facility treats the effluent from an area of 500 square miles including Duluth and nearby surrounding communities.[31] In addition, there are regional solid waste landfill operations.

*The extensive infrastructure of northeastern Minnesota can attract and support the transportation and information needs created by the growth of a stronger biobusiness economy.*

**POLICIES**

Previous reports have outlined the region's business climate with recommendations on improving the tax and business-related policies. Acknowledging these reports as areas for improvement, today there are numerous policies and incentives for businesses wanting to locate in northeastern Minnesota:

- The region has Minnesota-recognized Job Opportunity Business Zones (JOBZ) for financial benefits in the form of tax savings.
- The Duluth Seaway Port Authority operates a Foreign Trade Zone in Minnesota, which has a number of financial and operational benefits.

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[29] www.ironrangeresources.com, APEX, 'Think Big', page 15
[30] Wind Power is Pushing Duluth Port to a New Age, From the Minneapolis-St. Paul Star Tribune, November 25, 2008
[31] http://www.wlssd.duluth.mn.us/about.php

- New Market Tax Credits (NMTC) program for areas around Duluth/Superior that provides tax payers with federal tax credits for qualifying equity investments.
- Tax-increment financing (TIF) districts are available in the cities of Duluth and Superior. Property taxes generated by development within those TIF districts are used to pay the costs of public improvements that make the development possible. Business development projects are evaluated on an individual basis.
- Minnesota's research and development (R&D) tax credit provides help from the state for high-tech manufacturers. Any excess credit may be carried forward up to 15 years.
- The Minnesota Legislature has enacted an eight-year phase-in of single-sales apportionment of corporate income tax to be completed in 2014.
- Minnesota's sales tax law exempts capital equipment used in the manufacturing process.
- Minnesota does not have a personal property tax.

The region's economic development organizations are strong and well-connected. These organizations include:

- The Area Partnership for Economic Expansion (APEX), a new organization formed in 2003 to organize proactive, aggressive programs to attract new businesses to the region in partnership with other agencies and groups. APEX is also a source of business leadership information.
- The Northland Foundation,[32] a diverse organization involved in a broad array of programs to assist the children, families, older adults, businesses, and communities of northeastern Minnesota. The Northland Foundation offers grants, financing information, and is a source of networking contacts.
- Iron Range Resources[33] is a unique state agency located in Eveleth, Minnesota whose mission is to advance regional growth by stabilizing and enhancing the economy of northeastern Minnesota's Taconite Assistance Area. The agency provides a variety of financial incentive packages to businesses wishing to expand or relocate in its service area. Financial assistance is also available to foster community readiness for business development, encouraging growth in the region's core industries, and economic development efforts on key projects.
- County economic development agencies from each of the seven counties.

One regional economic development challenge is the perception that Minnesota is not open to investigating new technologies. That perception, articulated in interviews with experts and leaders nationwide, is not shared by those in northeastern Minnesota, who say the region remains open and committed to new technology. Policies will need to continue to address this issue to convey an attitude of openness. Because perceptions are hard to eliminate, it will take time and consistent effort to develop effective strategies to deal with this issue in a positive and proactive manner to attract biobusiness to the area.

*The current aggressive efforts by the economic development organizations and government agencies to portray a progressive region, and an excellent location to start a business, are appropriate and needed in light of the competitive environment for biobusinesses in other states and countries.*

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[32] http://www.northlandfdn.org

[33] http://www.ironrangeresources.org/

# 4.0 ENABLING KNOWLEDGE CLUSTERS

Enabling knowledge clusters are fundamental areas of science and engineering that provide core competencies upon which many industries are supported.

**CATALYSIS AND SYNTHESIS**

The state of Minnesota has tremendous capability that can be leveraged by NE Minnesota to develop its different industries. These capabilities are identified in each of the Destination 2025 industry reports that can be found on the BioBusiness Alliance of Minnesota website (www.biobusinessalliance.org). At the end of each of the six Minnesota specific industry reports, titled the Minnesota Vision Documents, you will find a detailed listing of the capabilities that are available in Minnesota. Although each of these reports contains several pages of academic as well as private and public sector capabilities, we know it is not complete. We highly recommend that before specific investments are made to add additional capability, efforts are made to establish partnerships with other organizations where investments have already been made.

Locally in NE Minnesota there are also significant investments and capabilities. UMD offers a number of engineering and science related degrees in the College of Science and Engineering, where undergraduate students perform research work. The colleges of engineering and science, medicine, and pharmacy have collaborative projects in solar energy, medical device, and renewable energy. Chemistry, biochemistry and biology degrees are offered at UMD, St. Scholastica,[34] and the University of Wisconsin in Superior (UWS). UMD offers chemical engineering degrees as well, and has an applied research institute focused on the development of natural resources. On the western border of the region, Bemidji State University also offers degrees in biology and chemistry.

The Natural Resources Research Institute (NRRI),[35] founded in 1985, consists of applied research and development in several areas: forestry, forest products, minerals, peat, chemical extractives, water resources, land resources, and cheminformatics. NRRI operates a minerals research laboratory providing research for mining industries, a diatoms research lab in Ely, Minnesota, focusing on water quality issues, and a Fens Research Facility in Zim, Minnesota, to study peatland restoration. The Chemical Extractives Laboratory was created as the primary research and development entity for the University of Minnesota's Chemical Extractives Program at NRRI. The main goal of the laboratory is the development of value-added products based on natural product waste streams (biomass wastes), such as paper-mill sludge, birch bark, paper-mill soap fraction, paper-mill black liquor, plant molasses, saw dust, hog-wood, wood chips, willow brush shreds, potato-skin, dried distiller grains and solubles (DDGS) from the ethanol industry, and other agricultural wastes. The stated goal of the laboratory is to develop and improve relationships between the University of Minnesota and industry throughout the Upper Midwest and the United States. NRRI's Chemical Extractives program, located in Duluth, has helped local companies develop early stage technology for pre-commercial pilot evaluations to establish proof-of-concept products and has performed process optimization assistance. It is one of the few laboratories equipped with both conventional chemical extraction equipment and higher technology super-critical fluid extraction. NRRI also has chemical synthesis capabilities with extensive experience working with natural compounds.

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[34] www.css.edu

[35] NRRI web site http://www.nrri.umn.edu/default

*To attract biobusiness, it is fundamental and critical that local facilities be able to develop and utilize catalysts as well as perform chemical synthesis. Research laboratories in northeastern Minnesota have the starting skills and knowledge for many chemistry operations, and may be positioned to offer advanced understandings for some technologies.*

**NANOTECHNOLGY AND MATERIAL SCIENCES**

Research is underway at UMD to develop a medical application using nanotubes to suppress or cancel noise. Other work being conducted by TECI (Tissue Engineering Consultants, Inc.) uses nanotechnology particles in a patented artificial tissue technology.[36] Local companies, such as Ikonics[37] and Van Technologies,[38] work in the area of material sciences and coatings.

The UMD engineering school is also actively pursuing technology to improve the efficiency of solar energy systems, which involves the evaluation of innovative materials used in the photovoltaic panels.

*Nanotechnology is recognized and used in the region and capabilities exist to apply and understand the material science benefits in both academia and industry.*

**BIOENGINEERING AND CLINICAL CAPABILITIES**

The region is home to two world-class healthcare systems and 18 hospitals.[39] The large hospitals and healthcare systems are in Duluth and include: St. Luke's and Essentia Health. Essentia Health includes St. Mary's/Duluth Clinic (SMDC),[40] Innovis Health and Essentia Community Hospitals and Clinics. In addition, Fairview University Medical System has facilities in Hibbing. The largest provider of medical services in the area is SMDC Health System. This organization was launched on January 1, 1997, through an integration of the Duluth Clinic and St. Mary's Medical Center. SMDC has 7,000 physicians and employees in four hospitals and 17 clinics that serve 400,000 patients annually in a rural region larger than the state of Delaware. Specialized health services provided by SMDC include neurointerventional radiology to neonatal intensive care.

The next largest provider of medical services is St. Luke's. This teaching hospital serves a 17-county region in three states, which includes a population of approximately 500,000. St. Luke's is a federally designated Regional Trauma Center with 2,261 employees and physicians. St. Luke's Whiteside Foundation[41] is its research organization that performs clinical trials and research in coordination with the UMD medical school. The staff is mostly M.D. level teaching staff with a small staff of Ph.D. researchers. The research staff focuses on collaborative projects, but is attempting to achieve more translation projects that move from the lab to the clinic. Areas of focus include research on cancer, lung and heart diseases as well as phase II, III, and IV clinical trials with a microbiology lab, a class 5 clean room and a laser dissection microscope.

UMD performs medical research in the areas of:

- cardiovascular monitoring
- cancer treatments
- metabolic rate and body function relationships

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[36] Personal conversations with inventor
[37] Ikonics web site: http://www.chromaline.com/
[38] http://www.vtcoatings.com/
[39] APEX web site, www.apexgetsbusiness.com
[40] SMDC web site, http://www.smdc.org/
[41] http://www.slhduluth.com/hospital/whiteside-institute/

- sound-analysis technology

UMD also has joint medical and pharmacy research programs. The Duluth Medical Research Institute (DMRI) was developed to advance health care by creating regional, national and international research collaboration to encourage medical discoveries. This program is about one year old and just starting to develop its potential. Many of its projects are early stage science and too nascent to disclose.[42] In addition, there is collaboration on projects with the medical school as well as separate medical technology-related projects with the schools of engineering and pharmacy. A listing of the equipment available for medical research is found on the UMD web site.[43]

SMDC conducts medical research studies on aging and also collaborates with other healthcare and educational institutions, such as Duke University, Mayo Clinic, and Cleveland Clinic.[44]

*A significant need for biobusiness is access to bioengineering, clinical capacity and medical talent as well as chemical/biological testing facilities. The region has ongoing medical research, access to medical personal, teaching and access to patients that are a good start for clinical research and offer some excellent capabilities, depending on the specific needs.*

**BIOINFORMATICS AND SYSTEMS BIOLOGY**

Systems Biology is a central part of UMD's large and growing Integrated Biosciences Graduate Program, which currently has 57 participating faculty with both M.S. and Ph.D. students.[45] NRRI uses bioinformatics research to understand and improve forest productivity of trees. Within the University of Minnesota's North Central Experimental Station in Grand Rapids, there is a group performing research in the areas of tree genetics and improvement. This program works closely with the Cloquet Forest Research Center and the USDA Forest Service Nursery in Eveleth, Minnesota.[46]

*The region has bioinformatics and systems biology capabilities beneficial for biobusiness.*

**GENOMICS, PROTEOMICS AND HIGH THROUGHPUT BIOLOGY**

NRRI is engaged with active hybrid poplar research for genetic improvements and yield issues, conducted in conjunction with Minnesota Forest Productivity Research Cooperative.

*The region has strong genetic research capabilities in forestry along with general proteomics experience and high-level biological testing capabilities for plants and humans.*

**IMAGING AND NAVIGATION**

Electron microscopy and genomic imaging capabilities exist at UMD in the pharmacy and biology departments. Imaging capabilities are available at St. Luke's and SMDC. Medical navigational capabilities were not found to exist in the region.

*The region has basic imaging capabilities that are important for the development of biotechnology.*

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[42] Personal Interviews with UMD staff
[43] http://www.med.umn.edu/duluth/research/equipment/home.html
[44] http://www.duluthclinic.org/otherspecialties/researchstudies/ourresearchteam.htm
[45] http://www.d.umn.edu/ibs/ and e-mail communication with head of UMD biology department.
[46] Proceedings of the Ninth Lake States Forest Tree Improvement Conference; Res. Pap. NC-47. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 25-28

# 5.0 COMMERCIALIZATION CATALYSTS

**LEADERSHIP TALENT**

A number of regional organizations provide general leadership training and mentoring programs, including the Blandin Foundation, Greenstone, Iron Range Resources, Northland Entrepreneurial Fund, Northland Foundation, McKnight Foundation and APEX. In addition, UMD, UWS, and St. Scholastica offer business degrees and advanced graduate business programs. Given the region's strengths in renewable energy and renewable materials, industrial leadership experience specific to those industries exist in the area. For the areas of biobusiness that would be new to the region, executive leadership talent is believed to be very limited due to the specialized knowledge required and the trend for start-up businesses to migrate to the other areas where executive leadership talent does exist.

*For leadership skills specific to renewable materials and renewable energy, the leadership pool is excellent. For other areas of biobusiness, northeastern Minnesota lacks a ready-to-go pool of experienced leadership talent.*

**SKILLED WORKFORCE**

The region possesses an educated workforce with a high work ethic.[47] Northeast Minnesota has a very high level of educational attainment. More than 86 percent of adults have a high school diploma; 53 percent have some post-secondary education or training.[48] In Duluth, 91.9 percent of those age 25 and older are high school graduates. This compares favorably to a statewide graduation rate of 90.9 percent and a national average of 84.2 percent. College education is also competitive, with 32.6 percent of Duluthians age 25 or older having a baccalaureate degree or higher, which compares to statewide average of 30.7 percent and national average of 27.7 percent.

Skilled labor is available, particularly following recent layoffs. As an example, 600 skilled employees were recently laid off from Hibbing Electronics when the company was sold and operations relocated. At the time of writing this report, it is believed around half of these employees are still in the area and available for work.[49]

A growing concern for the near future is that the region's population is aging, reflecting the national trend as baby boomers begin retiring. This is projected to significantly slow the labor force growth over the next two decades.[50] Inability to continue to operate small or family businesses is a concern for labor intensive components of biobusiness industries such as logging[51] and commercial fishing[52] that tend to be passed from one generation to the next.

*The trend of skilled labor shortages, unless changed, could dampen economic growth. Unless the region increases its workforce growth rate, increases labor force participation rates or improves skill-matching measures in job placement, the tighter labor force could pose serious challenges to regional businesses,*

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[47] APEX Brochure, 'Think Big', Page 12

[48] Labor Market Profile, NE MN, http://www.deed.state.mn.us/lmi/__shared/assets/region311410.pdf

[49] Personal Conversation with Hibbing Economic Authority personnel on 1/22/09.

[50] Labor Market Profile, April 2006, http://www.deed.state.mn.us/lmi/__shared/assets/region311410.pdf

[51] Survey of Minnesota Logging Operators in 2004, A Vital Forests / Vital Communities Report to the Blandin Foundation

[52] http://www.dnr.state.mn.us/volunteer/novdec04/fishing.html

*including economic development created by an increased biobusiness presence. This situation would also be especially true for new biobusinesses, which rely heavily on a skilled and educated workforce.*

**FUNDING**

The region has a significant amount of funding sources, as shown by the Northland Foundation's regional funding summary in Appendix I. Recently the Lake Superior Angel Network, a group of angel investors, organized a Minnesota fund connected to angel funds in Wisconsin. These funds have difficulty assessing early-stage, high-growth technology companies.[53] Biotech companies are fundamentally quite different from retail or manufacturing start-up endeavors, and therefore require different skill sets in evaluating risks and achieving commercial reality.

*It is difficult to assess the quality of funding for biobusiness activities. There is certainly a large number of funding instruments available for more conventional retail, service, tourism and manufacturing businesses in this region of the state; but, according to entrepreneurs and BBAM stakeholders, funds for biotechnology start-up companies are difficult to access in Minnesota, particularly compared to other states, such as Maryland. "Good" funding must be available to sustain biotech start-up companies through a longer development timeline that includes regulatory, product testing, and technology transfer issues.*

**TECHNOLOGY TRANSFER AND INCUBATOR PROGRAMS**

For new technologies developed within the University of Minnesota system, there is a defined process for moving scientific ideas from concept through the patent process to commercial development. That process relies on a centralized department that uses local and main campus resources. Within UMD, the Office of Economic Development assists start-up companies. For technologies not pioneered within the University, the path for commercializing business ideas is less well-defined. The entrepreneur must seek out assistance and, based on need and merit, can get access to local technology transfer processes to go from concept to commercial reality. This is, of course, only available where there is a match between concept and available technologies.

Incubator space is available in Two Harbors and provides office space and light manufacturing operations, where lower-cost rent can be obtained with JOBZ benefits. NRRI offers the closest to a true incubator space arrangement that possesses lower-cost rent and access to scientific resources. In addition, regional colleges offer small-business office space with access to office equipment. A total of 41 industrial parks are found in the region.[54]

*A rigorous, formal technology transfer program in the region does not exist specifically for biobusiness. There also does not appear to be a source of leadership talent to guide biobusiness ventures, but it is not clear that this would impede development since demand for such talent is low and leadership talent can be sourced and relocated. Informal arrangements and structures do exist for accessing senior-level people with related business development experience. Incubator space also exists, but with limited or no support services for funding, management development, technical know-how, or other types of early-stage biotechnology company support.*

[53] Conversation with an Angel Fund Manager

[54] IRR Web Site, www.ironrangeresources.org

**INTERNATIONAL BUSINESS SUPPORT CENTER**
UMD's economic development center and APEX offer regional companies looking to enter global markets access to international companies. APEX also offers access to regional markets and U.S. markets for international companies. The port of Duluth gives the region experience in importing and exporting goods.

*The region has staff and experience to assist in international business activities.*

**COMPONENT AND SERVICE SUPPLIERS**
The region has a complete and mature supply chain for the forest products, renewable energy and the mining industries. The region has extensive engineering support, as evidenced by the presence of consulting engineering, fabrication, and construction companies, including regional offices of larger engineering and consulting firms. NRRI has rapid prototype capabilities for creating three-dimensional models.[55]

*For the mature industries, the component and service supply is complete and fully functioning.*

# 6.0 BIOBUSINESS MARKET ANALYSIS

The purpose of this section is to analyze the various biobusiness markets, starting with the international markets and then zooming into Minnesota and finally arriving at specific conclusions for northeastern Minnesota. The definitions for these markets are found in Appendix B.

## 6.1 MARKET ANALYSIS: MEDICAL DEVICE

### MARKET SUMMARY

The worldwide medical device market is more than $170 billion when considering the top 19 countries of the world that have a medical device presence.[56] Using statistics reported by BBAM, the global medical device market is projected to grow 4.6 percent per year for the next five years starting in 2008. The industry employs 423,000 people in 15,000 companies around the world. The D2025 medical device market analysis[57] concluded this is the largest sector of Minnesota's bioscience economy and is known throughout the world for its strength and capability. Minnesota's supply chain and service sector that supports the device industry is truly world-class and complete. All of the top six medical device companies in the world are found in Minnesota and includes Medtronic, the world leader in cardiology devices. According to BBAM's Statewide Assessment:

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[55] Northern Lights Technology Center http://www.nrri.umn.edu/NLTC/default.htm
[56] D2025, Focus on the Future of Medical Device Industry, The BioBusiness Alliance of Minnesota and Deloitte Development, LLC, January, 2009
[57] Minnesota's Medical Device Industry: A Vision for the Future, The BioBusiness Alliance of Minnesota, January 2009

- The Minnesota medical device industry employs more than 29,000, nearly four times the national average for medical device manufacturing employment. In addition, using a job multiplier of 5.7, this ratio would suggest that approximately 200,000 people are employed directly or indirectly because of the existence of Minnesota's medical device industry.
- These jobs pay on average 69 percent more than the average private-sector job. 77.7 percent of bioscience employment in the state is in the medical device industry.
- Data included in BBAM's BIOMAP, an online inventory of the state's bioscience assets, shows there are 248 end-product medical device companies in the state (2008) and 585 medical device-related companies in Minnesota.
- Minnesota ranked first per capita in the United States in the number of jobs related to medical technology and is second only to California in both medical device industry employment and the value of shipments from the electromedical and electrotherapeutic apparatus manufacturing industry.
- Minneapolis ranked first for the medical device industry, based on the number of employees, relative industry growth, number of establishments, and size of overall life science employment, according to a Milken Institute study comparing 11 metro areas.

**NE Case Study**
GeaCom Inc. has developed communication technology for medical personnel that bridges the language barrier between patient and care giver. Geacom solved this issue and a myriad of other language related challenges with a unique device called Phrazer. GeaCom, Inc., founded in Minnesota in 2007, has been developing proof of concept and demo models in preparation for a 2008 unveiling. The company headquarters are in Duluth Minnesota

Source: www.geacom.com

### NORTHEAST MINNESOTA MEDICAL DEVICE ACTIVITY

Product Activity:

1. GeaCom, is developing a health care communications technology for early-stage product development and testing.
2. UMD has technology for analyzing sounds and holds a patent covering technology used in a "smart stethoscope", a more sophisticated heart rhythm analysis device that is mobile and designed to aid in the diagnosis of heart conditions. This technology was developed using equipment for analyzing heart sounds with sound-filtering capabilities. It has applications for cardiology and neurosciences.
3. Tissue Engineering Consultants, Inc., a Duluth-based startup company, has a patent covering the technology for artificial tissue and 3-D cell research technology for cancer and stem cell research.

## CONCLUSIONS

| Table 4, NE MN Market Analysis—Medical Device | |
|---|---|
| **Strengths** | **Next Steps** |
| A presence of medical device design achievements and testing experience upon which to build. | Develop a medical device consortium upon which to gain ideas and expose research capabilities and gain target projects. |
| Extensive medical and health care capabilities to perform clinical testing and medical device | Assist local companies in connecting with device manufacturers, financing organizations and |

| | |
|---|---|
| research and serve as source of ideas. | clinical support capabilities. |
| Strategic academic research collaboration between the medical, pharmacy and engineering schools, which are in turn interacting with the main University of Minnesota campus. | |
| Specialized labs and equipment upon which to develop niche programs for designing and testing devices. | |

As shown in Table 4, the medical device presence in northeastern Minnesota is in the early entrepreneurial activity stage. Methods are needed to speed the entrepreneurial endeavors underway and to offer guidance toward a high probability of success. Greater awareness of capabilities in the Northeast combined with targeted networking programs developed through the BioBusiness Resource Network in the Twin Cities metro area working in cooperation with local agencies will assist in broadcasting these niche areas. Additions to existing capabilities will assist in the growth of medical device companies.

## 6.2 MARKET ANALYSIS: BIOLOGIC AND BIOPHARMACEUTICAL

**MARKET SUMMARY**

Using definitions developed by BBAM, the biologic and biopharmaceutical market includes drugs or other products that are derived from life forms. Biologics are biology-based products used to prevent, diagnose, treat, or cure disease or other conditions in humans and animals. The full definition of this market sector is in Appendix B, which will give the reader a more complete explanation of these terms.

In this analysis we will only focus on human-related products, however, the crossover between humans and animals is becoming more common and opportunities might exist in animal health applications as well. As defined by the Food and Drug Administration (FDA), biologics generally include products such as vaccines, blood and blood components, allergenics, somatic cells, genes, proteins, DNA, tissues, recombinant therapeutic proteins, microorganisms, antibodies, immunoglobins, etc. BBAM further expanded this definition to all cell therapies, tissue therapies, organ and partial-organ technologies and xenotransplantation, which includes the transplantation of animal cells, tissues, and organs into humans. Biopharmaceuticals are produced using biotechnology and are made from proteins, genes, antibodies, nucleic acids, etc. **Biopharmaceuticals are often referred to as "large-molecule" drugs.** These two definitions are frequently used interchangeably. For the purpose of our discussion, we consider biologics to include all categories of products where the basic building blocks of biology are used to create products.

In comparison, the pharmaceutical market includes traditional chemical-based drugs for the prevention, diagnosis, treatment, and cure of diseases. **Chemical-based pharmaceuticals are often referred to as "small-molecule" drugs.**

Estimates of the size of the world-wide biologic and biopharmaceutical market vary as a result of differences in how the industry is defined. According to one estimate, the total world market for biologic and biopharmaceutical products in 2006 was about $93 billion, accounting for about 15 percent of the $653 billion world pharmaceutical market (not including biodefense procurements of biopharmaceuticals). The biologic and biopharmaceutical market is growing about 15 percent annually, roughly twice the rate of the pharmaceutical industry as a whole.

The Minnesota biotechnology and pharmaceutical industry employed more than 3,000 people in 2007 and had total sales of $871,685,986 in 2006, according to the Minnesota Department of Employment and Economic Development. Minnesota has experienced a 36 percent growth in pharmaceutical employment between 1995 and 2005, higher than the national average of 19 percent for the sector.[58] Between 2003 and 2007, Minnesota's pharmaceutical jobs grew from 2,299 (0.79 percent of the U.S. total) to 3,028 (1.03 percent of the U.S. total pharmaceutical jobs).[59] However, this trend in growth is unlikely to continue with the loss of several major pharmaceutical companies in Minnesota, unless we take strong action to reverse the trend. Using the multiplier of 5.7 jobs in other industries for every pharmaceutical job,[60] this would indicate approximately 17,000 jobs in Minnesota are supported by the pharmaceutical industry.

The Minnesota biotechnology and pharmaceutical industry is primarily located in the Twin Cities metro area, although there is a large presence in the southeast region and also in the northwest region, primarily in the Fargo/Moorhead community. The animal health biotechnology industry is primarily located in the Twin Cities metro area, Worthington and Willmar.[61]

**NE Case Study**

In 2000, NaturNorth Technologies, LLC was formed as a local partnership in Duluth to extract bioactive (small molecule) compounds from birch bark. Birch bark was chosen because of the high concentration of bioactive material found in this low-value material. The company was issued patents for the technology to extract, purify and synthesize an array of bioactive compounds, including pharmaceutical critical intermediates. In April, Myriad Pharmaceuticals acquired NaturNorth in 2008 as a strategic acquisition for their drug development program.

Source: Karen Mills, AP, http://www.aegis.com/news/ap/2003/AP031224.html

58 U.S. Department of Labor, Bureau of Labor Statistics, Quarterly Census of Employment and Wages (ES-202)
59 U.S. Department of Labor, Quarterly Census of Employment and Wages (QCEW). 203-2007. http://data.bls.gov/LOCATION_QUOTIENT/servlet/lqc.ControllerServlet. Accessed: 12/16/08.
60 http://www.angeloueconomics.com/pharma2008.html, Accessed 12/16/2008
61 BioBusiness Alliance of Minnesota BIOMAP, 2008

## NORTHEAST MINNESOTA BIOLOGIC AND BIOPHARMACEUTICAL ACTIVITY

There are three commercial players in this space including Tate and Lyle, ANI Pharmaceuticals and Myriad Pharmaceuticals, formerly NaturNorth Technologies. Tate and Lyle produce a number of products used in pharmaceuticals. ANI Pharmaceuticals[62], originally Rowell Laboratories, located in Baudette, had its start as a company that made a high-quality source of cod liver oil extracted from fresh water fish (burbot).[63] ANI no longer makes the cod liver oil product and has since expanded into other pharmaceutical products. ANI has a fully-cGMP qualified manufacturing site for liquid and solid dose production and has state-of-the-art analytical and stability laboratories. The technology for Myriad was pioneered at NRRI and the department of chemistry at UMD.[64] Myriad's production activities have been slowed while FDA testing for an HIV application occurs.

The region is also home to two other noteworthy biopharma technology breakthroughs. Tissue Engineering Consultants, Inc (TECI) developed patented, nanoscale, biomimetic materials (hydrogel). This technology is suitable for applications ranging from three-dimensional cell biology research (*in vitro*) to human regenerative medicine (*in vivo*). In another technology breakthrough being commercialized by VitalMedix,[65] UMD researchers developed a potentially significant treatment to save human organs. The innovation was developed based on the biochemistry of hibernating ground squirrels. The patented formulation reduces the damage to organs due to massive blood loss.[66] Funding for this research was sponsored by the U.S. Department of Defense. The immediate market for this technology is first aid on the battlefield; however it has far-reaching uses in a range of hemorrhagic shock conditions. In battlefield situations, wounded soldiers can be given the treatment to reduce organ damage, allowing precious time for critical care to be given.

## CONCLUSIONS

**Table 5, NE MN Market Analysis—Biologic and Biopharmaceutical**

| Strengths | Opportunities |
|---|---|
| There is a small presence of biologic and biopharmaceutical companies upon which to build. | Conduct market analysis to identify potential products. |
| Knowledge of how to investigate for new compounds and knowledge of natural product chemistry. | Encourage market development, product concepts, process technology, marketing expertise, technology transfer expertise. |
| Abundant natural resources as starting materials in close proximity to existing facilities. | Create "good" funding for early stage, high growth biotechnology companies. |
| Large existing companies with forest products material handling infrastructure and knowledge ideally suited for biorefinery or related technology to produce value-added products. | Develop cost-effective technologies.<br>Identify leadership to steer an organization in the unclear and challenging early-stage start-up phases on the path to commercialization. |

62 http://www.thefreelibrary.com/ANI+Pharmaceuticals,+Inc.+Acquires+State-of-the-Art+Rx+Facilities+and...-a0163062833
63 http://www.absoluteastronomy.com/topics/Burbot
64 Karen Mills, AP, http://www.aegis.com/news/ap/2003/AP031224.html
65 In July 2009, VitalMedix announced their move from Minnesota to Wisconsin to take advantage of tax credits for investments in high-growth companies. www.vitalmedix.com
66 Conversation with Dr. Matthew Andrews, UMD Biology Professor and Department Head

As shown in Table 5, the biologic and biopharmaceutical presence in northeastern Minnesota is at an early stage. Key missing ingredients needed to support early-stage, high-growth technology companies are:

1) presence of "good" funding,
2) leadership talent,
3) higher-level research personnel, and
4) sufficient technology transfer capabilities.

Funding for these sorts of endeavors is more difficult to achieve due to higher risks, longer time horizons for commercialization, and the critical role that intellectual property, regulatory approvals and technology transfer play in the commercialization process. One limitation is the rate at which technology moves from lab to commercial or pre-commercial scale. This is a key process for any new technology. Scaling the process from lab-size equipment to larger equipment that would produce commercial quantities can be challenging and, in many ways, an art form. The ability to scale up technologies in northeastern Minnesota using current capabilities would exist for some concepts, but technology transfer would likely need to be done elsewhere at this time because pilot equipment is limited in the region. The long-term availability of pilot-scale equipment in northeastern Minnesota to evaluate new technologies would encourage development and attract companies to evaluate technologies here that were conceived elsewhere.

## 6.3 BIOBUSINESS MARKET ANALYSIS—ANIMAL HEALTH

### MARKET SUMMARY

BBAM defines the animal health and nutrition market as a broad spectrum of products – mechanical, electrical, chemical, biological, software, and veterinary – used to prevent, diagnose, treat, or cure animal diseases. Among these are feed additives, vaccines, pharmaceuticals, antimicrobials, parasiticides, topical solutions, imaging software and equipment, devices, and diagnostics.

The D2025 study on animal health went on to describe the market for animal health as showing steady growth. Revenues have risen 41.8 percent over four years to an estimated $16.1 billion in 2006. The world animal health market has been estimated at over $18 billion in 2008, as projected using the 7.7 percent growth in 2006 over the previous year, according to the latest Wood Mackenzie Report.[67]

During the last Census of Agriculture – 2002,[68] Minnesota had a total of 2.4 million cattle and calves (2.5 percent of the U.S. inventory) with 968,000 dairy animals (5.7 percent of the U.S. inventory). Minnesota also has 6.4 million hogs and pigs (10.7 percent of the U.S. inventory). These two species represent the bulk of the livestock that would consume animal health

**NE Case Study**
Another use for wood pellets is to line horse stalls. A number of companies offer forest products bedding materials for animals. These low cost products are ideally suited for such a use.

67 Animal Health Market by Product Group. Wood Mackenzie Report. 2006. http://www.ifahsec.org/Industry/animal2006_2.htm website.
68 Census of Agriculture – 2002. http://www.agcensus.usda.gov/Publications/2002/index.asp

products. The dairy inventory dropped from the 1997 census by 14 percent and hogs and pigs gained in inventory by 13.6 percent. Dog and cat populations in the state were not available to the authors, but a reliable estimate could be obtained from the state's rabies vaccination records. The world animal health market has been estimated at more than $18 billion in 2008, as projected using the 7.7 percent growth in 2006 over the previous year, according to the latest Wood Mackenzie Report.[69]

**NORTHEASTERN MINNESOTA ANIMAL HEALTH ACTIVITY**

Animal health activity includes animal bedding, which was found listed on the web sites of four companies. Lonza advertises animal health care products made from its LAG product. The use of tree leaves as a supplement for animal food has been investigated and found to have health benefits[70] related to animals.

**CONCLUSIONS**

| Table 6, NE MN Market Analysis—Animal Health | |
|---|---|
| **Strengths** | **Next Steps** |
| Potentially large volumes of low cost materials that could be further specialized for niche applications. | Identify where existing animal health products could be modified and given properties that would allow expansion into new applications and markets. |
| Lonza's animal care product indicates the potential for natural products in animal health applications. | Expand existing products into new markets. Leverage animal husbandry knowledge contained in the state with product possibilities located in NE Minnesota. |

From a biobusiness point of view, there is a small presence of animal health market activities upon which to grow the animal health market. There is a recognition of animal health opportunities, but the area is not strongly agricultural, so animal health product concepts would need some encouragement to identify more opportunities. Intrinsically, the relatively low cost of pellets and forest residues would seem to be a good match with the more price-sensitive animal bedding and animal care markets. Additionally, many animal health applications emanate from human applications. Table 6 identifies strengths and opportunities in the animal health market. The potential exists to expand applications for human use into animal health, much as Lonza has accomplished with its LAG product. The market growth strategy would be to branch off into other related markets by either creating a new use through marketing or introduce product modifications that make products competitive for other applications.

# 6.4 BIOBUSINESS MARKET ANALYSIS—FOOD

**MARKET SUMMARY**

69 Animal Health Market by Product Group. Wood Mackenzie Report. 2006, http://www.ifahsec.org/Industry/animal2006_2.htm website.

70 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC5-4FM9MMM-1&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=57fec5ad564a18aa43095c063a688cdc

Food is any substance, whether processed, semi-processed, or raw, that is intended for human consumption. This includes drinks, chewing gum, and any substance that has been used in the manufacture, preparation, or treatment of “food”; but it does not include cosmetics, tobacco, or substances used only as drugs.

Using information developed in the D2025 food vision document,[71] the scale and scope of the U.S. food industry is the biggest in the world. In 2006, it was a $1.4 trillion sector, accounting for 12.3 percent of gross domestic product and 17 percent of the country’s workforce – the second largest U.S. employer behind government. Food specifically includes poultry, animal husbandry (meat and dairy), food crops, processed foods, seafood, aquaculture, and functional foods and dietary supplements.

Functional foods fall into a gray area between conventional foods and medicine. The World Bank defines functional foods as “food-type products that influence specific physiological functions in the body, thereby providing benefits to health, well-being or performance, beyond regular nutrition, and are marketed and consumed for this value-added property.” The FDA does not currently have a definition nor a specific regulatory rubric for foods marketed as “functional foods.” Instead, they are regulated the same as conventional foods under the authority of the Federal Food Drug and Cosmetic Act. The growing market for functional or health-enhancing foods has emerged as a response to global demographic trends, patterns of health and disease, and innovation.

**NE Case Study**
Lonza Inc, a Swiss company with $3B in world-wide sales with a plant in Cohasset, MN is the exclusive manufacturer of the nutritional compound called larch arabino-galactan (LAG), a natural soluble fiber extracted from harvested larch trees first isolated by St Regis paper mill scientists. LAG, a natural, bioactive compound for use in human and animal nutrition, personal care and industrial applications. LAG is approved by the Food and Drug Administration (FDA) as a direct food additive.

www.lonza.com

## NORTHEAST MINNESOTA FOOD ACTIVITY

The region is a large producer of wild rice, which is harvested by teams of two people. Minnesota wild rice is known throughout the world and is typically labeled and marketed as coming from “Minnesota.” Naturally grown and harvested wild rice is considered better than paddy grown rice.[72] Lonza makes functional food-related products from tree (larch) extracts, and the Tate and Lyle plant in Duluth produces fumaric and maleic (malic) acids for use in making foods[73] (see table of uses provided in Appendix J).

Commercial fishing operations, once very common along the Minnesota North Shore, now focus mostly on herring, which is sold to North Shore restaurants and smokehouses during the summer and to specialized markets. Each year fisheries in Grand Marais processes approximately 550,000 to 650,000 pounds of fish (herring), most of which comes from Canadian commercial fishermen. Much of the herring is exported to Iowa for final processing, where it is used to make gefilte fish, a traditional ethnic

[71] Destination 2025, Minnesota’s Food Industry: A Vision for the Future.
[72] http://www.glifwc.org/publications/Wildrice_Brochure.pdf
[73] Tate and Lyle product information: http://www.tateandlyle.com/TateAndLyle/products_applications/product_application_grids/americas/default.htm

dish that is sold on the U.S. East Coast. In processing the herring, the eggs also known as roe, are separated, processed and sold as caviar. Although some of the roe is sold locally, about 70,000 pounds of frozen caviar is shipped to Scandinavia.[74]

There are several areas of activity related to the production of food in northeastern Minnesota. Peat is harvested and shipped out of the region to be used as a soil enhancer for agriculture purposes. There are three locations where peat is harvested in northeastern Minnesota.

UMD possesses technology for extracting and isolating compounds from natural substances that would be used as food.

## FOOD MARKET ANALYSIS

Conventional food products in general have low profit margins, with margins on commodity food items being notoriously low. Profit margins on functional foods are more attractive, largely due to niche applications, less competition and value-added performance. Even with the higher margins, however, regulatory and FDA registration requirements can create additional expenses that could overcome the profit potential and make a product's profit margin unattractive. Nonetheless, functional food is still a good growth market. Along with functional products, natural and organic offerings in the U.S. healthy food and drink sales were $129 billion in 2007.[75] Functional foods alone are reported to be a $60 billion market.[76] In addition, the trend continued in 2008 with many food producers coming out with new functional food lines. According to Mintel's Global New Products Database, 142 new functional foods or beverages aimed at digestive health and 134 new functional products targeted to cardiovascular health were launched in the United States between Jan. 1 and Sept. 23 of 2008.

"We've been talking about functional foods for the last decade, and all of a sudden they are here in a big way," said Jeff Hilton, co-founder and partner of Salt Lake City-based Integrated Marketing Group (IMG). According to U.S. nutrition industry experts, 2008 was the year food manufacturers tapped into Americans' growing awareness of the connection between diet and health with a barrage of functional food and beverage launches. Americans expect to eat or drink their way to better digestive, cardiovascular, cognitive or general health.

With growing demand for functional foods as well as food in general, and with Minnesota's reputation as a food-producing state, there is an opportunity to leverage those skills and make more functional foods in northeastern Minnesota. One suggested tactic is to more fully market entire parts of the agricultural product to take advantage of food applications. In many parts of the world, people eat parts of plants or trees other than the fruit.[77] For example, a local company General Mills uses chicory root in their Fiber One bars. Benecol makes cholesterol lowering butter from pulp and paper industry black liquor soap.[78]

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[74] http://www.dnr.state.mn.us/volunteer/novdec04/fishing.html and personal communications with the commercial fishery owners in Grand Marais, MN
[75] Functional Foods and Beverages Are Finally Making a Big U.S. Splash, National Business Journal, October, 2008.
[76] Entrepreneur, Innovation in the Foods Industry: Functional Foods, July 2008, Thomson, Abby, K., Moughan, Paul J., http://www.entrepreneur.com/tradejournals/article/182614579.html
[77] Food and Nutrition, http://www.fao.org/DOCREP/006/U5620E/U5620E03.htm
[78] Benecol http://www.benecol.com/home2

Peat production, which is tangentially related to food production, faces environmental challenges, particularly regarding concerns about the release of methane when peat is exposed to air. Because methane is 20 times more effective at trapping UV radiation than carbon dioxide, its release contributes significantly to global warming. The management practices associated with peat increase the difficulty in developing commercial applications. Even so, the challenge is also an opportunity if the environmental issues can be managed, tapping the extensive reserves of peat in the region. The Natural Resources Research Institute in Duluth has an active program to develop the state's peat resource.[79]

**CONCLUSIONS**

| Table 7, NE MN Market Analysis—Food | |
|---|---|
| **Strengths** | **Next Steps** |
| Extensive natural resources as potential raw materials for food sources, such as forest residuals, processing co-products, and "as processed/harvested" materials. | Develop and share knowledge of what is possible. |
| Presence of large food companies in Minnesota upon which to gain knowledge on how to develop and market food products. | Identify potential food ideas from raw materials and natural sources found in northeastern Minnesota. |
| "Minnesota" brand. | Develop more product marketing with the "Minnesota" brand identity. |

Table 7 identifies strengths and opportunities for the food market. The functional food market is a potential niche opportunity for northeastern Minnesota, but is a very different market due to the regulatory hurdles and special processing needs. As a result, careful guidance is needed. However, the expertise exists in Minnesota to take on these hurdles. As an observation, value adding uses for fish found in the Northeast, i.e. caught in Lake Superior and inland lakes (including mine pit lakes), seems to be a relatively unexplored activity that could have biobusiness potential.

As an interesting example of the power of a "brand," Minnesota wild rice is a very well recognized product throughout the world. This same sort of brand image marketing has been used successfully by Land O'Lakes[80]. If not overused, the strong Minnesota "brand name" could be used as a regional strength. In the area of food, natural products from Minnesota have a strong market appeal and name recognition.

## 6.5 BIOBUSINESS MARKET ANALYSIS—RENEWABLE ENERGY

### Market Summary

The renewable energy market includes the various sources of renewable energy that can be applied to the transportation, electricity, residential, commercial, and industrial sectors. Examples of renewable energy sources include ethanol (corn-based, biomass-based, cellulosic, and other feedstocks), biodiesel,

[79] NRRI Peat Research Activities, http://www.nrri.umn.edu/cartd/peat/default.htm
[80] Land O'Lakes company history built on quality image: http://www.landolakes.com/ourCompany/LandOLakesHistory.cfm

combustible biomass, wind, hydrogen, photovoltaic (solar) or geothermal. Although Bioscience-based energy is typically defined as renewable fuels, this definition includes all renewable energy sources, not just renewable fuels, because all of these sources of energy will become integrated over time.

Using data developed and presented in the D2025 recommendations on renewable energy, global renewable energy capacity was 240 Gigawatts (GW) in 2007, which represented 5 percent of global power capacity, excluding large hydropower. This represents a 50 percent growth from 2004.[81] U.S. energy consumption totaled 102 quadrillion BTU in 2007. Non-hydro renewables accounted for 4.4 quadrillion BTU, or 4.3 percent of the total. Petroleum, natural gas and coal production accounted for 85 percent. The remaining 10.7 percent was nuclear power and hydropower. Total U.S. electricity generation in 2007 was 44,161 billion kWh. Non-hydro renewable accounted for 105 billion kWh of this total.[82]

According to Clean Edge, the 2008 world market value for biofuels was $34.8 billion, with 17 billion gallons of ethanol production and 2.5 billion gallons of biodiesel produced.[83] Production of ethanol in 2008 totaled 9 billion gallons in the United States, which represents a significant increase over 2007 production of 6.5 billion.[84] United States production of biodiesel was more than 690 million gallons for 2008, though volatile commodity prices, the financial crisis and slow demand are likely to cause a decrease in production for 2009.[85]

## Northeast Minnesota Renewable Energy Activity

***BIOFUELS***

Biomass as a source of fuel is currently the primary form of renewable energy in the region and is used extensively, as shown by Table H2 in Appendix H. Northeastern Minnesota has demonstrated the infrastructure, leadership, and resources to make renewable energy a major part of the economy. Biomass is used as a source of fuel in a number of forms: chips (whole tree or debarked), sawdust, slabs or other processing residuals such as extracted wood fiber, pellets, bark, lignin and extracts contained in spent pulping chemicals (black liquor), waste treatment sludge (where ash content is acceptable), thinnings, brush, storm-damaged trees and firewood.

**NE Case Study**

Two cities in NE MM, Hibbing and Virginia, formed the Laurentian Energy Authority to create a unique win-win partnership. Two Central Heating and Power (CHP) plants use biomass that has a total economic value equal to $1.2 billion over 20 years, which includes 60 – 100 new jobs and 35 MW annual electricity production capacity at an average price of 10.2 cents/kwh. The biomass comes from either its own local closed-loop tree plantations or from a variety of sources including brush, right -of-way clearings, and local logging operations.

Source: LEC report, City of Hibbing

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[81] Ren21 (2008) Renewables 2007 Global Status Report. Page 6 Paris: Ren21 Secretariat and Washington, DC: Worldwatch Institute

[82] US Department of Energy, Office of Energy Efficiency and Renewable Energy. (2008, September) Renewable Energy Data Book. Pp. 7-10 http://www1.eere.energy.gov/maps_data/pdfs/eere_databook_091208.pdf [Accessed December 17, 2008]

[83] Makower, Joel, Ron Pernick and Clint Wilder (2009) Clean Energy Trends 2009. http://www.cleanedge.com/reports/pdf/Trends2009.pdf [Accessed July 27, 2009]

[84] Renewable Fuels Association Industry Statistics. http://www.ethanolrfa.org/industry/statistics/ [Accessed July 27, 2009]

[85] Gonzalez, Angel (2009) *Awaiting Mandate, US Biodiesel Makers Stall.* Dow Jones Newswire, June 27, 2009. Featured by First Enercast Financial. http://www.firstenercastfinancial.com/e_news.php?cont=31751 [Accessed July 27, 2009]

A relatively recent entrant to the forest products mix of biofuels is pellets. The primary reasons for transforming woody material into pellets, with costs and energy inputs, are to remove moisture and to densify the material to ease transport and handling. Undried wood is typically in the 40 to 50 percent moisture range, but pellets will have a targeted moisture content of less than 10 percent for utility grade pellets and down to 6 percent for higher quality pellets.[86] The benefits of drying the material to increase energy release during combustion can be significant. Another, and less realized, benefit of producing pellets is to minimize moisture related mold formation that can occur in storage. Two plants in northeastern Minnesota produce pellets for use as an energy source, with a third in process of coming on line (Appendix E, Table E5). The pellets from these plants currently go to the more developed markets in Europe and in Eastern United States. The market for pellets is growing at a strong pace and the industry is beginning to put good management practices and standards in place.

The major opportunity for the region is how to further use available resources. At present, there are no facilities producing biofuels from cellulose. Considerable effort is focused on using cellulose to produce more energy, either electrical/thermal energy or transportation fuel. Bill Berguson of the NRRI is a regional expert on this topic and has studied uses of cellulose extensively. Appendix G is his analysis of this topic, which raises valid concerns over the relative value of cellulose for transportation fuels versus electricity. Within the region, a number of biofuels investigations are underway. To make informed, data-based, long-term decisions about cellulosic ethanol versus butanol or electricity, policy makers and others need criteria for prioritizing options as well as long-term values and objectives. These criteria include factors such as economic impact for jobs, environmental efficiency (for example miles per lb of cellulose or net KW/lb of trees), and metrics for transportation fuel such as energy density, feedstock flexibility, related costs such as handling, materials, corrosivity, blendability with other fuels. On the surface, butanol would appear to be the preferred transportation fuel, but the technology is not yet cost effective. The questions, therefore, are whether to wait or whether to proceed with cellulosic ethanol or biodiesel until the technology is developed or whether to invest in developing the technology. An ethanol process cost-reduction project is also under investigation by NRRI.

In cold weather climates, like northeastern Minnesota, biodiesel is known to cause "gelling" problems. A research project at UMD is evaluating methods to make biodiesel more resistant to cold weather viscosity issues. A byproduct of the biorefining process of biomass is levulinic acid, a fuel additive that decreases cloudiness (a cause of biodiesel "gelling") in biodiesel. Levulinic acid is an early stage byproduct of refining biomass for use in renewable materials and as biofuels. Biorefining of biomass is an opportunity for the state of Minnesota to support the growth of both renewable fuels and the renewable materials industries.

Due to the sheer magnitude of energy needs, the potential demand for cost effective biomasss may become significant. Issues such as forest productivity, preservation of the logging infrastructure, cap-and-trade legislation interactions, carbon credits and long-term raw material costs for existing industries will be important issues to develop effective policy solutions.

### ***HYDROELECTRIC ENERGY***

The area has numerous large rivers, which have provided a key resource for hydroelectric facilities to produce low cost, renewable hydroelectricity. Minnesota Power owns all of the hydroelectric facilities for the public power generation in northeastern Minnesota, with the balance owned by paper

[86] A Feasibility Study Guide for an Agricultural Biomass Pellet Company, AURI, November 2007

companies for internal use. The nine hydroelectric dams in northeastern Minnesota, as shown in Table 5, have a capacity to generate 109 megawatts of electricity. The largest and one of the oldest hydroelectric facilities, Thomson Station, was built over several years starting in 1903 and refurbished many times to be a modern facility. In addition to these hydroelectric facilities, Minnesota Power operates five hydroelectric facilities in nearby counties in northern Minnesota. As stated in the public brochures,[87] Minnesota Power has plans to further expand its hydroelectricity capacity.

***WIND ENERGY***

Northeastern Minnesota is both a generator of wind energy and active in the supply of wind energy components (see page 12). Minnesota Power recently completed the 25-megawatt project, called Taconite Ridge I Energy Center. A study completed by the University of Minnesota Duluth[88] concluded there are regions along the North Shore that have sustained average wind speeds of 14 – 19 mph, which compares favorably to the average wind speed of 16 mph on Minnesota's Buffalo Ridge in southwestern Minnesota, home to large wind farms. Generally speaking, however, northeastern Minnesota does not have large open areas needed for wind farms, and even the possible North Shore locations would be challenging due to difficult access with heavy equipment, concerns about wildlife, such as migratory birds and bats, and adverse impact on tourism and aesthetics – especially along the North Shore of Lake Superior.

***HYDROGEN***

A team of researchers at UMD were recently awarded a grant to evaluate alternative means of producing[89] hydrogen gas as a transportation fuel.

***SOLAR***

Research is underway at UMD looking for ways to examine several aspect of solar energy, including the costs and benefits of solar energy in the region, and to develop technology improvements. Northeastern Minnesota has an advantage of longer days during the summer, but this benefit is offset by shorter days during winter. To obtain better data on the solar potential for the region, UMD has installed 28 experimental solar arrays on the roof of the recently built recreational stadium to gather solar power collection information and evaluate different materials for photovoltaic cells.

***GEOTHERMAL***

Based on information from the U.S. Energy Information Administration,[90] northeastern MN has minimal geothermal potential. A recent grant to NRRI provides funding to develop accurate geothermal data to assess the availability of geothermal energy.[91] Smaller more localized geothermal projects exist, including a local group's proposal to install geothermal energy heating/cooling for the Finland Community Center.

***GASIFICATION OR PYROLYSIS***

There is one gasification or pyrolysis project underway in the region. The Bois Forte Band initiated a feasibility study approximately one and a half years ago to study producing pyrolysis biofuels. The project recently received funding to complete a test burn in an industrial furnace using liquid bio-oil

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[87] Minnesota Power, http://www.mnpower.com/

[88] Wind Power a Possibility Along the North Shore, Peter Passi, Duluth News Tribune, December 23, 2008, www.duluthnewstribune.com

[89] Personal conversation with UMD engineering department personnel

[90] Energy Information Administration, http://www.eia.doe.gov/emeu/reps/rpmap/rp_wnc.html

[91] Conversation and written correspondence with NRRI Staff, June 2009

produced from the pyrolysis process.[92] Separately, representatives with Boise Cascade paper company have stated they would be quite interested in a biomass energy project, such as torrefaction or pyrolysis projects at their International Falls site.[93]

The University of Minnesota Morris[94] (UMM) completed a $9 million gasification project to provide up to 80 percent of the campus heating and cooling needs. This facility uses residual agricultural crops, such as corn stover and other fibrous plants, as fuel sources. The gasification plant is seen as significant step toward UMM's goal of reaching energy self-sufficiency by 2010. The cost for biomass was reported to be $54 per ton at the time of starting the plant. The biomass energy plant will replace most of the natural gas the campus uses, at a savings of $900,000. A similar effort could be beneficial for UMD and the region as a demonstration project.

In addition to being a model for commercial application of biomass in heating and cooling systems, this facility also allows researchers to address important collection, processing, and storage issues, improve permitting, establish best management practices to ensure environmental sustainability of biomass systems, and provide valuable information on the economic impact of using biofuels on rural economies.

***ENERGY REDUCTION***

Mining and ore processing are well developed in terms of investments and infrastructure. While mining itself is not an apparent source of biobusiness activity or feedstock, the enormous energy used by these large operations presents opportunities for potential efficiency projects that reduce energy consumption, reduce greenhouse gases and fossil fuels through the use of low-carbon biomass or produce more electricity through the use of co-generation technology.

## CONCLUSIONS

| Table 8, NE MN Market Analysis—Renewable Energy | |
|---|---|
| **Strengths** | **Next Steps** |
| Abundant source of cellulose biomass. | Gain a clear understanding of how much biomass is available to prevent over commitment/use and policy to support long-term sustainability. |
| Leadership and Infrastructure exists for harvesting, processing and delivering biomass to energy centers and the complete supply chain. | Create wood biomass demonstration projects. |
| Abundant low cost hydroelectric energy. | Achieve clarity on the best use of biomass regarding electricity vs. transportation fuels and the type of transportation fuel. |

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[92] http://www.boisforte.com/documents/BFNAprilfinal.pdf, Bois Forte News, April 2009

[93] Personal conversations with Boise Cascade technical staff

[94] (http://renewables.morris.umn.edu/biomass) and Http://www1.umn.edu/umnnews/Feature_Stories2/From_field_to_furnace.html

| | |
|---|---|
| Minnesota's requirements for 25 percent renewable energy production by 2025 can foster considerable effort to achieve more renewable energy sources. | Establish forest productivity goals and plans to meet forest productivity goals. |

From a biobusiness perspective, renewable energy is clearly a strength for northeastern Minnesota (Table 8). With approximately 170 MW of electrical energy produced for public consumption from renewable sources, the region has achieved significant progress toward energy self-sufficiency. This is especially true when considering the significant use of biomass by industry for energy that is not represented in the above statistic.

The region's pellet capacity is increasing in response to market needs, but market demand is outstripping current capacity. Pellet demand, for both Minnesota's internal needs and for shipping to other states or countries, will, for the near term, require additions to incremental or modular capacity to match market demand. There is a need to re-evaluate policies that impact how biomass supplies are managed to meet the multiple demands of the various constituents.

The options for making transportation fuel versus electricity – and for deciding which transportation is the best long-term choice – should be examined head on. Careful thought and planning is needed to ensure that development is not haphazard and that outcomes mesh with the region's values and goals -- for example, taking into account that existing industries not be dislocated and important resources be preserved. Working models, such as the Laurentian Energy Authority provide valuable insights on existing policies and practices that can be copied or modified to produce the greatest benefit for region. Armed with decision tools based on fact and objective criteria, the region can be encouraged in one direction or another using incentives and free-market economic factors, such as return on invested capital.

As the region considers how to best use its resources to reach renewable energy goals and maximize economic gain, careful thought and analysis is needed by the decision leaders to understand fully what is potentially involved before resources are allocated.

## 6.6 BIOBUSINESS MARKET ANALYSIS—RENEWABLE MATERIALS

### MARKET SUMMARY

The renewable materials market includes materials made from renewable biological sources. These materials include biochemicals, bioplastics, biofuels, and primary (traditional) forest products.

#### *BIOCHEMICALS*

Based on research developed by the D2025 project, the worldwide market for chemicals dependent on industrial biotechnology in 2008 was estimated to be $95.5 billion, representing 7 percent of total chemical industry revenue.[95] The Biotechnology Industry Organization estimates that in 2008, U.S. chemical production using biomass as a primary feedstock was 8 million metric tons.[96]

#### *BIOPLASTICS*

[95] Guilford-Blake, R., Strickland, D. (2008) Guide to biotechnology 2008. *Biotechnology Industry Organizations.*72
[96] Guilford-Blake, R., Strickland, D. (2008) Guide to biotechnology 2008. *Biotechnology Industry Organizations.*63

In 2007, the United States had 260,000 tons of bio-based plastics capacity, 80 percent of which was biodegradable. That figure was expected to nearly triple by 2009 to 730,000 tons, with 505,000 tons of that biodegradable. Growth is likely to continue, with an expected capacity in 2011 of 1,460,000 tons, 855,000 tons of which are likely to be products that are both renewable and biodegradable.[97]

***FOREST PRODUCTS***

American paper and wood products companies produce more than 204 million tons annually. It is an industry worth $243 billion and employing more than 1.1 million Americans. Two-thirds of total value, or $156 billion, comes from the pulp and paper sector.[98] American production of paper and paperboard for 2006 was 83 million metric tons.[99] Worldwide production of wood pulp was 170 million metric tons in 2003. Almost one-third of this production was in the United States.[100] The forest products industry in Minnesota employees approximately 38,000 people in the related primary and secondary businesses during normal business conditions (see Table F1, Appendix F). A great majority of the primary businesses are located in northeastern Minnesota. The Minnesota Forest Industries, a commercial trade organization, reported the industry has a value of shipments of $8.6 billion, but the true economic impact is even greater when considering there are nearly 300 Minnesota cities that are home to businesses from which the forest products industry purchases goods and services.

**NE Case Study**

Epicurian is a Duluth-based maker of high-quality composite cutting boards for home use in the kitchen. This company started out making skate board park components, which was recently sold. Various researchers at NRRI were quite instrumental in the development of the technology for these products that use wood fiber. This product competes head to head with luxury cutting boards made from plastic and wood.

www.epicurian.com

## NORTHEAST MINNESOTA RENEWABLE MATERIAL ACTIVITY

### BIOCHEMICALS

Two companies process wood fiber for subsequent extraction of valuable chemical products, Lonza and Myriad Pharmaceuticals (formerly NaturNorth Technologies). Lonza, because they make food and animal health products, is discussed more extensively in the food and animal health market sections. Lonza performs the chemical extraction processing at its site in Cohasset. Myriad extracts bioactive materials from birch bark, however, it only processes birch bark into pellets in the region—the subsequent extraction of bioactive materials from the pellets is done elsewhere under contract. As a common denominator, these companies receive their raw material from other processing operations and also create residuals that are used as desirable biofuels.

### FOREST PRODUCTS

Northeastern Minnesota hosts a total of four pulp and paper mills,

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97 European-Bioplastics. http://www.european-bioplastics.org/index.php?id=646 ***[Accessed May 10, 2008]***

98 Agenda 2020. (2004) Nanotechnology for the Forest Products Industry. Pg. 3 http://www.fpl.fs.fed.us/resources-products/research-highlights/nanotechnology/forest-products-nanotechnology.pdf [Accessed May 5, 2008]

99 Benway, Stuart J (2008). Paper and Forest Products. *Industry Surveys*, January 31, 2008, *176(5)* , section 1. Page 19, Standard and Poor's.: New York.

100 Thomson Gale. (2007)"Pulp Mills." *Encyclopedia of Global Industries*. . Page 9*. Gale Virtual Reference Library.*.: Detroit [Accessed April 9 2008]

one manufacturing facility that make panel or oriented strand board (OSB), one hardboard manufacturing plant and 92 sawmill operations.[101] The largest operations are listed in Table E4 in Appendix E along with other more major forest products companies located in the region. The industry is supplied with harvested lumber from 218 logging operations in northeastern Minnesota.[102] Furthermore, numerous suppliers, service providers and organizations support these loggers and processing operations. At the time of writing this document, the industry is in a significant period of contraction, consisting of slowdowns and mill closures due to low product demand. All three of the Ainsworth OSB plants located in northern Minnesota have been shut down permanently due to soft housing markets. Weyerhaeuser in Deerwood had already shut down permanently. In spite of this, forest products maintain a significant presence in the region. SAPPI recently completed an Environment Assessment Worksheet (EAW) for the addition of a paper machine in their Cloquet operations.

***BIOFUELS***
See discussion under renewable energy for coverage of biofuels.

***BIOPLASTICS***
Minnesota is home to NatureWorks LLC, a manufacturer of bioplastics based out of the Minneapolis area and a Cargill joint venture. NatureWorks is the first company to make commercially available low carbon footprint polymers derived from 100 percent annually renewable agricultural resources with cost and performance that compete with petroleum-based packaging materials and fibers. This biopolymer currently uses 65 percent less fossil fuel resources to produce and reduces greenhouse gas emissions by 80 to 90 percent compared to traditional petroleum-based polymers. The company applies its unique technology to the processing of natural plant sugars to create a proprietary polylactide biopolymer.

NatureWorks was the first Minnesota company involved in bioplastics, followed by Segetis and Draths,[103] with both located in the metropolitan area. Similar technology can be applied to make bioplastics from forest-derived materials in northeastern Minnesota using a biorefinery concept.

## CONCLUSIONS

| Table 9, NE MN Market Analysis—Renewable Materials | |
|---|---|
| **Strengths** | **Opportunities** |
| Extensive existing wood processing capacity and infrastructure. | Adding secondary manufacturing capacity and biorefining capability to extract multiple compounds and additional value from the raw material. |
| Extensive leadership in logging and trained workers. | Leveraging existing skills and resources within the state. |
| Underutilized species. | Using underutilized species and waste streams for value-added products. |

[101] DNR web site , http://www.dnr.state.mn.us/forestry/index.html
[102] E-mail correspondence with Chris DeRosier, Minnesota Logger Education Program, Duluth, MN
[103] In June 2009, Draths made the decision to move company operations from Minnesota to Michigan to take advantage of the state's incentives.

The technology is rapidly evolving for the conversion of natural products into commercially useful products. This industrial sector may hold the greatest promise for the resources of northeastern Minnesota. The region has clear advantages, both in resources and infrastructure, to justify investments (Table 9). These advantages can be further leveraged by utilizing resources elsewhere in the state.

This market sector is a stronghold for northeastern Minnesota and is positioned well for expansion into new product areas. The expansion opportunity lies in keeping this an area of strength in the midst of global changes. The declining overall capacity of U.S. pulp and paper operations presents an opportunity for these large integrated facilities to leverage their existing supply-chain infrastructure, as well as their knowledge of how to process biomass, to develop new applications and higher-value-added products. New revenue streams can be created by developing integrated forest biorefineries, where fuel and chemical production is added to existing product lines. The vision is suggested by the Dovetail Partners report:[104]

> *What success will look like is not as yet clear, but one model would be a network of biorefineries across the landscape, coupled with a number of secondary manufacturers of chemical products including bio-plastics, lubricants, medicinal products, synthetic fibers, and so on. Ideally these new industries would generate significant local employment, taxes, and enhancement of quality of life (socially, environmentally, and economically), and would be sustainable over the long term. Minnesota has several characteristics that support the state's potential to contribute to biomass energy developments. Minnesota's available biomass resources, biomass harvesting standards, and existing forest industry capacities all offer the state a strong starting position.*

# 7.0 SUMMARY OF BIOBUSINESS ACTIVITY FOR NORTHEASTERN MINNESOTA

## CONCLUSIONS

Activity was found in all industrial biobusiness sectors, with some sectors showing significantly more activity than others, as shown in Table 10 on page 43. This is not surprising. The region clearly has major strengths in the areas of renewable energy and renewable materials. The food and biologic and biopharmaceutical markets are second in terms of significance as measured in activity and the presence of products, followed by animal health and medical device.

**When looking at the overall picture for Minnesota, the state has a significant level of biobusiness experience; and this experience should be carefully factored into plans for northeastern Minnesota. For example, strengths within Minnesota can be leveraged to increase biobusiness growth in the northeast. The strong biologic and biopharmaceutical presence in the Twin Cities metro area can be used to accelerate the growth of this sector in northeastern Minnesota. More globally, Minnesota is a leader in the medical device sector and is a hotbed of animal health research, especially in the area of**

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104 Dovetail Partners, Inc. and Ramaswamy, Shri, An Assessment of the Potential for Bioenergy and Biochemical Production From Forest-Derived Biomass in Minnesota, A Report for the Blandin Foundation Vital Forests/Vital Communities Initiative and Iron Range Resources, August 2007.

**animal vaccines.[105] The food industry, an overall strength for Minnesota, could be used to further develop the food industry in northeastern Minnesota. The region possesses or has access to many of the resources, both natural and human, to spur a significant biobusiness economy when leveraged with the assets and knowledge found in other parts of Minnesota. Furthermore, biobusiness can, if developed correctly, offer significant solutions to the major challenges we face in northeastern Minnesota. With an active program to build on what has already been accomplished by using solid strategies and focused resources to capitalize on the region's competitive advantages, biobusiness in northeastern Minnesota seems poised for growth.**

A feeling of excitement has grown in the region toward biobusiness opportunities among a wide range of people, from those in academia, to government administrators and officials, to industrial employees. Overall, there is an openness and recognition that biobusiness makes sense and has significant potential. There are concerns, however, that were raised in discussions with local economic development and industrial leaders that need to be addressed. One concern consistently voiced is whether the region has enough biomass to meet all of the potential uses. Other concerns focus on the shortage or lack of researchers to tackle larger projects and sophisticated technical challenges, the loss of technology developed in the region to other areas, and the need to have projects that stimulate local economies. Optimism toward biobusiness needs to be balanced with the risks inherent in these business ventures, including: long product development lead time, regulatory hurdles, raw material needs, manufacturing and scale-up challenges, and market barriers.

The region has a history of economic struggle, with entire communities struck by hard times as companies have changed ownership, relocated or terminated operations. On occasion these events have led to an exodus of people from the area to find work elsewhere. The region also has a well documented trail of efforts, paved with good intentions to develop sustainable solutions. Yet the region also has a tremendous history of overcoming challenges and becoming innovators, such as 3M, Potlatch,[106] Blandin and many other ventures. There have been many successes upon which to build. It is therefore the hope and desire that the leaders of northeastern Minnesota will act now to bring to the region a set of solutions that are fundamentally different from the past, achievable and sustainable. "The best way to predict the future is to create it."[107] It is therefore believed that decisive action is needed now. To this end, the recommendations will focus on what can be done to foster the regional presence of biobusiness that will, in turn, be a major driving force to foster a stronger economy for northeastern Minnesota. Biobusiness has a seemingly bright future in northeastern Minnesota.

Before going to the recommendations, we will briefly recount some observations that were made during this document's development.

## OBSERVATIONS

During the course of developing this document, a number of observations were made that have value, if for no other reason than to provide a succinct summary of the region's needs. The following summary of these observations will benefit northeastern Minnesota and provide a starting point for action from the BioBusiness Resource Network, other leadership groups and economic development agencies. Because so much of the region's biobusiness activity is related to the health of the forests and forest

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[105] Destination 2025, Roadmap Document, BioBusiness Alliance of Minnesota

[106] Potlatch developed a means of making a coating that produced a high quality printing paper making it world leader in printing papers.

[107] Peter Drucker.

products activities, most of these observations will focus on those issues. In all sectors, healthy forests and a strong forest products industry will have either a direct or indirect positive effect on biobusiness.

1. **Forest Products Related Observations**
   A. Existing forest product companies, stakeholders and future biobusinesses associated with forest products need assurances that the exuberance to jump on the biobusiness train will not drive up their already high -- at least by international standards – raw materials costs, thereby threatening the region's global and regional competitiveness. Biobusiness investment requires confidence in the long-term raw material cost projections. This is simply a business need. These issues, as difficult as they may be to address, will hinder biobusiness investments and product development unless resolved. This is especially true for price-sensitive products such as pulp and paper, building materials, and biofuels. Even higher-value products such as pharmaceuticals and bioactives, which can be more resilient to the cost of raw materials, cannot be made cost effectively if incoming raw materials are not available or if poor economies of scale increase raw material unit costs.

      In order to provide some degree of confidence in those long-term supply and pricing issues, a workable and realistic policy is needed to ensure existing forest products companies are not economically disadvantaged by the drive to use forest biomass as a fuel, as either a biomass energy source or as a source for making transportation fuels – a trend that could increase their raw material costs. It would be in the region's best interest to not see the existing companies in a position of having their already high raw material costs increase as a result of expanded biobusiness activity, thus putting them at further competitive disadvantage in the global marketplace. The solution to this problem of market dislocations may lie in careful study of biomass market responses to the introduction of biomass-powered facilities, as well as continuing efforts to quantify the state's biomass inventories, production and removals.[108] Other questions are: What would be the highest-value use of Minnesota's unused biomass? And, what are the most efficient means of harvesting and processing them? More study is needed, for example, on potential uses of biomass as a feedstock for bio-based manufactured products or in biorefineries. Whatever is done, it is vitally important that efforts to bolster supplies of one critically important resource, such as energy, not end up depleting other critically important resources for the health and well being of regional communities.

   B. There is an opportunity to manage Minnesota's forest lands for higher productivity, as supported by DNR comparisons with other states. The challenge, however, is to find the right balance between forest productivity metrics and investments. Government agencies, academia and industrial groups are discussing this issue. Their goal is to identify the relationships between the incremental costs versus the incremental benefits to define the best level of investments for a given outcome. One challenge in modeling this relationship is the need for accurate assessment of how much biomass is available, how much is harvested, the projections of long-term need and the effects of various management practices on the growth rates of the various species. Ideally, management would 1) maximize what can be sustainably and economically grown and harvested and 2) maximize the use of all fiber that can be collected from all sources. One related issue is the need to develop uses for the underutilized species, such as tamarack, ash, and low-value black spruce as well as brush species.

[108] Milestone 5: Biomass Maps and Strategies Identifying Effective Biomass Strategies: Qualifying Minnesota's Resources and Evaluating Future Opportunities, Center for Energy and Environment, March 2007

C. There may be an opportunity to convert existing, depreciated assets into local biomass production centers, particularly where there is an existing use or close to where biomass is being collected or concentrated. At such centers, sufficient quantities of biomass can be processed cost effectively. The supply chain for making pellets is shown in Appendix H, and illustrates the commercial opportunities, which are not just a part of biomass production. One example would be encouraging the production of pellets where wood is being concentrated from an existing operation, which could leverage existing assets and infrastructure. Such an approach would increase the availability of cost-competitive pellets and provide added revenues to existing facility owners. Such local capabilities would encourage more efficient use of miscellaneous sources of biomass, such as road right-of-way cuttings and other clearing, or thinning operations related to commercial or residential activities. Ultimately, local pellet mills or biomass converting operations could be scattered throughout the region to minimize transportation costs and boost local economies. Co-ops or entrepreneurs would be able consolidate output for exports if justified and competitive.

D. Equipment needs to be purchased by operators to harvest brush efficiently. The equipment, which now does exist, would not only allow the harvesting of a readily available source of biomass, it would also create an opportunity for an equipment manufacturing entity with supporting manufacturing or distribution assets. With new markets and unreliable contracts, funding to purchase the equipment is difficult to obtain.

E. The region would benefit from policy that would allow the expanded use of forest resources on public lands, i.e. cutting on public lands with the recognition that cutting and thinning can be used to enhance wealth as well as increase the availability of biomass and increase forest productivity.

**2. General**

A. The region needs to explore a two-part regional approach to marketing products. The first step is to encourage the practice of buying from local producers when possible and practical.

B. The second step is to build a stronger "brand" for Minnesota bio-based products produced in northeastern Minnesota, similar to the strong, worldwide "Minnesota" brand for wild rice as a unique (value-added) product.

## RECOMMENDATIONS

The following are four strategies to increase the presence of biobusiness in northeastern Minnesota.

### *FOUNDATIONAL STRATEGIES*

Foundational components of a strategy are elements that will build the infrastructure and environment which help to establish a community's ability to compete. They include:

A. **Knowledge Access**: Establish and support communication channels between stakeholders in the northeastern region with complementary parties in other parts of Minnesota and other parts of the world to: 1) facilitate the exchange of information with the goal of developing international markets, and 2) educate stakeholders so there is continual growth in biobusiness knowledge. A specific recommendation is to organize an annual regional biobusiness forum to exchange ideas, to showcase regional biobusiness capabilities and achievements, and encourage valuable networking discussions. The conference would be attended by private industry, academia and government agencies. The target date for the first event would be the summer of 2010 with UMD being an ideal host site.

B. **Adequate Funding and Leadership**: To keep start-up companies in the area, it is important to have adequate funding and leadership resources available to assist these companies. This can be accomplished by augmenting existing funding programs with: 1) sources of long-term funding needed for high-growth biotechnology projects that require longer time horizons to achieve commercial reality; and 2) a pool of seasoned executive leaders to "shepherd" early stage biotechnology companies, provide strategic insights (especially from intellectual property and regulatory perspectives) and be involved in the early-stage planning to develop business plans for achieving commercial reality and attracting investors. Even something as simple as providing expert assistance in analyzing project risks for a start-up company's funding can be a significant step toward success for those entrepreneurs.

C. **Forest Policy:** As stated in the observations section, regional and state forest policy needs to be updated to minimize or prevent the potential dislocation effects created by rising raw material costs if wood is used for biofuels while ensuring sustainable raw material supply for existing and new biobusiness-related companies.

D. **Local Support of Biobusiness:** This would include regular informal and formal information exchanges with trade organizations, economic development groups, targeted industrial groups and groups of investors to actively and aggressively support: 1) awareness of projects and capabilities and 2) provide ongoing information on achievements that could stimulate innovation. A key aspect of this recommendation is the focus on "industry creation" versus individual company support.

"***IDEA-TO-COMMERCIAL REALITY" STRATEGIES***

The following strategies focus largely on activities to bring biobusiness concepts to commercial success.

A. **Develop Specialized Regional Academic and Entrepreneurial Knowledge**: As a longer-term solution, which can be accomplished in multiple phases starting in the near term, encourage academic projects to help regional biobusiness companies and entrepreneurs gain unique technologies or competitive advantages by solving technical issues or by developing new technologies. This could be done by selectively offering Ph.D. degree programs, targeting specific needs through existing programs or curriculum or seeking grants to support strategic areas of biobusiness that need research-based solutions or proof-of-concept investigations. As an example, UMD has developed expertise in the area of tissue engineering. This expertise could be grown into regional enabling knowledge cluster capability to leverage existing biological and engineering capabilities.

   **Create a World-Class Capability for Biorefinery Technologies, Biosynthesis, and Renewable Materials**: In a phased approach, establish world-class *capability* to apply the knowledge and technology for extraction and the biosynthesis (use of biorefineries) of compounds derived from natural materials–specifically forest products. The first phase of this activity would logically be accomplished through a series of collaborative programs utilizing existing resources from around the state and world as suggested in the previous recommendation. Such a "cluster capability" would be an innovation source for Minnesota and magnet for biotechnology development. This system could consist of a central location (hub) and satellite operations (nodes) that use other existing infrastructure and sources of knowledge to cost effectively leverage resources and to support local economies as much as possible while developing products and technology. What is important is access to the capability and the ability to apply it locally.

Northeastern Minnesota is uniquely positioned to develop products derived from the region's renewable resources using leading-edge technology, such as that found in biorefineries and other natural product processing operations. To facilitate this vision, it is proposed that the "hub" engage world-class researchers from academia, government and the private sector through strategic partnerships (nodal relationships). The effort should be supported by public and private sector funding and grants, with the goal of spawning new businesses complete with markets and technology for new products. This cluster capability would focus on the production of biochemicals from natural products – including the isolation and characterization of compounds, development of commercial isolation or synthesis technologies – with complementary and rigorous incubation programs to launch new businesses as well as complete disclosures for the establishment of strong intellectual property rights.

This capability will draw upon the talents of UMD, the Entire University of Minnesota System (such as the Department of Bioproducts and Biosystems Engineering), the Minnesota State College and University System, local, regional and international research and academic organizations, and attract the best scientists and technology from around the world. This concept would add to the capabilities of northeastern Minnesota and foster effective competition in all six biobusiness sectors. An important element of this centralized "hub" capability is providing for critical technology to support scale-up. Technology has been shown to leave an area due to poor funding and lack of local scale-up or production capabilities.

The **first phase** in this process would be to: 1) develop and issue a comprehensive list of natural products that are available or could be produced in the area (i.e. greenhouses, biorefineries or miscellaneous methods such as approved "farming" practices, with farming intended to have a much broader application than just agricultural activities) with known uses gleaned from public literature sources or sound expert judgment; and 2) a comprehensive listing of relevant product ideas using university and private sector intellectual property. The vision for this hub needs to be further defined by the regional leaders along with methods for disseminating the information with the goal to attract business interest.

The **second phase** to this plan would be to join existing academic and private forces to create an operationally coordinated "hub capability", be it centralized or virtual, using existing resources.

The **third phase** would be to institutionalize this proactive initiative in a physical structure with a private sector organizational structure. Its mission would be not only to bolster biobusiness in northeastern Minnesota but to also be a world-class organization with worldwide reach. This could be a "hub and node" model as described above.

C. **Technology Transfer:** Seek out and create partnerships and incentives for companies to develop local technology transfer capabilities for the production of renewable materials.

***INDUSTRY SECTOR STRATEGIES***

Because the various sectors were found to be at different levels of maturity, recommendations must be specific to those sectors. For the market sectors showing the most strength, **renewable energy and renewable materials**, efforts should focus on maintaining leadership status, increasing renewable material applications as well as renewable energy production through innovation, and, in general, sharing knowledge to gain further strengths.

A. **Renewable Energy Demonstration Projects**: Encourage regional demonstration projects based on cost effectiveness to evaluate new renewable energy technologies. In the near term, support biomass conversion facilities that contribute to local economies, as discussed in the observations section (pages 39-41).
B. **Large Biotechnology:** Encourage the development of business models and policies to support growth and construction of biorefinery operations. This would mean developing an understanding of the regulatory issues in order to proactively develop a soft landing for these technologies. To prove this capability, northeastern Minnesota should complete the installation of a biorefinery project. This may require aggressive efforts, but securing a viable biorefinery project in the region should be considered a major win.

The **food and biologic and biopharmaceutical** sectors are potential growth areas. The strategy for these sectors is to accelerate growth.

A. **Academia**: Clearly identify the region's resources and add capability to enhance the region's ability to generate new knowledge in this area of study.
B. **Product Development and Technology Transfer Capabilities:** Actively seek out companies that will develop local biologic and biopharmaceutical technology transfer capabilities.

**Medical Device and Animal Health**: Identify "low-hanging fruit" opportunities in these sectors and leverage state-wide resources to grow these industries in the region. Effort should be made to identify specific communities with specific capabilities, interest and commitment to target the creation of a local industry. An example is Hibbing leveraging its excess electronic manufacturing workforce to produce medical technology products.

***IMPLEMENT THE BIOBUSINESS RESOURCE NETWORK***

An overarching recommendation is the implementation of the BioBusiness Resource Network (BRN) or comparable focused capability in northeastern Minnesota to support regional biobusiness strategies. Effective support for the BRN will require an active board of regional supporters (champions). The local contact and representative with the BRN will need to coordinate activities in northeastern Minnesota with those in the rest of the state, serving as one of the many communication conduits as well as the point person for communications in the Northeast. The BRN and regional representative will need support from a team of recognized regional leaders who have decision-making authority for resources and policy. The first action would be to develop a region-wide plan for completing projects that increase the presence of biobusiness. Regional champions will be involved in these tasks.

Specific objectives of the regional BRN:

1. Spearhead the development and completion of an overall biobusiness plan for the region. This plan will be developed with local stakeholder participation and possess a clear vision with objectives and milestones for attaining the goals.
2. Communicate information and be a conduit for key sources of information.
3. Maintain awareness of issues and solutions to provide the region with extra uniquely trained and qualified insights and eyes.
4. Support solutions to issues identified in the observations.

5. Leverage local economic development associations.
6. Help bring statewide BRN resources to bear on regional issues and projects.
7. Be a resource to complete general and specific strategies.
8. Support BIOMAP data accuracy by submitting information for new data points.
9. Work in partnership with existing organizations and resources as well as with other national and international organizations.

## CLOSING COMMENTS

Our country, especially Minnesota, was settled and developed by hard working pioneers with an entrepreneurial spirit. This same entrepreneurial spirit combined with the potential of bioscience and sound implementation plans can bring a matrix of solutions to the environmental, social and economic challenges our country faces. The extent upon which we can convert the potential of bioscience depends on the success we achieve in wisely leveraging resources through research programs, technology development, business expansion plans and investment choices. We hope that, by reading this report, you have been encouraged to support the expansion of biobusiness in northeastern Minnesota and unleash the potential.

**Table 10, Primary Activity Summary of Biobusiness for NE Minnesota**

| Medical Device | Biologic/ Biopharma | Animal Health | Food | Renewable Energy | Renewable Materials |
|---|---|---|---|---|---|
| Phrazer healthcare communications device | ANI Pharmaceuticals | Lonza (LAG) Animal Health Products | Lonza (LAG) Products | 4 Paper Mills Boise Cascade, UPM Blandin Paper, New Page, Sappi | 3 Large Sawmill Operations |
| UMD—sound analysis technology | Myriad Pharmaceuticals | Pellet Mfrs making animal care | Commercial fishing and fish processing | 9 Hydroelectric Facilities(1) | 4 Paper Mills |
| UMD Medical School | TECI 3D Tissue Cultures | NRRI Chemical Extractives | Wild rice harvesting and processing | 3 Biomass Power Plants(2) | Owner/Operator sawmills |
| St. Luke's and SMDC's clinical trial capability and labs | St. Luke's and SMDC's clinical trial capability and labs | | NRRI's peat evaluation programs | 2 Central Heating and Power Plants (Laurentian Energy Authority) | Primary Wood Products |
| TECI, Artificial Tissue | School of Science and Engineering | | Malic Acid Manufacturing | UMD Engineering | 2 Oriented Strand Board Mills or Compressed board products |
| School of Science and Engineering | UMD Medical School | | Peat as a soil conditioner product for growing food | NRRI Biomass programs | Acoustical Tile manufacturer |
| | NRRI Chemical Extractives | | NRRI Chemical Extractives | 25 MW Wind Farm(3) | Secondary Manufacturers |

| | | | | | |
|---|---|---|---|---|---|
| | | | **Research** | | |
| | **DMRI** | | | | **Loggers / Truckers** |
| | **School of Pharmacy** | | | | **Suppliers** |
| | | | | | **Recycle paper facility** |
| | | | | | **Support/ Maintenance Organizations** |

(1) Minnesota Power Managed (7), Sappi (1), Boise Cascade (1)
(2) Minnesota Power in Cloquet, Grand Rapids, and Duluth
(3) Minnesota Power Taconite Ridge


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Minnesota Logger Education
Northland Foundation
NRRI
Short Elliot and Hendrickson (SEH) Architects and Engineers
SMDC
St. Luke's
UMD Colleges of Science and Engineering, Pharmacy, and Medicine
UPM, Blandin Paper Company

# LISTING OF APPENDICES

A. Definition of Abbreviations

B. Glossary of Terms

C. An Assessment of the Potential for Bioenergy and Biochemicals Production from Forest-Derived Biomass in Minnesota

D. Education

E. Department of Natural Resources, Report for Forest Resources—2007 (Excerpts)

F. Forest Products Contributions to Minnesota's Economy

G. Minnesota's Woody Biomass Resources and Opportunities in the Emerging Energy Industry

H. Renewable Energy

I. Summary of Regional Funding

J. Uses of Fumaric and Malic Acid

# Appendix A, Definitions of Abbreviations

APEX--Area Partnership in Economic Expansion

BBAM—BioBusiness Alliance of Minnesota

BIOMAP—BioBusiness Alliance of Minnesota Map of biobusinesses found in Minnesota

BRN—BioBusiness Alliance of Minnesota's 'BioBusiness Resource Network'

DNR—Department of Natural Resources

IRR—Iron Ranges Resources

OSB—Oriented Strand Board

USDA—United States Department of Agriculture

USFS—United States Forest Service

UMD—University of Minnesota Duluth

WLSSD—Western Lake Superior Sanitary District

# Appendix B, Glossary of Terms

The definitions are broken down into three areas: markets, enabling knowledge areas, and commercialization catalysts.

## Markets

Biobusiness is defined as the economic activity related to the development or commercialization of bioscience or bioscience-related technologies, products or services. Markets are a clustering of similar products and services based on research and enabling technologies. Markets are where the highest potential for job creation exists and the domain of the private sector. The following are Glossary of Terms as developed by The BioBusiness Alliance of Minnesota for life science community definitions.

- *Renewable Energy*
  The renewable energy market includes the various sources of renewable energy that can be applied to the transportation, electricity, residential, commercial, and industrial sectors. Examples of renewable energy sources include ethanol (corn-based, biomass-based, cellulosic, and other feedstocks), biodiesel, combustible biomass, wind, hydrogen, photovoltaic (solar), geothermal, etc. Bioscience-based energy is typically defined as renewable fuels. This definition includes all renewable energy sources, not just renewable fuels, because all of these sources of energy will become integrated over time.

- *Renewable Materials*
  The renewable materials market includes materials that are made from biological sources. These can be biofibers, biopolymers, biodegradable plastics, bio-packaging.

- *Medical Device*
  The medical device market includes all instruments, apparatuses, implements, contrivances, implants, in vitro reagents, or component parts or accessories which are used to prevent, diagnose, treat, or cure diseases or other conditions in humans or animals.

- *Biologic and Biopharmaceutical*
  The biologic and biopharmaceutical market includes drugs or other products that are derived from life forms. Biologics are biology-based products used to prevent, diagnose, treat, or cure disease or other conditions in humans and animals. Biologics generally include products such as vaccines, blood, blood components, allergenics, somatic cells, genes, proteins, DNA, tissues, recombinant therapeutic proteins, microorganisms, antibodies, immunoglobins, etc. Biopharmaceuticals are produced using biotechnology and are made from proteins, genes, antibodies, nucleic acids, etc. Biopharmaceuticals are often referred to as “large molecule” drugs.

- *Animal Health*
  The animal health market includes any and all products, mechanical, electrical, chemical, software, veterinary, and biological, to prevent, diagnose, treat, or cure diseases that affect animals other than humans. Animal health products include feed additives, vaccines, pharmaceuticals, devices, antimicrobials, topical products, imaging, parasiticides, diagnostics, etc.

- *Food*
  The intersection of the life sciences and the food market includes the use of scientific techniques to produce desired traits in plants or animals to enhance the quality, safety, nutritional value and variety of food and increase the efficiency of food production. It also encompasses food ingredients and nutraceuticals.

## Enabling Knowledge Clusters

Enabling knowledge clusters are the basic knowledge and technologies that allow the development of products. Enabling Knowledge Clusters are the domain of academia and corporate R&D.

### Catalysis and Synthesis

Catalysis and synthesis relate to the development processes for both small and large molecule (chemical and biological) pharmaceutical products, or post processing of biomass using enzymes or other means to produce products such as ethanol or biomaterials.

<u>Examples of technology involved:</u>

- Assay development
- High throughput screening
- X-ray crystallography
- Physical characterization
- Medicinal chemistry
- Toxicology
- Formulation
- Preclincial trials
- Clinical trials
- Enzyme production

<u>Example Applications:</u>

- Drug development
- Stem Cells
- Gene therapy
- Renewable Energy
- Renewable materials

### Nanotechnology and Materials Science

Materials science is an interdisciplinary field involving the properties of matter and its applications to various areas of science and engineering. This science investigates the relationship between the structure of materials and their properties. It includes elements of applied physics and chemistry, as well as chemical, mechanical, civil and electrical engineering. Nanotechnology refers broadly to a field of applied science and technology whose unifying theme is the control of matter on the atomic and molecular scale, normally 1 to 100 nanometers, and the fabrication of devices within that size range.

Examples of technology involved:

Industrial applications of materials science include materials design, cost-benefit tradeoffs in industrial production of materials, processing techniques (casting, rolling, welding, ion implantation, crystal growth, thin-film deposition, sintering, glassblowing, etc.), and analytical techniques (characterization techniques such as electron microscopy, x-ray diffraction, calorimetry, nuclear microscopy (HEFIB), Rutherford backscattering, neutron diffraction, etc.).

Example Applications:

- PLA (biodegradable plastic)
- Turning bio-based materials into plastics
- Implant
- Nanomedicine
- Electronics
- Coatings
- Films
- Drug delivery
- Information storage and communication technologies
- Renewable energy
- Food

## Biological Engineering

Biological Engineering is a discipline that applies engineering principles to biological systems for the purpose of developing new technologies and services to improve the living standards of societies. It requires traditional engineering skills to exploit new developments in molecular biology, biochemistry, cell metabolism, microbiology, ecology and engineering principles and applies them in order to understand living systems and to bring solutions to various problems associated with these systems. Bioengineers work closely with medical doctors and other health professionals to develop technical solutions to current and emerging health concerns.

Examples of technology involved:

- Bioprocess engineering
- Bioprocess design
- Biocatalysis
- Bioseparation
- Bioinformatics
- Genetic engineering
- Synthetic biology
- Cell engineering
- Tissue culture
- Molecular biology
- Biochemistry
- Microbiology
- Neurosciences

- Sensing
- Electronics
- Imaging
- Genetics
- Pharmacology
- Biomechanics
- Surface science
- Polymer science

Example Applications:

- Medical devices
- Diagnostic equipment
- Imaging equipment
- Biocompatible materials
- Agricultural engineering

## Bioinformatics and Systems Biology

Systems Biology is an approach to analyzing biological complexity and understanding how biological systems function. Systems biology is the study of an organism, viewed as an *integrated* and *interacting network* of genes, proteins and biochemical reactions which give rise to life. Instead of analyzing individual components or aspects of the organism, such as sugar metabolism or a cell nucleus, systems biologists focus on all the components and the interactions among them, all as part of one system. These interactions are ultimately responsible for an organism's form and functions[109].

Systems biology relies on bioinformatics and computational biology to understand how biological systems function. According to the National Institutes of Health, Bioinformatics is the research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral or health data, including those to acquire, store, organize, archive, analyze, or visualize such data.

Computational Biology is the development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavioral, and social systems.

Examples of technology involved:

- Applied mathematics
- Statistics
- Informatics
- Computer science

[109] Institute for Systems biology, University of Washington

- Artificial intelligence
- Chemistry
- Biochemistry
- Physics
- Engineering
- Behavioral science

Example Applications:
- Personalized medicine
- Large and small molecule development
- Diagnostics (human and animal)
- Protein folding
- Sequence alignment
- Gene finding
- Genome assembly
- Protein structure
- Gene expression

## Genomics, Proteomics and High Throughput Biology

Genomics is the study of an organism's entire genome. This includes determining the DNA sequence and genetic mapping. Proteomics is the study of proteins, particularly their structures and functions. High Throughput Biology includes using the techniques from biology, physics, chemistry, mathematics, computer science and engineering to speed research and knowledge creation. It is the basic technology that supports the rapid screening and development of new biologic and chemistry-based products. These three disciplines study the interactions of chemical compounds, gene products, cells and organisms and the networks formed by these interactions.

Examples of technology involved:
- Crystallography
- Computational prediction of protein folding
- High throughput “next generation” DNA sequencing
- High throughput genotyping (analysis of individual variation in gene structure)
- High throughput gene expression profiling (microarrays)
- Biobanking
- RNAi resources
- Assay development
- Physical characterization
- Medicinal chemistry
- Toxicology
- Formulation
- Preclinical trials

- Clinical trials
- Robotics
- Mass spectrometry
- Bioinformatics
- Mathematics
- Engineering
- Physics
- Chemistry
- Biology

Example Applications:
All forms of life sciences, including:

- Gene Therapy
- Pharmacogenomics
- Gene discovery, mutation analysis and functional studies
- Identification of new drug targets
- Rational drug design
- Biomarker discovery and validation
- Clinical test development
- Identification of pathogens
- DNA mapping
- Biologic and chemistry-based pharma
- Personalized medicine
- Genetic engineering of crops and natural materials for use in biofuels and renewable products

## Imaging and Navigation

Imaging science is concerned with the generation, collection, duplication, analysis, modification, and visualization of images. As an evolving field it includes research from physics, mathematics, electrical engineering, computer vision, computer science, and perceptual psychology, among others.

Navigation is the integration and registration of medical devices that are used to deliver therapies and create an image to allow for precise delivery of therapies or diagnostic capabilities to identified target locations.

Examples of technology involved:

- MRI
- Fluoroscopy
- CT scans
- Catheter delivery systems

- Biological implants
- Mechanical and electrical implants
- 3D computer graphics
- Animation
- Digital imaging
- Color science
- Digital photography
- Microdensitometry
- Remote sensing
- Radar imaging
- Radiometry
- Ultrasound imaging
- Printing technologies
- Holography

Example Applications:
- Delivery of gene therapy
- Delivery of autologous cells
- Precise positioning of materials-based implants
- Ablation

## Commercialization Catalysts

Commercialization catalysts are generic environmental and infrastructural support to convert knowledge into products. They link and leverage talent to achieve more effective and efficient use of resources, time and leadership. Commercialization Catalysts are the domain of the public, private, and academic sectors

### Leadership Talent

Leadership talent is defined as having access to leaders who are experienced CEOs, executives, and advisors who are willing to help guide and build a structure around the technology to commercialize the product and get it to the marketplace. Leadership has both a strong academic and private sector experience base.

### Skilled Workforce

A skilled workforce is necessary for achievement in the biosciences. This includes adequate training programs, links between industry and academia, and quality mentorship programs.

### Funding

Funding is critical to starting a business. Funding for businesses comes from several different areas, including:

- Traditional: This includes obtaining loans from banks to start a business
- Venture Capital: Venture Capital is a type of private equity capital that is generally held by professional organizations that invest the money businesses in exchange for an equity stake in the company. Venture capital may be invested at any stage of the business development cycle, although it is more likely to be invested in later stages of development.
- Angel: Angel funders are high-net worth individuals who provide money to start up a business in return for a convertible debt or ownership stake in the company. Often times angel investors pool resources in the form of an angel network.
- Grants: Grants are "gifts" of money that are provided to businesses for a specific purpose. Grants can be provided by many sources, including non-profit organizations, foundations, government agencies, or other sources.
  - SBIR/STTR

## Academic Technology Transfer

Academic tech transfer capabilities are critical to ensuring that the innovative research conducted at academic institutions has an avenue to be further developed and commercialized for the benefit of the public. Tech transfer capabilities include patent support, commercialization support, funding support, management support, licensing, or other assistance in helping discoveries made at the academic institution become a product available to consumers.

## Acceleration and Incubation

Incubation is a shared and often subsidized space where companies can locate in their early stages to continue their product development work. Acceleration is space, plus the addition of money, management, technical resources, and other skills that help a business speed up its product development timeline.

## Component and Service Suppliers

Component and service suppliers are those companies and organizations that provide needed expertise to help companies commercialize their products. They can be contract research support, manufacturing support, design support, component suppliers, legal counsel, regulatory services, etc.

## Facilities

Most companies need space in which to operate the business. This can include laboratory space for further research and development, general office space for things such as sales and marketing, or manufacturing space to make the product.

### Business Planning

Business planning support includes advice or contract support about the various aspects of the business, from marketing and sales, technology assessment, finance, value chain development, to business strategy.

## Foundational Capabilities

Foundational Capabilities are the fundamental building blocks that underlie any life science or business endeavor. Foundational Capabilities are the domain of the Public Sector.

### Education

A high quality education system from Pre-K, through K-12, and into higher education, with particular strength in math, biology and other sciences are required to support a bioscience economy.

### Infrastructure

Basic infrastructure, such as roads, sewers, buildings, internet/telecommunications capabilities, and other amenities must be in place to support the development of businesses in the community. Infrastructure is of special importance to new industries where no current infrastructure exists to support this new type of technology-based business.

### Policy

There must be sound public policy concerning the regulation of business and sciences to support the bioscience industry sector. In addition, there need to be public policy decisions that help to catalyze innovation and formation of new industries and companies. It is important that catalysts are targeted to encourage and leverage private sector investment.

# Appendix C, An Assessment of the Potential for Bioenergy and Biochemicals Production from Forest-Derived Biomass in Minnesota

Chemical compounds or substances produced from living organisms – natural products – often have a biological activity which may be useful in pharmaceuticals. These natural chemical compounds may be extracted from tissues of terrestrial plants, marine organisms or microorganism fermentation broths. A crude extract from any one of these sources typically contains novel, structurally-diverse chemical compounds. Most biologically-active natural product compounds are secondary metabolites which are not directly involved in the normal growth, development or reproduction of organisms. A good example of this is the compound betulin that is found in the outer layer of birch bark. The function or importance of secondary metabolites to the organism is usually of an ecological nature as they are used as defenses against predators, parasites and diseases. The antifungal properties of betulin are well documented in many studies[110]. Plants have always been a rich source of useful drugs (e.g. morphine and quinine). Clinically useful drugs which have recently been isolated from plants include the antimalarial agent artemisinin (an extract from the sweet wormwood bush that was used in Chinese medicine as a fever cure for 500 or 600 years) and the anticancer agent paclitaxel (Taxol) from the yew tree. Microorganisms produce a large variety of antimicrobial agents which have evolved to give their hosts an advantage over their competitors in the microbiological world. Marine sources such as coral, sponges, fish, and marine microorganisms have chemicals with interesting biological activities. For example, curacin A is obtained from a marine cyanobacterium and shows potent antitumor activity. Animals can be a source of new drugs.

## Mechanical Processing to Alter Physical Properties

The technology for this concept uses simple mechanical methods such as grinding, mixing, shredding the natural product to simply reduce the size of the material or alter the original structure. This technology relies on the presence of natural products in high enough concentrations or in synergy with other substances to produce the desired efficacy through absorption or other chemical transfer method. An example of this would be the grinding of bark to create a poultice, such as what was practiced by aboriginals in treating wounds and infections. This concept would also apply for low cost products for treating high volume material, such as producing a natural, low cost powder to treat seeds to prevent rot, mildew or types of damage or loss.

## Extraction and Purification

Next in order of complexity, is the use of conventional solvents to extract chemicals out of biomass. A subset to this technology is the use of supercritical fluid extraction using variety of gases and solvent combinations. The most popular solvent system is simply carbon dioxide. The beauty of extraction technology is it is relatively simple but can be tailored to many starting materials and can be modified greatly to affect the final product purity, where final cost and application is related to purity and impurity profiles. This technology also tends to be lower cost and suitable for products needed in high volumes. Products from this technology can then be 1) used as is or 2) converted to other compounds using conventional chemical reactions and processes or processes using biotechnology.

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[110] Birch Bark Research and Development, Pavel A. Krasutsky, *Natural Product Reports,* 2006, ***23***, 919–942 | www.rsc.org/npr

Even though each has different end-market applications and different processes, NaturNorth Technologies and Lonza use this type of technology to produce their products. NaturNorth, now an operation of Myriad, uses birch bark and Lonza use eastern larch (tamarack), with different solvent systems, to produce their respective products.

### Biorefineries

There are many other processes for converting biomass components to value-added products, fuels, and power that use biochemical technology. The biorefinery concept has developed to broadly classify the technologies using thermochemical or biochemical conversion processes either separately or together with other technologies. As can be expected from the industry that needs efficiency to be competitive and much like the other technologies just described, biorefineries can be used in harmony with other processes to produce a number of product outputs such as fuels, various chemical products, energy products and starting materials for other operations.

The major advantage to integrated biorefineries is the synergies gained by connecting a number of somewhat separate, but related processes into one continuous operation. This allows the products from biorefineries to compete to be cost competitive with products made with very mature technology that uses non-renewable fossil-fuel sources of feedstock. In fact, the combined use of various technologies [111] offers the greatest opportunity for optimizing the conversion of biomass into a variety of different fuels, chemicals, and energy products. In summary, Biochemical technologies use enzymes or microorganisms to convert biomass feedstocks to desired products such as complex protein and other large molecules (e.g., through fermentation). These kinds of technologies may be used alone, or may augment more traditional thermochemical technologies such as those used to remove wood extractives or separate fiber. Thermochemical technologies may utilize catalysts (acid, metal, or a combination) and/or high pressure and temperature to convert biomass components to the desired product. Thermochemical processes such as gasification and pyrolysis have been explored to some degree for the production of energy products and biochemicals but are not in widespread commercial use. The primary products of biorefineries are five and six carbon sugars. Biomass sugars represent the most abundant renewable resource available. Using these sugars as starting chemical platforms or building blocks, there are unlimited chemical conversion reactions available to transform sugars into bioproducts. As an example, using these products in a fermentation process, you can produce a number of common products, such citric acid, ethanol, lactic acid. Using other technologies or biological forms such as microorganisms and enzymes, the fermentation of sugars holds great potential for new bioproducts.

As a means illustrating the potential of these sugars, Table C1 was revised from the Dovetail Partners report and inserted here to illustrate the potential markets for products made from glucose sugars.

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[111] Dovetail Partners, Inc. and Ramaswamy, Shri, , An Assessment of the Potential for Bioenergy and Biochemical Production From Forest-Derived Biomass in Minnesota, A Report for the Blandin Foundation Vital Forests/Vital Communities Initiative and Iron Range Resources, August 2007

| Table C1, Glucose Derivatives | |
|---|---|
| **Butanol** | Used in high volume as a solvent and in plasticizers, amino resins, and butylamines, and as a liquid transportation fuel itself (more efficient than ethanol). Butanol is a starting chemical for 1,4-butanediol (BDO) and its derivatives (the projected demand is high and there is a market opportunity to replace fossil fuel raw material). |
| **Lactic acid** | Lactic acid has many potential uses as well, which include many potential derivatives, such as ethyl lactate, acrylic acid, propylene glycol, and pyruvic acid, some of which are new chemical products, and others that represent bio-based routes to chemicals currently produced from petroleum. |
| **Succinic acid** | Derivatives of succinic acid, such as THF (tetrahydrofuran), BDO, GBL (gamma butyrolactone), NMP (n methylpyrolidone), 2-pyrrolidone, and succinate salts are either cost-competitive or nearly cost competitive with accepted commercial processes. |
| **L-Lysine** | L-Lysine is a bio-based animal feed additive typically produced from corn starch and molasses using fermentation. This is also used as raw material for pharmaceutical salts, peptide drugs and as diagnostic aids. |
| **1,3-propanediol** | With terephthalic acid, is used to produce polytrimethylene terephthalate (PTT). PTT is a polymer with remarkable "stretch-recovery" properties, and is used in apparel, upholstery, specialty resins, and other applications where properties such as softness, comfort-stretch and recovery, dyeability, and easy-care are desired. It is currently manufactured by Shell Chemical (CORTERRA Polymers) and DuPont (Sorona® 3GT). Studies have shown that the properties of DuPont's Sorona® surpass nylon and polyethylene terephthalate (PET) in fiber applications and polybutylene terephthalate and PET in resin applications such as sealable closures, connectors, extrusion coatings, and blister packs. PTT polymers currently on the market are made using fossil-based 1,3-propanediol. However, Genencor International and DuPont have been collaborating to develop the metabolic pathway in E. coli to produce 1,3-propanediol directly from glucose at a lower cost. Commercial production of bio-based 1,3-propanediol has been successfully practiced by DuPont. |
| **Polyhydroxy alkanoates (PHAs)** | PHAs are a family of natural polymers produced by many bacterial species for carbon and energy storage. They are extremely versatile and can be used in a broad range of applications. Their performance exceeds that of PLA and PHAs could capture a large share of the plastics market if they could be produced at a competitive cost. Bacterial fermentation of PHAs, specifically poly-3- hydroxybutyrate-co-3- hydroxyvalerate) (PHBV), has been performed commercially by Zeneca and then Monsanto and under the trade name Biopol™ in the 1990s. PHBV has |

| | |
|---|---|
| | been used to make plastic bottles and coated paper. |
| **3-hydroxy propionic acid (3-HP)** | This chemical is just now being actively investigated by Cargill, Inc. Many high volume products can be made from 3-HP creating the potential for a platform intermediate similar to lactic acid and succinic acid. The synthesis of acrylic acid, and the process for obtaining the salts and esters of acrylic acid from 3-HP have been demonstrated in the laboratory. There are other derivatives under consideration. As with polylactide, there is no commercially-viable production route of 3-HP from fossil fuel feedstocks. The conversion of 3-HP to acrylic acid is expected to be "easier" and may require less energy than the oxidation of propylene to acrylic acid that is currently practiced from petroleum. As new conversion technologies are developed, the challenge will be to make them cost competitive with the current fossil-based routes to acrylic acid. |

### Plants and Trees: Chemical Factories

Researchers have studied the composition of many plants and trees to determine the chemical content of bark, leaves, roots, and the wood itself, but still a lot is not known. When multiplied by the possible derivatives of these compounds or combinations of various treatments in combination or mixture with other compounds, the possibilities are limitless. Lonza was started by specifically using the left over stumps of western larch trees as a starting substrate for extracting arabinogalactin.

Researchers have in addition created various grades of aribinogalactan to create more market possibilities. As another example of the this technology, duck weed, which is found in Minnesota lakes and rivers, has been genetically engineered to produce specific recombinant proteins and peptides[112] that can be used to make commercially valuable vaccines or antigens[113].

The natural feedstock for these mechanical/chemical/biochemical processes can be any number of natural materials. Taxol, a cancer treatment, started out using the leaves from yew trees[114]. Leaves have been long known as a source of chemicals, food and medicine[115]. Given this background, an illustrative list containing the many chemical products produced from wood, leaves, bark, and roots would be extensive.

### Biomass Feedstock Issues

The major drawbacks to using natural materials as a starting resource are:

1) Raw material harvesting, collection handling costs
2) Control of moisture and contamination
3) Inconsistency of incoming product quality

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[112] Patent disclosure discussed http://www.wipo.int/pctdb/en/wo.jsp?IA=US2001023400&DISPLAY=DESC

[113] Viral Vectors for the Expression of Proteins in Plants, Yuri Gleba http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VRV-4NC5SXY-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=4ed87f4ead98ef6c90d6c2ccb2026187

[114] Nature Medicine, The Story of Taxol: Nature and Politics in the Pursuit of Anti-Cancer Drug, 2001, http://www.nature.com/nm/journal/v7/n2/full/nm0201_148.html

[115] Medical Resources of the Tropical Forest, Biodiversity and Its Importance to Human Health, Michael J. Balick, et. Al,

Handling costs for natural sources are typically very expensive when incurred for a relatively small volume of material or without the benefit of another use, likely the primary, to allocate handling costs over a greater number of units. Much of the handling cost is due to the size of the machinery and skilled labor costs needed on a commercial scale to handle the materials. For example, any side stream from a primary raw material flow will have lower costs if the costs would have been incurred anyway to transport the primary material to the processing facility. In fact, there may be incentives to find alternate uses for the 'by-products' rather than pay disposal costs.

Typically, raw materials will need to be collected from a large area, where a variety of harvesting methods or pre-collection technologies may be used that make subsequent use more difficult. As an example, there are several types of debarking mechanisms. Some procedures and equipment generate a large amount of wood splinters in addition to the bark. If relatively clean bark is sought as a starting raw material, some types of debarking machinery and operational practices would not produce an acceptable raw material, i.e. there would be too much contamination from 'good wood' splinters getting mixed with the desired materials.

Most natural products start with relatively high moisture and must be stored or dried to reduce the moisture content to a workable range. These issues can be resolved, but require capital and create ongoing expenses. Inconsistency of incoming product quality can be resolved by having a robust process that in the early stage can handle a wide swing in product quality or feedstock properties.

# Appendix D, Education

| Table D1, Universities/Private Colleges and Community and Technical Colleges | | |
|---|---|---|
| **Organization Name** | **Degree Programs** | **Location** |
| **College of St. Scholastica** | 4yr / Masters | **Duluth** |
| **Duluth Business University** | 2 yr | **Duluth** |
| **Fond du Lac Tribal and Community College** | 2 yr | **Cloquet** |
| **Hibbing Community College** | 2 yr | **Hibbing** |
| **Itasca Community College** | 2 yr | **Grand Rapids** |
| **Lake Superior College** | 2 yr | **Duluth** |
| **Mesabi Range Community and Technical College** | 2 yr | **Eveleth** |
| **Mesabi Range Community and Technical College** | 2 yr | **Virginia** |
| **Rainy River Community College** | 2 yr | **International Falls** |
| **University of Wisconsin-Superior** | 4 yr/Masters | **Superior** |
| **University of Minnesota Duluth** | 4 yr/Masters / Medical and Pharmacy schools | **Duluth** |
| **Vermillion Community College** | 2 yr | **Ely** |
| **Wisconsin Indianhead and Technical College (WITC)** | 2 yr | **Superior** |

## Appendix E, Forest Resource Statistics

| Table E1, Total Wood Harvested and Utilized by Industry and Fuelwood Users in Minnesota [116] | | | | | |
|---|---|---|---|---|---|
| (In Thousand Cords - by Species – From Timberland) | | | | | |
| (Pulpwood 2006; Sawtimber 2004; Fuelwood 2002-03) | | | | | |
| | | | | | |
| **Species** | Pulpwood | Sawlogs & Others | Fuel Residential* | Fuel Commercial | Total |
| **Aspen and Balm** | 1,599.2 | 70.8 | 16.7 | 0.7 | 1,687.4 |
| **Birch** | 161.3 | 27.1 | 41.0 | 6.3 | 235.7 |
| **Ash** | 15 | 8.3 | 15.1 | 0.2 | 38.6 |
| **Oak** | 0.2 | 73.3 | 45.1 | 1 | 119.6 |
| **Basswood** | 12.5 | 21.6 | 1.3 | 0 | 35.4 |
| **Maple** | 117.6 | 12.7 | 15.8 | 4.7 | 150.8 |
| **Cottonwood** | 0. | 11.6 | 0 | 0 | 11.6 |
| **Other Hardwood** | 0 | 13.8 | 8.1 | 0 | 21.9 |
| **Sub-Total Hardwood** | 1,905.8 | 239.2 | 143.1 | 12.9 | 2,301.0 |
| | | | | | |
| **Pine** | | | | | |
| **Red** | 29.6 | 114.7 | 2.9 | 0 | 147.2 |
| **White** | 1.3 | 7.6 | 1.4 | 0 | 10.3 |
| **Jack** | 115.4 | 147.7 | 1.7 | 0 | 264.8 |
| **Spruce** | 194.7 | 18.4 | 0 | 0 | 213.1 |
| **Balsam** | 160.4 | 7.2 | 0 | 0 | 167.6 |
| **Tamarack** | 33.9 | 1.8 | 0.7 | 0 | 36.4 |
| **Cedar** | 0 | 6.6 | 0.4 | 0 | 7.0 |
| **Other Softwood** | 0.8 | 1.1 | 0 | 0 | 1.9 |
| **Sub-Total Softwood** | 536.1 | 305.1 | 7.1 | 0 | 848.3 |
| **Total** | 2,441.9 | 544.3 | 150.2 | 12.9 | 3,149.3 |

[116] Minnesota Forest Resources, Department of Natural Resources, December 2007, page 19 http://files.dnr.state.mn.us/forestry/um/minnesotaforestresources_rt2007.pdf

| Table E2, Sustainable Harvest vs. Actual Harvest (cords) [117] | | |
|---|---|---|
| **Species** | Sustainable Harvest Levels | Actual Harvest (2006) |
| **Aspen/Balm** | 2,358,000 | 1,687,400 |
| **Basswood** | 288,300 | 35,400 |
| **Birch** | 371,500 | 235,700 |
| **Maple** | 429,600 | 150,800 |
| **Oak** | 499,300 | 119,600 |
| **Other Hardwoods** | 505,700 | 15,000 |
| **Pine (Jack, White, Red)** | 461,600 | 422,300 |
| **Spruce/Fir** | 712,000 | 380,700 |
| **Tamarack** | 114,800 | 36,400 |
| **Cedar** | | 7,000 |
| **Total** | **5,740,800** | **3,149,300** |

Species, along with numbers, having excess capacity are shown in the shaded areas.

The sustainable harvest levels from the DNR in Table E2 are individual species estimates. The total for these estimates (5.7 million cords) does not total to the 5.5 million cords composite number used in the GEIS model.

Minnesota's forests are healthy and increasing. The USDA Forest Service Report (NRS Web site for Forest conditions: http://www.nrs.fs.fed.us/pubs/rb/rb_nrs12.pdf) concluded the following highlights:

- The number of live trees on timberland increased in Minnesota from 1977 to 2003--sapling and sawtimber trees increased while the number of poletimber trees decreased.
- The total dry biomass of all-live trees on timberland increased from 1977 to 2003—a 5.6 percent.
- The volume of growing-stock trees from 1977 to 2003 with the largest increases in volume were in tamarack (117-percent increase), sugar maple (95 percent), red pine (91 percent), bur oak (84 percent), and northern white-cedar (77 percent).
- All-live cubic foot volume per acre on timberland increased from 1977 to 2003.
- The volume of sawtimber on timberland increased from 1977 to 2003 because of an increase in both the number and size of sawtimber trees.
- Average annual net growth of growing stock, over 1990-2002, was 404 million cubic feet for Minnesota. This is equivalent to 2.6 percent of the total growing-stock volume in 2003.

[117] 2008 Minnesota DNR Forest Report and e-mail communications with the regional DNR office in Grand Rapids. 2006 Harvest data is from the table found on page 19, http://files.dnr.state.mn.us/forestry/um/forestresourcesreport_08.pdf

In contrast the USFS concluded there are some challenges with our forest lands:

- High mortality rates have led to a 27-percent decline in the volume of balsam fir and a 14-percent decline in the volume of paper birch.
- The majority of sawtimber is in lower valued tree grade 3 for both hardwoods and softwoods.
- Just over half (53 percent) of the forest land in Minnesota is fully stocked or overstocked compared to 57 percent in Wisconsin and 62 percent in Michigan.
- The average annual mortality for Minnesota over 1990 to 2002 was 272 million cubic feet. This is equal to 1.8 percent of the total growing-stock volume in 2003—a rate significantly higher than the 1.2 percent reported in 1977 and the 1.3 percent reported in 1990.
- Eastern spruce budworm, forest tent caterpillar, jack pine budworm, introduced larch casebearer, and other defoliating agents have been active, sometimes on some of the same land at the same time. Many trees that are repeatedly defoliated sustain measurable growth loss, which in turn, may lead to mortality.

## Table E3, Growth vs. Actual Harvest (cords) [118]

[118] Minnesota Forest Industry data

| Table E4, NE Regional Major Forest Products Industrial Operations (1) | | | |
|---|---|---|---|
| **Company Name** | **Location** | **Type of Operation (2)** | **Round Wood Consumption (cords/yr)(3)** |
| **Ainsworth Engineered** | Cook | Oriented Strand Board (OSB) using Aspen, Birch, Balm, Pine, Maple, Tamarack, and Ash | **O (4)** |
| **Boise Paper** | International Falls | Kraft Pulp Technology and Business Paper Mfg using Aspen, Balm, Pine, Spruce, Balsam, Fir, Birch, Tamarack, Ash, Maple. | **650,000** |
| **Jardin Home Products (Formerly Diamond Brands)** | Cloquet | Wooden Utensils using Aspen | **<20,000** |
| **Georgia-Pacific** | Duluth | Industrial Hardboard (fiber composite) using Aspen, Pine, and mixed hardwoods | **85,000** |
| **Lonza** | Cohasset | Food and animal health products from larch extracts | **Data Not Available** |
| **Louisiana Pacific** | Two Harbors | Oriented Strand Board—Engineered Siding Panels using Aspen, Balm and Birch | **110,000** |
| **Hedstrom Lumber** | Grand Marais | Dimensional Lumber for Construction using Pine, Fir, Spruce, Birch, Aspen | **40,000** |
| **International Bildrite** | International Falls | Construction Sheathing using Aspen, Balm and recycled paper | **22,000** |
| **Mat Inc.** | Floodwood | Wood fiber mulches and bonded fiber mats for hydraulic seeding using Balm, Aspen, and Birch | **9,000 (5)** |
| **New Page (formerly Stora Enso)** | Duluth | Uncoated, lightweight supercalendered magazine and publication papers using Balsam, fir, pine, spruce | **150,000** |
| **Sappi Fine Paper** | Cloquet | Kraft Pulping Operation and High Quality Publishing. | **780,000** |
| **Rajala Companies (Timber, Veneer, Milling)** | Deer River | Animal bedding, Components, Construction Materials, Custom Logging, Custom Services, Firewood, Flooring, Fuel, Logs, Lumber, Moldings, Paneling, Siding, Pellets, Vacation Homes | **NA** |
| **UPM (Blandin Paper Company)** | Grand Rapids | Mechanical Pulp, Finnish LWC magazine paper | **180,000** |

(1) Although not located in the 7-county northeastern Minnesota region, Norbord Minnesota, located in Solway, near Bemidji, uses 280,000 cords per year to make OSB using aspen, birch, balm, maple, and jack pine. Also not reported is the Weyerhauser's laminated strand lumber plant in Deerwood operation in that permanently closed in late 2007.

(2) Minnesota Department of Natural Resources, Forest Report, 2007, http://files.dnr.state.mn.us/forestry/um/minnesotaforestresources_rt2007.pdf

(3) DNR data records

(4) The last of three plants closed in 2009--roundwood consumption for Ainsworth was 900,000 cords at full production capacity.

(5) Reported as 20,000 tons/yr, converted to cords using the equivalence of 4,500 lbs/cord

| Table E5, Pellet Production | | |
|---|---|---|
| Company | Location | Annual Production Capacity (Tons) |
| BioPellets (1) | Deer River | 25,000 |
| Valley Forest Products (2) | Marcel | 50,000 |
| Mountain Timber Wood (under development) | Mountain Iron | 100,000 (3) |

(1) Located adjacent to Rajala Timber, but separate ownership
(2) Business North.com, http://www.mttimber.com/Press-News.html
(3) Proposed capacity based on designed plant capacity.

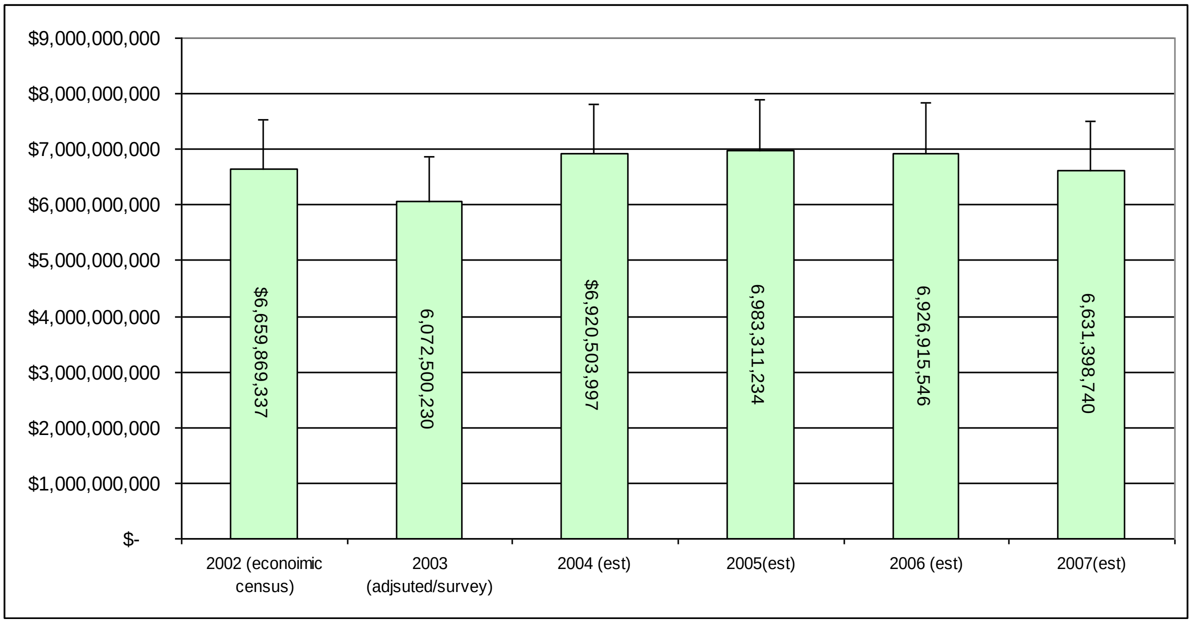
# Appendix F, Forest Products Contributions to Minnesota's Economy

| Table F1, Forest Products Employment[119] | | | | | | |
|---|---|---|---|---|---|---|
| Year/Employees | | | | | | |
| Sector | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| **Pulp/Paper/Converted Paper Products** | 14,205 | 13,149 | 12,386 | 12,099 | 11,773 | 11,716 |
| **Sawmills/EWP** | 16,482 | 16,733 | 16,980 | 17,178 | 15,701 | 14,441 |
| **Miscellaneous Wood Manufacturing** | 8,366 | 8,626 | 8,897 | 9,434 | 9,331 | 8,695 |
| **Logging (FT/PT)** | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| **Totals** | **42,053** | **41,508** | **41,263** | **41,711** | **39,805** | **37,852** |

| Table F2, Wages Paid to Employees ($) | | | | | | |
|---|---|---|---|---|---|---|
| Sector | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| **Pulp/Paper/Converted Paper Products** | 700,061,752 | 663,652,264 | 647,162,760 | 625,686,922 | 677,065,480 | 648,703,744 |
| **Sawmills/EWP** | 642,443,066 | 700,926,996 | 747,765,940 | 782,523,947 | 742,480,388 | 845,535,132 |
| **Misc Wood Manuf** | 693,005,679 | 265,523,769 | 316,516,147 | 321,969,461 | 334,160,196 | 343,735,660 |
| **Logging (FT/PT)** | 60,000,000 | 60,000,000 | 60,000,000 | 60,000,000 | 78,000,000 | 78,000,000 |
| **totals** | 2,095,510,497 | 1,690,103,029 | 1,771,444,847 | 1,790,180,330 | 1,831,706,064 | 1,915,974,536 |

[119] Forest Products Employment and Wages Information provided by Minnesota Forest Products organization

## Figure F1, Forest Product Value



Appendix G, Minnesota's Woody Biomass Resources and Opportunities in the Emerging Energy Industry

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# Executive Summary

Recent developments in alternate energy may present new opportunities to expand the economy of northern Minnesota using wood resources. At the same time, increased wood usage in the state can affect the existing industry. The purpose of this document is to evaluate various wood resources and discuss opportunities for growth in the energy industry in the context of the existing forest products industry. Minnesota's wood products industry is an important part of the state's economy contributing approximately $6.9 billion to the state's economy. While a portion of the forest products industry is not entirely dependent on local resources for raw material, the majority of northern Minnesota's forest products industry is dependent on wood produced through harvesting of stands located within Minnesota or neighboring states and provinces of Canada. Understanding the forest resource is critical to inform decisions on policies such as harvesting plans or subsidies to an emerging energy industry to ensure that the health of the state's forest products industry and forests is maintained.

In the past, wood for fuel has been used primarily for residential heating with very little wood purchased solely for industrial energy applications. Up to this point, wood wastes produced in industrial processes such as bark, sawdust, edgings and planer shavings have been used to produce energy but use of wood exclusively for energy has not been widespread. Recently, prices of petroleum-derived energy sources such as heating oil and natural gas have risen to the point where wood might be considered an economically viable alternative to fossil fuels. A comparison of the price of fossil fuels and woody biomass shows that wood chips, and in some cases roundwood, may be considered a viable replacement to higher priced fossil fuels such as natural gas.

The capacity of the state's forest resource to provide timber supply to the forest products industry in a sustainable manner has been a subject of intense study. Minnesota is a nationally recognized leader in this area through the process of the Generic Environmental Impact Statement on Forestry. The GEIS evaluated forest resources in the context of environmental impacts including long-term soil productivity, water quality and wildlife populations. After evaluation of several harvest levels and associated impacts, the GEIS identified a level of 5.5 million cords as a sustainable long-term harvest level. This harvest level was also stated as a goal of the Governor's Task Force on the Competitiveness of the Forest Products Industry. A recent follow-up study to the GEIS indicates a high level of implementation of recommendations to mitigate environmental impacts. Given a sustainable harvest level of 5.5 million cords and current usage by the forest product industry of 4.2 million cords, an estimated 1.3 million cords of roundwood could be available in the future to produce energy or forest products.

In addition to roundwood harvests, forest harvest residues, specifically tops and limbs, could supply feedstock for energy production. An evaluation of the proportion of harvest residues shows that approximately one million dry tons of harvest residues are currently produced resulting from a harvest level of 3.7 million cords of pulpwood and sawtimber.   Using the same ratio of harvest residues to roundwood shows that a harvest level of 5.5 million cords would produce approximately 1.5 million dry tons of harvest residue biomass.  Accounting for environmental mitigation, estimates of total available harvest residues are 750,000 and 1.15 million dry tons, at harvest levels of 3.7 and 5.5 million cords, respectively.  Current and proposed facilities could demand 500,000 dry tons annually, leaving about 250,000 tons of forest harvest residues available at the present time.

Additional biomass could be obtained through a variety of sources including thinning of Red Pine plantations and Aspen.  Thinning of Red Pine could contribute an additional 100,000 cords annually above current levels, or approximately 115,000 dry tons.  Aspen thinning is a potential option to recover volume that is otherwise lost to mortality.  The NRRI has conducted research on precommercial thinning of Aspen and estimates that ten tons per acre of ovendry biomass could be harvested at year ten to fifteen. Also, there may be opportunities to thin older stands. A need exists to conduct thinning trials using available equipment and evaluate impacts on subsequent stand growth at various ages of thinning.   If Aspen thinning were widely practiced, it is possible to produce one million dry tons annually, a potentially significant amount of biomass.

In addition to forests, shrublands and hybrid poplar plantations could supply woody biomass in the future.   Quantifying shrubland acreage and stand density is difficult and work is underway by the Minnesota Department of Natural Resources and the UM-NRRI to develop methods to estimate shrub biomass more accurately.  Using available information and conservative assumptions, shrublands may contribute an additional 400,000 dry tons annually.

Hybrid poplar plantations grown on agricultural lands enrolled in the Conservation Reserve Program have the potential to supply large quantities of woody biomass.  A national study of biomass supply estimates that almost one third of the total biomass available in the future could come from dedicated energy crops such as hybrid poplar, switchgrass or prairie mixes. Assuming a yield of 3.5 ovendry tons per acre per year, the total amount of biomass available in the state may be as high as 5.6 million ovendry tons, a portion of which could be woody biomass from hybrid poplar plantations.

The potential demand for alternate energy is extremely large.  Complete replacement of gasoline and coal-derived electricity in Minnesota would require a total of sixty million dry tons of biomass, a staggering number.   However, progress can be made toward that goal. Technology under development to produce ethanol from cellulose focuses on two primary pathways, biochemical and thermochemical.  Biochemical ethanol production employs specific enzymes and genetically modified yeasts to degrade cellulose into sugars and ultimately to ethanol.  Thermochemical processes involved gasification and catalytic conversion of synthesis gas to a variety of liquid fuels including ethanol.   The economics of ethanol production using local wood sources was estimated using data published in a recent study by the National Renewable Energy Laboratory.  This baseline analysis was adjusted to reflect prevailing prices for wood in Minnesota.  The estimated breakeven price of ethanol produced from residue chips is $1.17 and $1.44 per gallon using roundwood feedstock, an average of $1.30 per gallon.  A comparison of ethanol to gasoline shows that after adjustment for reduced energy content and mileage using ethanol, the current mileage-adjusted value of ethanol that is competitive with gasoline is $1.89 per gallon. Assuming that conversion technologies advance to the point suggested in the NREL report, wood-based ethanol could be competitive with gasoline at current wood prices in Minnesota.

An alternate transportation technology that may compete with cellulosic ethanol is plug-in electric vehicles. A comparison of fuel costs between ethanol and electrically-driven vehicles shows that fuel cost is $0.10 per mile for an ethanol-powered vehicle compared to $0.02 per mile for a plug-in electric in full-electric mode. After adjustment to account for highway taxes, the cost of an electrically-powered vehicle is $0.033 per mile, roughly one third the cost of an internal combustion engine burning ethanol. A comparison of the efficiency of conversion of biomass between an ethanol-powered vehicle and a plug-in electric vehicle shows that approximately 2.5 times more miles can be derived from a ton of biomass using plug-in electric vehicles.

While there is uncertainty about the rate of oil depletion and global reserves of fossil fuels, there is no doubt that demand for alternate energy will increase. Biomass sources including roundwood, forest harvest residues, forest thinnings, brushlands and energy crops could provide a significant amount of woody biomass to be used as feedstock to produce alternate energy in Minnesota, possibly enough for three additional wood-based plants using current supplies of timber from the forest land base. Additional opportunities exist in new biomass sources such as brushlands and poplar plantations. As this industry develops, a number of points are important:

- Legislators and policymakers concerned about the economy in the forested areas of Minnesota should appreciate the potential impact of energy subsidies on the forest products industry,
- Support for research at the state level to develop conversion and biomass production technologies, specifically energy crop development, brushland biomass assessments, aspen thinning options and impacts, forest harvest residue bundling equipment and conversion technologies is needed,
- Ethanol produced from local wood resources may be competitive with gasoline at current prices,
- Smaller-scale conversion technologies that are publicly available are needed and may require targeted research and development by the State,
- Picking ultimate winners is difficult and the most competitive options will depend on technology advancements in the fields of liquid fuels conversion and batteries.

**Introduction and Background**

Minnesota's wood products industry is an important part of the state's economy contributing approximately $6.9 billion to the state's economy (Minnesota Forest Industries, 2007). Over 22,000 people are employed in the various facets of the forest products industry manufacturing lumber, oriented strandboard, engineered composite products as well as pulp and paper. While a portion of the forest products industry is not entirely dependent on local resources for raw material, the majority of northern Minnesota's forest products industry is dependent on wood produced through harvesting of stands located within Minnesota or neighboring states and provinces of Canada. Understanding the forest resource is critical to inform decisions on policies such as harvesting plans or subsidies to an emerging energy industry to ensure that the health of the state's forest products industry is maintained. The purpose of this document is to summarize information on Minnesota's forest products industry and provide perspective on the potential for expansion of the wood-using industry in energy production.

<u>Energy Prices and Wood Energy Value</u>

It is common knowledge that energy prices have risen dramatically over the past several years with the effects of energy price increases being felt in every sector of the economy and all socioeconomic levels. Concerns over long-term supply of petroleum products and continued expansion of the economies of China, India and other countries have contributed to tightening supplies worldwide. The U.S. produces only about one-third of its oil domestically and a steady petroleum supply is critical to the U.S. economy. In the past, wood for fuel has been used primarily for residential heating with very little wood purchased solely for industrial energy applications. Up to this point, wood wastes produced in industrial processes such as bark, sawdust, edgings and planer shavings have been used to produce energy but use of wood exclusively for energy has not been widespread.

Recently, prices of petroleum-derived energy sources such as heating oil and natural gas have risen to the point where wood might be considered an economically viable alternative to fossil fuels. Table 1 shows the average net realized price per unit of usable energy assuming various rates of conversion efficiency of common energy sources. After taking into account conversion efficiency, the cost per million British Thermal Units (mmBTUs) of wood-based energy is currently lower than heating oil and propane and similar to natural gas depending on wood form, either chips or roundwood. The price advantage of wood over some fossil fuels is unprecedented and will likely become greater in the future. The differential in price between heating oil or propane and wood is sufficient to encourage near-term investment to replace these higher-priced sources. Thus, the use of wood to produce energy can be expected to increase and could become a significant part of the future economic landscape of the state. While coal remains the least expensive energy source by a wide margin, permitting of new coal-burning facilities is becoming increasingly difficult due to concerns over emissions of carbon dioxide as well as other pollutants. Use of low $CO_2$ fuels such as natural gas or no-net $CO_2$ fuels such as biomass are becoming attractive options.

Table 1. Comparison of common fuels and net realized price per mmBTU.

| Fuel Type | $/unit | Unit | $/mmBTU | Conversion Efficiency | Net Cost ($/mmbtu) |
|---|---|---|---|---|---|
| Natural Gas | $5.60 | Mmbtu | $5.60 | 0.9 | $6.22 |
| Heating Oil | $1.99 | Gallon | $14.21 | 0.85 | $16.72 |
| Propane | $1.20 | Gallon | $13.10 | 0.9 | $14.55 |
| PRB Coal | $10.00 | Ton | $0.57 | 0.6 | $0.94 |
| Round Wood | $75.00 | Cord | $3.83 | 0.6 | $7.35 |
| Wood Chips | $25.00 | Gr. Ton | $2.94 | 0.6 | $4.90 |

## Minnesota's Forest Products Industry Overview

The state's forest products industry produces a range of products and is geographically dispersed with mills located across the Arrowhead and as far west as Solway, near the prairie-forest border (Minnesota Department of Natural Resources, 2006). Tables 2 and 3 show the location, type of wood used and product produced from the pulp and paper and oriented strandboard industries located in the state.

Table 2. Minnesota's pulp and paper industry (source: MN DNR, 2006 Forest Resources)

| Firm | Wood Used | Product |
|---|---|---|
| UPM - Blandin Paper Mill Grand Rapids | Aspen, Balsam Fir and Spruce | Lightweight coated publication papers |
| Boise Cascade, LLC International Falls | Aspen, Balm, Pine, Spruce, Balsam Fir, Birch, Tamarack, Ash, Maple | Office papers, label and release papers, basesheets, business and specialty printing grades |
| Verso Paper Sartell | Aspen, Balsam Fir, Spruce | Coated and uncoated publication papers |
| Stora Enso North America Duluth | Balsam Fir, Pine, Spruce | Uncoated, lightweight supercalendered magazine and publication papers |
| SAPPI North America Cloquet | Aspen, Balm, Maple, Basswood, Birch, Tamarack, Pine | Coated freesheet fine printing and publication paper, market pulp |
| Recycling Mills | | |
| Rock-Tenn Company St. Paul | Recycled Paper & Corrugated | Cardboard and corrugated boxes |
| Stora-Enso Recycled Fiber Mill Duluth | High Grade Office Paper & Computer Paper | Market pulp |
| Liberty Paper Company Becker | Recycled Paper & Corrugated | Cardboard and corrugated boxes |

Table 3. Minnesota's OSB industry (source: MN DNR, 2006 Forest Resources)

| Firm | Wood Used | Product |
|---|---|---|
| Ainsworth Engineered USA<br>Grand Rapids | Aspen, Balm, Birch, Pine, Maple, Tamarack, Ash | OSB (Temporary shutdown 9/06) |
| Louisiana-Pacific<br>Two Harbors | Aspen , Balm, Birch | OSB – engineered siding panel |
| Northwood Panelboard<br>Bemidji | Aspen, Balm, Birch, Maple | OSB |
| Ainsworth Engineered USA<br>Bemidji | Aspen, Balm, Birch, Pine, Maple, Tamarack, Ash | OSB (One closed 8/06, one line still operating) |
| Ainsworth Engineered USA<br>Cook | Aspen, Balm, Birch, Pine, Maple, Tamarack, Ash | OSB (Temporary shutdown 9/06) |
| Trus Joist - a Weyerhaeuser Business<br>Deerwood | Aspen, Balm, Birch | Engineered lumber products for industrial and structural applications |

Assuming that the Ainsworth plant at Grand Rapids resumes operations in the future, the total timber demand of Minnesota's mills is expected to be 4.2 million cords annually (Governor's Task Force Report, 2006). However, not all of this demand is satisfied by in-state harvest and the industry is dependent to some degree on fiber imported from neighboring states and Canada. The Department of Natural Resources publishes a report of annual statewide harvest levels, prices and timber availability by species. The 2006 publication of "Minnesota's Timber Resources" indicates that approximately 3.6 million cords are harvested in the state including pulpwood, sawtimber and fuelwood. Of this total, slightly less than 2.9 million cords, or eighty percent is pulpwood. Given the fact that mill demand exceeds in-state supply by approximately 600,000 cords, this amount is assumed to be imported from other states and Canada. As energy markets develop, it is highly possible that imported fiber may be more difficult to obtain due to high demand for timber in areas that currently ship fiber to Minnesota. As a result, mills may be more reliant on locally produced timber in the future.

Emerging opportunities in the area of energy production have the potential to complement and possibly compete with the current forest products industry. Wood resources are finite and prices and competitiveness of segments of the industry can be affected by the level of competition for raw material. The recent history of wood prices in Minnesota is a clear demonstration of the interaction of supply and demand and potential to affect the industry. For example, average stumpage prices have ranged from a low of $30.00 to a high of $60.00 during the period 2000-2005 (Minnesota Department of Natural Resources, 2006, Figure 2). If markets for forest products remain high and stable, profit margins will be sufficient to allow the industry to pay high prices for raw material and maintain competitiveness nationally and globally. However, this has not been the case and market prices for raw material and products can fluctuate widely. Over the past four years, prices for oriented strandboard in the north central region have ranged from $150.00 to over $400.00 per thousand square feet on a 7/16 inch basis (Figure 1, RISI 2000-2006). Recently, the combination of historically low prices for oriented strandboard coupled with high timber prices have led to a contraction in the industry. Consideration of any new industrial expansion in the forest products industry, be it wood products or energy, must take into account the current industry and the capacity to supply sufficient amounts of raw material at prices that allow the existing and proposed new industry to produce a profit and remain viable in the long term.

Although there is potential for competition for resource in the emerging energy industry, synergies are also possible.  Many paper mills in the state are biorefineries in one sense and new markets may provide additional opportunities to expand the mix of products being manufactured, diversify the product mix and contribute to greater stability of the industry.   In particular, gasification of black liquor and opportunities to add value through the production of liquid fuels has potential immediate application.

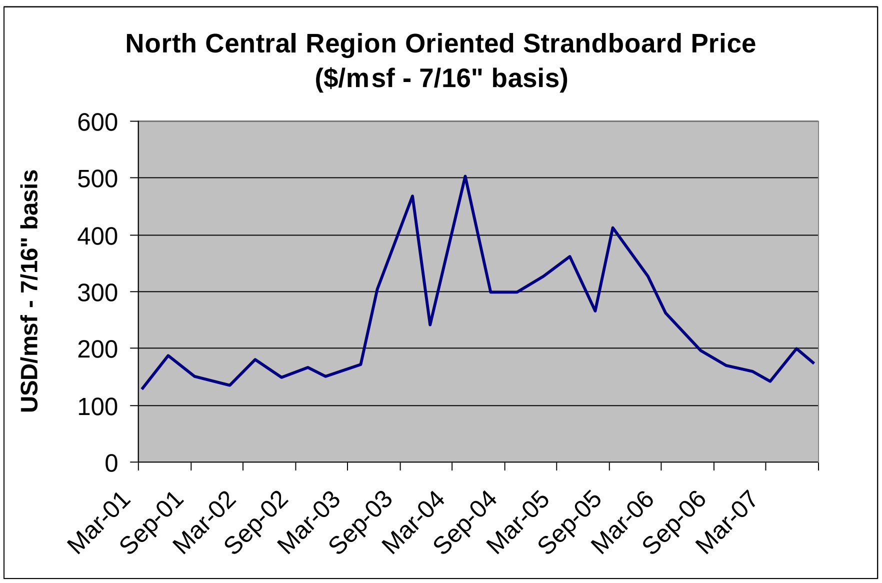


Figure 1.  OSB prices - 2001-2007 (source: Crow's Reports)

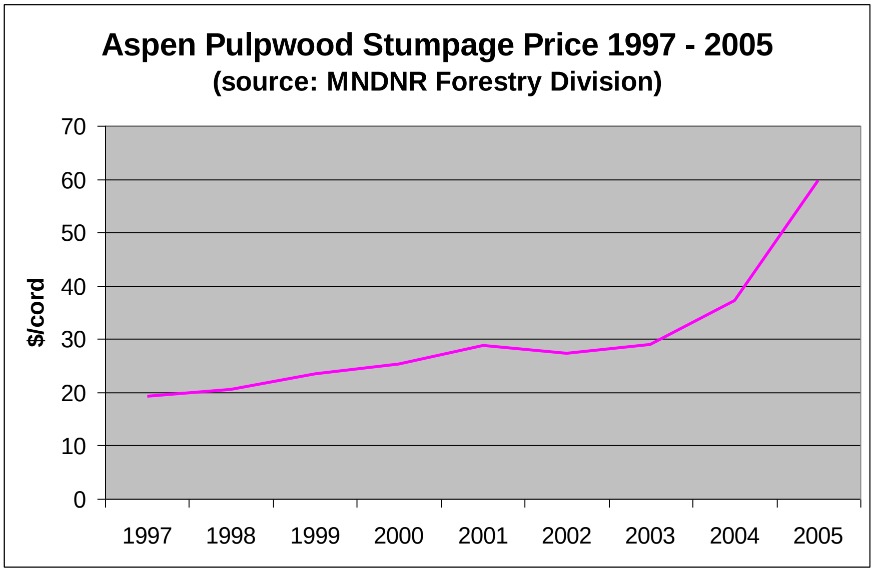


Figure 2. Historical aspen stumpage price (source: MN DNR, 2006 Forest Resources)

In addition to the forest products mills, instability in the forest products industry directly affects the logging industry. Minnesota's logging contractors employ approximately 3,000 people and the logging industry is a vital part of northern Minnesota's economy (Minnesota Forest Industries, 2007). Obviously the economic vitality of the area's mills and loggers are directly linked and the recent downturn in the forest products industry has led to an associated reduction in output in the logging industry. Based on recent experience, the willingness of logging contractors and area bankers to invest in expanded logging capacity to supply additional raw material will likely require supply contracts that will ensure that loans on equipment can be paid back within a reasonable time. The logging industry has undergone changes over the past decade with the industry consolidating to larger logging firms accounting for a greater share of the timber production. According to the Blandin Foundation's 2004 report on a survey of the logging industry in the state, sixty percent of the total timber volume was harvested by the largest twenty five percent of the logger operations (Powers, 2004). Thus, any significant expansion of the logging industry, whether for energy or forest products, will likely take place through additional harvest from the largest logging contractors in the state, further consolidating the logging industry.

**Minnesota's Forest Resource**

Of the total 50.8 million acres of land in Minnesota, 16.2 million acres is forested, 26 million acres is agricultural land and the remainder is urban, water and other land types such as brushland and grassland. Of the 16.2 million acres classified as forestland in the state, slightly more than one million acres are in reserved areas such as the Boundary Waters Canoe Area and not available for commercial timber harvest. The total land area potentially available for timber harvest, referred to as timberland by the FIA, is approximately 14.7 million acres (Miles and Brand, 2007). For purposes of this report, information presented on forest resources is restricted to commercially available timberland as these lands are expected to provide the predominant wood supply in the future. Alternate wood sources such as hybrid poplar plantations on agricultural lands, brushland biomass and thinning opportunities are also discussed below.

Compared to other regions of the country such as the Southeast and Pacific Northwest, the state's forest is characterized by diversity both in terms of species mix and ownership. Minnesota's forestlands are comprised of a wide variety of species types which occur in mixed stands as well as relatively pure-species stands. Prior to settlement, a greater proportion of the forest was in climax forest dominated by longer-living species such as white pine, the source of timber that built the cities of the Midwest. Since that time, harvest of many of these stands has led to reversion to early successional species such as aspen, birch and jack pine. Also, abandonment of land that had been cleared for agriculture has accomplished the same effect of "resetting the successional clock" to early successional species. As a result, the state's forest is a mix of species, age classes and ownership with a blend of early- and late-successional forest types.

Species Composition

Using the Minnesota Department of Natural Resources cover type classifications, Minnesota's forests are comprised of nineteen major forest types (Table 4). Aspen is by far the dominant forest cover occupying about one third of the total forested acreage or 4,849,747 acres, over four times the acreage of the next largest forest type. The criteria for assignment of land to a cover type is based on plurality of stocking of a given tree species. While aspen is a large forest cover type, aspen stands are characterized by a mix of species within these stands. Aspen fiber is highly desirable both for manufacturing of oriented strandboard as well as paper. As a result, of the total pulpwood sold in Minnesota, approximately sixty percent of the volume is aspen. Compared to other tree species, aspen stands are unique in that they regenerate naturally from root sprouts (suckering) and require no replanting and little financial input to reestablish after harvest. This makes aspen attractive both from a silvicultural and financial point of view.

The next largest forest cover types are northern hardwoods with 2,050,457 acres, black spruce with 1,335,033 acres and lowland hardwoods with 1,104,834 acres followed by a mix of other covertypes as shown below.

Table 4. Minnesota's forest cover types, acreage and proportion.

| Forest Type-MnDNR | Acreage | Proportion |
|---|---|---|
| **Total** | 14,988,760 | |
| **Aspen** | 4,849,747 | 32 percent |

| | | |
|---|---|---|
| **Balsam fir** | 393,381 | 3 percent |
| **Balsam poplar** | 464,007 | 3 percent |
| **Birch** | 999,186 | 7 percent |
| **Black spruce** | 1,335,033 | 9 percent |
| **Cottonwood / Willow** | 107,074 | 1 percent |
| **Eastern redcedar** | 25,623 | <1 percent |
| **Eastern white pine** | 151,107 | 1 percent |
| **Jack pine** | 356,355 | 2 percent |
| **Lowland hardwoods** | 1,104,834 | 7 percent |
| **Non stocked** | 228,235 | 2 percent |
| **Northern hardwoods** | 2,050,457 | 14 percent |
| **Northern white-cedar** | 571,915 | 4 percent |
| **Oak** | 724,512 | 5 percent |
| **Other** | 79,694 | 1 percent |
| **Other softwoods** | 5,665 | <1 percent |
| **Red pine** | 562,656 | 4 percent |
| **Tamarack** | 868,215 | 6 percent |
| **White spruce** | 111,063 | 1 percent |

Land Ownership Patterns

In contrast to the southeastern U.S. where a large proportion of land is owned and managed by the timber industry, Minnesota's forests are owned by a broad range of entities ranging from non-industrial private landowners (NIPF) to public land management agencies such as the Minnesota Department of Natural Resources, counties and the US Forest Service (Fig. 3). NIPF lands are usually held for a multiplicity of uses including hunting, recreation as well as timber production. As a result of this diverse ownership pattern, procurement of timber for the state's mills involves a very active program working with different agencies with varying purposes for their land and policies affecting management. Some landowners, such as public agencies, are actively managing their lands for multiple benefits and timber sales are an integral part of the overall forest management program. NIPF landowners may be involved in forest management organizations such as the Minnesota Forestry Association or have assistance of professional forester but this is not always the case. Diversity in land ownership is important from a timber availability standpoint because it has a direct effect on the proportion of timber resources potentially available for harvest and the rate that timber is brought to market.

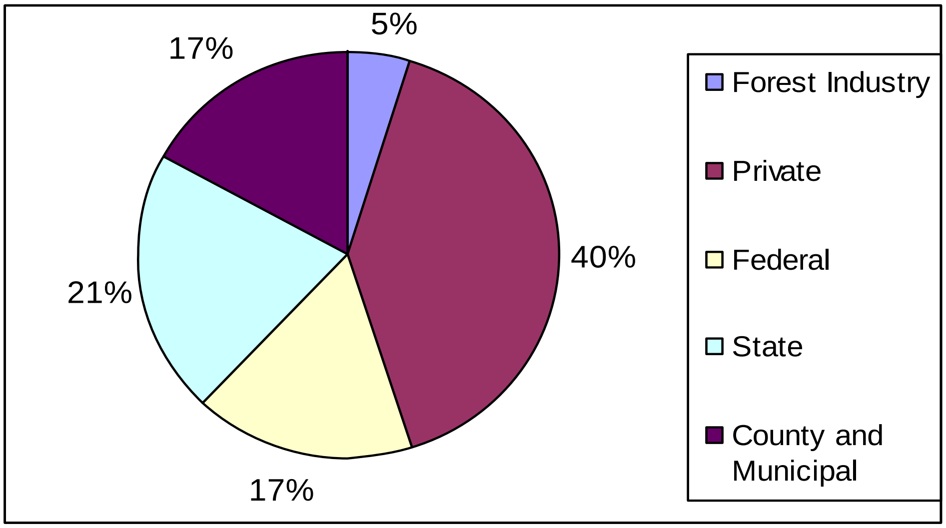


Figure 3. Ownership of forestland in Minnesota.

Land ownership affects the process by which timber is sold. Public land agencies identify stands that are ready for harvest using geographic information systems and inventory data. Once stands are identified for harvest, a forester will conduct a cruise of the stand volume using a "cruise course," a set of points within the stand where data on timber volume and species composition are collected. Using this information, the stands are put up for sale to the public, either through sealed bids or oral auction. Thus, the stumpage price will fluctuate depending on demand by mills, sometimes quite dramatically as shown above. Sale of timber volume on private lands, a significant portion of the land base, is not as formalized as sales on public lands. A landowner may be contacted by a local logger or forester and the negotiation of price is done between the landowner and the forester or logger. Thus, the process of locating stands for harvest, determining stand volume and stand value can differ depending on the land owner.

## Growth and Expected Allowable Harvests

The central question related to evaluating future opportunities for development of a next-generation, wood-based energy industry is wood supply. According to the USDA-FIA Inventory (Miles and Brand, 2007), the total net annual growth of the state's forests on timberland acreage is approximately 7.0 million cords. This value includes in it the volume that is lost to mortality, estimated to be 3.8 million cords. Taken together, a combination of net growth and some portion of annual mortality represents the biological potential of available forest lands and does not take into account practices employed to accommodate other forest values such as wildlife, water quality and long term soil productivity. In 1990, in response to a citizen petition, the State of Minnesota, Environmental Quality Board commissioned a large scale study of the state's forests entitled the Generic Environmental Impact Statement (GEIS) on Forestry (Jaakko Poyry

Consulting, 1994). The purpose of the GEIS was to evaluate the interaction of timber harvesting and environmental impacts on the state's forests. The GEIS on Forestry is one of the largest undertakings of its kind in the nation and serves as a model to other states.

The GEIS considered the impact of forest harvesting on environmental values at several harvest levels and recommend mitigation strategies to reduce environmental impacts. The harvest levels chosen were intended to approximate the current annual harvest level as of 1990 (4.0 million cords), expected near-term harvest levels anticipated in 1995 (4.9 million cords) and a maximum harvest level of 7.0 million cords (FIA total net growth). In addition, mitigation strategies such as extended rotation forestry, riparian buffers and uneven aged management were included in harvest simulations to estimate the effect of implementing these strategies on timber supply. This analysis was done at the FIA plot-level to allow summarization of impacts and harvest levels by forest cover type and ownership within seven major ecoregions over time.

Criteria for assessing impacts on wildlife species were based on a maximum of 25 percent change in a species' habitat within any of the seven ecoregions. In addition, for those species considered threatened or endangered, a maximum allowable threshold for habitat change in any ecoregion was 5 percent. The results of this effort, in addition to many useful background products, was an estimate of the sustainable harvest level for the state and strategies to maintain the health of forest ecosystems over the long term. Based on the GEIS analysis, the maximum harvest level that may be sustained while maintaining ecological values is estimated to be 5.5 million cords. It should be noted that this value is assuming implementation of mitigation strategies to the level assumed in the GEIS.

A follow-up study entitled the GEIS Report Card (Kilgore, et.al. 2005) was published to evaluate changes in harvest levels, wildlife populations, old-growth forests and application of mitigation strategies since completion of the GEIS. This report identified several changes or sources of variance from that predicted by the GEIS. First, harvest levels were found to be slightly lower than expected. Bird populations fluctuate widely with some species showing unexpected increases and some showing unexpected decreases with a net decrease in habitat for 10 of the total 136 species included in the study. The area of old forest did not increase as much as expected due to a greater amount of acreage undergoing mortality than originally assumed. Little change in designated old growth forest was noted due to changes in management of a portion of forestland managed by the Department of Natural Resources. Finally, a survey of land managers indicated widespread adoption of Best Management Practices on forestlands. Given the overall agreement of the Report Card report with conditions predicted by the GEIS, the potential harvest value of 5.5 million cords will be assumed to be a sustainable harvest level for purposes of this analysis. Related to this, the Governor's Task Force on the Competitiveness of the Forest Products Industry (Governor's Task Force on the

Competitiveness of Minnesota's Primary Forest Products Industry, 2007) recommended that the annual harvest level of 5.5 million cords be a goal for the state's forests.

Estimate of Available Timber Supply

Beginning with a total sustainable harvest level of 5.5 million cords from forestlands in Minnesota and assuming that imported fiber will not be available in the future; subtracting the current demand of the forest products industry of 4.2 million cords produces an estimated 1.3 million cords potentially available annually. This is the maximum sustainable amount potentially available for industrial expansion. In addition, identification of high-risk stands and thinning may capture a portion of the estimated 3.5 million cords lost to mortality each year. An analysis of mortality by covertype and age class using the USDA-FIA Mapmaker Program shows that approximately seventy percent of the total mortality occurs in stands older than fifty years of age. This suggests that the bulk of mortality would be captured through identification of stands at risk for pathogenic mortality losses.

**Additional Biomass Sources**

Red Pine Thinning

Based on analysis of the FIA data, thinning of stands to capture competition-induced mortality (mortality in stands less than 50 years of age) could account for a maximum of thirty percent of the total mortality loss reported in the FIA inventory. Thinning of Red Pine and Aspen stands could contribute additional harvest volume assuming the price for thinning products and harvesting technology make thinning of these stands economically feasible. Of the total 245,000 acres of Red Pine plantations in the state, slightly more than half are less than age thirty and a large amount of acreage will be ready for first thinning over the next decade (Fig. 4). Current annual harvest of Red Pine is approximately 160,000 cords compared to a short term allowable harvest of 270,000 cords annually. As stands age and become ready for first thinning, the average annual harvest could rise to 356,000 cords, or 409,000 dry tons by 2012 and increase annually thereafter (Minnesota DNR, 2006). Based on our experience, about half of this volume is small-diameter sawbolts with the remaining half being pulpwood. Compared to current harvest levels, Red Pine thinning could supply an additional 225,000 dry tons annually including all products.

Markets for Red Pine pulpwood are soft which limit opportunities to thin plantations at this time. Because care must be taken to avoid damage to the stand, productivity of a logging operation is reduced which decreases the value of volume from thinnings. A critical factor in first-thinning of Red Pine is the amount and size of material that can be removed while still maintaining the proper number and quality of trees to maintain value in the future. For example, if a greater proportion of the larger, more valuable sawbolt-sized trees can be removed at the first thinning without impacting the future value of the stand, greater value can be extracted which offsets the cost of handling smaller diameter material that is an inevitable part of harvested volume, particularly in the first thinnings. In contrast, if only lower-valued pulpwood is able to be removed, the financial returns to the logger and landowner are reduced which limits opportunities to practice first thinning in a timely manner. Research is underway by the NRRI under the auspices of the Minnesota Forest Productivity Research Cooperative to determine the optimal mix of residual stand volume and stem size distribution for first-thinning of Red Pine plantations to maximize value to the landowner.

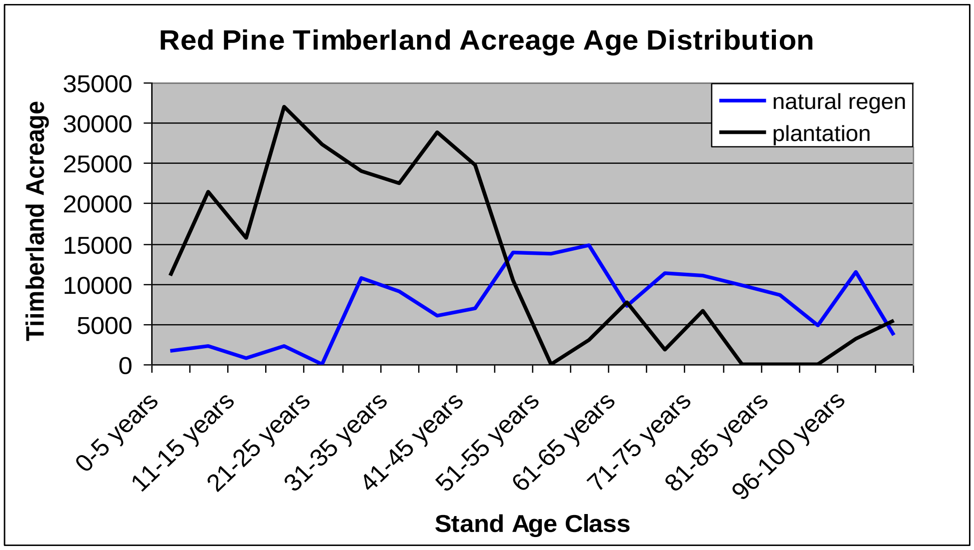


Figure 4. Age class of Red Pine timberland acreage - natural regeneration and plantations.

<u>Aspen Thinning</u>

After harvest, aspen stands are unique in that they naturally regenerate from root suckers with a very high stem density, often achieving 10,000 stems per acre. This is compared to an ultimate harvest stem number of 400 to 600 trees per acre (Fig.5). During the early stages of stand growth, stands undergo high mortality due to competition-induced effects. It may be possible to capture some of this mortality through precommercial thinning. The UM-NRRI has been involved in strip-thinning studies of aspen since 1989 and has developed a dataset of stand growth since thinning. Stands were strip-thinned at age ten to fifteen removing two-thirds of the stand basal area using skidders and bulldozers. No difference in overall stand basal area has been found after sixteen years post-thinning with thinning having the effect of changing stem-size distribution to larger tree size in thinned stands. Larger average tree size increases the recovery rate of merchantable volume depending on the top-diameter specification used by mills. The average stand biomass on sites at the time of thinning is estimated to be fifteen ovendry tons per acre. Removing two-thirds of the stand could yield ten tons per acre of small-diameter biomass material. If all of the aspen acreage were harvested on a fifty year average rotation, approximately 100,000 acres could be thinned annually for a total statewide biomass potential of one million dry tons. This is obviously the maximum amount potentially available. Also, it may be possible to thin older stands, age 20 to 30, to recover a portion of stand mortality. However, the impact of later thinning on final harvest volumes and rotation ages needs to be better understood. The technical, economic and ecological feasibility of precommercial and commercial aspen thinning and the optimum age to conduct thinning needs to be addressed before aspen thinning can be considered a viable source of biomass for energy applications.

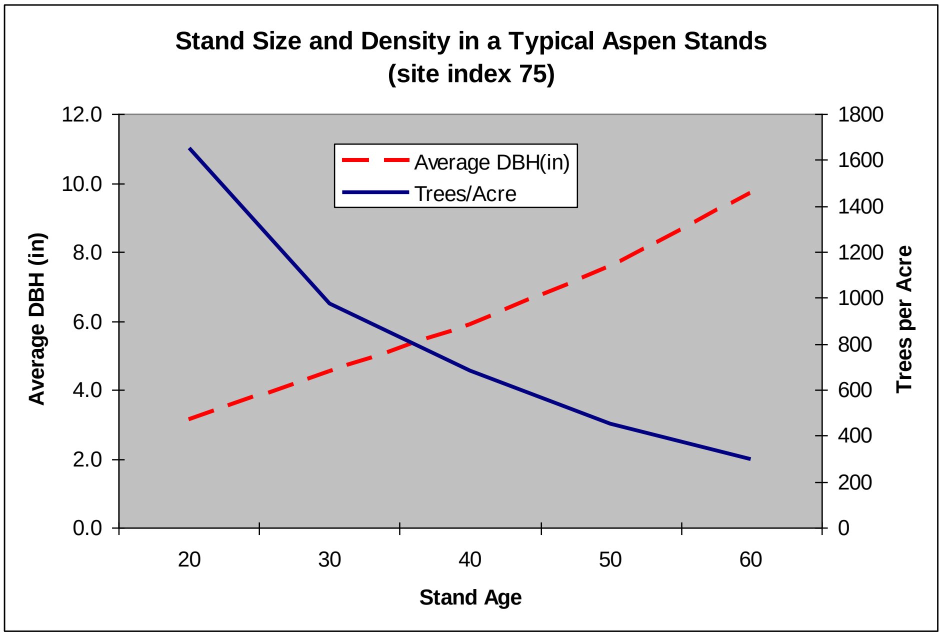


Figure 5. Average tree size and trees per acre over time in normally-stocked aspen stands.

Brushlands

In addition to native forests, brushlands could supply additional biomass for energy production. Opportunities exist to shear brushland areas both for biomass harvest and habitat improvement for sharptail grouse. Using satellite classification (adjusted GAP level 3); Minnesota's brushland acreage totals approximately 2.4 million acres. Brushland sites are extremely variable in stand density and uniformity and, as such, estimation of the total amount of biomass on these sites is inexact. A method is needed to efficiently classify brushland cover and density before commercial brushland harvesting can be implemented. Because shearing costs are fixed on a per-acre basis, it is necessary to select sites that have a sufficient amount of biomass to distribute fixed costs over a greater amount of biomass, thereby minimizing per-ton shearing costs. Research to identify high-density sites is beginning under a cooperative project between the MN-DNR Forestry Division and the NRRI.

At this time, costs of shearing and grinding are known or can be estimated with reasonable certainty. However, the unknown cost factor in brushland harvesting is the cost of collecting sheared material. Shrub biomass is left in windrows as a result of the shearing operation. A mechanism is needed to efficiently collect this biomass and transport it to a chipper or grinder near a roadside. Tests of a modified forwarder designed to carry low-density biomass are planned for this year under a project funded by the DOE through the Laurentian Energy Authority.

The NRRI conducted a study in 1997 to evaluate the biomass density and productivity of brushland acreage in Minnesota. This study involved biomass surveys and estimated brush biomass on 16 study sites. The average brushland density for the 16 study sites is 13.2 dry tons per acre. After adjustment for non-stocked area, this value decreases to 4.2 dry tons/acre. The annual increment of the fully-stocked areas within the brushland complex is approximately 1.5 tons/acre/year. Assuming a biomass density of eight dry tons per acre (e.g. sixteen green tons/acre) is the economic threshold for brushland harvesting and that 20 percent of brushlands meet this criterion, the total amount of standing biomass is estimated at 3.7 million green tons. Also, based on a mean annual increment of 1.5 dry tons per acre per year, the annual production of brushlands statewide is estimated to be 400,000 dry tons per year. However, questions remain regarding identifying high-density sites, biomass amounts and costs of forwarding biomass material to a landing.

Hybrid Poplar on Agricultural Lands

Analyses of national biomass resources such as the "Billion Ton Study" (Perlack, et.al. 2005) indicate that agricultural residues (e.g. corn stover, wheat straw, other plant parts), forest harvest residues and thinnings, and energy crops are expected to be the dominant sources of available cellulosic feedstock. Of the total 1.4 billion tons identified in the Billion Ton Study, approximately one fourth (377 million dry tons) is expected to be produced annually through planting of energy crops on agricultural lands currently enrolled in the Conservation Reserve Program (CRP). At this time, there are approximately 1.6 million acres of land enrolled in the CRP in Minnesota. Most of this land is slated to be taken out of the CRP over the next three years, depending on provisions in the new Farm Bill.

There are several energy crops that could be considered included trees and grasses. The NRRI has been conducting research on tree energy crops since the early 1980s and manages one of the largest poplar breeding and field-testing programs in the United States. Also, work is underway by a number of groups to evaluate yield and management inputs of grass crops and mixed prairie species (Tilman et.al. 2006, Casler and Boe, 2003). Based on work done by the UM-Crookston, NRRI and the Agricultural Utilization Research Institute over the past decade, yields of poplar plantations on CRP sites in northwestern Minnesota, an area of high CRP enrollment, have been shown to average 3.5 ovendry tons per acre annually. Research is ongoing to better define yields of other energy crops in other areas of the state. Using an average annual yield of 3.5

tons per acre of energy crops, the total potential biomass production of this resource could approach 5.6 million ovendry tons.  This resource will require a significant investment to achieve but a portion of wood supply for future energy production could come from energy crops.  Work is needed to identify optimum sites, inputs needed and yields of energy crops on a range of site throughout Minnesota.

**Forest Harvest Residues**

The most immediately available, lowest cost source of wood for energy is residual top and limb material. Forest harvest residues are produced through delimbing and slashing of merchantable trees as a part of the logging operation. Up to this point, most of this material has been left on site due to lack of markets. Demand for harvest residuals from forest products mills producing board products have existed for decades but markets have been limited. With the construction of the biomass burning facilities in St. Paul and the Laurentian Energy Authority project on the Iron Range, demand for energy wood has increased considerably. Also, Minnesota Power is evaluating the feasibility of a 50 megawatt biomass-fired plant at the Syl Laskin location near Hoyt Lakes in northern Minnesota. The Minnesota Power project is partially in response to the recent passage of the 25 X 25 legislation in Minnesota which sets a goal to replace twenty five percent of the coal-fired electrical generation by the year 2025. While this goal will be accomplished through a variety of sources, notably a significant amount of wind power, demand for all forms of biomass will undoubtedly increase. Biomass has advantages as part of the energy mix due to the fact that it can be stored and become a dependable part of the baseload generation capacity of an electrical utility.

<u>Harvesting Systems</u>

The production of forest harvest residues is particularly well suited to conventional logging systems commonly in use in Minnesota today. There are two dominant logging systems in use in Minnesota; conventional and cut-to-length (CTL) systems. According to Minnesota Logger Education Program staff (Dave Chura, personal communication), conventional systems account for eighty eight percent of the timber volume harvested in the state while CTL systems are used to harvest the remaining twelve percent of volume. Conventional logging systems consist of a feller-buncher which falls trees and produces bunches of trees to accommodate skidding. Skidders then move the bunch of trees from the site of felling to a central landing area. Using a stroke delimber or processor, trees can either be delimbed near the site of felling or at the landing, depending on whether the logger wants to process tops and limbs or leave them scattered on site. If the intention of the logger is to collect harvest residues for further processing, the trees are typically skidded in whole-tree form to the landing where delimbing occurs. The main bole is then either loaded onto a truck directly in tree-length form or slashed to 100-inch lengths as shortwood, the most common form delivered to mills in the state. Due to the fact that trees can be felled and skidded to the landing in whole-tree form, there is little additional cost to transporting the tops and limbs to the landing area. However, further processing requires additional chipping or grinding equipment to produce a form of material that is easily transported and handled at the mill. Given the setup of the conventional logging system, production of harvest residues can be integrated into the current logging system with little modification. The issue of producing additional quantities of harvest residues in the future is not the need for different harvesting equipment but more a lack of steady markets to allow a logger to recoup an investment in additional equipment. As markets for energy chips become better established, the logging infrastructure could be expanded to accommodate demand through purchase of additional chippers, grinders and chip vans assuming long-term contracts are made with wood-using facilities.

In contrast to conventional systems, CTL systems buck trees in the woods at the point of felling. The CTL system is generally more flexible than a conventional system with respect to operating conditions and the type of products that can be produced. CTL systems are particularly well suited to produce a wider variety of products, such as longer length sawlog-sized material in those stands having larger diameter, sawlog quality trees. However, because the tops and limbs are severed at the point of felling, the CTL system does not lend itself as easily to collection of forest harvest residues. The residual material must be piled in windrows or piles to allow collection by the forwarder separate from the roundwood. While it is possible to produce harvest residues using the CTL harvesting system, more effort is involved which will likely add to the expense of the residue product.

An important issue for mills using forest harvest residues relates to seasonality of harvest and storage. Chips and ground material have the advantage of being easily handled and transported in vans designed to carry this material. However, storage of chips at a central wood-using facility can become an issue. Due to soil conditions in Minnesota, harvesting occurs most commonly in the winter months with the bulk of volume being produced during that time. The episodic nature of harvesting requires storage of chips or ground material for months to ensure a constant supply. Care must be given to the size of piles to prevent self-heating of piles and potential fires. Also, in most instances forest harvest residues will be delivered at field moisture content, typically fifty percent moisture (green weight basis). High moisture material will reduce the available heat due to losses associated with vaporizing water on combustion. Once chips are in piles, little drying occurs. A potential improvement over the current logging systems may be the development of cost effective bundling technology such as that developed in Scandanavia. However, up to this point, bundlers have been mounted on relatively expensive forwarders to allow collection of biomass material on sites where a CTL system has been used. While this arrangement may have advantages in Scandanavia, it adds additional expense in those instances where collection is done to a central landing such as is the case in conventional logging systems. There appears to be a need to develop cost-effective, trailer mounted bundling systems that could be used to produce bundles suitable for hauling on conventional trailers designed for hauling roundwood. Bundles could be transported to the wood-using facility, stacked and air-dried prior to chipping at a woodyard. In this way, chipping costs could be minimized due to the high utilization rate of a chipper at a woodyard. Research is needed to develop cost-effective bundling technology that is robust enough to handle the coarser type of material produced in Minnesota forests (e.g. hardwood tops and limbs) and withstand the rigors of logging conditions in the state.

Estimate of Forest Harvest Residue Volumes

The amount of biomass available from forest harvest residues is dependent on the species being harvested, top-diameter utilization criteria for roundwood, guidelines to mitigate soil and wildlife concerns as well as the overall amount of timber being harvested in the state. There are a variety of methods used to estimate forest harvest residue amounts ranging from on-site surveys, whole tree biomass measurements and individual-tree biomass estimation equations. Because of the potential impact of assumptions about forest harvest residue availability on the overall future energy industry in the northern part of the state, a review of methods and development of a reasonable estimate of harvest residue percentage is presented.

In a study done by Grigal (2004) as part of analyses associated with the LEA project, he states that crown biomass accounts for 25 and 21 percent of total biomass for hardwoods and conifers, respectively. A large dataset of equations developed on individual trees published by Jenkins (Jenkins et.al. 2004) suggests similar numbers with hardwoods and conifers accounting for 25 percent and 15 percent, respectively. These data sources generally agree that biomass of nonmerchantable material is likely to comprise approximately 25 percent of hardwood total biomass and between 15 and 20 percent of merchantable softwood stem biomass. In cooperation with the USDA Forest Service at Rhinelander, we have collected data on biomass components of hybrid poplar in plantations in Minnesota and Wisconsin for many years. While hybrid poplar and aspen are not directly comparable, they are similar in taper. Based on individual biomass of hybrid poplar trees, the average proportion of branch biomass as a percentage of total tree biomass (bole bark and wood + branch bark and wood, without foliage) is 25 percent. Residues percentage expressed as a proportion of total stem biomass is 33 percent. Over the past year, we have begun a project to evaluate harvest residue biomass on winter-logged sites with particular emphasis on aspen. The average branch and top biomass percentage using a three inch top limit was found to be 15.3 percent of the total main bole biomass with a minimum site average of 11 percent and maximum of 18 percent. Work is ongoing to expand this dataset. Based on the available individual-tree data, the average residue percentage value is approximately 25 percent with a minimum value for aspen of 15 percent assuming pure-aspen stands. In reality, stand-level residue percentages will be higher due to the hardwood component present in most aspen cover types having higher residue percentages. As an aside, conversations with loggers indicate that the 15 percent value is not uncommon in relatively pure aspen stands based on their experience of shipping one to two loads of chips per day producing 100 cords of roundwood per day on these sites.

The most extensive and recent study of stand-level residue amounts was done by the Minnesota Department of Natural Resources entitled the “Minnesota Logged Area Residue Analysis” published in August of 2006 and revised in April 2007. This project measured coarse and fine biomass on 124 sites throughout the state and included a range of forest types. The results in terms of cordage per acre of coarse and fine woody material are shown in Table 5 below.

Table 5. Coarse and fine woody debris of forest types from MN DNR Logged Area Analysis study.

| Forest Cover | Coarse and Fine Woody Debris (cords/acre) | Coarse and Fine Woody Debris Biomass (green tons/ac) |
|---|---|---|
| Aspen | 5.7 | 12.8 |
| Other Hardwoods | 7.54 | 19.2 |
| Lowland Conifers | 4.3 | 9.5 |
| Upland Conifers | 4.71 | 10.9 |
| Unknown | 6.12 | 13.8 |

While the data produced in the Logged Area Analysis study is very helpful and the best data of its kind available, a limitation to application of these data is the lack of information on stand volumes and amounts of roundwood removed from these sites. Having information on the amount of roundwood removed and stand volumes prior to harvest allows calculation of the percentage of harvest residuals which is necessary to estimate annual production of harvest residues on a statewide basis. Through the cooperation of the Minnesota Department of Natural Resources, Division of Forestry, we were provided an extensive database of sale volumes. This database contains sale data from slightly less than 60,000 acres of timber sales on state lands. Table 6 shows the DNR Cover Type, the Logged Area Analysis grouping, acres and average stand volume for each cover type in the DNR timber sale database. Using a combination of the sale data volumes and the forest harvest residue data from the Logged Area Analysis, I calculated the percent of harvest residues that can be expected to be available from within each of the Logged Area Analysis groupings.

Table 6. DNR timber sale data by cover type, average volume per acre and residue percentages calculated from a combination of sale data and residue volumes.

| Cover Type | LAA Group | Acres Sold | Roundwood Cords/Acre | Group Cords/acre Wt.Average | LAA Residue Biomass (cords) | percent Residue |
|---|---|---|---|---|---|---|
| **Aspen** | Aspen | 29,041 | 22.2 | 22.2 | 5.7 | 25.7 percent |
| **Northern Hardwoods** | Hardwoods | 545 | 14.3 | 16.6 | 7.54 | 45.4 percent |
| **Oak Species** | Hardwoods | 301 | 15 | | | |
| **Paper Birch** | Hardwoods | 8,586 | 16.8 | | | |
| **Black Spruce** | Lowland Conifers | 5,189 | 18.8 | 17.4 | 4.3 | 24.7 percent |
| **Tamarack** | Lowland Conifers | 3,362 | 15.3 | | | |
| **Balsam Fir** | Upland Conifers | 1,572 | 15.1 | 17.2 | 4.71 | 27.4 percent |

| | | | |
|---|---|---|---|
| **Jack Pine** | Upland Conifers | 6,519 | 21 |
| **Red Pine** | Upland Conifers | 4,879 | 12.75 |

Another source of similar data is shown in the DNR Summer 2007 Marketplace publication. These data are independent estimates of percentage of harvest residues based on analysis by DNR staff and are a composite of data derived from biomass equations as well as experience (personal communication, George Deegan-DNR Forestry). While there is some difference in specific residue percentages, particularly in the pines, the residue percentages are similar overall and similar to the values discussed above based on individual tree data. Residue percentages for pine types were lower in the DNR Marketplace publication but aspen and hardwoods are in general agreement. In order to produce a conservative estimate of total harvest residues, the DNR Marketplace percentages were used in subsequent analysis. Using the combination of annual harvest data, percentage of harvest residues and cordage conversions, the total amount of residues produced each year can be estimated.

Table 7 shows the estimated timber harvest levels by species group reported by the DNR in the 2006 Forest Resources document, the percentage residues reported by the DNR Marketplace, conversions to estimate green tons from cordage and the resulting estimated amount of residues produced through harvesting of pulpwood and sawlog products.

Table 7. Volumes harvested by major species, residue percentages and estimated residue availability statewide.

| | Cords (1,000s) Harvested by Product Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Pulpwood | Sawlogs | Residential* | Commercial | Total | percentResidue | Cord:gr ton conversion | Residue (gr tons) |
| Aspen | 1794.4 | 69.6 | 16.7 | 0.6 | 1881.3 | 25 percent | 2.25 | 1,058,231 |
| Birch | 240.2 | 27.1 | 41 | 6.3 | 314.6 | 33 percent | 2.30 | 238,781 |
| Balm | 119.2 | 1.2 | 0 | 0.1 | 120.5 | 25 percent | 2.40 | 72,300 |
| Ash | 17.4 | 8.3 | 15.1 | 0.2 | 41 | 33 percent | 2.50 | 33,825 |
| Oak | 0.8 | 73.3 | 45.1 | 1 | 120.2 | 33 percent | 2.75 | 109,082 |
| Basswood | 24.7 | 21.6 | 1.3 | | 47.6 | 33 percent | 2.30 | 36,128 |
| Maple | 98.9 | 12.7 | 15.8 | 4.7 | 132.1 | 33 percent | 2.50 | 108,983 |
| Cottonwood | 0.6 | 11.6 | 0 | | 12.2 | 25 percent | 2.50 | 7,625 |
| Other Hardwood | 3.1 | 13.8 | 8.1 | | 25 | 33 percent | 2.50 | 20,625 |
| | | | | | | | | |
| | | | | | | | | |
| Red Pine | 46.4 | 114.7 | 2.9 | | 164 | 11 percent | 2.35 | 42,394 |
| White Pine | 2.4 | 7.6 | 1.4 | | 11.4 | 11 percent | 2.20 | 2,759 |
| Jack Pine | 155.9 | 147.7 | 1.7 | | 305.3 | 11 percent | 2.30 | 77,241 |
| Spruce | 164.5 | 18.4 | 0 | | 182.9 | 23 percent | 2.10 | 88,341 |
| Balsam | 167.1 | 7.2 | 0 | | 174.3 | 23 percent | 2.35 | 94,209 |
| Tamarack | 39.7 | 1.8 | 0.7 | | 42.2 | 11 percent | 2.50 | 11,605 |
| Cedar | 0.2 | 6.6 | 0.4 | | 7.2 | 23 percent | 1.45 | 2,401 |
| Other Softwood | 0.1 | 1.1 | 0 | | 1.2 | 23 percent | 2.20 | 607 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Total Hardwood | 2299.3 | 239.2 | 143.1 | 12.9 | 2694.5 | |
| Total Softwood | 576.3 | 305.1 | 7.1 | 0 | 888.5 | |
| Total All Species | 2875.6 | 544.3 | 150.2 | 12.9 | 3583 | 2,005,137 |

From the above table, the total biomass produced annually is estimated to be roughly two million green tons or one million dry tons at 50 percent moisture content (green weight basis). The ratio of green tons of harvest residues to the overall cordwood volume is 0.56 (2,005,137 green tons divided by 3,583,000 cords harvested). Assuming the same species mix is harvested in the future, this ratio can be applied to the maximum cordage harvest level of 5.5 million cords to estimate potentially available harvest residues assuming future harvest should approach the 5.5 million cord level. The estimated amount of harvest residues associated with this level of harvesting is 1,540,000 dry tons of forest harvest residues. This value must be reduced to account for mitigation of environmental effects. For purposes of this analysis, I have used a 25 percent reduction to account for management guidelines. Therefore, a more realistic maximum value is closer to 1,155,000 dry tons of harvest residues potentially available in the future.

Using a weighted average conversion of cordwood to dry tons of 1.15 (2.3 green tons/cord at 50 percent moisture content on a green-weight basis) and 1.3 million additional cords of roundwood potentially available yields a value of 1,495,000 dry tons of additional roundwood biomass. Taken together, the total amount of forest harvest residues and additional roundwood volume is approximately 2.7 million dry tons.

As mentioned above, demand for harvest residues has increased in the recent past and could increase significantly in the near future. At this time the total estimated demand for forest harvest residues is not known precisely and is a subject of current work being done by the DNR-Forestry Division (personal communication, Keith Jacobsen). Including current annual demand by the Laurentian Energy Authority of 125,000 dry tons, the proposed Minnesota Power project of 250,000 dry tons and an estimate of other demand at 150,000 dry tons per year (includes current Minnesota Power plants, St. Paul District Energy, SAPPI-Cloquet, Georgia Pacific-Duluth), the total near-term demand could exceed 500,000 dry tons, again assuming the proposed Minnesota Power project were to go forward. Using the above value of 1.15 million dry tons of harvest residues associated with an annual harvest level of 5.5 million cords of roundwood, the foreseeable demand could account for half of the potentially available residue material. If harvest levels were to remain at 3.7 million cords annually, the total amount of harvest residues produced in the near term is closer to 750,000 tons, accounting for a 25 percent reduction due to environmental mitigation practices. Based on this analysis, the potential exists to use a significant amount of available harvest residues in the near term with a maximum long term available amount of 250,000 to 500,000 dry tons left unused.

In summary, Table 8 shows biomass sources identified with estimated biomass values expressed in ovendry tons available annually.

Table 8. Estimated annual biomass availability in Minnesota currently, in the near term and future potential by source.

| Biomass Source | Current | Near-Term Achievable | Future Potential | Notes |
|---|---|---|---|---|
| | dry tons/yr | dry tons | dry tons | |
| Roundwood | 0 | 1,495,000 | 1,495,000 | current: 3.7 million cord harvest, future 5.5 million cord harvest |
| Harvest Residues | 750,000 | 1,155,000 | 1,155,000 | residues from 3.7 million cord harvest, 5.5 million cord harvest |
| Red Pine Thinning | 184,000 | 310,500 | 409,400 | 50 percent of total volume in first thinning assumed fuelwood |
| Aspen Thinning | 0 | 0 | 1,000,000 | 100,000 acres @ 10 tons/acre |
| Brushlands | 0 | 400,000 | 400,000 | |
| Energy Crops | 0 | 0 | 5,600,000 | 3.5 tons/acre/year yield, 1.6 million acres |
| **Total** | **934,000** | **3,360,500** | **10,059,400** | |

**Potential Energy Demand**

In order to put timber demand and supply figures into context, it is instructive to consider the potential size of the biomass industry. While this subject has been visited by authors in a companion paper, it bears repeating. About 400 million gallons of gasoline are consumed daily in the United States (http://tonto.eia.doe.gov/oog/info/twip/twip_gasoline.html). Based on a national average per capita consumption rate of 1.3 gallons per day, the total demand for gasoline in Minnesota can be estimated to be approximately 2.4 billion gallons per year. Assuming an average ethanol conversion rate of 90 gallons per ovendry ton of biomass and a 15 percent reduction in mileage with ethanol, the potential demand for fuel with complete replacement of gasoline in the state would require roughly 32 million ovendry tons of biomass annually. In addition, coal burning plants in Minnesota have 6 gigawatts of power generation capacity with an estimated coal consumption of approximately 30 million tons (www.powerofcoal.com). The combined potential energy demand assuming 100 percent replacement of gasoline and coal is approximately 60 million dry tons annually. Obviously, 100 percent replacement of the state's energy needs is not going to occur anytime soon but it is instructive to consider the sheer volume of biomass that would be required. Even assuming a 20 percent replacement target, the amount of ovendry biomass required would be 12 million tons annually, roughly four times the estimated combined total amount of 2.7 million dry tons of potentially available roundwood and harvest residues. Although a significant amount of biomass is available in the agricultural sector in the form of crop residues (e.g. corn stalks, cobs, wheat straw, etc.), future demand for energy has the potential to dwarf the current total wood usage by the timber industry.

**An Estimate of the Economics of Cellulosic Ethanol**

Estimation of the total woody biomass amounts available and potential demand is a part of the picture. However, this information doesn't provide insight into the potential for application of new energy technologies using wood. Market demand for alternate fuels and price will ultimately determine the rate at which emerging energy technologies will be adopted and opportunities for development of the industry in the state. In order to provide some context in this regard, a brief review of available technologies and the estimated cost of production is needed. While the technology to produce liquid fuels is in a state of flux and commercial application may be several years away, it is instructive to look at the expected input costs and estimated breakeven price of ethanol produced in a theoretical cellulosic ethanol plant.

The field of liquid fuels production, particularly cellulosic ethanol, is receiving unprecedented attention. The President, in his most recent State of the Union speech emphasized the need for the United States to develop alternate sources of energy both from a standpoint of energy security and reduction of carbon dioxide emissions. The U.S. Department of Energy, in order to accelerate commercial development is supporting fundamental research at the national laboratories and universities as well as commercial scale-up of technologies to produce ethanol from cellulose on a large scale. Two primary pathways are envisioned for production of cellulosic ethanol; biochemical and thermochemical. The biochemical route relies on pretreatment and fermentation using specially developed enzymes and genetically modified yeasts to break down cellulose and hemicellulose into simpler sugars and, ultimately, to ethanol. Companies such as Iogen and Mascoma are examples of companies employing this method. The thermochemical process involves gasification of material and conversion of the synthesis gas to liquid fuels using catalytic conversion, commonly referred to as the "Fischer-Tropsch" process. Range Fuels is one such company scaling up the thermochemical process for the production of ethanol.

These processes differ in fundamental ways and feedstock requirements have an effect on the efficiency of the specific process being used. The biochemical pathway is more sensitive to feedstock than the thermochemical process. For example, bark is not amenable to conversion in the biochemical process, at least not using current technology (personal communication, Andy Aden – NREL). Also, terpenes present in pines can inhibit the fermentation process and, as such, deciduous trees or grasses are the desired feedstock for the biochemical route. In contrast, the thermochemical pathway is more robust and can use a wide variety of material. Even relatively wet materials such as green wood can be used because sufficient waste heat from the gasifier is available to dry the wood prior to gasification (Phillips et.al. 2006). In light of the greater flexibility of the thermochemical process, the thermochemical route was chosen for this analysis.

The National Renewable Energy Laboratory (NREL) at Golden, Colorado operates pilot plants to facilitate scale-up of both cellulosic ethanol production pathways. The NREL has recently published assessments of both pathways including detailed engineering, process flow diagrams and economic evaluation of the biochemical and thermochemical routes. Most recently, Phillips, et.al. (2007) published an analysis of the thermochemical route including computer modeling of the process and an economic assessment of the cost components that contribute to the final breakeven price. While the reader is encouraged to review this document in its entirety, the analysis presented here will concentrate on the breakdown of costs and implications to future wood-based ethanol production using the financial information shown in Appendix A of this report (Appendix F in the Phillips-NREL report).

Appendix A shows a detailed breakdown of cost components from the NREL report including capital, operating expense, feedstock purchase and other items. In this case, wood is assumed to be the feedstock used in the process. Among many assumptions too numerous to mention, the base case used in the economic analysis includes a $35.00 per ovendry ton feedstock cost. This analysis assumes an ethanol yield of 80.1 gallons per ton and an additional 14 gallons of higher-chain alcohols. While this yield level is not currently realized, expectations are that research will make this possible in the next five years. In conversation with representatives of Range Fuels (Patrick Wright, Range Fuels), the target conversion rate in their plants is 100 gallons of ethanol and 20 gallons of mixed alcohols, significantly higher than the assumed conversion rate in the NREL report. Using the assumptions outlined in the report, the base case economic analysis calculates a breakeven ethanol price of $1.01 per gallon FOB plant gate. While economic analysis of early-stage technology is fraught with uncertainty, this analysis helps to put the current best estimates of costs and operating parameters into a framework in which cost components can be identified and the relative effect on ultimate production price more easily understood.

As mentioned, the assumed feedstock cost in the base case is set at $35.00 per ton. This is a very low value compared to wood in Minnesota. Even if corn stover were assumed to be the feedstock, it is my opinion that the feedstock cost is too low. For purposes of this analysis, I'm assuming a delivered green chip price of $24.00 per green ton ($48.00 per ovendry ton) and a roundwood value of $80.00 per cord ($69.56 per ovendry ton) for mixed species. Actual delivered price will vary widely depending on location, species and form of the product but these prices are more in line with current local markets (personal communication, Keith Jacobsen, MN DNR). Using the NREL sensitivity analysis, the contribution of feedstock cost at $35.00 per ton to the end-product ethanol cost is $0.44 per gallon, slightly less than half of the overall per-gallon ethanol production cost. This translates to a $0.012 increase in production cost for every dollar of feedstock. Using this value, the breakeven cost per gallon of ethanol is estimated to be $1.17 and $1.44 using chips and roundwood feedstock, respectively, an average of $1.30 per gallon.

The next logical question is, can ethanol compete at these prices? In order to answer that question, a review of the components of gasoline pump price is needed. The price paid at the pump for gasoline includes the price of crude oil, refining, taxes and distribution. These components are shown in Figure 5 below. After removing taxes and distribution costs, the cost of crude oil and refining is $2.23 per gallon based on a pump price of $2.97 per gallon. Ethanol contains approximately 60 percent of the energy content of gasoline (75,700 BTU/gallon versus 124,000 for gasoline). However, engines designed to burn ethanol will likely get higher mileage than energy content alone would suggest due to the higher octane of ethanol and opportunities to modify engines to take advantage of higher-octane fuels. For purposes of this analysis, I've assumed that the mileage of ethanol-fueled vehicles will be reduced by 15 percent per gallon compared to an internal combustion engine using gasoline. At a gasoline value of $2.23 per gallon, the mileage-adjusted value of ethanol is $1.89 per gallon.

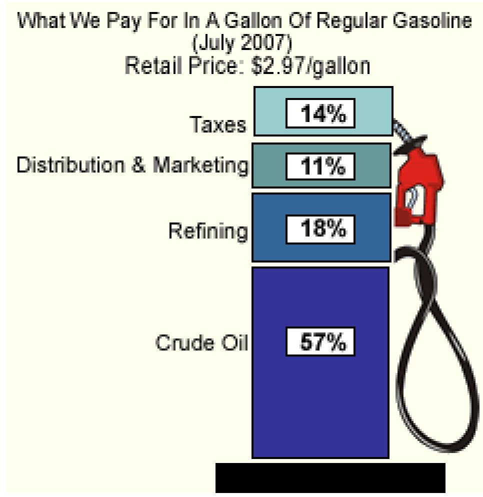


Figure 6. Breakdown of components of gasoline pump price (source: USDOE-EIA)

Based on an average breakeven price of $1.30 for wood-based ethanol cited above, it appears that it is possible to compete with gasoline at the current mileage-adjusted price of $1.89. This analysis suggests that it may even be possible to compete with current gasoline price using higher-valued roundwood at an estimated price of $1.44 per gallon. Obviously, many assumptions about production prices and processes were made in this analysis. The current state of the technology is not advanced to the point that is assumed in the NREL analysis. However, technology improvements, namely ethanol yield such as that expected by Range Fuels (100 gallons of ethanol per dry ton), could significantly reduce the breakeven price to a value lower than that assumed by NREL (80.1 gallons of ethanol per dry ton), the foundation of this analysis. The recent commercial scale-up of ethanol production technologies will help refine cost estimates and reliability of conversion technology.

Assuming a size of plant suggested in the NREL study, the biomass required annually would be 850,000 dry tons. The total estimated available biomass of roundwood and residues statewide is 2.7 million dry tons (5.4 million green tons), approximately enough for three plants of the size suggested in the NREL report. Each plant is assumed to require 54 employees including management and shift workers. Given this level of employment, the bulk of additional jobs will likely be in the logging infrastructure to support these plants and not in the plants themselves. Assuming an average harvesting rate of 100 cords per day, the total amount of 1.3 million additional roundwood would result in an additional 13,000 operating-days per year, approximately 70 additional logging operations. This does not include processing of harvest residues. Additional employment would be required to harvest and process forest residues.

My observation of the process of research and development of technology raises a concern over the future availability of improved technology. Most of the work being done at the NREL is being done under cooperative agreements with larger companies under confidential arrangements. The current model of the starch-based ethanol industry is a high proportion of local ownership located in rural Minnesota. The technology to hydrolyze and ferment corn to ethanol is well developed and not characterized by highly proprietary technology. However, new processes in cellulosic ethanol technology are based on highly confidential technology. There is a risk that, unless advanced technology is developed by universities and made publicly available, the model of local ownership of production facilities may not be possible in the future cellulosic ethanol industry. The development of catalysts in the thermochemical process is an area of need to allow smaller-scale production of ethanol by independent, locally-owned producers.

**A Final Observation - Electric-Based Transportation**

A potentially disruptive transportation technology could be electric vehicles. Plug-in electric vehicles have existed for over a decade with a relatively long track record of operation. Two such vehicles, the General Motors EV1 and Toyota RAV4-EV have demonstrated continued on-highway operation typically achieving mileage of 4 miles per kilowatt-hour (Boschert, 2006). Using an electric rate of $0.08 per kilowatt-hour, the fuel cost is $0.02 per mile. By comparison, an internal combustion engine using gasoline at 30 miles per gallon and $3.00 per gallon will cost $0.10 per mile, roughly five times more than an electric vehicle. Adjusting electric vehicles to account for road taxes would add another $0.013 per mile to electric transportation for a total of 3.3 cents per mile ($0.40 per gallon federal and state tax combined), roughly one third the per-mile driving cost of an internal combustion engine using gasoline. Assuming battery technology is developed to allow plug-in vehicles to be competitively priced, plug-in electric vehicles could become a significant mode of transportation in the future.

Energy independence and carbon-neutral transportation are stated goals of domestic energy policy and technologies that make the most efficient use of the biomass resources will likely be favored. Table 9 shows a comparison of transportation based on cellulosic ethanol-fueled vehicles versus electrically-based transportation. Comparing a 30 mile-per-gallon gasoline mileage vehicle (25.5 mpg running on ethanol) to an electric vehicle shows that electric vehicles could be driven roughly 2.5 times farther than an ethanol-fueled vehicle. The production and distribution network for electricity obviously exists. If biomass-fueled power plants were to become more commonplace in the future, electric vehicles could be a very efficient, carbon neutral means of transportation.

Table 9. Comparison of mileage driven per ton of biomass processed between an ethanol-fueled internal combustion engine versus electrically driven vehicle.

| | | |
|---|---|---|
| **Cellulosic Ethanol-Fueled Vehicle** | | |
| Biomass Input (ton) | 1 | oven dry ton of biomass |
| Conversion Efficiency | 100 | gallons ethanol per oven dry ton (future) |
| Vehicle Mileage (gasoline) | 30 | mpg-vehicle using gasoline |
| Ethanol Mileage | 25.5 | 15 percent deduction for reduced energy |
| Miles Driven | 2550 | miles driven per oven dry ton |
| **Plug-In Electric Vehicle** | | |
| Biomass Input (ton) | 1 | oven dry ton of biomass |
| Conversion Efficiency | 0.33 | conversion efficiency biomass-to-electricity |
| Electricity Produced | 1,643 | kwh produced per ton of biomass |
| Vehicle Mileage | 4 | miles per kwh |
| Miles Driven | 6572 | miles driven per oven dry ton |
| | **2.58** | ratio of electric vehicles to ethanol-powered vehicles |

**Conclusion**

While there is uncertainty about the rate of oil depletion and global reserves of fossil fuels, there is no doubt that demand for alternate energy will increase. In particular, the development of new means of transportation, whether liquid-fueled or electrically-driven, will result in jobs and economic growth in forested and agricultural areas having available biomass. New jobs and economic growth will be created in the fields of biomass production, collection, conversion and distribution. Biomass sources including roundwood, forest harvest residues, forest thinnings, brushlands and energy crops could provide a significant amount of woody biomass to be used as feedstock to produce alternate energy in Minnesota, possibly enough for three additional wood-based plants using current supplies of timber from the forest land base. Additional opportunities exist in new biomass sources such as brushlands and poplar plantations. As this industry develops, a number of points are important:

- Legislators and policymakers concerned about the economy of the forested areas of Minnesota should appreciate the potential impact of energy subsidies on the forest products industry,
- Support for research at the state level to develop conversion and biomass production technologies, specifically energy crop development, brushland biomass assessments, aspen thinning options and impacts, forest harvest residue bundling equipment and conversion technologies is needed,
- Ethanol produced from local wood resources may be competitive with gasoline at current prices,
- Smaller-scale conversion technologies that are publicly available are needed and may require targeted research and development by the State,

- Picking ultimate winners is difficult and the most competitive options will depend on technology advancements in the fields of liquid fuels conversion and batteries.

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**Appendix A.** Operating parameters, capital costs and resulting cost per gallon of a theoretical thermochemcial ethanol plant (Phillips, et.al., 2007).

## Ethanol from Mixed Alcohols Production Process Engineering Analysis

2012 Market Target Case
2,000 Dry Metric Tonnes Biomass per Day
BCL Gasifier, Tar Reformer, Sulfur Removal, MoS2 Catalyst, Fuel Purification, Steam-Power Cycle
All Values in 2005$

Minimum Ethanol Selling Price ($/gal) **$1.01**

| | |
|---|---|
| EtOH Production at Operating Capacity (MM Gal / year) | 61.8 |
| EtOH Product Yield (gal / Dry US Ton Feedstock) | 80.1 |
| Mixed Alcohols Production at Operating Capacity (MM Gal / year) | 72.6 |
| Mixed Alcohols Product Yield (gal / Dry US Ton Feedstock) | 94.1 |
| Delivered Feedstock Cost $/Dry US Ton | $35 |
| Internal Rate of Return (After-Tax) | 10% |
| Equity Percent of Total Investment | 100% |

| Capital Costs | |
|---|---|
| Feed Handling & Drying | $23,200,000 |
| Gasification | $12,900,000 |
| Tar Reforming & Quench | $38,400,000 |
| Acid Gas & Sulfur Removal | $14,500,000 |
| Alcohol Synthesis - Compression | $16,000,000 |
| Alcohol Synthesis - Other | $4,600,000 |
| Alcohol Separation | $7,200,000 |
| Steam System & Power Generation | $16,800,000 |
| Cooling Water & Other Utilities | $3,600,000 |
| Total Installed Equipment Cost | $137,200,000 |
| | |
| Indirect Costs | 53,600,000 |
| (% of TPI) | 28.1% |
| Project Contingency | 4,100,000 |
| | |
| Total Project Investment (TPI) | $190,800,000 |
| | |
| Installed Equipment Cost per Annual Gallon | $2.22 |
| Total Project Investment per Annual Gallon | $3.09 |
| | |
| Loan Rate | N/A |
| Term (years) | N/A |
| Capital Charge Factor | 0.180 |
| | |
| Maximum Yields based on carbon content | |
| Theoretical Ethanol Production (MM gal/yr) | 158.9 |
| Theoretical Ethanol Yield (gal/dry ton) | 205.8 |
| Current Ethanol Yield (Actual/Theoretical) | 39% |
| | |
| Gasifier Efficiency - HHV % | 76.6 |
| Gasifier Efficiency - LHV % | 76.1 |
| Overall Plant Efficiency - HHV % | 47.4 |
| Overall Plant Efficiency - LHV % | 45.8 |
| | |
| Plant Hours per year | 8406 |
| % | 96.0% |

| Operating Costs (cents/gal product) | |
|---|---|
| Feedstock | 43.7 |
| Natural Gas | 0.0 |
| Catalysts | 0.3 |
| Olivine | 0.7 |
| Other Raw Materials | 1.6 |
| Waste Disposal | 0.4 |
| Electricity | 0.0 |
| Fixed Costs | 19.5 |
| Co-product credits | -20.7 |
| Capital Depreciation | 15.4 |
| Average Income Tax | 11.8 |
| Average Return on Investment | 28.5 |

| Operating Costs ($/yr) | |
|---|---|
| Feedstock | $27,000,000 |
| Natural Gas | $0 |
| Catalysts | $200,000 |
| Olivine | $400,000 |
| Other Raw Matl. Costs | $300,000 |
| Waste Disposal | $300,000 |
| Electricity | $0 |
| Fixed Costs | $12,100,000 |
| Co-product credits @ $1.15 per gal | -$12,800,000 |
| Capital Depreciation | $9,500,000 |
| Average Income Tax | $7,300,000 |
| Average Return on Investment | $17,600,000 |
| | |
| Total Plant Electricity Usage (KW) | 7,994 |
| Electricity Produced Onsite (KW) | 7,998 |
| Electricity Purchased from Grid (KW) | 0 |
| Electricity Sold to Grid (KW) | 4 |
| | |
| Steam Plant + Turboexpander Power Generated (hp) | 66,451 |
| Used for Main Compressors (hp) | 55,168 |
| Used for Electricity Generation (hp) | 11,283 |
| | |
| Plant Electricity Use (KWh/gal product) | 1.5 |
| Gasification & Reforming Steam Use (lb/gal) | 9.9 |

# Appendix H, Renewable Energy

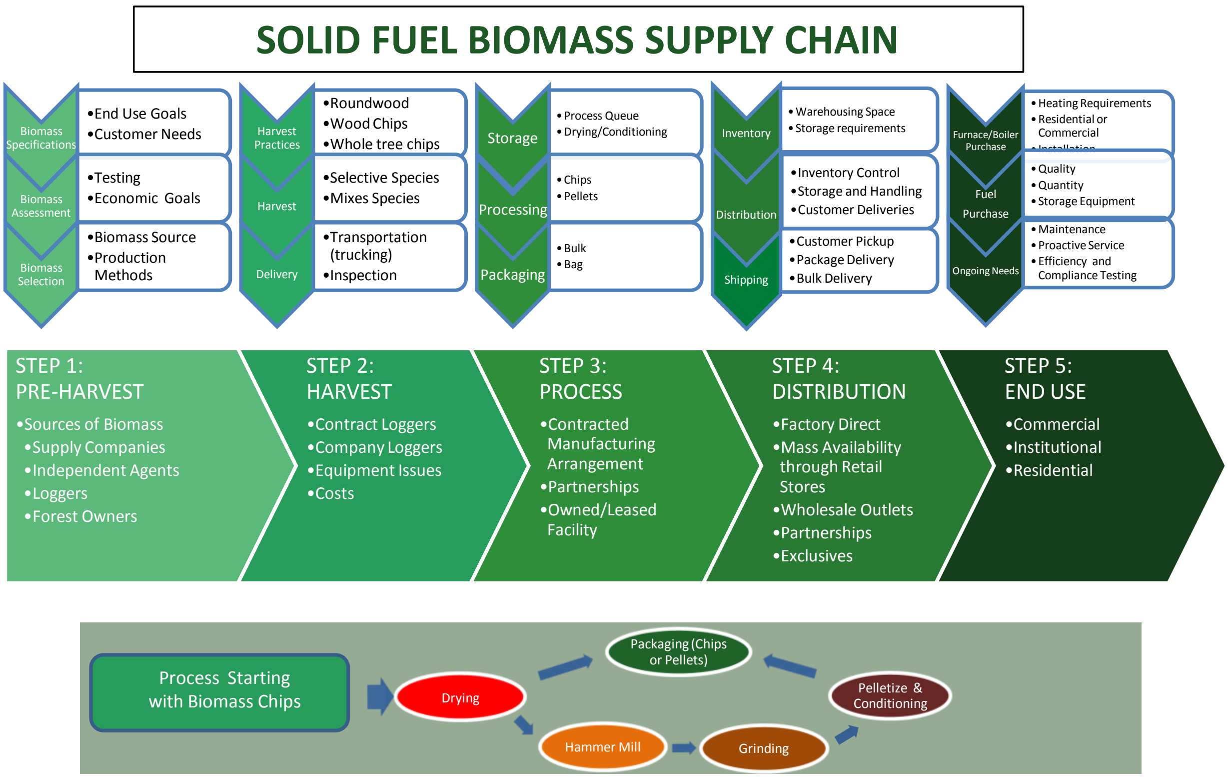
| Table H1, Hydroelectric Facilities in Northeastern Minnesota | | | | |
|---|---|---|---|---|
| Dam Name | Dam Owner | River | County | Generation (MW) |
| **Blandin** | Minnesota Power | Mississippi | Itasca | 2.1 |
| **Fond du Lac** | Minnesota Power | St. Louis | Carlton | 12.0 |
| **International Falls** | Boise Cascade | Rainy | Koochiching | 10.1 |
| **Knife Falls** | Minnesota Power | St. Louis | Carlton | 2.4 |
| **Prairie River** | Minnesota Power | Mississippi | Itasca | 1.1 |
| **Sappi** | Sappi Fine Paper | St. Louis | Carlton | 6.5 |
| **Scanlon** | Minnesota Power | St. Louis | Carlton | 1.6 |
| **Thomson Station** | Minnesota Power | St. Louis | Carlton | 69.6 |
| **Winton** | Minnesota Power | Kawishiwi | Lake | 4 |

Minnesota DNR web site, Hydropower Sites in Minnesota, Listed by type and owner, http://www.dnr.state.mn.us/waters/surfacewater_section/stream_hydro/hydropower_sites.html

| Table H2, Major Energy Production Centers for NE Minnesota That Use Biomass Fuel | | | | |
|---|---|---|---|---|
| **Company** | **Location** | **Energy Produced (Steam or Heating)** | **Energy Generated (Electricity)** | **Electricity Produced for Public Consumption** |
| **Ainsworth** | Grand Rapids (shut down) | **Yes** | **No** | |
| | Cook (shut down) | **Yes** | **Yes (1)** | |
| **Boise Cascade Paper** | International Falls | **Yes** | **Yes (1)** | |
| **Diamond Brands** | Cloquet | **Yes** | **No** | |
| **Georgia-Pacific** | Duluth | **Yes** | **No** | |
| **Laurention Energy Authority** | Hibbing and Virginia | **Yes** | **Yes** | **35MW** |
| **Louisiana Pacific** | Two Harbors | **Yes** | **No** | |
| **Hedstrom Lumber** | Grand Marais | **Yes** | **No** | |
| **International Bildrite** | International Falls | **Yes** | **No** | |
| **Minnesota Power** | Sappi Turbine Generator | **Yes (2)** | **Yes(1) 23 MW** | |
| | Rapids Energy Center | **Yes (2)** | **Yes(1) 32MW** | |
| **MinnTac** | Mountain Iron | **Yes(1)** | **No** | |
| **New Page Paper& Recycle/ Minnesota Power** | Duluth, Hibbard Energy Center(3) | **Yes** | **Yes (1) 53MW** | |
| **Sappi Fine Paper** | Cloquet | **Yes** | **Yes (1)** | |
| **Rajala** | Deer River | **Yes** | **No** | |
| **UPM / Blandin Paper Company)** | Grand Rapids | **Yes** | **No** | |
| **USG** | Cloquet | **Yes** | **No** | |

(1) Electrical energy used for internal consumption
(2) Operated by Sappi, Owned by Minnesota Power, Energy and steam used by host facility
(3) M.L. Hibbard Facility utilizes waste wood which provides a renewable, recyclable, low sulfur fuel source. Approximately 90 percent of all ash produced at the M.L. Hibbard Facility is utilized as a soil nutrient on area farmlands, reducing the amount of ash being put in landfills.

Figure H1, Biomass Supply Chain




***Key Performance Indicators (KPI's):*** *Efficiency ($/unit produced); Quality of Biomass ($/ton or pound); Equipment Capacity (tons/hour)*
*At Step 3, biomass feedstock may be delivered to a* ***biorefinery*** *where it may be converted through biochemical or thermochemical processes for combined heat and power (CHP) or fuels, chemicals, and renewable materials.*
*Step 3 may include the processing of biomass feedstock that results in* ***densification****, whereby, further steps may be required to get a product to end market for use in biomass heating appliances (reflected in Steps 4 & 5).*

## Appendix I, Summary of Regional Funding

| Fund Name/Area | Funding Amount | Eligibility |
|---|---|---|
| Aitkin Growth First County Fund, Aitkin County | Maximum participation in any loan request is $50,000. | For-profit businesses engaged in manufacturing or assembling, processing operations, tourism and any other business operation, which tends to lead the county economy. |
| Arrowhead Regional Development Commission Revolving Loan Fund | The loan minimum is $10,000 and the loan maximum is $100,000. | For-profit owner operated businesses engaged in manufacturing, value added products, tourism, the office sector and technological innovative industries. |
| Carlton County Revolving Loan Fund, Carlton County | No maximums or minimums. However, loans may not exceed 25 percent of the total project cost. The range of loans has been between $10,000 and $75,000. | Resorts/tourism businesses; energy related businesses that use indigenous fuels, technologically innovative industries, manufacturing and industrial operations, forestry/wood products, industries using indigenous mineral resources and other businesses whose presence will create jobs and expand the tax base. |
| Cook County Development Loan Program | The loan maximum is $100,000 subject to the availability of funds | For-profit businesses organized in any manner permitted by law consistent with program objectives. |
| Duluth 1200 Fund | The loan maximum amount is $500,000. | This program is directed toward existing businesses, which have been in operation three or more years. New business start-ups are not normally eligible. |
| East Range Joint Powers Board Development Loan Program | The loan maximum is $25,000. | Resorts/tourism projects which attract tourism expenditures from outside the region, energy related businesses which utilize indigenous fuels, technologically innovative industries, manufacturing/industrial operations, industrial service/supply, forestry/wood projects, industries based on utilization of the area's indigenous mineral resources; agriculture and other businesses to the extent they are in compliance with the goals of the program. |

| | | |
|---|---|---|
| Eveleth Economic Development Authority Community Development Revolving Loan Program | $1,000 / $150,000 loan based on availability of funds. | The funds are available only to those who need the funds for GAP Financing or have been denied by a loan lender and a review of the following criteria has been completed: Demonstrated repayment ability, equity commitment, adequate collateral coverage, management capability, letter of commitment from primary lending source, or letter of denial and the availability of funds. |
| Great River Energy E3 (Energy Efficient Equipment) Commercial Loan Program | The loan minimum is $20,000 and the loan maximum is $200,000. | Loan applicants must receive electrical service from a GRE member system rural electric cooperative. Loan applicants must be business owners or operators. |
| Great River Energy LEED Certification Commercial Loan Fund Program | The loan amounts will cover 100 percent of the total eligible project costs with a maximum loan amount of $1,000,000 per project | Projects within the GRE service area who receive retail electric service from any all-requirements member are eligible to apply for a loan. Eligible applicants must meet minimum energy performance standards as defined by the U.S. Green Building Council.<br>Applicants may include:<br>Private-for-profit businesses<br>Cooperative businesses<br>Municipal, county, state or federal governments<br>Non-profit businesses and organizations<br>School districts<br>Tribal governments |
| Hibbing Economic Development Authority Revolving Loan Fund | $50,000 or less | The emphasis of this program is to provide assistance to "leaders" of the economy. With this in mind, the following types of businesses have been determined to be eligible for assistance under the program:<br><br>a. manufacturing/assembly;<br>b. tourism projects which attract tourism expenditures from outside the region; and<br>c. technologically innovative industries.<br>d. businesses having a significant impact on the community<br>e. retail/service<br><br>The business to be assisted must be a for-profit operation, but may be a new start-up or existing business, and may be organized as a proprietorship, partnership, or corporation. |

| | | |
|---|---|---|
| Iron Range Resources Bank Participation Loan Program | The maximum participation is $250,000 in any single project. | For-profit businesses engaged in manufacturing/assembly, tourism businesses, which attract tourism expenditures from outside the region and businesses, which produce technologically innovative products |
| Iron Range Resources Industrial Revenue Bond Program | -Tax Exempt Issues<br>-Below Ten (10) Million Dollars Taxable Issues<br>-No Cap | Start-ups or expansions in the industrial or manufacturing sectors. |
| Koochco, Inc. Loan Program | The loan minimum is $10,000 and loan maximum is $100,000. | For-profit or non-profit businesses. Businesses eligible for Koochco, Inc. loans must be considered "basic" (businesses that sell their products to non-local markets). |
| Minnesota Community Capital Fund | The loan minimum is $50,000 and the loan maximum is $2,500,000. MCCF members can originate loans of up to ten times the amount they contributed to the Fund. | Funded project must be within a member's area of operations. Borrower may be a for-profit business entity, non-profit entity, cooperative, or local unit of government. |
| Minnesota Indian Business Loan Program | Loans may not exceed the funds available to any one tribe and are limited to 75 percent of the cost of the project that is being financed. | Eligible applicants must be enrolled members of a federally recognized Minnesota-based band or tribe. Businesses may be located anywhere in the state, although most of the loans are made to businesses on a reservation. |
| Minnesota Investment Fund | There is a maximum of $500,000 per grant. | Cities, counties, townships and recognized Indian tribal governments are eligible for this fund. |
| Minnesota Jobs Skills Partnership Program | Up to $400,000 Requests for wage subsidies and tuition reimbursements are ineligible. | Accredited public and/or private educational institutions within the state and businesses located or intending to locate in Minnesota. |

| | | |
|---|---|---|
| Northeast Entrepreneur Fund | The loan minimum is $100 and the loan maximum is $100,000. | A business should be located in Aitkin, Carlton, Cass, Cook, Crow Wing, Itasca, Koochiching, Lake, Pine or St. Louis counties in Minnesota or Douglas County, Wisconsin. Applicants must have a realistic business plan and can show a need for financing. |
| Northland Foundation Business Loan Program | The loan maximum is $150,000. | For profit business owner operated businesses engaged in manufacturing, wood products, agriprocessing, information industries, tourism, etc. Funds may not be used for retail development projects and most service businesses. |
| Northland Foundation Loan Guarantee Program | The loan guarantee is one-half the outstanding loan balance, up to a maximum of $80,000 or 80 percent of the loan deficiency after expenses, whichever is less. | For-profit business owner operated businesses engaged in manufacturing, wood products, agri-processing, information industries, and tourism etc. Funds may not be used for retail development projects and most service businesses. |
| Northland Foundation Royalty Investments | Generally limited to $100,000.<br>The structure of a Royalty Investment involves repayment in two ways. First, repayment is made in the form of a low-interest promissory note. Second, repayment is also tied to a percentage of earnings and cash flow (the royalty). The amount of the royalty payments due over time usually does not exceed the total of the original investment | Applicants must demonstrate long-term financial potential and a strong likelihood of repaying the investment from profits and cash flow.<br>Major features include deferral of principal payments, low interest rates and the sharing of some profits with the Northland Foundation. |
| Silver Bay Economic Development Authority Revolving Loan Program | The City of Silver Bay provides low interest loan gap financing to qualifying businesses. | Must be a business whose business plan provides for:<br>1. Other significant capital investment<br>2. Full employment and/or equivalent<br>3. Increase the local tax base |

| | | |
|---|---|---|
| State of Minnesota Job Opportunity Business Zones | This state incentive does not involve loans, but provides a variety of tax breaks for each eligible applicant. This tax relief includes corp. franchise tax; income tax for operators or investors, including capital gains tax; sales tax on goods and services used in the zone if the goods and services were purchased during the duration of the zone; property tax on commercial and industrial improvements but not on land; wind energy production tax, and; employment tax credit for high paying jobs. | Tax exemptions apply only to qualified businesses that start up or expand into a Sub-zone, business relocations from other states, and business relocations from Minnesota if the business increases employment by a minimum of 5 jobs or 20 percent, whichever is greater, within the first full year of operations in the Sub-zone.<br><br>A qualified business, as defined by M.S. § 469.310 subd.11, will be eligible for JOBZ through the execution of a local Business Subsidy Agreement and Relocation Agreement (if necessary). A qualifying business must pay each employee compensation, including benefits not mandated by law, that on an annualized basis is equal to at least 110 percent of the federal poverty level for a family of four. Retail development is not eligible for JOBZ benefits. |
| State of Minnesota Pathways Program | Up to $400,000 per grant can be awarded for a project. Costs are paid on a reimbursement basis. A short-form application is also available for grants of up to $50,000. | Accredited public and/or private educational institutions partnering with businesses within the state are eligible. Preference will be given to projects that provide full-time employment with benefits and projects with defined career paths. Further preference will be given to projects that demonstrate the active participation of local human service agencies or nonprofit organizations that provide employment and training services. Requests for wage subsidies and tuition reimbursements are ineligible. |
| State of Minnesota Small Business Development Loan Program | Loans up to a maximum of $5 million may be made for any one business. | Those eligible for loans through the Small Business Development Loan Program include manufacturing and industrial businesses located or intending to locate in Minnesota, as defined by Small Business Administration size and eligibility standards (generally, those with 500 employees or fewer).<br>Applications, using the Business and Community Development Application, are accepted on a year-round basis, but must be received by the first of each month to be considered at that month's |

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| | | MAEDB meeting. |
| Two Harbors Development Commission Financing Program | Loans may not exceed 50 percent of the aggregate amount of the project up to a maximum of $200,000. | The recipient of such loans or other financial assistance may be businesses or other entities organized in any manner permitted by law, consistent with program objectives. |

NORTHLAND CONNECTION℠

Data provided by Northland Connection

# Appendix J, Uses of Fumaric and Malic Acid

| | CITRIC ACID | SODIUM CITRATE | POTASSIUM CITRATE | FUMARIC ACID | MALIC ACID |
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| Carbonated Beverages | • Buffer system modifies tartness & enhancess flavor.<br>• Increases effectiveness of preservatives. | • Buffer system modifies tartness & enhances flavor | • Buffer system modifies tartness & enhances flavor.<br>• Excellent source to reduce sodium content. | | • Provides tartness & enhances flavor.<br>• Lowers pH & increases preervative effectiveness. |
| Dry Beverage Mixes | • Excellent solubility buffering capapbility & flavor blending characteristics.<br>• Provides bulk in artificially sweetened products. | • Buffer system to regulate tartness & enhance flavor. | • Buffer system modifies tartness & enhances flavor.<br>• Excellent source to reduce sodium content. | • Non-hygrocopic nature allows for cost savings on moisture resistant packaging. | |
| Natural & Artificially Flavored Fruit Drinks | • Increases acidity & provides tartness.<br>• Excellent chelation properites inactivate trace metals to reduce flavor & color oxidation. | • Buffer helps attain smooth levels of desired tartness.<br>• Used with Citric Acid to increase aspartame sol-ubility & stability. | • Buffer helps attain smooth leels of desired tartness.<br>• Used with Citric Acid to increase aspartame sol-ubility & stability. | • As a stronger acid with low pH, allows for relatively low use levels. | • Enhances flavor of fruit drinks & extends flavor sensation without masking natural flavor notes. |
| Wine | • Adjust acidity & enhances flavor in fruit-flavored wines<br>• Excellent cleaner for processing lines & filters. | | | • Approved to correct acidity after fermentation is complete. (At levels not to exceed 0.3% in finished product.) | • Corrects natural deficiencies in wine or fruit juice.<br>• May be added prior to or during fermentation. Only acidulant allowed in apple wine. |
| Fresh, Frozen & Canned Fruits & Vegetables | • Adjust pH & trace metal chelation to optimize color, flavor, & texture.<br>• Improve ascorbic acid retention.<br>• Reduces heat processing requirements in canning by lowering pH. | | | • Used with sodium benzoate & boric acid to prevent degradation of fresh vegetables. | • Acid certain canned products to protect color & reduce heat-processing requirements |
| Jams, Jellies & Preserves | • Adjusts & maintains proper pH to insure optimum gel formation. | • Buffer system to maximize flavor development & enhancement | • Buffer system to maximize flavor development & enhancement | • As a stronger acid with low pH, allows for relatively low use levels. | • Provide great tart taste with slightly high pH in fruit pie filling.<br>• Higher pH helps prevent weeping in fruit pie fillings. |
| Gelatin Desserts & Puddings | • Superior flavor blending & enhancement.<br>• Provides proper pH for optimum gel strength. | • Buffer controls pH<br>• Buffer helps modify flavor | • Buffer controls pH<br>• Buffer helps modify flavor<br>• Ideal for quick-setting formulas with carageenan. | • Non-hygrocopic nature allows for cost savings on moisture resistant packaging. | • Clean flavor note & higher pH allows for lower use of gelatin for setting of the protein gel system.<br>• Gives a tang to fruit-flavored pudding. Prevents weeping of starch gels. |
| Confections | • Enhances fruit flavors, prevents sugar crystallization & flavor oxidation.<br>• Adjusts pH for proper gel in compressed candy tablets, cream candies & starch-based jellies. | • Reduces & controls inversion.<br>• Regulates tartness | • Buffering salt of choice in candy manufacture. | • Economical acidulant for chewing gum and jelly-like candies (e.g.: gummy bears.)<br>• Provides clean longer lasting acid taste. | • Lowers melting point & improving dispersion in the syrup of hard candies, reducing kneading & folding requirements.<br>• Produces clear products |
| Pharmaceutical Products | • Buffer system to optimize stability & effectiveness in effervescent formulations. | • Buffer system & chelating agent helps prevent ingredient degradation. | • Buffer system & chelating agent helps prevent ingredient degradation. | • Generates carbon dioxide when combined with sodium carbonate & potassium carbonate.<br>• May be tableted with other ingredients to make cleaning agent for dentures. | |
| Detergents | • Functions as a builder, solubility aid and pH adjuster.<br>• Used with sodium citrate in hard surface cleaners as acid & chelator to:<br>  • dissolve hard water<br>  • increase efficacy of surfactants (as a builder). | • Environmentally acceptable replacement for phospates. | | | |
| Animal Feeds & Fertilizers | • In animal as a builder, solubility aid and pH adjuster. Used with sodium citrate in hard surfaces cleaners as acid & chelatorto:<br>  • dissolve hard water deposits.<br>  • increase efficacy of surfactants (as a builder). | | | • As animal feed additive:<br>  • improve growth rate<br>  • increase feed consumption<br>  • improves efficiency of feed utilization | |
| Other Industrial Applications | • Electrodeposition of metals retards setting times for concrete, mortar & plaster.<br>• Buffer for textile dying & wrinkle resistance and leather tanning & cleaning.<br>• Chelating agent in paper & plastic products. | • Used as buffering salt forcitric/citrate systems. | • Used as buffering salt for citric/citrate systems. | • Used for productions of vinyl acetate copolymers & vinyldene chloride copolymers for paper & paperboard food packaging.<br>• Used for production of styrene butadiene latex in paints, paper, coatings, adhesives, carpet backing & linoleum. | |

Source: Tate & Lyle Website