The BioBusiness Alliance of Minnesota™

Minnesota's Forest Biomass Value Chain:

A System Dynamics Analysis

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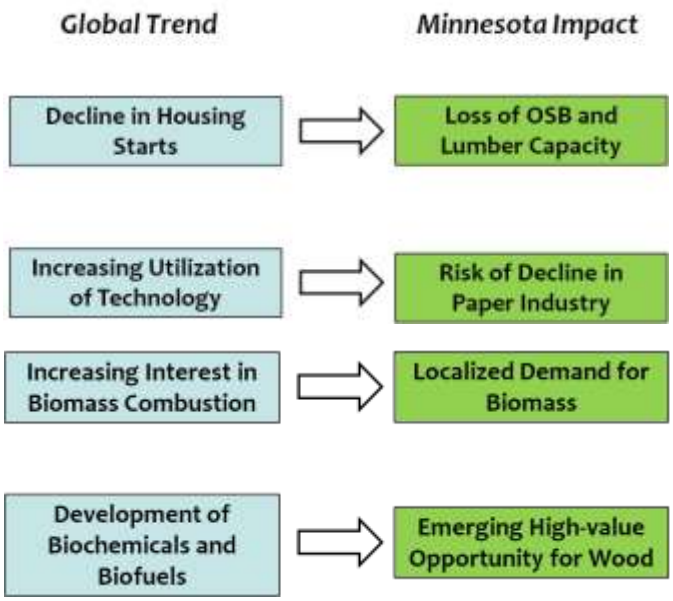
Executive Summary

Minnesota stands at a crossroads. The forest products industry of past decades is rapidly changing, creating both short-term challenges and short- and long-term opportunities for the state. Minnesota has the opportunity to excel in manufacturing sustainable, renewable forest-based products, including biochemicals, biofuels, and biomass heat and power. The challenge that lies ahead for Minnesota will be to capitalize on the promise of these new technologies, while supporting the continued health of more traditional forest products industries, including paper, lumber, and oriented strand board (OSB), which are critical to the state's economy. The following systems analysis will attempt to tackle this challenge.

Forest products remain big business in Minnesota. In 2009, it accounted for 40,400 jobs throughout the forest products industry value chain and 3.2 billion dollars in economic activity. The state's forest products industries, however, have not been immune to the global economic downturn. Traditional industries are being shaken to their core by the ongoing housing crisis, changes in the way information is consumed, and competition from growing worldwide manufacturing capability. Since 2007, three of the state's five OSB mills have shut down, and the state's consumption of wood for industrial processing has dropped by over 1 million green tons, representing a 20 percent drop. Meanwhile, the state's pulp and paper industry, which accounts for 60 percent of the wood consumed in Minnesota, has managed to avoid plant closures. Overall, there is a 3.2 million green ton surplus of wood as compared to historical supply data and economic price thresholds. As a result of the reduction in demand, chronic underutilization of the Minnesota forest resource has placed the state's logging infrastructure at risk of permanent decline. In the future, if demand for forest products increases, the greatest risk will not be a shortage of wood, but rather an inability to procure the wood due to the lack of loggers and equipment.

Figure 1: Impact of Global Trends on Minnesota's Forest Products Industries



The decline in forest utilization is also threatening Minnesota's ability to implement and improve forest management programs. These programs – which are designed not only for timber harvest, but also for fire risk management, wildlife habitat enhancement and ecological health – are critical for balancing the multiple uses of the forest in a sustainable manner. While managed wood harvests do not ensure all of these sustainable activities happen, they are an important component of the system that sustains forest health.

As these economic forces are challenging traditional forest product industries, other market forces are creating new opportunities for wood utilization. Interest in alternative energy has risen across the world in response to growing concerns over carbon emissions, energy trade balances, and higher fossil fuel costs. Wood is increasingly being

turned to as a fuel source for heat and electricity in European countries and in some parts of the United States. This growing interest in renewable energy has also resulted in new technologies being developed for producing transportation fuels and biochemicals from organic cellulosic materials. Fortunately, Minnesota has been at the center of this development activity for years.

These emerging industries could help provide a stable market for wood in the long term, provided that these new uses can be balanced with the needs of the state's traditional forest products industries. Recognizing the need for careful analysis of these markets, The BioBusiness Alliance of Minnesota partnered with the Minnesota Department of Natural Resources and the Minnesota Forest Resources Council to identify issues and opportunities in the growth of biomass-based industries, particularly those relating to forest products. A one-year analysis engaging more than 100 experts from industry, academia and government, along with development of a System Dynamics (SD) computer simulation model, has culminated in four recommendations and related actionable tactics that are detailed in this report. These recommendations are summarized below.

Recommendation 1: Ensure long- term supply of raw materials through forest management and increasing utilization.

Why: Maintaining forest management capability and long-term supply is a prerequisite for successful long-term growth in any forest-based industry. Furthermore, underutilization of Minnesota's forests is threatening Minnesota's logging infrastructure.

Tactics: Minnesota must continue investing in programs that maintain and improve the ecological health of the forest in both the short and long term. These programs should encourage sustainable management techniques that ensure forests continue to play the aesthetic, recreational, and habitat roles that are important to Minnesotans. At the same time, programs must be implemented to ensure the health of the logging industries. Activities must be undertaken to ensure access to wood for the logging industry, develop forest-based markets, and support programs that ensure loggers have access to capital necessary to keep the industry competitive globally.

Recommendation 2: Support efficient utilization of wood for heat and power generation.

Why: With the slowdown in traditional forest products industries, biomass combined heat and power (CHP) generation presents an opportunity to develop markets for Minnesota's timber industry. Technological barriers are relatively low, and manufacturing capability can be established quickly. In addition to sustaining the industry infrastructure, ramping up biomass heat and electricity generation would help the state achieve its goals of greenhouse gas emissions and energy efficiency savings while reducing its reliance on fossil fuels.

Tactics: Existing policy tools should be expanded to create incentives for proper utilization of wood energy. This includes providing credit toward the Conservation Improvement Program goal of 1.5 percent energy savings for energy produced in biomass powered cogeneration facilities owned by regulated utilities. The long-term vision is to encourage outcome-based energy standards that focus on efficient renewable energy production. Additionally, tax credits for expenditures on wood energy equipment should be comparable to tax credits for other types of renewable technologies. These investments would be a significant step in getting loggers back to work and provide private landowners a return on their land that can keep "forests as forests."

The SD model produced for the current analysis predicts that 800,000 green tons of wood utilized for pellet manufacturing and an additional 400,000 green tons being consumed in CHP markets is sustainable without causing harm to existing industries. This growth in market demand would add a total of 570 direct jobs to Minnesota's economy. It is important to note, however, market growth beyond these levels could result in diminishing returns in employment as producer competition for feedstock would drive up prices and negatively affect market dynamics. This potential reinforces the need for careful analysis by policy makers and the private sector prior to making strategic investments.

Recommendation 3: Actively pursue emerging high-value opportunities.

Why: Long-term policies and action should focus on creating maximum value from the forests. This is because higher value emerging industries, such as advanced biofuels and biochemicals, can sustain themselves in the longer term, just as lumber and paper have stood the test of time for over a century.

Tactics: Integration of advanced biofuels and biochemicals with the forest biomass supply chain infrastructure needs to be supported, as these high-value industries are quickly developing technologies for commercial-scale manufacturing. Industries across Minnesota that produce and utilize biomass, including those in the agricultural and forestry communities, need to work together to explore and foster commercial manufacturing partnerships. Further, by helping set a strategic direction and providing assistance for capital expenditures, the state can play a critical role in diffusing risk for the razor-thin margins under which commodity processing industries operate. The SD model created in the current analysis suggests that these efforts would result in the recruitment of jobs at biochemical and biofuels production facilities. If 800,000 green tons of wood are consumed in these industries, the model shows 325 jobs created in northern Minnesota for logging and initial bioprocessing, with a total of 620 created across the value chain. Furthermore, these industries can support efforts to retain traditional industry in the state through stable, profitable partnerships.

Recommendation 4: Foster cooperation in the implementation of these recommendations.

Why: Enormous potential exists if Minnesota can manage its forest biomass supply chain in such a way that creates opportunity for both traditional and emerging forest-based industries. Yet, none of this will be possible without an unprecedented level of cooperation, where communities across greater Minnesota pursue opportunities for biomass processing as part of an integrated statewide strategy that marries old with new, higher value with lower value.

Tactics: Fostering collaboration among forest-based economic development groups is critical, given the pressing need to increase wood utilization in the short-term. Minnesota's strength in the diversity of biomass feedstock that grows here needs to be recognized and built upon by the agricultural and forestry communities.

As the state pursues these new opportunities in emerging forest products, it will be critical that these efforts be pursued in such a way that they do not negatively impact more traditional industries that compete for the same sources of biomass. This report provides a research-based, data-driven analysis that was designed to provide the foundation for a consolidated statewide strategy. It offers a strong vision with actionable implementation tactics for forest biomass utilization that maximize

the value of the state's forest resources from an economic, recreational, and ecological perspective for now and the future.

Economic Impact of Recommendations

Utilizing the SD model, it is predicted that implementation of these recommendations would result in a net gain of 700 direct jobs in the state of Minnesota; 1,400 jobs are created when including indirect and induced jobs. Furthermore, assurance of a long-term stable supply of wood could spur additional investments in the forest products industry. An estimated 1,500 direct jobs and 3,300 jobs when including indirect and induced impacts are likely to be created in the 'best case scenario,' which includes expansions in lumber, OSB, paper production, pellet manufacturing, heat and electricity production, and aggressive investment in biofuels and biochemicals.

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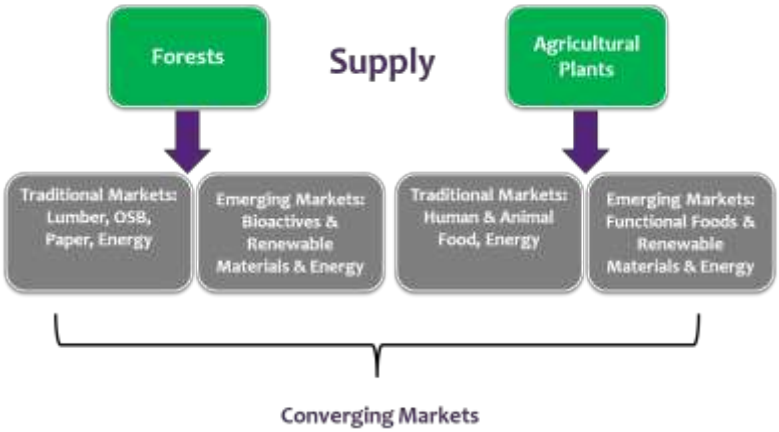
Introduction

The BioBusiness Alliance of Minnesota (BBAM) is a 501 (c) (3) not-for-profit organization with a focused mandate: to foster and cultivate the long-term viability of the state's bioscience sector. The organization works across life science-based industries to support companies, communities, and regions throughout the state of Minnesota in developing their opportunities for growth.

In January 2009, BBAM released *Destination 2025*, a collaborative effort between BBAM and Deloitte Consulting LLP to develop a 20-year strategic plan and roadmap for Minnesota in the six life science markets in which the state participates: medical devices, biologics and biopharmaceuticals, animal health, food, renewable energy, and renewable materials. The process involved over 600 people who work in and with the industry and who are experts in their area of focus.

One of the important findings of the *Destination 2025* strategic planning process was that Minnesota needed to better understand how to effectively evaluate and manage the tradeoffs associated with the convergence of various biomass supply chains, most notably, those based in forestry and agriculture. Traditionally, forest and agricultural resources have been utilized to produce items such as paper, lumber, and food.

Figure 2: Markets for Forest and Agricultural-based Industries



Since these resources will continue to be relied upon to sustain our way of life for generations to come, it is important to understand how these competing demands for raw material will affect each other over time. In July 2009, BBAM was made aware of the development of a BioEconomy Strategic Map commissioned by the Governor's Forestry sub-cabinet. The Map would provide strategic direction related to the ongoing development of Minnesota's forest biomass resources, a goal consistent with the needs outlined by BBAM in *Destination 2025*, and this led to development of strong partnerships with the MN DNR and MN Forest Resource Council.

As part of this effort, BBAM has led a collaborative, statewide stakeholder process to understand and formulate strategies and recommendations related to the opportunities that exist within the state's forest biomass value chain. The goal is to ensure the long-term availability of forest-based biomass to supply existing value-added industries, as well as new opportunities that expand wealth creation within Minnesota. This project evaluates the great potential offered by both traditional markets for forest-based biomass and by new markets emerging as the result of rapid advancements in technology, environmental issues, carbon sourcing, hydrocarbon pricing, and energy security. The goal of the project identifies those issues facing traditional industries and overlays them with the needs of emerging industries to formulate a holistic strategy and vision for a diversified forest-based bioeconomy in Minnesota.

Given the complexity of the problem, for its analysis, BBAM elected to use a method known as System Dynamics (SD) modeling to create a data-driven framework in which experts from multiple perspectives can interact and share their individual "mental models" that are critical to solve problems. System Dynamics modeling can be used to answer such real-world questions as: How many jobs would be created through the establishment of a wood pelletization industry in Minnesota? At what point would the growth of this industry be outweighed by negative impacts or unintended consequences for other industries that compete for the same sources of biomass? Too often, important and costly initiatives and policies are undertaken without the data that such analyses can provide.

During this project, the team consulted over 100 experts located throughout the state. Input was received from loggers, existing and emerging industry players, environmental groups, consumers, government and non-government organizations, and academic researchers. A detailed explanation of the Systems Dynamics modeling process and how the technique was used for this project can be found in the appendices.

Minnesota Forest Products Industry: Economic Impact

Minnesota's forest products industry has been an economic engine for the state since the early 20th century and continues to be an important part of the state's economy.[1] From the forests to the mills and beyond, the industry contributed over 40,400 jobs and $1.8 billion in wages in 2009, making it the state's fourth-largest manufacturing industry by employment and generating 11 percent of revenues from all manufacturing shipments in the state.[2] It is estimated that for every $1 of timber sold, over 41 dollars of economic activity is created, which is a significant economic impact multiplier.[3]

Economic impact multipliers are magnified in Greater Minnesota, where forest products play an integral role in local economies. For example, 10 percent of jobs in International Falls, Minnesota, are at the local paper mill. Taking into account the multiplicative effects along the supply chain, plus retail and other services supporting the forest products industries, it quickly becomes clear that protection and growth of forest-based manufacturing is necessary for the long-term viability of this and similar communities. In policy and economic development, this concern must be considered by decision makers across Minnesota.

In general, traditional forest product markets function under commodity cycles that are heavily dependent on the broader economy. Processes are often capital intensive, and cost minimization is important to an individual plant's survival. The resulting imperative to utilize greater proportions of raw forest materials has led to the creation of niche industries that use the byproducts of the traditional forest products industry. Today, half of the raw material going into lumber mills, for example, is used as an input into another process to manufacture such products as paper, animal bedding, pellets, industrial process energy, and others.[4] Like lumber mills, paper mills, and oriented

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[2] Deckard, Don (2010). *Economic Opportunities for Minnesota Wood.* Minnesota Department of Natural Resources Division of Forestry.

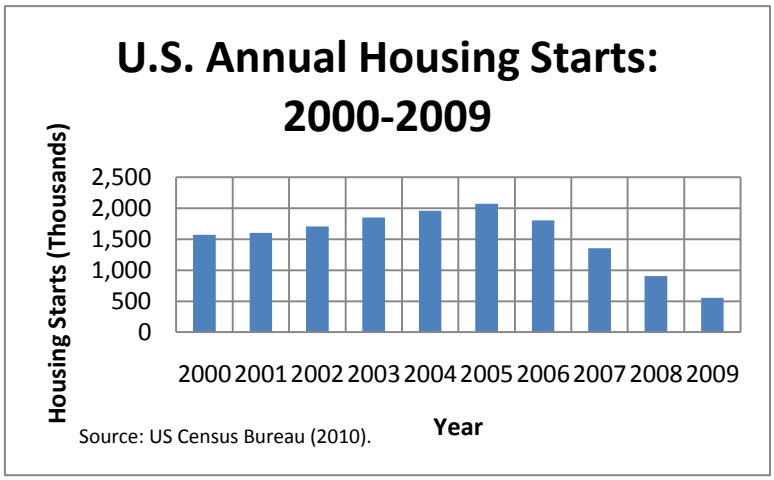
[3] Minnesota Department of Natural Resources. (2004). Value Added Economic Impact of Timber Harvested in Minnesota. Retrieved on October 24, 2010, from http://files.dnr.state.mn.us/forestry/um/value_added_brochure.pdf

[4] Energy Center of Wisconsin (2005) *Biobased Industry in Wisconsin: Technical Report*. Retrieved on July 14, 2009, from ftp://doaftp04.doa.state.wi.us/doadocs/120605_Technical_Report_Part_1.pdf

strand board (OSB) mills are also reducing waste through increased utilization of byproducts. Through this interaction, the forest biomass value chain maximizes the significant economic impact Minnesota's natural resources provide.

Global Forest Industry: Time of Change

Figure 3: U.S. Annual Housing Starts, 2000-2009

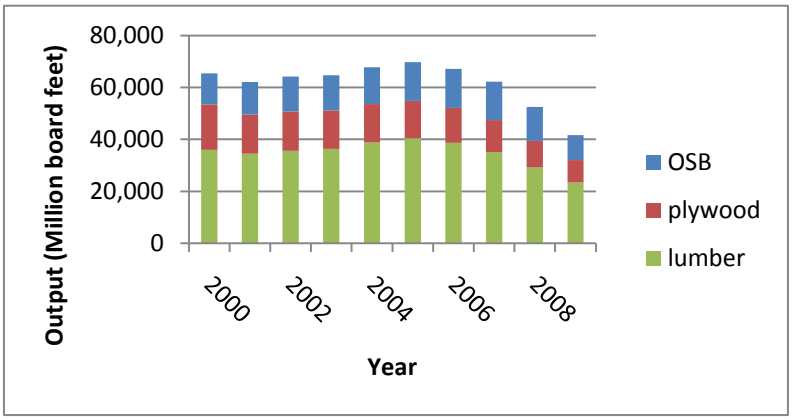


Recent economic and environmental trends have conspired to bring about declining demand for traditional forest products, such as lumber, OSB, and paper. At the same time, emerging markets have begun to expand. These emerging markets include liquid fuels, combustible forms of biomass, renewable materials, biochemicals, and biopharmaceuticals derived from woody biomass, all of which are dependent on the forests for their material supply chain. In many of these industries, fossil fuels are being displaced by biobased sources of carbon, from agriculture, the forest, and emerging sources such as algae.

Decline in Housing Impacts Forestry Industry

The collapse in the U.S. housing market that precipitated the recent financial crisis has caused stark impacts in the wood product manufacturing industry, affecting lumber, plywood, and OSB production. New construction and remodeling are the primary drivers of demand for lumber, plywood, and OSB. Approximately 50 percent of all U.S. lumber is consumed in new residential construction, and another 30 percent in remodeling.[5] As shown in Figure 3, when the housing market collapsed, U.S. single and multi-family housing starts dropped from their peak of 2.06 million in 2005 to 554,000 in 2009, a decrease of 73 percent, and the lowest level since the government began keeping track in 1959.[6]

Figure 4: U.S. Lumber, Plywood, and OSB Output, 2000-2009



Sources: Plywood and OSB: APA-The Engineered Wood Association; Lumber: Western Wood Products Association and Southern Forest Products Association.

[5] Benway, Stuart (2010). *Industry Surveys: Paper & Forest Products*. p. 4. Standard & Poor's. Retrieved on July 6, 2010, from http://www.standardandpoor's .com

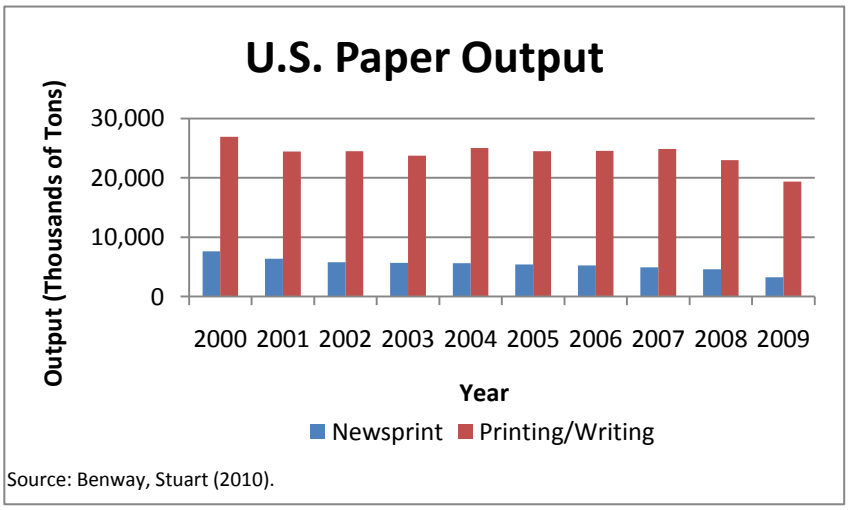
[6] US Census Bureau (2010). *New Privately Owned Housing Units Started.* Retrieved on September 28, 2010, from http://www.census.gov/const/startsan.pdf

The collapse in demand and subsequent excess inventories caused a decline in lumber and OSB prices and output, as seen in Figure 4. Both lumber and OSB prices were nearly cut in half, with lumber dropping to its lowest level since 1991.[7] This led to mills being closed across the country and a significant decline in output. The decrease in industrial capacity has since enabled a small recovery, but prices and output remain far below historic levels.

American Paper Industry Struggles

Over the past decade, Asia, and China in particular, have emerged as major competitors in global paper markets. The Chinese paper industry grew at an annualized rate of 15 percent from 2007 to 2009,[8] while U.S. output declined 2.6 percent.[9] Although Chinese growth was slower in 2009, long-term trends for China suggest continued growth.[10] Moreover, pulp mills in the northern United States are facing competition from areas with longer growing seasons, such as the southern United States and equatorial countries. Lower labor and timber prices in these areas decrease the cost of pulp production and make it economical for Minnesota paper mills to import pulp for paper production. While this can decrease costs for the mills, logging jobs and forest management activities are not realized within Minnesota.

Figure 5: U.S. Printing/Writing and Newsprint Output: 2000-2009



Source: Benway, Stuart (2010).

The global pulp and paper industry also has been significantly impacted by changes in modes of information consumption across the world. Competition from online sources of news led to slashes in the length and size of newspapers and reduced circulations, contributing to a 56 percent decrease in United States newsprint output between 2000 and 2009, to 3.25 million tons.[11] More recently, substitution of e-mail and electronic filing for paper has hurt sales of printing and writing paper, demand for which has traditionally correlated with economic activity. Even as U.S. real GDP expanded between 1999 and 2009, demand growth flattened and cost considerations led to a 29 percent decline in output of printing and writing papers, to 19,369,000 tons.[12] These trends are expected to be duplicated in the markets for textbook and magazine coated paper grades due to recent increases in the use of e-books by school districts and universities, combined with the increasing popularity of magazines and books viewed on e-readers and smart phones.

[7] Benway, Stuart (2010).
[8] Ibisworld and ACMR (2010). *Ibisworld and ACMR China Industry: Paper and Paperboard Manufacturing in China.* P. 5. Retrieved on October 20, 2010, from http://www.ibisworld.com.cn/industry/summary.aspx?indid=242
[9] Benway, Stuart (2010).
[10] Ibisworld and ACMR (2010).
[11] Benway, Stuart (2010).
[12] Benway, Stuart (2010).

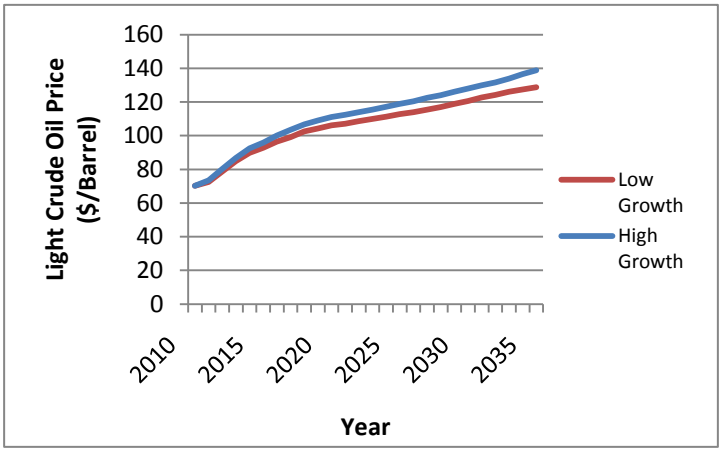
Increasing Interest in Renewable Resources

A number of environmental and political concerns have driven increasing interest in using biomass instead of petroleum and other fossil-based resources to produce heat, power, fuel, and industrial chemicals.

Global concern about climate change has led governments around the world to create policies incenting the use of renewable energy sources that yield lower net carbon dioxide (CO_2) emissions than fossil fuels. Policies intended to support compliance with renewable energy standards have jump-started demand in biomass markets, especially in the European Union. Biomass combustion is the first wood-based market to be impacted by carbon policies, though carbon controls are likely to have impacts across forest-based industries. It is likely that carbon will continue to gain increased focus in the next few decades as scientists continue to understand the impacts of climate change.

Rising energy prices and concerns over the contributions of energy to the U.S. trade deficit have sparked interest in the development of alternative sources of energy in small-scale, localized biomass energy systems and liquid fuels. Benefits of these systems include retention of money spent on energy in local economies, decreased transportation costs, and the use of a local resource.[13] There is an opportunity to keep energy dollars inside Minnesota and create jobs in local economies. These concerns drive the supply chain forward, providing a market development vehicle for biobased alternatives to imported energy.

Figure 6: Light Crude Oil Price Projections: 2010-2036



Source: Energy Information Administration (2010). *Annual Energy Outlook 2010.* Table 12: Petroleum Product Prices. Retrieved on October 20, 2010 from http://www.eia.gov/oiaf/aeo/

Emergence of New Markets for Woody Biomass

BBAM's *Destination 2025* report identified the renewable energy and renewable materials industries as opportunities for economic growth in rural areas throughout the state. Technology to develop and manufacture higher-value products such as industrial chemicals and liquid fuels has been progressing for the past two decades, and commercial-scale manufacturing is likely to occur in the coming decade. The outlook for increasing oil prices, as existing sources the sources of oil are increasingly difficult to access, suggest prospects for using alternative sources of carbon to be immense. Also, consumer demand for products that are safer for humans and the environment is driving increased utilization of bioplastics and alternative safer chemicals in a diverse array of bio-based products.

Many biofuel and biochemical technologies are reliant upon agriculture-based systems for feedstock at this time, but continuing developments relative to using cellulosic materials are improving

[13] Bratkovich, Steve (2009). Community-*Based Bioenergy and District Heating: Benefits, Challenges, Opportunities, and Recommendations for Woody Biomass.* P. 6. Dovetail Partners, Inc. Retrieved on August 17, 2010, from http://www.dovetailinc.org/files/DovetailDistHeat0409.pdf.

prospects for forest-based biomass to play a significant role in the market. Extraction technology for bioactive compounds and specialty chemicals has been utilized for years and provides a high-value niche market for biomass sources.

In addition to its use as a feedstock for the manufacturing of biofuels and biochemicals, biomass increasingly is being used to generate heat and power, with European countries leading the market's development. In the United States, the use of wood-based combined heat and power has been (and remains) concentrated in the traditional forest products industry, which produces a majority of its energy needs from mill residues. As new biomass-based industries develop, demand for raw materials will drive increased utilization of mill and logging residues. In addition, increasing importance will be placed on processes that densify wood residue to decrease transportation costs and increase combustion efficiency.

Global trade in biomass nearly doubled from just over 6 million tons in 2003 to an estimated 13 million tons in 2009.[14,15] Wood pellets, used for heat and electricity generation, accounted for 3.3 million tons of the 2007 trade.[14] Global sales of biomass are expected to continue their growth in the coming years. In the United States, 4.4 million tons of pellets were produced, with 250,000 tons going to export markets.[16]

Environmental Considerations

Forests have been shaped by thousands of years of human interaction. Ever since forestland was cleared by the early Native Americans,[17] forest management activities have worked along with natural processes to create a mosaic of forest cover across the state that is interdependent with human activities. Ecology of forestland is complex and slow moving, but the immense knowledge about the forest can continue to move all interests forward. There continue to be opportunities to use management techniques to ensure productivity of the forest while maintaining wildlife environments, ecological health, and water quality.

Carbon Impacts

Trees play a critical role in carbon storage, or sequestration, throughout their life cycles. This is a role that is critical to recognize when carbon policies are implemented. During the process of photosynthesis, trees take carbon dioxide out of the air, store the carbon in their roots, trunks, branches, and foliage, and release oxygen.[18] Some of this stored carbon is released after harvest, as the residues decompose or are burned for energy. However, the carbon stored in durable wood products, like lumber or OSB, remains locked up in those products until their disposal and decomposition.[19] This storage, especially in lumber, can be significant, and should be considered when accounting for carbon in durable goods.

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[14] United Nations (2010). *Forest Products Annual Market Review 2009-2010.* Retrieved on August 17, 2010, from http://timber.unece.org/fileadmin/DAM/publications/sp-25.pdf

[15] Jim Boywer, personal communication, October 5,2010

[16] United Nations (2010)

[17] Forest History Society (2010). American Prehistory: 8000 Years of Forest Management. Retrieved on August 31, 2010, from http://www.foresthistory.org/Education/curriculum/Activity/activ1/essay.htm

[18] Covey, Kristofer, and Orefice, Joseph. *Forests and Carbon: Science, management, and policy for carbon sequestration in forests*. P. 53. Retrieved on September 3, 2010, from http://environment.yale.edu/publication-series/5947

[19] United Nations Economic Commission for Europe (2008). *Harvested Wood Products in the Context of Climate Change Policies*. Retrieved on August 10, 2010, from http://www.unece.org/timber/workshops/2008/hwp/Proceedings_28Oct08.pdf

While some forest management programs can lead to an initial increase in carbon emissions, in the long term, these treatments may decrease the risk of catastrophic releases of stored carbon in fires while improving ecosystem health and stability. Management programs can boost the amount of carbon sequestered by re-stocking unhealthy or overly-thinned stands and by restoring forest on unforested lands. Carbon payments can improve the economics for those management regimes. Although the capability is limited, increasing sequestration using forestland proves cost-effective when compared to alternative sequestration systems.[20]

Carbon benefits extend into the combustion of wood for energy, depending on the type of wood being used, the efficiency of the combustion system, and the fuel being displaced. The emissions from combustion of wood are offset as the trees on that site regenerate and rapidly re-uptake carbon. Although the net emissions may be lower than some fossil fuels, the life cycle impact is not carbon negative due to the timing of the sequestration and the emissions from transportation and handling of wood. [21]

Other Pollutants

One of the greatest emissions benefits from the utilization of biomass as a substitute for coal is the reduction in mercury emissions. In 2005, energy production, mostly from coal, accounted for approximately 58 percent of Minnesota's total emissions.[22] Coal contains 6 to 26 times more mercury than woody biomass does.[23,24] This is critical to the state, since 989 out of the 1,458 lakes in Minnesota designated as impaired are on the list due to mercury contamination, which in turn leads to guidelines limiting game fish consumption across the state.[25]

While biomass generally produces fewer emissions than coal, particulate matter emissions are relatively high for biomass energy.[26] As a result, particulate emission has emerged as an important issue for regulation of wood-based energy. A regulation soon to be implemented by the U.S. Environmental Protection Agency on "Boiler Maximum Achievable Control Technology" (Boiler MACT) is likely to provide significant challenges for the emerging biomass combustion industry. For biomass combustion, this rule would limit particulate and carbon monoxide (CO) emissions to levels that some in industry deem unachievable, and uncertainty around the rule is already stalling project

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[20] Stavins, Robert, and Richards, Kenneth. (2005). *The cost of U.S. forest-based carbon sequestration.* Retrieved on September 16, 2009, from http://www.pewclimate.org/docUploads/Sequest_Final.pdf

[21] Walker, et. Al. (2010). Biomass Sustainability and Carbon Policy Study. Manomet Center for Conservation Sciences. Retrieved on August 5, 2010 ,from http://www.manomet.org/sites/manomet.org/files/Manomet_Biomass_Report_Full_LoRez.pdf.

[22] The Manomet Center for Conservation Sciences noted in this recent Massachusetts-specific life cycle assessment on biomass utilization that, depending on forest management regimes, biomass sources utilized, energy conversion technology used, and the fossil fuel source that biomass is replacing, the carbon benefits could be significantly delayed. However, if low-value sources of wood and products of sustainable harvesting practices are utilized in high-efficiency systems as a substitute for fuels like coal or fuel oil, carbon benefits can be significant. In addition, appropriate forest management practices mimic natural disturbances and decrease the risk of catastrophic emissions from pests, diseases, and fires.

[22] Minnesota Pollution Control Agency (2005). *2005 Mercury Reduction Progress Report to the Minnesota Legislature*. Retrieved on October 1, 2010, from http://www.pca.state.mn.us/index.php/topics/mercury/mercury-in-minnesota-research-and-reduction-initiative.html?menuid=&missing=0&redirect=1

[23] Thy, Peter, and Jenkins, Bryan (2010). *Mercury in Biomass Feedstock and Combustion Residuals*. Journal of Water, Air, and Soil Pollution. 2010, vol. 209, n°1-4, pp. 429-437 DOI: 10.1007/s11270-009-0211-9

[24] Mastalerz, et al. Mercury content and petrographic composition in Pennsylvanian coal beds of Indiana, USA. International Journal of Coal Ecology. Volume 68, Issues 1-2, 1 August 2006.

[25] Minnesota Department of Health (2010). *Fish Consumption: Frequently Asked Questions*. Retrieved on October 27, 2010, from http://www.health.state.mn.us/divs/eh/fish/faq.html

[26] Nussbaumer, Thomas et. al. (2008) Particulate Emissions from Biomass Combustion in IEA Countries. Pg. 1. Retrieved on November 1, 2010 from http://www.scribd.com/doc/28334087/Particulate-emissions-from-biomass-combustion

investments.[27] The final rule is expected to be released no later than January 2010.[28] Along with these issues, emission control technologies that minimize sulfur oxides and nitrogen oxides will also be important for wood-based energy systems, as these emissions are generally higher for wood than for fossil fuels.[29]

Environmental Challenges to the Health of Forests

Diseases and Pests

The introduction of invasive tree diseases and pests, combined with decreasing severity of winter kills of these agents due to climate change, has contributed to an increase in the prevalence of various diseases and infestations that have the potential to devastate certain species across the state. Emerald ash borer (EAB), first found in Minnesota in St. Paul in 2009, is expected to spread throughout the state over the next few decades. Minnesota has the highest concentration of ash forestland in the United States, with an estimated 867 million trees in low-lying ash swamps, along with a high concentration of street trees.[30] With its near 100 percent mortality rate, EAB will have profound effects on Minnesota's ash resource for years to come.[31] Mitigation efforts include diversification of ash-dense areas through harvest of the existing trees in addition to seeding or planting other species.

Fire

Fire is an integral ecological component for many of Minnesota's forest cover types. Historically, fire cycles of 50 to 100 years stimulated fire-dependent species like black spruce and jack pine to release seeds and prompted regeneration of aspen and birch.[32] Human suppression of fires, combined with an increase in temperatures and humidity over the past 100 years, has significantly lengthened the fire cycle. Subsequent fuel accumulation in forests has led to more intense, stand-replacing fires with the potential to sterilize soil and an inability to regenerate fire-reliant species.

Climate Change

Increases in temperature associated with climate change are predicted to have profound effects on Minnesota's forests. While warming temperatures and the rise in atmospheric carbon dioxide is predicted to cause a slight increase in the productivity of boreal forests,[33] stresses caused by increases in wildfires and potential drought are predicted to negate this productivity increase. Minnesota sits at the meeting place of the prairie, hardwood forest, and boreal forest biomes.[34] As temperatures change, those borders are likely to transition to other types of forests, changing the ecological composition of the state.[24]

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[27] Deckard, Don (2010). *Wood Markets Monthly: August 30, 2010*. Minnesota Department of Natural Resources. Retrieved on October 25, 2010, from http://forest.nrri.umn.edu/documents/10Aug%20MARKET%20NEWS.pdf/view

[28] Wisconsin Paper Council (2010).Presentation at the Forest Resource Association Annual Meeting, Duluth, MN, October 25, 2010.

[29] Jess Richards, personal communication, July 25, 2010.

[30] Minnesota Department of Agriculture (2010). Emerald Ash Borer Prevention, Early Detection & Rapid Response. Retrieved on May 5, 2010, from http://www.mda.state.mn.us/plants/pestmanagement/eab.aspx

[31] Emerald ash borer is just the most imminent threat to Minnesota's forests. Other invasive threats include Dutch elm disease, the Asian long-horned beetle, the hemlock woolly adelgid and the balsam woody adelgid, and sudden oak death.[31] Warmer temperatures could also lead to more chronic infestations of native diseases and pests, like the mountain pine beetle and the eastern larch beetle. Appropriate management of stand age and composition will be necessary to combat these threats.

[32] Frelich, Lee, and Reich, Peter (2009). *Wilderness conservation in an era of global warming and invasive species: a case study from Minnesota's Boundary Waters Canoe Area Wilderness.* Retrieved on August 31, 2010, from http://forestecology.cfans.umn.edu/FrelichNAJ2009.pdf.

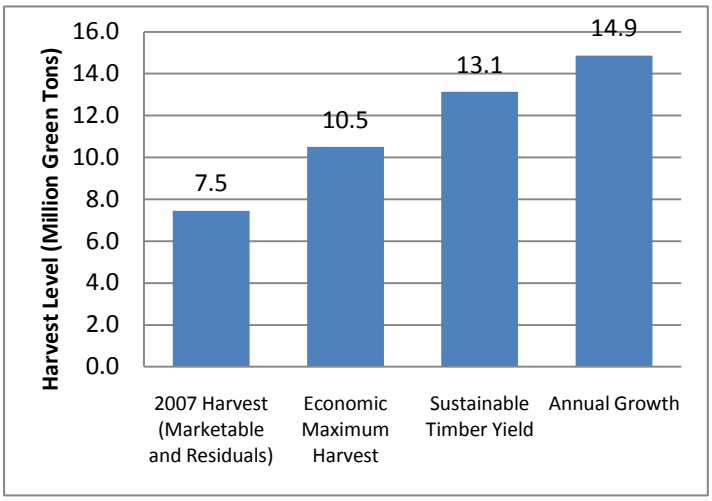
[33] Chen, et al (1999). *Effects on climactic variability on the annual carbon sequestration by a boreal aspen forest.* Retrieved on September 1, 2010, from http://research.eeescience.utoledo.edu/lees/papers_PDF/Chen_1999_GCB.pdf.

[34] Frelich, Lee, and Reich, Peter (2009).

State of the State: Minnesota's Forest-Based Industry

Supply Overview

Figure 7: Minnesota Timber Harvest Benchmarks

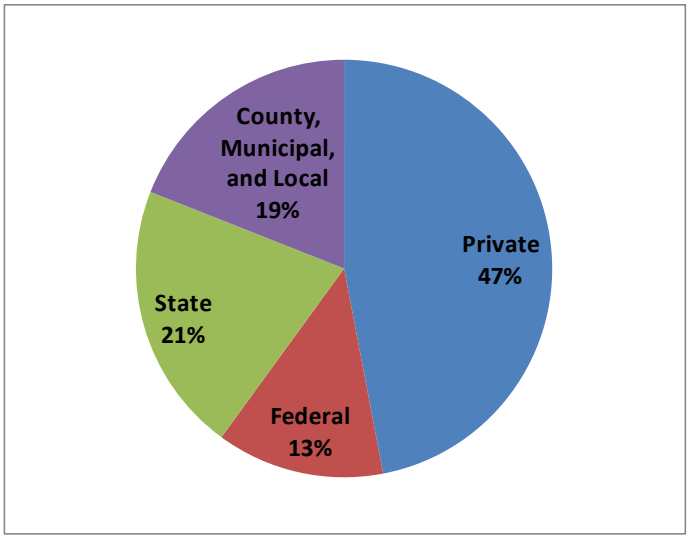


Source: Minnesota Department of Natural Resources (2009).

Minnesota has the capacity to harvest 12.6 million green tons (MMGT) while sustaining the existing inventory of forest, though this level has never been reached.[35] The peak annual harvest of wood in Minnesota occurred in 2005 at 8.6 MMGT, which also marked the peak annual import of wood to the state at 1.6 MMGT.[36] However, the economic maximum timber harvest is estimated to be 10.5 MMGT including logging residual harvest, and 9.5 MMGT if logging residual is not included.[37] In 2008, timber harvests were 6.8 MMGT, a 26 percent drop from the 2005 peak. Of this, 5.8 MMGT was pulpwood and 1 MMGT were sawlogs. Currently, there is a 3.2 million green ton surplus of wood according to a Minnesota Department of Natural Resources analysis done in 2010 using historical supply data and economic price thresholds, with the majority of this being in pulpwood and residual markets.[38]

Minnesota's recent loss of OSB and lumber capacity has led to weak demand for timber and a chronic underutilization of Minnesota's forest resources, translating to lost jobs and an inability to properly manage some forested areas. In the long term, this could lead to lasting damage to the forest products logistics system, decreases in forest productivity, and a sharp decline in wages and quality of life in forest-reliant communities across northern Minnesota.

Figure 8: Minnesota's Forest Land Ownership



Source: Minnesota Department of Natural Resources (2009).

Land Ownership

Minnesota's 15.6 million acres of timberland consists of 47 percent private and 53 percent public land.[39] Private lands

[35] Schwalm, Christopher R. (2008) *Forest Harvest Levels in Minnesota: Effects of Selected Forest Management Practices on Sustained Timber Yields.* Revised 2009. Retrieved October 15, 2010 from http://files.dnr.state.mn.us/forestry/um/sustainedyieldreport.pdf

[36] Minnesota Department of Natural Resources (2009).

[37] Deckard, Don. (2010) Economic Opportunities for Minnesota's Wood. Unpublished Document. May 2010.

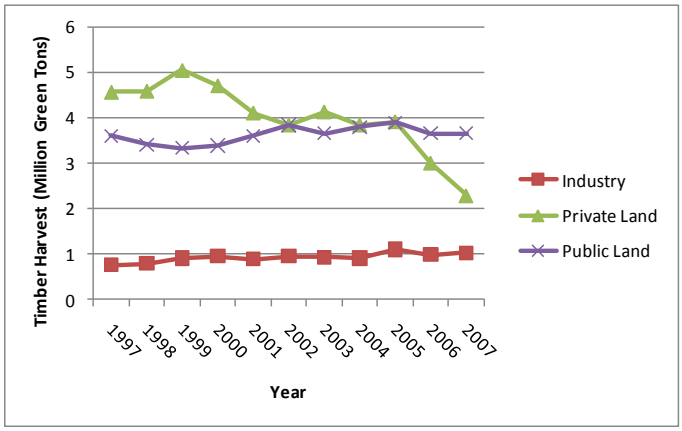
[38] Deckard, Don. (2010) Economic Opportunities for Minnesota's Wood. Unpublished Document. May 2010. Don Deckard, personal communication May 15, 2010. The surplus assumes a small reserve capacity to remain in the forest for market stability.

[39] Minnesota Department of Natural Resources (2009).

are held by a diverse array of owners, including small landowners and industrial timberlands owned by paper companies, timber investment management organizations, (TIMOs), and real estate investment trusts (REITs). As shown in Figure 8, the largest portion of recent harvest declines has been on private lands, primarily because historically low stumpage prices diminished the attractiveness of timber sales, and led to private landowners pulling stumpage out of the market. [40,41]

On public lands, declining revenues have increased pressure on public budgets that fund the administration of timber sales and forest management operations. In 2009, Minnesota's public agencies earned revenue of $33.6 million from timber sales, down from $42.2 million in 2008.[42] This 20.4 percent revenue decrease corresponded with a 5 percent decrease in stumpage sold. This could potentially create a risk of declining staff for timber sales administration and continuing operation of forest management activities. While these types of activities might not always directly bring profits to the state government, they stabilize forest-reliant communities and provide stable supplies for industrial activity across the state. As state budgets grow tighter and low stumpage prices make it more difficult to cover costs, the risk of harvest declines on public lands is expected to increase, with stark implications for forest health and the overall health of forest-based industries in Minnesota.

Figure 9: Timber Harvests by Land Ownership Type



Source: Minnesota Department of Natural Resources, Minnesota Forest Resources Report.

Sustainable Forest Management Guidelines

Spurred by public concern about increasing harvest levels to meet demand from emerging OSB markets in the 1980s, in 1989 Minnesota's Environmental Quality Board commissioned a timber harvesting Generic Environmental Impact Statement (GEIS).[43] This report investigated the economic, ecological and social impacts of timber harvesting at three different levels in the state. This process led to the eventual passage of the Minnesota Sustainable Forest Resources Act, which remains some of the strongest voluntary protection of forest health by a state. [44] This legislation established the Minnesota Forest Resources Council (MFRC) and set Minnesota's high goals for sustainable management of the forest on public lands. Today, forest certification programs provide oversight to ensure the implementation of management plans that provide for the long-term ecological health of the forest. The council's robust site-level management guidelines and landscape-level education and conservation programs help to ensure that Minnesota maintains sustainable and healthy working

[40] Minnesota Department of Natural Resources (2008). *An Initial Estimate of Harvest Level Impacts of Mill Shutdowns/Slowdowns*. Retrieved on July 22, 2010 from http://www.mlep.org/documents/mnestimatedwooduse121508.pdf

[41] Minnesota Department of Natural Resources (2009).

[42] Minnesota Department of Natural Resources (2010). *Public Stumpage Price Review*. Retrieved on August 3, 2010 from http://files.dnr.state.mn.us/forestry/timber_sales/stumpage/stumpageReviewReport2009.pdf

[43] The full report can be found here: http://iic.gis.umn.edu/download/geis/documnts.html

[44] Kilgore, et al. (1996). *Innovative Forestry Initiatives: Minnesota Prepares for the Future.* Journal of Forestry 94(1) 21-25. View the act here: https://www.revisor.mn.gov/statutes/?id=89a&view=chapter

forests. Combined with certification of almost 8.4 million acres of public and private forestland,[45] these guidelines help preserve the state's forest legacy while helping forest product companies meet their sustainable procurement goals and target niche markets.

Silvicultural Improvements

Activities to increase the output of forestland while supporting ecological health are likely to expand in the coming decades in response to rising concern about forest health, consumption of logging residuals, carbon pricing, and increasing demand for forest-based products due to global population and economic growth. With intermediate treatments, such as partial thinning, some of the trees and biomass in a stand are harvested, thus decreasing competition for light and nutrients for the timber left standing. Thinning, especially when it leads to greater biodiversity and restoration of healthy stand dynamics, can increase the total biomass produced in some forest types, while reducing the risk of catastrophic releases of carbon from fires or disease.[46] This usually will increase carbon sequestered in the forest. Additionally, partial thinning allows for more frequent utilization of timber and, thus, greater incentives for sustainable forest management on private lands.[47]

Supporting strong markets for biomass can increase the incentive to conduct these silvicultural operations. This presents an opportunity to increase the amount of biomass available for existing and emerging industries while protecting wildlife and ecological health by following Minnesota's harvesting guidelines.

Types of Biomass

Mill Residue

The vast majority of biomass supply comes from mill residue. This includes bark, chips, sawdust, and other components of the wood that did not make it into the final products. Nearly all of the mill residue produced from forest product operations is already used,[48] though there is interest in ensuring the value from these resources is maximized. Supply of this biomass is strictly dependent on production from traditional industries.

Residuals from Logging Operation

The tops and limbs of trees harvested during traditional logging operations have been gaining increasing interest as biomass markets develop. However, since industry requires a steady, stable supply to make investments, this market has been slow to develop. Logging residuals are not always cost-effective to harvest and transport at current prices, and in some cases in today's markets, roundwood can be delivered to a facility at a lower cost. In 2009, 1 million green tons of wood from logging operations were used for energy, and 600,000 green tons was marketable roundwood.[49] Transportation of this type of biomass can be especially difficult, so smaller-scale facilities are more likely to be capable of using logging residual.

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[45] Minnesota Department of Natural Resources (2010). *Minnesota Forest Certification Data*. Retrieved on September 19, 2010, from http://www.dnr.state.mn.us/forestry/certification/certifiedforest_data.html

[46] Bowyer, Jim (2009). *The power of silviculture: Employing thinning, partial cutting systems, and other intermediate treatment.* P. 2. Dovetail Partners Inc. Retrieved on June 3, 2010, from http://www.dovetailinc.org/files/DovetailSilvics0509.pdf

[47] Bowyer, Jim (2009).

[48] Anna Dirkswager, Personal Communication, October 21, 2010.

[49] Anna Dirkswager, Personal Communication, October 21, 2010

Commoditization of the resource can provide stability in availability and price, and this can occur through the creation of value-added arrangements along the value chain. A market structure that rewards landowners, loggers, and biomass producers for providing clean residual, while being delivered for a reasonable cost, is likely to develop over time as demand increases. Payments to support ecological services and silvicultural practices can accelerate supply development as well.

Dedicated Energy Crops

The increased utilization of short-rotation woody crops has the potential to increase the amount of available biomass, both for energy and pulpwood. Short-rotation woody crops, consisting primarily of willow and hybrid poplar planted in close vicinity for rotations of four to 15 years, are a new potential source of small-diameter biomass.[50] Verso Paper's mill in Sartell, Minnesota, currently procures 25 percent of its hardwood supply from short-rotation hybrid poplar plantations near Alexandria, Minnesota.[51] With current policy incentives for these types of plantations, their utilization for paper and energy is expected to increase in the coming years.[52]

Other Woody Biomass

There is a significant amount of biomass across the landscape, and opportunities abound for finding local, small-scale supply chains. Urban wood waste from storm damage and urban development provides a significant amount of wood supply for District Energy, the wood-fired combined heat and power facility that provides steam heat to downtown St. Paul.[53] Furthermore, brushland has the potential to be a resource for certain procurement circles if the price for biomass is high enough to justify the harvest and transport of these sprawling trees. These species, such as willow, alder, and hazel, and these lands could yield millions of green tons annually.[54]

Agricultural Biomass

Minnesota's vast array of farmlands is likely to be a significant resource available to industry. Agricultural residues and processing wastes can provide the feedstock for multiple bio-based fuels, chemicals and materials that will continue to develop over time. It is important to consider opportunities for synergies among the forestry and agricultural communities that will become more clear as biomass industries continue to develop.

[50] Dickmann, Donald. *Silviculture and biology of short-rotation woody crops in temperate regions: Then and now.* Michigan State University Department of Forestry. Biomass and Bioenergy 30(8-9) P. 696-705.

[51] Eric Dykhuis, personal communication. August 18, 2010.

[52] At this point, newly planted short-rotation woody crops and whole tree wood is not included in the national advanced biofuel standards.

[53] Ever-Green Energy (2008). *Frequently Asked Questions.* Retrieved on September 2, 2010, from http://www.districtenergy.com/faq.html

[54] Rack et. al. (2010). Development of Procedures to Assess Brushland Resources for Woody Biomass Energy Markets. Minnesota Department of Natural Resources. Retrieved on October 6, 2010, from http://files.dnr.state.mn.us/forestry/um/nrri-DNRBrushlandAssessmentReport-2010.pdf

Demand Overview

In 2007 in Minnesota, 74 percent of harvested wood went into pulp and paper and OSB production, while 17 percent went into lumber and specialty products markets. The final 9 percent of the annual harvest, primarily made up of logging and mill residues or byproducts, was used to produce heat and electricity.[55] Thus, Minnesota has a diverse array of industries utilizing wood today, including use of wood for energy generation, and an understanding of Minnesota's assets is critical in understanding the relevant interactions for emerging industry growth.

Figure 10: Minnesota's 2007 Harvest: Wood Use

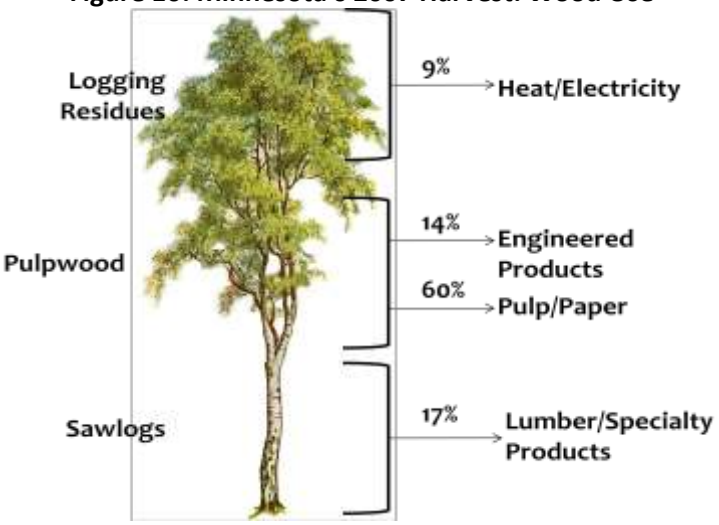
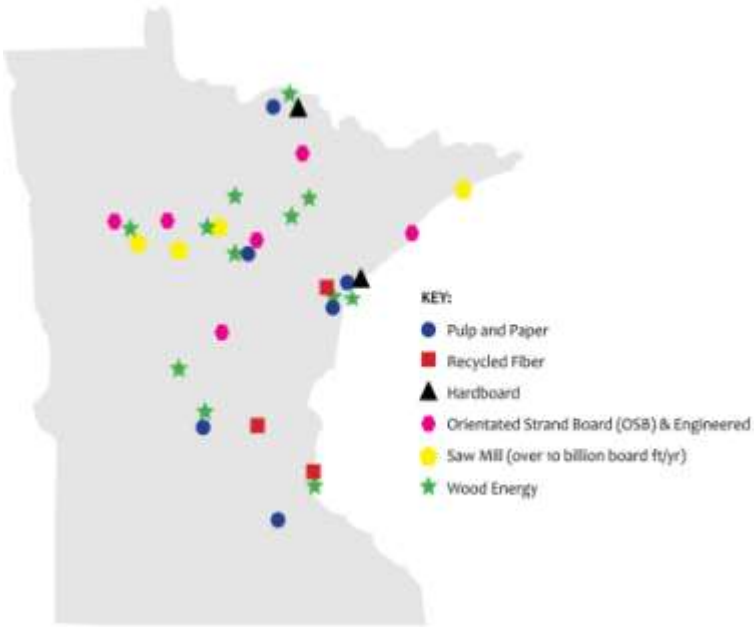


Figure 11: Minnesota's Wood-Using Industries



Sources: Becker, Dennis et. al. (2010) 2010 Outlook for Forest Biomass Availability in Minnesota: Physical, Environmental, Economic, and Social Availability. Retrieved October 19, 2010 from http://www.forestry.umn.edu/Publications/StaffPaperSeries/index.htm and Minnesota Department of Natural Resources (2009).

Pulp and Paper

The pulp and paper industry is the largest consumer of wood in the state, having procured 75 percent of the pulpwood sold in 2008, at 4.3 MMGT (1.9 million cords). Direct employment in these mills totals 3,024 people, and total shipments are 1.7 billion dollars.[56]

Six mills that use freshly harvested fiber are currently operating in the state.[57] Five of these mills procure their own wood and extract fibers in pulping processes, while one buys pulp on the open market. Two other mills are using recycled paper as raw material for manufacturing paper products.

Minnesota primarily produces printing and writing papers, and its mills generally are impacted by the same broad trends and issues that affect the industry nationally. The state's paper mills have kept up on capital investments and are well-positioned in terms of technology

[55] Minnesota Department of Natural Resources (2009).
[56] Includes 2 Recycled Mills. U.S. Economic Census (2007). NAICS code 32212.
[57] Virgin fiber refers to cellulose that is derived from logs that have recently been harvested, while recycled fiber refers to mills that utilize recycled paper as a feedstock.

and cost-competitiveness in the global market,[58] so there is not a threat of a permanent paper mill closure in the near-term. Even though downward trends for paper demand could prove challenging over the long-term, there are some prospects for expansion of existing mills in the state.

Oriented Strand Board (OSB)

The massive decline in demand due to the recession combined with increased competition from imports has contributed to the closing of three of the state's five OSB mills.[59] Minnesota has very little plywood production, but this, too, has followed similar trends across the nation. From its peak, the OSB industry shed about 750 direct jobs across northern Minnesota, which consists of over three quarters of the industry's workforce.[60] It has been estimated that each direct job in an OSB plants supports an additional 2.66 jobs in the local economy.[61] With that multiplier effect, the loss of 750 direct jobs translates into an estimated 1,995 jobs lost across northern Minnesota. The human impacts of these losses are significant and lasting. The closed OSB plants consumed a combined total of 1.1 MMGT of pulpwood and sawlogs.[62] In this industry, consumption of pulpwood has declined to about 380,000 green tons and total employment now stands at about 280, primarily at Norbord's Bemidji, Minnesota mill and Louisiana Pacific's Two Harbors, Minnesota mill.[63,64]

Lumber

Like OSB, lumber has been hit hard by the housing decline. Minnesota has over 500 sawmills,[65] with about 60 percent of sawlogs harvested in the state processed in Potlatch's Bemidji, Minnesota mill.[66] Many of the other sawmills are small operations, and maintaining profitability has been challenging given the low demand.

Minnesota's sawmills procure 1 MMGT of wood per year[67] and employ 583 people.[68] Downstream processes include truss manufacturing, construction, furniture, and others. Notably, the state has the nation's largest wood-framed window industry. When including the downstream manufacturers of wood products with lumber, as well as furniture manufacturing, this sector employs over 21,000 people.[69] Beyond this impact, the industry's byproducts support the supply chain for multiple industries, including pulp and paper, animal bedding, and energy.

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[58] Don Deckard, personal communication, March 12, 2010.

[59] Weyerhaeuser Corporation (2007). *Weyerhaeuser to Indefinitely Curtail Three iLevel Building Products Plants*. Retrieved on August 11, 2010, from http://www.weyerhaeuser.com/Company/Media/NewsReleases/NewsRelease?dcrId=07-10-18

[60] Potlatch Corporation (2004). *Potlatch agrees to sell Minnesota Oriented Strand Board Facilities to Ainsworth Lumber Co. Ltd. For $457.5 Million.*Retrieved on August 11, 2010, from http://ir.potlatchcorp.com/phoenix.zhtml?c=100877&p=irol-newsArticle&ID=607195&highlight=

[61] University of Minnesota, Duluth Labovitz School of Business and Economics (2008). The Economic Impact of Declines in Forestry-Related Industries in Minnesota, Wisconsin and a Three-State Region Part 2: Targeted Impacts—Oriented Strand Board Wood Products Manufacturing. P. 11.

[62] Minnesota Department of Natural Resources (2008).

[63] Lakesnwoods.com: A Guide to Minnesota Communities (2009). *Bemidji, Minnesota Community Guide.* Retrieved on August 19, 2010, from http://www.lakesnwoods.com/Bemidji.htm,

[64]Two Harbors Chamber of Commerce. *Area Manufacturing. Retrieved on August 19, 2010, from* http://www.twoharborschamber.com/manufacturing.htm

[65] Minnesota Department of Natural Resources (2009).

[66] Pete Auby, personal communication. July 28, 2010.

[67] Deckard, Don (2010).

[68] U.S. Economic Census (2007). NAICS code 321113

[69] Minnesota Forest Industries (2008). *Minnesota Forest Facts : Economy.* Retrieved on September 4, 2010, from http://www.minnesotaforests.com/resources/pdfs/economy.pdf

Liquid Fuels and Biochemicals

Minnesota has been among the world leaders in the development of technology in the biochemical industry, and the opportunity to expand this value chain into manufacturing presents a unique opportunity to remain the world leader in the development of advanced renewable materials. Beginning from a Minnesota-based company, at least 12 companies have spun out to develop new businesses. These companies range from advanced biofuel manufacturers to plasticizers to large-scale polymer producers, and the market will continue to grow as the industry develops. The biochemicals market is projected to be worth up to $585 billion by 2025, representing a six-fold increase over today's value. [70] In Minnesota, there is an active biobased chemical operation extracting high-value chemicals from tamarack trees, and other companies in earlier stages of development. Furthermore, the state's agricultural industry was among the first to manufacture corn-based ethanol in high volumes, contributing significant wealth to rural communities.[71]

Heat and Electricity

As a cold-weather state with strong power demand from the manufacturing sector and significant biomass resources, Minnesota has substantial opportunities to produce heat and electricity from biomass. As of 2009, Minnesota had 41 facilities that consumed biomass for the production of heat and electricity.[72] Total consumption by these facilities was around 1.8 MMGT.[73] With at least seven more heat and electricity facilities either in the planning or permitting phases, this consumption is expected to expand dramatically in the next five years. Primary utilization can be broken into three main categories: utility, industrial, and commercial and residential.

- **Utilities.** In order to meet customer demand for renewable energy sources and comply with Minnesota's Renewable Electricity Standard (RES), a state statute established a goal that by 2025, 25 percent of electricity consumed in Minnesota would be produced from renewable resources (the goal for Xcel Energy is 30 percent by 2020). Wind is expected to be the primary source of this electricity, but biomass is playing a role in satisfying some of this demand as well. Minnesota's utilities have formed unique partnerships that utilize urban wood waste, mill residues, chipped railroad ties, and some roundwood to produce electricity and heat via combined heat and power systems, wood boilers, or through co-firing with fossil fuels. Large producers include Minnesota Power, the Laurentian Energy Authority, and St. Paul District Energy.

- **Industrial.** Minnesota's industrial generation of biomass energy is largely utilized by paper and lumber mills. All six of Minnesota's paper mills generate some of their power internally, helping to reduce costs in the mill, while providing a useful option for disposal for process wastes. Large industrial consumers include U.S. Steel's Minntac taconite kiln on the Iron Range and Potlatch's Bemidji, Minnesota sawmill. In order to comply with stricter emissions standards and reduce costs from fossil fuels, mining and taconite processing operations in northern Minnesota are likely to expand consumption of biomass in coming years.

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[70] Nieuwenhuizen, Peter and Arthur D. Little. (2010) Many Factors Could Affect the Success of Biochemical Production, So We Project a Market Share of 7-17% by 2025. Retrieved on October 23, 2010 from http://www.icis.com/Articles/2010/06/21/9368973/biochemical-market-forecasts-suggest-strong-growth.html

[71] Ye, Su. (2008) Economic Impact of the Corn and Ethanol Industry in Minnesota. Minnesota Department of Agriculture. Retreived on November 3, 2010 from http://www.mda.state.mn.us/news/publications/renewable/ethanol/cornethanolecon2008.pdf

[72] Anna Dirkswager Personal Communication, October 21, 2010

[73] Anna Dirkswager Personal Communication, October 21, 2010

- **Commercial and Residential.** A number of schools, hospitals, and homes are increasingly using biomass energy. To stimulate demand for wood, some programs have been developed to support consumption in these sectors. "Fuels for Schools" is an example of such a program in various parts of the country. Including wood that is harvested by individuals, residential consumption of fuel wood for heating is 1.5 MMGT.[74]

[74] Barzen, et. Al. *Residential Fuelwood Assessment: State of Minnesota, 2007-2008 Heating Season.* P. 26. Retrieved on September 7, 2010, from http://files.dnr.state.mn.us/forestry/um/residentialfuelwoodassessment07_08.pdf Figure Does not include wood burned for pleasure.

Recommendations for Strengthening Minnesota's Forest-Based Industries

The recommendations below are the result of a year-long process aimed at understanding the issues necessary for moving the forest-based biomass industry forward in a way that will benefit multiple stakeholders. There is a clear understanding that the forest biomass supply chain must integrate with the existing primary forest products industries, and the need for continued utilization is clear. Appropriate and targeted action in this area will help ensure Minnesota's economy and environment benefit in a sustainable manner.

Utilizing the SD model, it is predicted that implementation of these recommendations would result in a net gain of 736 direct jobs in the state of Minnesota; 1,423 jobs are created when including indirect and induced jobs. Furthermore, assurance of a long-term stable supply of wood could spur additional investments in the forest products industry. An estimated 1,500 direct jobs and 3,300 indirect and induced jobs are likely to be created in the 'best case scenario,' which includes expansions in lumber, OSB, paper production, pellet manufacturing, heat and electricity production, and aggressive investment in biofuels and biochemicals.[75]

Recommendation 1: Ensure long-term supply of wood through forest management and increased utilization.

Why: Maintaining forest management capability and long-term supply is a prerequisite for successful long-term growth in any forest-based industry. Furthermore, underutilization of Minnesota's forests is threatening Minnesota's logging infrastructure. Forest products provide a base for the economy, and good forest management programs are a long-term investment into the forest-based economy.

Tactics:

- **Ensure stability in the supply of forest raw materials to the industry by ensuring sustainable financial support for public forest management agencies.** This includes the Minnesota Department of Natural Resources, county land departments, and federal agencies responsible for managing the health of the forests and the supply of raw materials to the industry.
- **Maintain and expand active forest management for forest health, long-term forest productivity, and wildlife habitat.** Promote management practices that provide healthy, productive forests and wildlife habitat as well as a stable timber supply.

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[75] Multipliers have been derived from multiple studies. They should be considered to be estimates.

- **Paper:** University of Minnesota, Duluth Labovitz School of Business and Economics (2008). The Economic Impact of Declines in Forestry-Related Industries in Minnesota, Wisconsin and a Three-State Region Part 2: Targeted Impacts—Paper and Paperboard Mills in Wisconsin. P. 12. Retrieved on June 1, 2010 from https://lsbe.d.umn.edu/departments/bber/projects/Forestry-RelatedMNWIMI2006/part%202%2020june2008.pdf.
- **Engineered products:** University of Minnesota, Duluth Labovitz School of Business and Economics (2008). The Economic Impact of Declines in Forestry-Related Industries in Minnesota, Wisconsin and a Three-State Region Part 2: Targeted Impacts—Oriented Strand Board Wood Products Manufacturing. P. 11. Retrieved on June 1, 2010 from https://lsbe.d.umn.edu/departments/bber/projects/Forestry-RelatedMNWIMI2006/part%201%2020june2008.pdf.
- **Pellets:** Mace, Terry. (2010) Economic Impact Analysis of Wisconsin Pellet Plants. Wisconsin Wood Marketing Bulletin.. July, August, September 2010. Retrieved on October 15, 2010 from http://dnr.wi.gov/forestry/Publications/Newsletters/woodmarket/WWMB2010July-Sept.pdf
- Wisconsin Wood Bulletin, October 2010 .
- **Chemicals:** Mace, Terry. (2009) Unpublished Report
- **Heat and electricity:** Mace, Terry. (2009) Unpublished Report .

- **Ensure the health of the logging and logistics industry by supporting products that have immediate market-entry potential.** This includes pellet manufacturing and renewable energy in geographic locations where new plants will complement and not adversely affect existing forest industries. Utilization of wood is important for loggers to stay in business and for landowners to maintain forest management regimes. This should be a focus of state and local economic development organizations.
- **Improve access to capital to ensure the logging industry remains competitive**. This can be accomplished through establishment or expansion of programs that incent private sector investment, such as low interest loans that allow for expansion of logging operations.

The maintenance of the forest ecosystem and the infrastructure to manage the forest are fundamental needs for the health of the forests and the industries that rely on them. Forest management is needed on both public and private lands to sustain the industry. Ensuring immediate and long-term availability of forests for harvesting and a globally competitive logging and woody biomass processing industry will be necessary for Minnesota to capitalize on current and developing market opportunities.

Public dollars for forest management and stumpage sales multiply through the economy and add significant wealth in the state. With this in mind, shielding these county, state, and federal investments from budget cuts, or providing other funding mechanisms, is critical to the long-term viability of the forest-based economy. Volatility in wood supply negatively affects existing jobs and also increases investment risk for both traditional and emerging industries.

Forest management implementation helps ensure the long-term sustainable supply of wood. These practices create jobs in their implementation, and certain practices can yield biomass for immediate consumption. The state should follow well-established, long-term integrated forest management schemes and introduce new practices to further strengthen the sustainability of the forests and supply of raw materials to the industry. Recommended tools include:

- Bonding dollars for timber stand improvement;
- Utilization of state Legacy Fund dollars for forest retention and management;
- Improvements to private land management incentives; and
- Forest stewardship contracts.

Model Output - Pellets

If pellet production increased by 800,000 green tons over the next four years, this would create approximately 250 pulpwood logging jobs and another 150 jobs in the pellet plant. The model also shows that stumpage price would increase by approximately $2 dollars.

To remain competitive, loggers need access to capital that allows them to acquire state-of-the-art equipment. Investment in new logging equipment has not occurred in the past four years at a rate that maintains capital stock and efficiency. Capital has been squeezed due to a steep decline in demand, and low prices and availability of capital is likely to be a risk for the industry in ramping up demand for timber and improving industrial efficiency. A program for loan guarantees or capital infusions for efficient logging equipment could help ensure the long-term health of the industry and could help keep Minnesota fiber costs down.

Model Output - Aggressive Pellets

If 1.6 MMGT of pulpwood is consumed by emerging industries stumpage prices increase by $4. At this price, competition for resources increasingly affects existing industry.

A fundamental factor in ensuring the viability of loggers and forest-based communities is utilization of wood. Densification through pellet manufacturing or torrefaction, and efficient combustion of wood are some of the near-term opportunities to quickly develop markets for timber. Though there is not the same value-added for these products as for other products of existing forest industries, local and regional markets can be quickly developed. The recent losses in consumption due to OSB factory closures have left loggers under threat. Increasing utilization through emerging industries can keep infrastructure in place while high-value industries continue to develop and logging capability can grow with it.

When considering emerging industries, guiding principles were conveyed by contributors to the current analysis to ensure the greatest benefits for communities, industries, and forests. Appropriate scales of emerging industries should balance local environmental and economic supply factors with the need for economies of scale. An understanding of local supply and demand parameters is necessary for this to occur, and the availability of information for studies detailing wood and biomass availability is a necessity. Furthermore, every effort should be made to use underutilized wood, including in a manner that enhances forest productivity and is within the recommendations of the Minnesota Forest Resources Council Harvest Guidelines for sustainability.

The SD computer simulation model created as part of the project showed that a healthy wood pellet industry in Minnesota would result in approximately 400 new direct jobs and increased stumpage prices. However, the model also showed diminishing benefits beyond 800,000 green tons of pellet manufacturing as increased utilization pushed stumpage prices higher, increased costs across all industries, and changed the market dynamics in a negative manner. These higher prices will present challenges for both existing forest product industries, as well as the emerging pellet industry. These concerns can be mitigated by ensuring a stable, growing supply of wood over the long term.

Recommendation 2: Support efficient utilization of biomass for heat and power generation.

Why: With the slowdown in traditional forest products industries, biomass combined heat and power (CHP) production presents an opportunity to develop markets for Minnesota's timber industry that will allow the health of the industry to be maintained. Technological barriers are relatively low, and manufacturing capability can be established quickly. In addition to sustaining the industry infrastructure, ramping up biomass combined heat and power production would help the state achieve its goals of greenhouse gas reduction and energy efficiency savings while reducing its reliance on fossil fuels.

Tactics:

- **Allow biomass heat and electricity from cogeneration facilities owned by regulated utilities to count towards Conservation Improvement Program (CIP) mandates for energy savings goals.** For example, a utility could receive credits from energy produced in a biomass-fueled combined heat and power system to count toward CIP requirements, as combustion is more efficient and fewer fossil fuels are consumed. This move would aim to increase partnerships among utilities and large users of heat, including industrial facilities and community district heating systems. Most importantly, it would reduce the state's reliance on fossil fuels.
- **Over the long term, explore efficiency-based standards for energy that would award additional credits toward renewable portfolio standards for efficient energy generation.**

For example, using the best available technology for energy production could yield some level of "bonus credits" for every unit of energy generated. This would reward efficient biomass heat generation and CHP.

- **Expand existing tax incentives** for renewable energy systems to include biomass heating and cooling systems, including CHP.

Minnesota has positioned itself as a leader in transitioning from a system that is primarily fossil fuel-based to one that is lower-carbon, sustainable, and innovation-driven. In 2007, Governor Tim Pawlenty signed into law a bill that set a goal for utilities in the state to obtain 25 percent of their power from renewables by 2025 (30 percent by 2020 for Xcel Energy) , which would result in a total renewable requirement of about 27.5 percent of electricity sales by 2025. Other legislation created the Conservation Improvement Program, which requires an energy savings goal of 1.5 percent annually for all regulated utilities. Likewise, Minnesota has minimum liquid transportation fuel content requirements for ethanol at 20 percent by 2013, and a biodiesel mandate of 20 percent by 2015.[76] In contrast, although heat generation accounts for 37 percent of energy consumed in Minnesota, it continues to receive little attention in policy development at both the state and federal level. This lack of attention has actually helped to dis-incentivize the adoption and utilization of clean, highly efficient, and energy-saving technologies specifically designed for direct heat and CHP applications. Any future changes to renewable energy policy should emphasize and ensure efficient utilization of limited resources to reduce Minnesota's greenhouse gas emissions while stimulating Minnesota's economy.

Model Output - CHP

Assuming that this increases the utilization of wood for combined heat and power, the model shows us that at a 400,000 green ton increase, one would expect an increase in total employment of about 130 jobs, the majority in logging.

One policy option for ensuring efficient combustion of wood is to allow heat produced in regulated utility-owned CHP systems to count towards current goals for improving energy efficiency. This mandate is anticipated to be more difficult to meet than the state's Renewable Electricity Standard (RES), and clean, efficient combustion of wood would help address the state's goal of reducing reliance on fossil fuel imports. Credit should be given to utilities supporting these investments on an energy-equivalent basis, where equal value is given for energy and heat production. This could be in the form of heat generation credits that are calculated on a kilowatt-hour basis. Such a measure could be catalytic in fostering development of community based district heating and cooling systems, as well as partnerships with industries concerned with their carbon footprint, such as the steel industry and agriculture-based advanced biofuels. [77]

Furthermore, steering the state toward efficiency-based bonus credits could serve as another step toward ensuring biomass is used in efficient systems, and could help to accelerate the replacement of traditional fossil-fuel dependent systems.

[76] The Ecology Center (2007). *States' Ethanol, Biodiesel and Low-Carbon Fuel Legislation.* Retrieved on October 27, 2010, from http://www.mda.state.mi.us/renewablefuels/documents/ecocenter-SummaryRFS0327.pdf

[77] One billion gallons of the federal government's Renewable Fuels Standard, created with the 2005 Energy Policy Act and expanded with the 2007 Energy Independence and Security Act, can be satisfied with starch-based fuels that lower the carbon footprint by 50 percent under gasoline. Combustion of biomass for process energy is likely to achieve the goal. This does not include corn-based ethanol. http://www.epa.gov/otaq/fuels/renewablefuels/index.htm

Given the limited value added from combustion of wood, it is important to capture value across the value chain. The establishment of companies that manufacture renewable heating systems using the world's best technology is critical to maximize economic impact.

These policies could add jobs in the logging industry for local communities and retain wealth in the region rather than exporting dollars for energy. However, utilizing the SD model, pellet manufacturing scenarios have shown that there is a diminishing return from growth in production, so this policy should be closely monitored before 800,000 green tons lower quality roundwood are consumed annually, given today's market conditions and the current analysis. Beyond 800,000 green tons being utilized for wood pellet manufacturing, the model shows that competition over high-quality feedstocks would result in negative, unintended consequences impacting profitability of all forest industries. Therefore, strategically-planned market development for manufacturing of wood pellets and consumption of roundwood can be supported, and for these reasons, it is recommended that the state support investments in biomass-based heating or become a direct consumer of biomass-based energy systems.

Recommendation 3: Actively pursue emerging high-value opportunities.

Why: Long-term policies and actions should focus on creating maximum value from the forests, so that emerging industries, such as advanced biofuels and biochemicals and biofuels, can sustain themselves in the longer term, just as lumber and paper have stood the test of time for hundreds of years.

Tactics:

- **Develop a strategy for fostering effective partnerships for biofuel and biochemical manufacturing. As a first step, create an inventory of assets** capable of and willing to support the production of biobased chemicals and biofuels in the state, including sawmills, paper mills, agricultural processors, existing ethanol infrastructure, and other feedstock providers.
- **Develop financial programs to encourage and accelarate investment,** including government loan guarantees, to mitigate risk for capital equipment investment for integration of existing and emerging industry.

In the long term, Minnesota has an immense opportunity to lead the world in the development and adoption of advanced bioprocessing toward high-value chemical fuels and products. The state has been among the world leaders in the development of technology in the biochemical industry, and the capability to expand this value chain forward into manufacturing presents an enormous economic opportunity. Co-location or strategic partnerships between existing and emerging players is particularly attractive to this industry to leverage current supply chain availability and to minimize capital expenditures. Loan guarantees and other financial programs that alleviate risk for existing forest-product industries are needed and should be actively pursued.

Model Output - Chemicals and Fuels

An 800,000 GT increase in production of chemicals and liquid fuels could produce 80 jobs in these emerging sectors in a few years, with an additional 250 logging jobs created. The value of these products is significantly higher than heat or electricity. Due to the significant multiplier this industry has, total jobs created would be 620.

The *Destination 2025* report revealed that strengths in materials science, agriculture and forestry processing, technology innovation, and biomass feedstock availability uniquely position Minnesota to lead the world in advanced bioprocessing. Given the impending global growth in this industry, the opportunity to be a recognized global leader will quickly pass Minnesota by if it does not act quickly and decisively. In addition to job creation, there is potential for retention of significant employment through maintained profitability of local paper mills and sawmills that choose to partner as a feedstock supplier or processor. This should be considered a long-term opportunity, as technology continues to develop.

In addition to academia and government, targeted companies in key industries and environmental interests should be involved in the process of creating a vision to develop a strong biochemical manufacturing base for Minnesota's economy. These industries include the traditional forestry industries, loggers, agriculture processors, farmers, and biofuels firms.

Recommendation 4: Foster cooperation in implementation of these recommendations.

Why: Enormous potential exists if Minnesota can manage its forest biomass supply chain in such a way that creates opportunity for both traditional and emerging forest-based industries. Yet, none of this will be possible without an unprecedented level of cooperation, where communities across greater Minnesota pursue opportunities for biomass processing as part of an integrated statewide strategy that marries old with new, and high value with lower value.

Tactics:

- **Formalize relationships among forest-based economic development groups and create joint agendas.** To ensure that the public is aware of forestry issues, collaboration must be maintained between and among the various forest groups located throughout the state.
- **Promote and support education regarding forestry issues and biomass opportunities**, leveraging the capacity of public agencies and forestry groups.
- **Explore and advance integration and collaboration between the agricultural and forestry communities.** Key players, including industry, academia, and government ought to be convened to discuss critical issues necessary for the expansion of the state's biomass-based industries. This should build upon the work that has been done by the Governor's Forestry Sub-cabinet, and the Next Generation Energy Board.

Groups advocating for forest-based issues must speak with a unified voice whenever possible. Discussions among local groups and statewide policy analysts can lay the foundation for building consensus around needs for forest policy. It will be important to have a clear channel of communication focused on forest sector needs from both economic and ecological perspectives. Formally convening regular meetings of representatives from groups throughout the state can ensure sustained progress on policies. Such groups may include the Bemidji Area Forestry Affairs Council, Grand Rapids Chamber of Commerce Forestry Affairs Council, The Koochiching County Biomass Board, and statewide groups such as the Minnesota Forest Resources Council, Minnesota Forest Resources Partnership, the Associated Contract Loggers and Truckers, the Minnesota Logger Education Program, Minnesota Timber Producers, and Minnesota Forest Industries.

Among the key tasks of forestry groups is to foster a general understanding of the issues facing the state's forests and forest-based economy. Public support is critical to growth of the industry. Ensuring that the Minnesota Department of Commerce's Office of Energy Security, Minnesota

Department of Natural Resources, Minnesota Pollution Control Agency, and others in the forestry industry are promoting a shared understanding of issues and opportunities is critical.

One of Minnesota's assets is that it is home to both strong agricultural and forestry industries. Collaboration between these two sectors could prove valuable in developing the full value chain necessary for supporting and expanding biobased products. In many cases, the integration of forest and agricultural resources will be necessary for a biobased economy to move forward. This places Minnesota in a unique and advantageous position. An example is the site integration of wood combustion to support grain-based second generation and advanced biofuels production in an attempt to minimize the operation's carbon footprint. Another is supplemental use of wood in late winter and early spring in agriculturally derived biomass-using facilities to reduce biodegradation of biomass after long periods of storage. This would result in a win-win while cellulosic conversions continue to develop.

APPENDICES

Appendix A: System Dynamics Modeling and Its Application to the Current Report

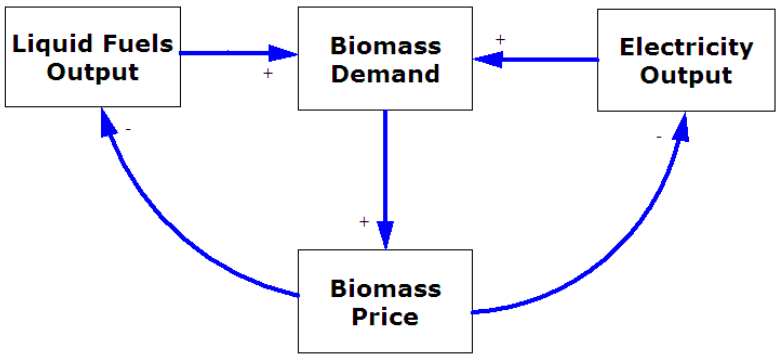
Forestry in Minnesota is a complex sector with many different constituents, ranging from recreational users to end-product manufacturers. These complexities are further compounded by the growing environmental concerns for our planet. In the face of this complexity, System Dynamics (SD) modeling was utilized as a tool for this project, to guide discussions and create understanding among the many experts who supplied their unique perspectives to this analysis. System dynamics analysis was used to build a computer simulator that could be used by project participants to test multiple scenarios and guide final policy recommendations.

With SD modeling, participants have an opportunity to share their "mental models" and project their individual viewpoints into the development of a computer simulation model. SD is used to create a common understanding of the issues, and develop a simulator to test scenarios. Once scenarios are modeled, discussion of the results will tend to confirm or disprove preconceived ideas and identify new issues. This thinking process enables participants to track the causality, and consequently develop a more clear understanding of cause-and-effect relationships. This is critical to understand the real impact of decisions under consideration by businesses and policymakers.

Organizations routinely encounter important problems that impact multiple stakeholders differently in terms of apparent causes, frequency, type and magnitude of impact, timing, and desired solution. SD modeling is a favored option to understand and solve these problems by integrating the various stakeholder needs and demands into an integrated model.

Figure 12 depicts a simple model that could be used for making a decision on an investment that depends on feedstock availability. This is a simplified version of the model being used for the current study. In the model in Figure 11, increasing output of either liquid fuels or electricity increases biomass price, which subsequently increases the total cost for both liquid fuels and electricity. All things being equal, this increase in cost is likely to decrease output. Since these decisions could be made at the same time, it is easy to see that without considering the possibility of increasing electricity output, the cost of production can easily be underestimated.

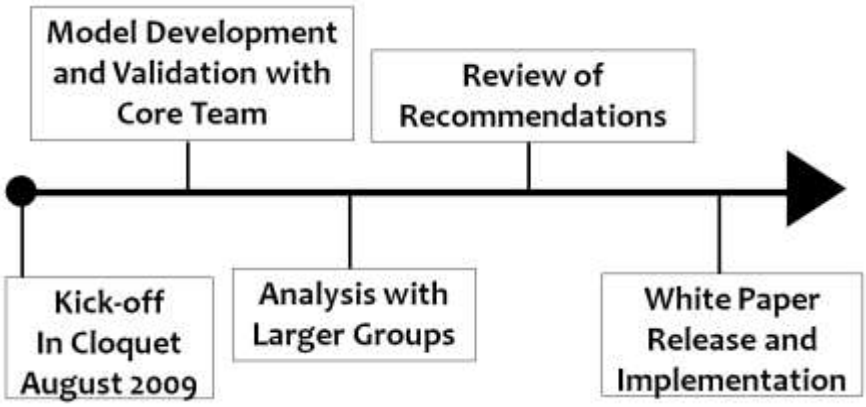
Figure 12: A Sample Model



Project Kick-off

The development of the forest biomass SD model began with a large group meeting with a diverse group of stakeholders, including paper mills, loggers, energy producers, landowners, and environmental groups. Based on the required feedback around the relationships necessary to understand the issues affecting forest biomass supply and utilization, the team continued to work with stakeholders to develop the SD model and collect applicable data.

Figure 13: Project Timeline



Model Development

Following this initial meeting, a core team was assembled to further define and evaluate the interactions in the SD model, validate results, and assemble a range of scenarios for Minnesota's forest products industry.

Figure 14: Statewide Presentations

Statewide Presentations

The preliminary results of these scenarios were presented to diverse stakeholder groups and individual stakeholders in venues across the state. Meetings occurred in Bemidji, International Falls, Duluth, Grand Rapids, St. Paul, and Sartell to continue validating the model, identify regional concerns, and gather statewide input on potential recommendations to enhance the health of the forest products industry in Minnesota.

White Paper Release

Using information derived from the discussions and literature review, the project team worked to consolidate and test scenarios utilizing the model. The work resulted in the recommendations presented in the current report.

Implementation

Over the next two years, teams of individuals and organizations will be assembled to implement the recommendations detailed above. Financial and resource allocations will be needed to accomplish this challenging goal.

Appendix B: Metrics Used in the System Dynamics Model

In order to consistently evaluate the results of each scenario, a few key variables were selected that would be presented in each simulation. These variables, shown in the table below, were selected because of their ability to show impacts on the forest-based economy as a whole. As policy changes or investments are considered during implementation, we will use the model to test those decisions before they are implemented to ensure their appropriateness.

Variable Name	Definition
Forest Products Staff (Full Time Equivelants)	# of employees in the following industries: pulp and paper, engineered products, lumber
Emerging Industry Staff (Full Time Equivelants)	# of employees in the following industries: heat, electricity, pellets, liquid fuels, chemicals
Total Logging Staff (Full Time Equivelants)	# of employees in the following industries: residual, pulpwood, and sawlog logging
Forest Products Wages ($ Millions)	Sum of total wages paid to employees in the following industries: pulp and paper, engineered Products, lumber
Emerging Industry Wages ($ Millions)	Sum of total wages paid to employees in the following industries: heat, electricity, pellets, liquid fuels, chemicals
Logging Wages ($ Millions)	Sum of total wages paid to employees in the following industries: residual, pulpwood, and sawlog logging
Residual Stumpage Price ($)	Price paid to landowner for right to harvest residual
Pulpwood Stumpage Price ($)	Price paid to landowner for right to harvest pulpwood
Sawlogs Stumpage Price ($)	Price paid to landowner for right to harvest sawlogs
Total Staff (Full Time Equivelants)	Total Employment in logging and wood based industries
Total Staff Wages (Full Time Equivelants)	Total wages paid to employees in logging and wood based industries.

Appendix C: Overview of Scenarios Used in the Current Report

Below we describe nine of the scenarios that were used for this project. These were designed to test the key variables associated with the growth of the forest products industry. Employment and wage impacts presented in tables are direct jobs that are representative of wood consuming industries and the loggers that supply them. Indirect and induced job figures take into consideration downstream impacts.

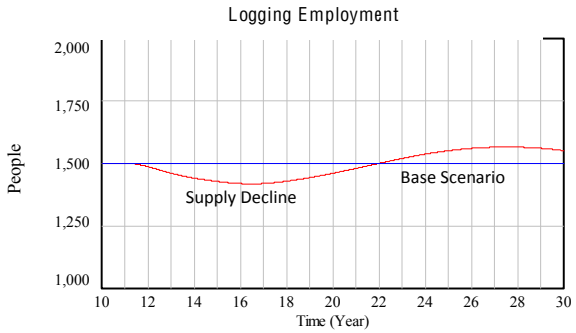
Public Supply of Wood Decreases by 20 Percent

Recommendation 1: Ensure long-term supply of wood through forest management and increased utilization.

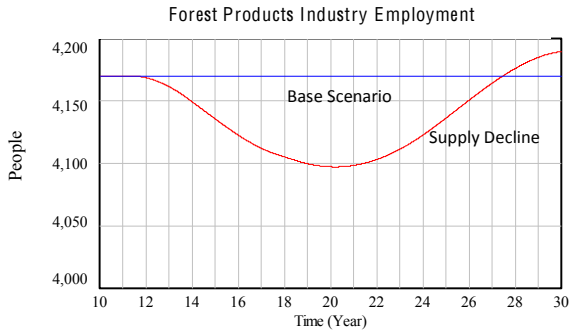
Background: This simulation shows the effects of diminished forest management capability. Through an erosion of funding for management and administration of timber sales, the scenario calls for a 20 percent drop in public supply of timber, corresponding to a 10 percent drop in overall stumpage supply. Given the heavily constrained government budgets of today's environment, the likelihood of dropping public timber sales is relatively high.

Results: A lack of focus on continued management for ecological, economic, and recreation activities will yield a significantly negative payback to public agencies that manage the land due to decreased sales and declining economic activity. Job losses total 138, and wages decline by $5.6 million before recovering. Furthermore, new investments are unlikely to occur in an environment where supply is highly uncertain, and public lands have the capability to ensure a level of certainty to supply. On the positive side, the results of this scenario could be reversed if management programs were treated as long-term investments for the economy and the environment.

Supply Decline		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4189	4097	-73	19
Change	Emerging Industry Staff (# of people)	25	25	25	0	0
Sawlogs: 100k	Total Logging Staff (# of people)	1500	1565	1420	-80	51
Decrease	Forest Products Wages ($ Millions)	219.8	221.0	216.3	-3.6	1.2
Pulpwood: 600k						
Decrease	Emerging Industry Wages ($ Millions)	1.4	1.4	1.4	0.0	0.0
	Logging Wages ($ Millions)	53.4	55.8	50.6	-2.9	1.8
	Stumpage Price ($)	1.50	1.54	1.50	0.04	0.04
	Stumpage Price ($)	17.00	22.36	17.00	5.36	4.73
	Stumpage Price ($)	8.00	10.05	8.00	2.05	2.03
	Total Staff (# of people)	5695	5771	5557	-138	71
	Total Staff Wages (# of people)	274.6	277.8	269.0	-5.6	3.1



The lack of supply leads to job losses in the logging industry, but increasing stumpage prices eventually lead to recovering output and jobs. It is likely that private lands capture market share.



Due to the increase in delivered prices for wood, a significant portion of jobs are lost in the forest products industry before recovering.

Wood Pellet Manufacturing (800,000 Green Tons)

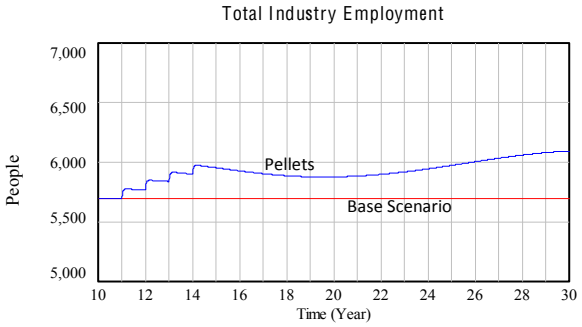
Recommendation 2: Support efficient utilization of wood for heat and power generation.

Background: Utilization of wood in the near term, to ensure loggers remain working and that forests continue to be managed, requires technology and markets that are available today. Pellet manufacturing for heat and electricity generation is one technology being explored in Minnesota. This simulation presented this industry consuming a portion of the state's pulpwood, totaling 800,000 GT, as a critical exercise in understanding impacts. This pulpwood is likely to come from underutilized species and some residual, hopefully minimizing the impact on existing industry.

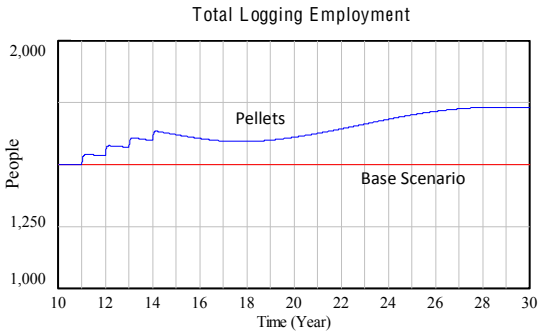
Results: Pellet manufacturing provides an opportunity to increase utilization of wood for the near term and puts loggers back to work. The upside for job creation is significant in the logging industry and the pellet mill, creating 400 direct jobs, corresponding to $17.6 million in wages over the next 20 years.

However, as a result of increased demand, stumpage price does increase and has a slight impact on the existing industry. There is a gradual loss of 86 jobs lost from 2010 to 2022 in the paper and engineered products sectors before recovering. While a small percentage of overall forest products jobs, all effort should be taken to alleviate the impacts on existing industry and protect the emerging industry by ensuring underutilized species are used where appropriate and facilities are appropriately scaled based on local market conditions.

Pellets Increase		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4181	4084	-86	11
	Emerging Industry Staff (# of people)	25	185	25	160	160
Change	Total Logging Staff (# of people)	1500	1732	1500	232	229
Pellets: 800k GT	Forest Products Wages ($ Millions)	219.8	220.5	215.1	-4.7	0.6
	Emerging Industry Wages ($ Millions)	1.4	10.2	1.4	8.8	8.8
	Logging Wages ($ Millions)	53.4	61.7	53.4	8.3	8.1
	Stumpage Price ($)	1.50	1.50	1.50	0.00	0.00
	Stumpage Price ($)	17.00	17.00	17.00	0.00	0.00
	Stumpage Price ($)	8.00	10.25	8.00	2.25	2.14
	Total Staff (# of people)	5695	6094	5695	399	399
	Total Staff Wages (# of people)	274.6	292.2	274.6	17.6	17.6



Total staff grows by 400 over 20 years. The step changes at the beginning of this period are assumed changes in demand that affect the other variables in the model.



Most of the staffing increase is from logging jobs, a critical need for Minnesota's forest-based communities.

Wood Pellet Manufacturing (1.6 Million Green Tons)

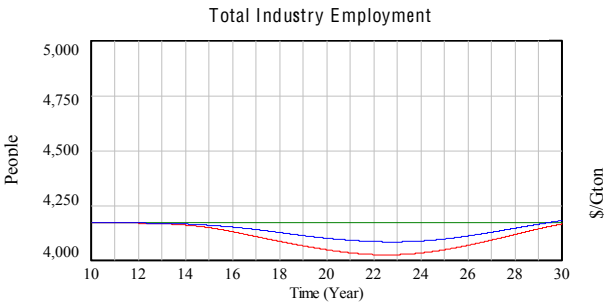
Recommendation 2: Support efficient utilization of wood for heat and power generation.

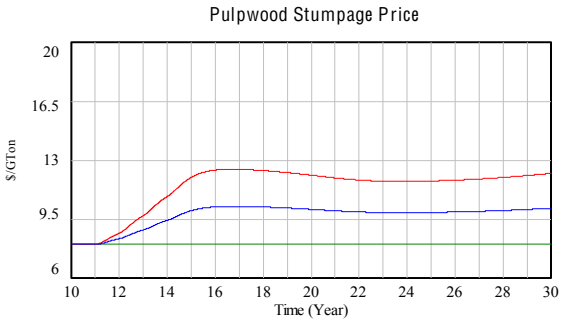
Background: To understand the level of support for emerging industries consuming pulpwood, a second scenario was developed for wood pellet manufacturing. By creating an aggressive scenario that doubles the annual increase in consumption of wood for pellet manufacturing to 1.6 MMGT, we were able to analyze the effects of increasing intensity of wood consumption on industrial activity.

Results: Minnesota experiences diminishing benefits from additional pellet manufacturing beyond 800,000 GT. Stumpage price increases by $4 per green ton in this scenario, leading to both slower growth in pellet manufacturing and declining output and jobs in pulp and paper and engineered products. While the previous scenario showed the addition of 400 net jobs and $17 million in wages from pellet manufacturing at 800,000 green tons, this scenario predicts that if production were doubled only 692 jobs, and $30.8 million would be gained. In sum, the second 800,000 green tons of pellet manufacturing produces fewer jobs than the first 800,000.

Pellets Double Increase		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4170	4026	-144	-4
Change	Emerging Industry Staff (# of people)	25	338	25	313	313
Pellets: 1.6 MMGT	Total Logging Staff (# of people)	1500	1883	1500	383	383
	Forest Products Wages ($ Millions)	219.8	219.8	212.0	-7.8	-0.2
	Emerging Industry Wages ($ Millions)	1.4	18.7	1.4	17.3	17.3
	Logging Wages ($ Millions)	53.4	67.1	53.4	13.6	13.6
	Stumpage Price ($)	1.50	1.50	1.50	0.00	0.00
	Stumpage Price ($)	17.00	17.00	17.00	0.00	0.00
	Stumpage Price ($)	8.00	12.45	8.00	4.45	4.21
	Total Staff (# of people)	5695	6387	5695	692	692
	Total Staff Wages (# of people)	274.6	305.4	274.6	30.8	30.8

Green: Base Scenario
Blue: Pellet Growth of 0.2 MMGT/ YR
Red: Pellet Growth of 0.4 MMGT/ YR





The benefits in terms of jobs and wages for the more aggressive scenario are lower per GT consumed.

The stumpage price increases past $12 per GT, and the model shows delivered pulpwood price increasing to $38. The pellet industry is likely to struggle in such a scenario, and existing industry is threatened as well.

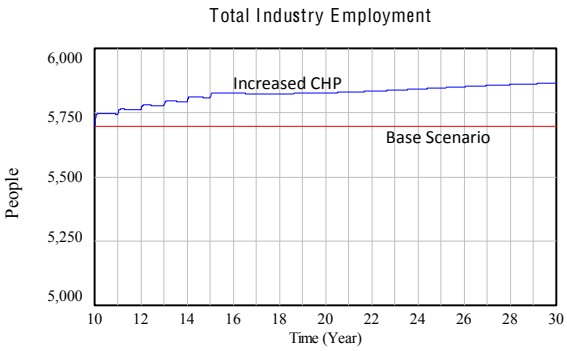
Heat and Electricity Production (400,000 Green Tons)

Recommendation 2: Support efficient utilization of wood for heat and power generation.

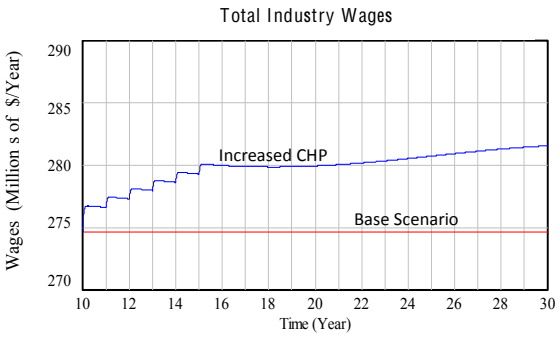
Background: Interest in renewable energy production has been increasing in importance over the last 10 years, and this scenario springs from that interest and additional policies necessary to ensure heat production from biomass. The scenario calls for an annual increase in consumption of residual wood and other forms of wood for heat. Although the model only shows residual consumption of 400,000 green tons, this recommendation also will result in local market development efforts for pellets and provide for immediate utilization of pulpwood.

Results: This scenario creates 170 jobs and adds nearly $7 million in wages before considering indirect and induced employment impacts. This can make a large difference for local communities that can save costs for heating through burning local wood and can put loggers to work. The magnitude of this shift can be greatly impacted by policy and development of systems for moving residual wood through the supply chain.

Increase CHP		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4170	4170	0	0
Change	**Emerging Industry Staff (# of people)**	25	72	25	47	47
Heat: 400k GT	**Total Logging Staff (# of people)**	1500	1623	1500	123	123
	Forest Products Wages ($ Millions)	219.8	219.8	219.8	0.0	0.0
Electricity: 400k GT	**Emerging Industry Wages ($ Millions)**	1.4	4.0	1.4	2.6	2.6
	Logging Wages ($ Millions)	53.4	57.8	53.4	4.4	4.4
	Stumpage Price ($)	1.50	1.66	1.50	0.16	0.16
	Stumpage Price ($)	17.00	17.00	17.00	0.00	0.00
	Stumpage Price ($)	8.00	8.00	8.00	0.00	0.00
	Total Staff (# of people)	5695	5865	5695	170	170
	Total Staff Wages (# of people)	274.6	281.6	274.6	6.9	6.9



Total staff grows by 170. A large majority of this increase occurs in the logging industry.



Not including investment in construction, a sustained increase in staff wages would be over $5 million per year

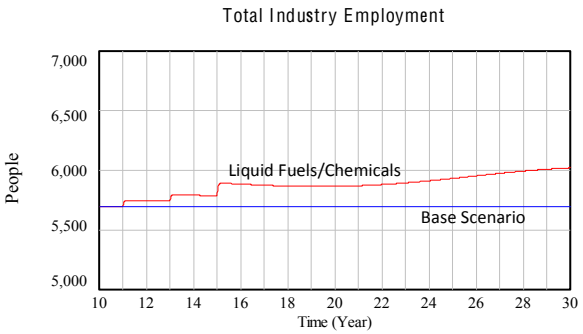
Biofuels and Biochemicals Manufacturing (800,000 Green Tons)

Recommendation 3: Actively Pursue high-value opportunities.

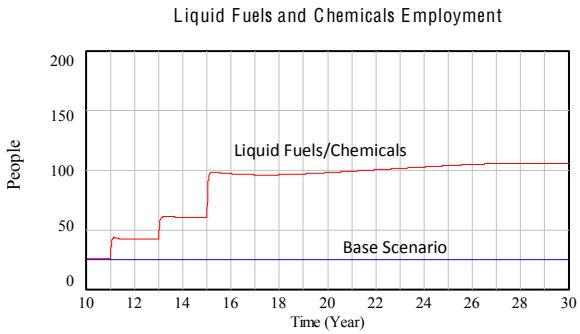
Background: Biochemicals and biobased fuels are an emerging opportunity for the state to explore. Technology continues to develop, and companies are increasingly looking for manufacturing capability. In many cases, this development will utilize existing infrastructure and mill waste from paper mills and sawmills, so both residual and pulpwood logging operations are assumed to be involved. The scenario assumes increasing demand to 800,000 green tons per year across several small- and large-scale facilities.

Results: In the facilities manufacturing biobased chemicals and fuels, 80 new jobs are created. Additionally, 246 jobs are created in logging sectors. An additional $13 million dollars in wages are added in logging and wood consuming industries. Because of the reliance on existing industry residuals and avoiding using significant pulpwood resources, the impact on existing industry is minimized. Furthermore, partnerships can support economic development goals by keeping existing employers active in Minnesota. Beyond growth shown in the model, it can be assumed that downstream manufacturing of chemicals and other products along the extensive chemical value chain multiplies employment effects significantly. Over 625 jobs are likely to be created across the value chain, without considering indirect and induced impacts.

Liquid Fuels and Chemicals Production		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4170	4121	-49	-1
Change	Emerging Industry Staff (# of people)	26	106	26	81	80
400k Chemicals	Total Logging Staff (# of people)	1500	1746	1500	246	246
400k Fuels	Forest Products Wages ($ Millions)	1.3	219.8	217.1	218.5	0.0
	Emerging Industry Wages ($ Millions)	53.4	5.7	1.3	-52.1	4.3
	Logging Wages ($ Millions)	1.5	62.2	53.4	60.7	8.8
	Residual Stumpage Price ($)	1.50	1.61	1.50	0.11	0.11
	Sawlog Stumpage Price ($)	17.00	17.00	17.00	0.00	0.00
	Pulpwood Stumpage Price ($)	8.00	9.07	8.00	1.07	1.07
	Total Staff (# of people)	5696	6021	5696	325	325
	Total Staff Wages ($ Millions)	274.6	287.6	274.6	13.0	13.0



Total staff increases by 325 over the 20 years. This corresponds with an increase in staff wages of $13 million.



In each industry, an assumption is made that a smaller scale (100,000 GT) investment in years 11 and 13, then a larger-scale (200,000 GT) investment in year 15. This increases emerging industry jobs to 100.

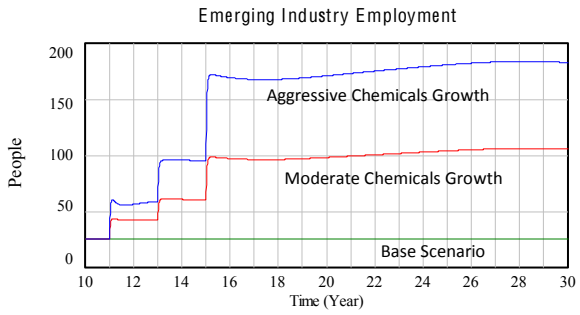
Aggressive Biofuels and Biochemicals Growth (1.6 Million Green Tons)

Recommendation 3: Actively Pursue high-value opportunities.

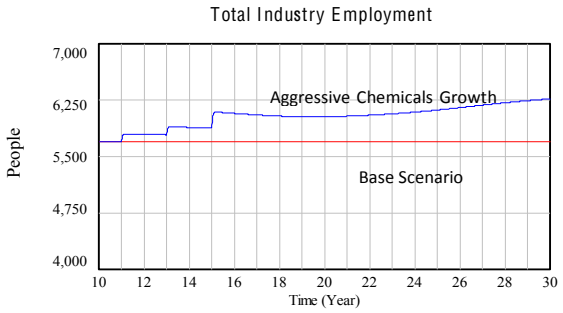
Background: A scenario was created whereby biofuels and biochemicals experiences increasing success in the state of Minnesota. This scenario shows a total increase of 1.6 MMGT increase in the amount of wood being consumed to manufacture liquid biofuels and biochemicals, which doubles the impact of the initial biochemicals and biofuels scenarios.

Results: Action taken that successfully creates this economic activity would add 571 direct jobs to the state of Minnesota which corresponds to an additional 23 million dollars in wages. Of this 571, 424 would be created directly in logging. Similar to the first chemicals scenario, half of this wood is coming from pulpwood, and half is using residuals. When taking multipliers into consideration, the 159 jobs created in the chemical and biofuels industry adds up to 1,256 jobs across the value chain.

Aggressive Liquid Fuels and Chemicals		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4170	4087	-83	-10
Change	**Emerging Industry Staff (# of people)**	26	184	26	158	157
Liquid Fuels: 800k GT	**Total Logging Staff (# of people)**	1500	1924	1500	424	424
Chemicals: 800k GT	**Forest Products Wages ($ Millions)**	1.3	219.8	215.3	218.5	-0.5
	Emerging Industry Wages ($ Millions)	53.4	9.9	1.3	-52.1	8.5
	Logging Wages ($ Millions)	1.5	68.5	53.4	67.0	15.1
	Residual Stumpage Price ($)	1.50	1.73	1.50	0.23	0.23
	Sawlog Stumpage Price ($)	17.00	17.00	17.00	0.00	0.00
	Pulpwood Stumpage Price ($)	8.00	10.16	8.00	2.16	2.12
	Total Staff (# of people)	5696	6266	5696	571	571
	Total Staff Wages ($ Millions)	274.6	297.6	274.6	23.0	23.0



This scenario doubles the impact of the initial biofuels and biochemicals scenario. When multipliers are considered, this growth creates over 1,256 jobs across the value chain.



Staff wages across forest-based communities increase over $23 million

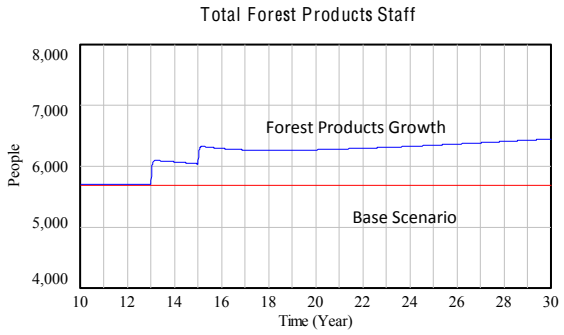
Traditional Forest Products Growth

Recommendation 1: Ensure long-term supply of wood through forest management and increased utilization.

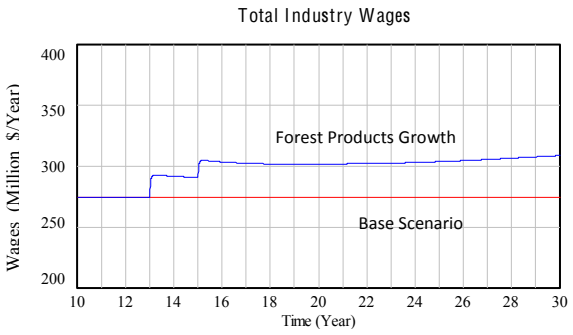
Background: The assurance of a long-term, stable supply of wood is a necessary condition to growth of traditional forest products industries. A scenario was modeled to understand the impacts of growth in these sectors. In this scenario, paper demand increased by 400,000 GT, engineered products recovered 400,000 GT of the last decade's lost capacity, and lumber production increased 200,000 GT.

Results: This scenario shows a growth of 742 jobs in the logging and wood consuming industries, and adds $34.2 million in wages. This gives the state high value for the wood moving into these industries, and after considering indirect and induced jobs from the 483 jobs created directly in the mills experiencing this demand, a total of 1,535 jobs are created. This scenario is the highest job creator per unit of wood consumed, followed by development of biofuels and biochemicals manufacturing cited previously.

Forest Products Growth		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4701	4170	531	483
Change	**Emerging Industry Staff (# of people)**	26	26	25	0	0
Paper: 400 k GT	**Total Logging Staff (# of people)**	1500	1770	1500	270	270
Eng. Products: 400k	**Forest Products Wages ($ Millions)**	1.3	246.4	219.8	245.1	24.6
GT	**Emerging Industry Wages ($ Millions)**	53.4	1.4	1.3	-52.1	0.0
Lumber: 200k GT	**Logging Wages ($ Millions)**	1.5	63.0	53.4	61.5	9.6
	Residual Stumpage Price ($)	1.50	1.50	1.50	0.00	0.00
	Sawlog Stumpage Price ($)	17.00	24.66	17.00	7.66	6.06
	Pulpwood Stumpage Price ($)	8.00	9.94	8.00	1.94	1.81
	Total Staff (# of people)	5696	6448	5696	752	752
	Total Staff Wages ($ Millions)	274.6	308.8	274.6	34.2	34.2



These scenarios show high value for the amount of wood moving into these markets. When including indirect and induced impacts, this scenario creates 1,535 jobs.



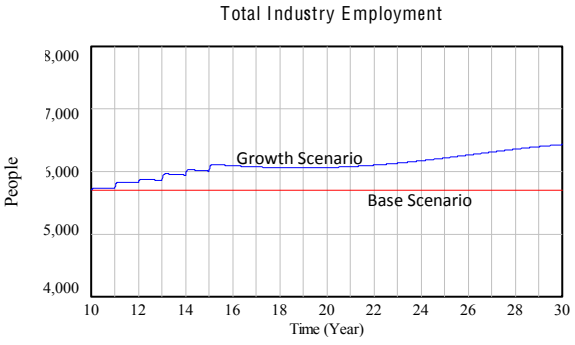
Staff wages across forest-based communities increase over $34 million, not including indirect and induced jobs. This is enabled by fostering continued forest management and maintenance of the logging industry, making the recommendations concerning these issues very critical.

Implemented Recommendations

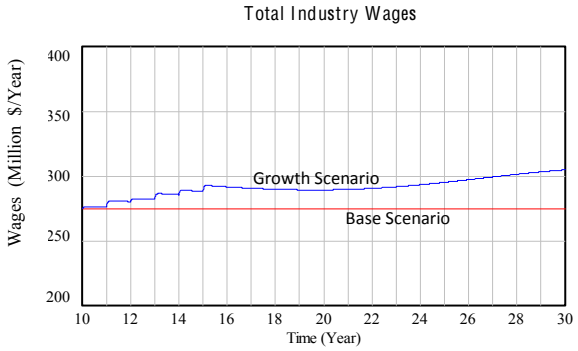
Background: In implementation of the preceding recommendations, certain emerging industries are likely to grow. This scenario grows pellet manufacturing by 800,000 GT, direct combustion of residual by 400,000 GT, and biofuels and biochemicals by a combined 800,000 GT.

Results: Implementation of these recommendations could result in an additional 736 jobs and $30 million in wages in logging and initial processing operations. When including indirect and induced impacts, 1,423 jobs are created across the state's value chain. Pulpwood harvest increases to 6.2 million GT, with an additional 1 million GT in residual harvest, and 1 million green tons in sawlog harvest. While overall impacts of this scenario are positive, there are some areas of concern. The increase in pulpwood price needs to be considered by businesses entering this market. Utilization of underutilized species and careful location of facilities is important to minimize this impact. Through these actions, the job losses in existing forest product industry staff can be minimized.

Implemented Recommendations		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4170	4059	-111	-5
Total Demand Growth	**Emerging Industry Staff (# of people)**	26	324	26	298	298
Pellets: 800k GT	**Total Logging Staff (# of people)**	1500	1942	1500	442	442
Heat: 200k GT	**Forest Products Wages ($ Millions)**	1.3	219.8	213.8	218.5	-0.2
Electricity: 200k GT	**Emerging Industry Wages ($ Millions)**	53.4	15.9	1.3	-52.1	14.6
Liquid Fuels: 400k GT	**Logging Wages ($ Millions)**	1.5	69.2	53.4	67.7	15.7
Chemicals: 400k GT	**Residual Stumpage Price ($)**	1.50	1.77	1.50	0.27	0.27
	Sawlog Stumpage Price ($)	17.00	17.00	17.00	0.00	0.00
	Pulpwood Stumpage Price ($)	8.00	11.23	8.00	3.23	3.20
	Total Staff (# of people)	5696	6432	5696	736	736
	Total Staff Wages ($ Millions)	274.6	304.7	274.6	30.1	30.1



This scenario adds significant number of jobs to the state's economy. When adding indirect and induced impact to the 736 job increase shown above, total employment impacts are 1,423.



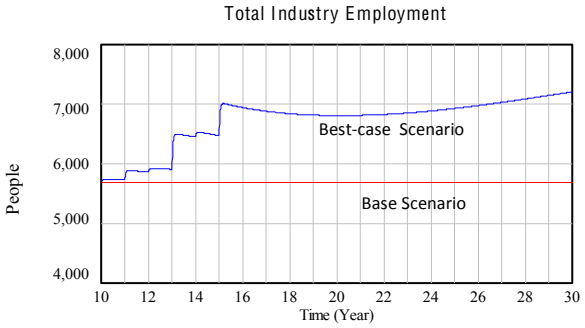
Staff wages across forest-based communities increase over $30 million, which is a significant stimulus to these local economies.

Implemented Recommendations- 'Best Case Scenario'

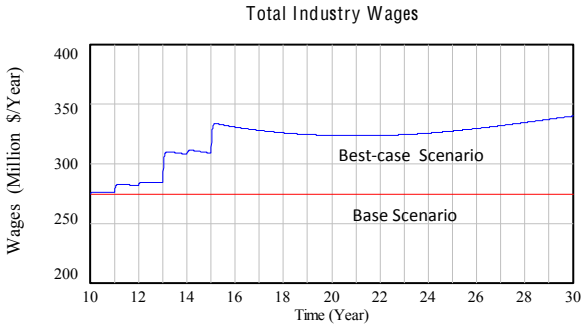
Background: This scenario combines all scenarios that detailed in the scenario entitled "Implemented Recommendations," plus an additional projection of growth that can be enabled through assurance of long-term supply. In this scenario, the following growth occurs: OSB by 400,000 GT, paper by 400,000 GT, and lumber by 200,000 GT. Emerging industries grow as well, as pellet manufacturing grows by 800,000 GT, direct combustion of residual by 400,000 GT, and biofuels and biochemicals by a combined 1,600,000 GT.

Results: Implementation of these scenarios would result in an additional 1,512 direct jobs and $65 million in wages. Including indirect and induced impacts, the total impact to the state is a growth in 3,337 jobs. Pulpwood harvest increases to 7.2 million GT, with an additional 1.2 million GT in both sawlog and residual harvest. This is approaching the maximum harvest levels perceived in the last decade, but even after this growth, further consumption is possible. While the scenario shows a significant number of jobs across all industries, it is also predicting a significant increase in stumpage prices that raises concern.

Implemented Recommendations-Best Case		Base Value	Peak Value	Trough Value	Net Change to Peak/Trough	Net Change to Year 30
	Forest Products Staff (# of people)	4170	4661	4167	491	420
Change	Emerging Industry Staff (# of people)	26	393	26	368	368
Paper: 400 k GT	Total Logging Staff (# of people)	1500	2224	1500	724	724
Eng. Products: 400k	Forest Products Wages ($ Millions)	1.3	244.3	219.6	242.9	21.3
GT	Emerging Industry Wages ($ Millions)	53.4	19.7	1.3	-52.1	18.3
Lumber: 200k GT	Logging Wages ($ Millions)	1.5	79.2	53.4	77.7	25.8
Pellets: 800k GT	Residual Stumpage Price ($)	1.50	1.88	1.50	0.38	0.38
Heat: 200k GT	Sawlog Stumpage Price ($)	17.00	24.66	17.00	7.66	6.06
Electricity: 200k GT	Pulpwood Stumpage Price ($)	8.00	14.12	8.00	6.12	5.82
Liquid Fuels: 400k GT	Total Staff (# of people)	5696	7208	5696	1512	1512
Chemicals: 400k GT	Total Staff Wages ($ Millions)	274.6	340.1	274.6	65.5	65.5



This scenario adds significant number of jobs to the state's economy. When adding indirect and induced impact to the 1,512 job increase shown above, total employment impacts are 3,337



Total wage impact in the initial steps of the forest value chain increases over 65.5 million dollars. This high growth is accelerated due to high value traditional industries growth providing significant wages in these communities.

Appendix C: Recommended Forest Management Programs:

(1) **Timber stand improvements (TSI)**

TSI includes both pre-commercial and commercial thinning, also provides feedstock to emerging and traditional industries in addition to increasing output of timber on forestland. These improvements should be viewed as a long-term investment for the state to increase available supply of wood in a sustainable manner, and as such, it is appropriate for bonding dollars to be used to support TSI on public lands.

(2) **Conservation Easements**

Conservation easements can support multiple sustainability and wildlife preservation goals, and Minnesota Forest Legacy dollars should be strategically used to keep forests in working lands while accomplishing sustainability goals. This is a step to maintain the level of working forests. Consideration of forest certification, biodiversity, and other environmental concerns is beneficial over the long run, and needs to be considered in negotiations. Furthermore, supporting county-level governments in management of the forest is critical to maintain the health of at-risk forests under their care.

(3) **Private land management incentives**

Current incentives for private-sector management of forests should be strengthened to ensure long-term viability of working forests. Legislative action should be taken to ensure that existing management plans for forest lands are being enforced.

(4) **Forest stewardship contracts**

Forest stewardship contracts are currently used on federal lands to provide incentive for loggers to manage land over time for ecological purposes while being able to use thinned wood for traditional industry or biomass combustion. This can ensure the forest remains ecologically healthy, ensures suitable wildlife habitat, and provides feedstock for traditional or biomass-based industries.

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About The BioBusiness Alliance of Minnesota

The BioBusiness Alliance of Minnesota (BBAM) is an industry-led, action-based 501(c) (3) not-for-profit organization dedicated to the advancement of bioscience-related industries to create jobs for the citizens of Minnesota. The charter of BBAM is to bring together all related areas of the biosciences in a coordinated effort to help ensure the long-term health and success of Minnesota's bioscience industry. BBAM relies on contributions from businesses, foundations, academia, individuals, and government to support its work in ensuring the long-term prosperity of biobusiness in Minnesota. To learn more and to donate go to www.biobusinessalliance.org/.