GREAT PLAINS INSTITUTE

Emerging Market Opportunities for Minnesota's Forest Products Industry

MANAGING FOR ECONOMIC IMPACT AND ENVIRONMENTAL SUSTAINABILITY

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Authors
Katelyn Bocklund, Great Plains Institute
Carly Gelderman, Great Plains Institute
Brendan Jordan, Great Plains Institute
Mariem Zaghdoudi, Great Plains Institute

Figure Authors
Elizabeth Abramson, Great Plains Institute
Dane McFarlane, Great Plains Institute

Editor
Jennifer Christensen, Great Plains Institute

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Finally, we would like to thank the members of the Bioeconomy Coalition of Minnesota for their leadership in shaping the Minnesota Bioeconomy Commercialization Consortium and guidance in shaping this project.

EXECUTIVE SUMMARY

The Bioeconomy Coalition of Minnesota, a statewide partnership facilitated by the Great Plains Institute, supports the growth of new biobased industries by focusing on policy development, research, information-sharing, and convening. The coalition is a collaborative effort between public and private partners and works with entities including the University of Minnesota's Forever Green Initiative, the Agriculture Utilization Research Institute, the Natural Resources Research Institute, and various private sector partners.

In 2017, the coalition established the Minnesota Bioeconomy Commercialization Consortium to identify and support promising, early-stage research and development priorities for the bioeconomy, as well as to enhance collaboration on increasing research funding. Informed by a stakeholder engagement process, the consortium identified emerging markets for wood as an area of interest along with biofuels from cash cover crops, anaerobic digestion of municipal solid waste to produce renewable natural gas, and new value-added technologies to produce high-value products from existing ethanol plants.

The Minnesota Department of Iron Range Resources and Rehabilitation and the Blandin Foundation provided funding for this white paper, which focuses on emerging markets for wood. The goals for this project are the following:

- Convene experts in the Minnesota forest industry sector to identify research and development priorities related to bioenergy, biofuels, biobased chemicals, building products, biobased materials, and other possible products from wood.
- Identify technology commercialization priorities and seek to increase funding for their research and development based on status in Minnesota, promising markets for emerging products, potential for progress in technology commercialization, and fit with Minnesota's forest resources.
- Make recommendations on other state priorities to enhance the economic and environmental potential of forestry and the forest products industry.

To achieve the goals mentioned above, the Great Plains Institute engaged various experts and stakeholders through structured elicitation interviews and meetings. Through this process, staff gathered input from the forest products industry, economic development community, biobased market experts, local and state government, and other community stakeholders. Several themes emerged from the outreach process:

- Minnesota should support existing forest products industry facilities and enhance existing markets, in addition to attracting emerging markets.
- The Bioincentive Program is currently supporting biomass thermal and biobased chemical projects using wood and could attract additional projects. The program must be fully funded in order to be successful, and the state should consider expanding eligibility to attract priority projects.
- The state should focus on developing new end-use markets for mill residuals given the importance to existing mills. Many mills depend on selling their residuals and markets for residuals have declined. Developing new markets is essential to the long-term health of

Minnesota's existing industries. Specific technologies that Minnesota could pursue are described in the white paper.

- There is an emerging need to remove and process ash trees killed by emerald ash borer. New markets will be needed to provide the economic incentive to remove dead ash and replant new species.
- Forestry and the forest products industry contributes to improved air, water, biodiversity, and greenhouse gas emissions management. The opportunity to continue and enhance this benefit should be highlighted to build support for increased investment in the sector.
- Core priorities of the forest products industry including energy and wood costs, transportation infrastructure, and wood supply are important for existing industries as well as new industries and should be addressed as part of a comprehensive strategy. Electricity rates paid by the Minnesota forest products industry have increased, putting a significant cost burden on Minnesota forest products facilities relative to other US states with forest products facilities.

Additionally, a literature review was conducted to assess the state of the forest products industry in Minnesota today, describe industry trends, and identify emerging market opportunities for Minnesota based on the regional and global experience. The literature review produced a set of conclusions about the status of Minnesota's forestry sector:

- Several Minnesota tree species are harvested well below their sustainable harvest level, meaning that they are underutilized and can be used for new value-added products.
- There are around 336 manufacturing facilities using Minnesota wood for industrial sectors such as pulp, paper, lumber, paperboard pallets and crating, millwork, wood shavings for the poultry industry, and engineered wood products.
- Following a similar trend in North America and in other regions of the world, Minnesota has lost numerous forest products industry facilities and production at remaining facilities in the past couple of decades, particularly pulp and paper production facilities, oriented strand board production facilities, and bioenergy production.

The stakeholder engagement process and literature review helped to identify specific emerging wood opportunities that Minnesota should consider:

- Demand for bioenergy as an alternative for fossil fuels has been increasing worldwide, largely due to rising concerns about energy security, environment, and climate mitigation. Minnesota recently reduced its support for domestic biomass electricity and has seen declines in wood used for this purpose. Despite this, demand for pellet production for export continues to grow worldwide and remains an opportunity for Minnesota. Pellet production for domestic heating is another opportunity. The Bioincentive Program supports commercial-scale biomass heating today. Pellet production and other bioenergy strategies are suitable markets for mill residuals, underutilized species, and bug-kill wood. Minnesota should work to prevent further declines in biomass electricity production while seeking further growth in bioenergy.
- The global market shows an increasing demand for wood pellets for both commercial- and residential-scale heating. While the wood pellet market offers a low-technology and

relatively low-risk opportunity to use underutilized species, Minnesota is disadvantaged in this market because of the high shipping cost of pellets to other states or internationally. Minnesota could choose to provide incentives to support the export of wood pellets and it could support the development of a domestic wood pellet heating market.

- International and domestic demand for biofuels is growing and is supported by policies at the national and state level. Despite the growth of electric vehicles that will eventually reduce demand for liquid fuels in some segments of the transportation sector, low-carbon liquid fuels will be required for difficult-to-electrify sectors such as aviation, long-haul trucking, and ocean shipping. There are ASTM specifications for diesel fuel and aviation fuel from wood. Some biofuel pathways could take advantage of mill residuals, underutilized species, and bug kill. Advanced biofuel production is supported by the Bioincentive program. This is a market Minnesota could pursue, although there are challenges that must be overcome.
- Thermally modified wood, biochar, and activated carbon are all materials resulting from the thermal processing of wood. These materials offer a wide variety of applications, as well as wide access to different markets. The ideal wood species will vary depending on the processing technology and the market application, but there is potential for thermally treated wood to use mill residuals, underutilized species, and bug-kill wood for certain product applications.
- The global market for biobased chemicals and biobased plastics is growing, which may present an opportunity for Minnesota's underutilized species and mill residuals. Process technologies vary and some are very specific with respect to the desired wood species, but there is potential for biobased chemicals and biobased plastics producers to use mill residuals, underutilized species, and bug-kill wood, particularly for thermochemical processing technologies.
- Because of the declining demand for traditional paper products, the industry is adjusting by manufacturing products that are more in demand such as packaging paper and chemical cellulose. Pulp and paper mills have traditionally utilized some mill residuals and could do so again if production expanded. The Bioincentive Program supports production of biobased chemicals at pulp and paper plants and should be fully funded to support additional private investment. The state should support research to develop new products from pulp and paper plants.
- There are additional opportunities to extract high value chemicals from wood. Some extractives that are already in production in Minnesota and elsewhere are used in food and dietary supplements. Lonza in Minnesota uses Tamarack for this purpose, and there is potential to produce extractives from other underutilized species such as Cedar. Research efforts should focus on identifying new extractives.
- Engineered wood products present a longer-term opportunity for underutilized wood species as well as wood residue. Engineered wood products include plywood, oriented strand board, cross-laminated timber, glued laminated timber, I-joist, laminated veneer timber, and medium-density fiberboard and particle board. Some oriented strand board

mills can use a variety of different species of wood to a limited degree, including some species that are underutilized in Minnesota Cross-laminated timber is a growing market and currently uses Douglas Fir and Southern Yellow pine but could utilize red and jack pine form Minnesota wood species. There is a near-term opportunity for secondary manufacturing in the state using regional SPF dimensional lumber supplemented with imported dimensional lumber, and a longer-term opportunity for research and development to develop new engineered wood products from Minnesota species.

Based on the stakeholder engagement and literature research, we developed recommendations for Minnesota to increase market opportunities for its forest products industry:

- **Support for the existing industry, including support of traditional industry priorities such as energy cost, wood cost and availability, and transportation.** Stakeholder cited this as important for developing future market opportunities.
- **Invest in research and development to allow Minnesota to serve emerging markets for mill residuals, other wood residuals, bug-kill wood, and underutilized species.** This report identifies specific market opportunities. All these market opportunities have their own challenges, and an organized effort will be critical to capture benefits for the state.
- **Make a clearer connection between a healthy forest products industry and environmental services from the forest.** Forests require active management and will require even more management in the future as a result of climate change. A great deal of forest management that occurs today in Minnesota is done by loggers and depends on markets for wood. Many stakeholders shared the message that there is "no management without markets." Having healthy forests for the long haul will require a healthy forest products industry and making smart decisions about what new industries to attract.
- **Educate the public to increase understanding, as well as engagement of private forest owners to build support.** This is essential to adopting a holistic and comprehensive strategy of wood utilization for greenhouse gas reductions and achieving environmental and economic benefits.

OVERVIEW

Introduction

The Bioeconomy Coalition of Minnesota is a state-wide partnership facilitated by GPI that is focused on building new biobased industries in the state through policy development, research, information-sharing, and convening. Establishing the Bioincentive program was an early focus of the coalition; this program was established by the state legislature in 2015 and provides a performance-based incentive for production of biobased chemicals, advanced biofuels, and biomass thermal energy.

The Bioincentive program is growing in popularity and is successfully attracting projects to the state. There has been steady growth in use of the program by companies, and it is currently being utilized by three companies. Increased growth is expected, with up to 13 companies planning to utilize the program in the State of Minnesota's 2020 and 2021 fiscal years. The program is working as intended, attracting new investments to the state.

The Bioincentive program is just one part of a comprehensive strategy for making Minnesota a center of excellence in the bioeconomy. The Bioincentive program supports companies that are already close to commercialization, influences the site selection process, and aids in project financing to establish more projects in the state. It does not, however, support earlier-stage research and development and technology transfer, another economic development strategy. And it doesn't address other barriers.

To address additional needs and barriers, the coalition launched a project in 2017 called the Minnesota Bioeconomy Commercialization Consortium (MBCC), focused on identifying and supporting the most promising state research and development priorities for the bioeconomy. The goal of the MBCC initiative is to identify state priorities and support collaboration and coordination to increase research funding. MBCC priorities were established after a stakeholder and expert engagement process in 2016 and 2017. MBCC prioritized technology areas based upon the following criteria: ability to utilize Minnesota resources from forestry, agriculture, and organic waste; demonstrated market demand for a product based on "voice of customer" interviews and market research; and ability of Minnesota's people and institutions to establish differentiating expertise and leadership in a specific technology area.

Following the MBCC stakeholder engagement process, the following broad areas of interest were established: 1) biofuels from "cash cover crops" such as camelina and pennycress that are being developed by the University of Minnesota's Forever Green Initiative; 2) anaerobic digestion of municipal solid waste to produce renewable natural gas; 3) emerging value-added technologies to produce new high-value products from existing ethanol plants; and 4) emerging markets for wood.

The MBCC is a collaborative endeavor leaning heavily on the research and development efforts of public and private partners. The Bioeconomy Coalition of Minnesota collaborates with the University of Minnesota's Forever Green Initiative, the Agricultural Utilization Research Institute, the Natural Resources Research Institute, and various private sector partners.

This white paper focuses on emerging markets for Minnesota's wood resource. The Minnesota Department of Iron Range Resources and Rehabilitation and the Blandin Foundation provided funding for GPI to conduct elicitation interviews, convene stakeholders, and conduct a literature review dedicated to narrowing in on the most promising market opportunities for Minnesota's wood resource and making recommendations for additional research and development and other proactive steps.

Project Goals

The goals established for this project are as follows:

1. Convene experts in the Minnesota forest industry sector to identify research and development priorities related to bioenergy, biofuels, biobased chemicals, building products, biobased materials, and other possible products from wood.
2. Identify technology commercialization priorities and seek to increase funding for their research and development based on status in Minnesota, promising markets for emerging products, the potential for progress in technology commercialization, and fit with Minnesota's forest resources.
3. Make recommendations on other state priorities to enhance the economic and environmental potential of forestry and the forest products industry.

The engagement, research, and elicitation process described below was designed to achieve these goals.

SUMMARY OF ENGAGEMENT

Summary of Elicitation and Engagement Questions

GPI worked with key project partners, including the Minnesota Department of Iron Range Resources and Rehabilitation, the Natural Resources Research Institute, and the University of Minnesota Office of Technology Commercialization to develop a set of open-ended questions to structure elicitation interviews and stakeholder engagement. Elicitation interviews aim to achieve a high ratio of interviewee talking to interviewer talking by asking open-ended questions.

The elicitation questions were:

- What are the most promising market demands for products that could potentially be produced from wood?
- What are the most promising emerging technologies for meeting that market demand?
- What are the main challenges to commercializing promising wood technologies in Minnesota?
- If we had more funding to invest in developing new technology, what should we invest it in?
- What are your goals for your own company or organization in this area?

These questions became the focus of one-on-one elicitation interviews and large group convenings. The goal of this process was to hear from the established forest products industry,

economic development community, biobased chemical market experts, large chemical market players, start-up companies, architects and designers, federal funding partners, societal and community stakeholders, and state government.

GPI staff gathered input through both in-person meetings and large group convenings and supplemented interviews with a review of information from published reports.

Bioeconomy Coalition of Minnesota Meetings

GPI gathered input from experts within the Bioeconomy Coalition of Minnesota (BCM) by presenting the wood technology issue area at a series of regular BCM meetings.

MARCH 20, 2018

The first coalition meeting in 2018 was held in Grand Rapids, Minnesota and featured a presentation from Itasca Community College about its wood boiler system. This meeting provided valuable information regarding a possible use for Minnesota's underutilized tree species as the project sourced wood directly from the forest.

AUGUST 29, 2018

The second coalition meeting in 2018 featured three presentations on wood technology. The Natural Resources Research Institute provided an overview on promising wood technologies and emerging markets, LSI presented about its goals in commercializing wood products, and GPI gave an overview of the research funded through the Minnesota Department of Iron Range Resources & Rehabilitation. Meeting attendees reviewed and provided feedback on questions used in the project's elicitation interviews with companies.

Grand Rapids Meeting

As an additional outreach effort, GPI facilitated an in-person stakeholder meeting on May 23, 2019, in Grand Rapids, Minnesota. The meeting was organized with the Blandin Foundation, Itasca Economic Development Corporation, Grand Rapids Area Chamber of Commerce, and the Bioeconomy Coalition of Minnesota.

The goal of the meeting was to convene forest product industry stakeholders, non-governmental organizations, state agencies, and economic development associations to discuss the future of the forest products industry in Minnesota. The meeting focused on identifying emerging markets and technologies, research and investment areas, barriers, and additional steps needed to support investment in these markets.

The meeting was attended by 26 individuals that represented a diverse mix of stakeholders in the forest products industry and northeastern Minnesota community.

After listening to presentations from the Natural Resource Research Institute and the Itasca Economic Development Corporation regarding emerging technologies and markets for wood, the group was split into small groups to share input. GPI facilitated the small group discussions around a set of questions:

- What resonated with you most about the emerging technologies you saw earlier?

- Based on what you saw earlier, what's missing from this picture? What do we need more clarity about regarding emerging technologies?
- What are the key dilemmas facing you today in the industry?
- If we had more funding to invest in developing new technology, what bold steps might we take next to overcome dilemmas?
- How can we support one another in taking the next steps? What unique contributions can we each make?

After receiving the feedback and insight from the stakeholders, some high-level conclusions emerged:

- There is a need for additional and diverse end-markets for wood residuals.
- Several barriers that are limiting current and future markets include a lack of end-markets, lack of transportation infrastructure, limited local markets, and capital and labor cost constraints.
- The industry needs to support existing markets and attract new markets through research and development.
- State incentives or subsidies could be used to support current and future markets.
- There are other benefits that the wood products industry provides, including improved water quality, clean air, and healthy forests.
- There needs to be a broader bioincentive program that includes wood pellets bound for thermal energy or electricity generation.

Expert Input

These individuals offered input and information through in-person meetings, elicitation interviews, or other consultations but have not endorsed any recommendations from this report.

Pete Aube, Consultant

Kristen Bergstrand, Minnesota Department of Natural Resources

Robert Buckler, representing UPM-Blandin

John Duplissis, Natural Resources Research Institute

Kyle Erickson, Blandin Foundation

Wade Fauth, Blandin Foundation

Katie Fernholz, Dovetail Partners

Janelle Greschner, Minnesota Department of Iron Range Resources and Rehabilitation

Craig Halla, Molpus Woodlands Group

Lisa Hughes, Minnesota Department of Employment and Economic Development

Mark Jacobs, Dovetail Partners, Inc.

Todd Jaranson, Lonza Inc.

Bernadine Joselyn, Blandin Foundation

Quintin Legler, UPM Blandin Paper

Tamara Lowney, Itasca Economic Development Corporation

Matt Lucas, Carbon180

Robert Matthews, UK Forest Research

David Peterson, Itasca BioEnergy

Brian Peterson, Nelson Wood Shims

Kathleen Preece, Minnesota Forest Resources Partnership

John Rajala, Rajala Timber Co.

Matthew Rajala, Rajala Timber Co.

Allen Raushel, Savanna Pallets

Mark Rudnicki, Michigan Forest Biomaterials Institute

Chuck Scherer, Nelson Wood Shims

Rob Schilling, Sappi

Wade Semeliss, PotlatchDeltic

Matt Shermoen, Area Partnership for Economic Expansion (APEX)

Eric Singsaas, Natural Resources Research Institute

Luke Skarlupka, United States Department of Agriculture

Bud Stone, Grand Rapids Area Chamber of Commerce

BIOECONOMY COALITION MEMBERS

3M

Agricultural Utilization Research Institute

Area Partnership for Economic Expansion (APEX)

Brightmark Energy

BTS Biogas

Cargill

Central MN Renewables

City of Benson, Minnesota

Christianson

Conservation Minnesota

Dovetail Partners Inc.

Enerkem

Fagen Inc.

Grand Rapids Area Chamber of Commerce

Great River Energy

Itasca Economic Development Corporation

LLJ Consulting and Business Development

Minnesota Corn Growers Association

Minnesota Department of Employment and Economic Development

Minnesota Farmers Union

Minnesota Power

Natural Resources Research Institute

Natureworks, LLC

Ramsey/Washington Recycling and Energy Board

Renewable Chemicals and Materials Alliance

Stoel Rives LLP

Wenck

BACKGROUND ON MINNESOTA'S FOREST PRODUCTS INDUSTRY

Timber Harvest Trend Data in Minnesota

In Minnesota, the timber harvest peaked at 3.82 million cords in 1999 and has declined since then, reaching 2.88 million cords in 2016. The decline in harvest comes in response to declining production by Minnesota's forest products industries. For example, reduced pulp and paper manufacturing has resulted in a decline in balsam fir harvest.[1]

The predominant forest type (or cover) in Minnesota is Aspen, followed by oak, northern hardwoods, black spruce, and tamarack. However, the most harvested species are, according to data from the 2017 harvest, aspen/balsam with 1,563.5 thousand cords, followed by paper birch with 154.8 thousand cords, then ash with 69.5 thousand cords.[2]

Several species are underutilized, with their actual harvest levels well below the estimated sustainable harvest levels as determined by the Minnesota Department of Natural Resources.[3]

There are also inadequate markets for logging residuals (e.g., slash, wood waste, other logging residuals) and mill residuals.

[1] Hillard, S., Bergstrand, K. Deckard, D. Minnesota's Forest resources 2017. Department of Natural resources; Division of Forestry, 101pp. Accessed November 14, 2019 at http://files.dnr.state.mn.us/forestry/um/forest-resources-report-2017.pdf

[2] Hillard, S., Bergstrand, K. Deckard, D. "Minnesota's Forest resources 2017," 22.

[3] Hillard, S., Bergstrand, K. Deckard, D. "Minnesota's Forest resources 2017," 34-87.

Table 1. Underutilized sustainable harvest levels in Minnesota in 2016

Species	**Annual Sustainable Harvest Level** Cords/Year	**Percent Harvested**	**Actual Harvest in 2016** in Cords	**Remaining Sustainable Potential Harvest** in Cords
Ash	459,427*	15.11%	69,422	390,005
Balsam fir	705,500	17.47%	123,259	582,241
Basswood	280,300	19.06%	53,444	226,856
Birch	371,500	41.67%	154,819	216,681
Maple	429,600	38.23%	164,258	265,342
Oak	499,300	29.38%	146,716	352,584
Red pine	345,000	93.96%	324,162	20,838
Spruce	705,500	35.03%	247,200	458,300
Tamarack	114,800	11.58%	13,298	101,502
White cedar	286,243*	1.41%	4,052	282,191
White pine	184,335*	10.49%	19,354	164,981

*Estimated net annual growth reported where sustainable harvest not specified by MN DNR
Source: Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017", Minnesota Department of Natural Resources Forestry Division. Published May 2019.

Regional Information for Minnesota, Wisconsin, and Michigan

Wisconsin's forests had 16.5 million acres of timberland in 2016,[4] while Michigan had 19.3 million acres of timberland in 2017.[5] The most common forest types in Wisconsin are maple-beech-birch, oak-hickory, and aspen-birch.[6] In Michigan, the dominating forest types are maple-beech-birch, and oak-hickory.[7] Timberland in Minnesota has increased from 15.8 million acres in 2016 to 15.98 million acres in 2017, due to several potential factors including land conversion as agricultural land is reclaimed by forest.[8]

Land Ownership

Timberland ownership in Minnesota is split between industrial (7 percent), US forest service (12 percent), state (23 percent), county and municipal (16 percent), and private (42 percent). From 1997 to 2014, harvesting from public lands increased slightly, harvesting from industrial lands declined slightly, and harvesting from private lands dropped almost in half. Private lands are a potential area for expanded harvest in the future. The Minnesota Department of Natural Resources manages several programs supporting sustainable management of private forest lands through development of the Woodland Stewardship Plan, including a cost-share program, the Sustainable Forest Incentive Act, and the 2c Managed Forest Land reduced property tax program.

Minnesota Wood Utilization

As of January 2017, there were around 817 wood manufacturing facilities in Minnesota in these industry sectors: pulp, paper, lumber, paperboard, engineered wood products, converted paper products, window and door components, kitchen cabinets and cabinet parts, store fixtures, wood office & residential furniture, pallets and crating, millwork, wood shavings for poultry industry, and wood biomass energy.[9] Table 2 shows the breakdown of the number of facilities based on industry sector. Figure 1 illustrates softwood and hardwood usage by sawmills in Minnesota.

[4] "Wisconsin's Forest Resources," Wisconsin Department of Natural Resources Division of Forestry, 2017:1-11. Accessed June 11th, 2019. https://dnr.wi.gov/topic/ForestBusinesses/documents/WisconsinForestResources.pdf

[5] Scott A. Pugh, "Forests of Michigan," US Department of Agriculture, Forest Service, Northern Research Station, 2018: 1-4. Accessed June 12th, 2019. https://doi.org/10.2737/FS-RU-153.

[6] "Wisconsin's Forest Resources," 2.

[7] Pugh, "Forests of Michigan," 3.

[8] Hillard, S., Bergstrand, K. Deckard, D. "Minnesota's Forest resources 2017."

[9] Hillard, S., Bergstrand, K. Deckard, D. "Minnesota's Forest resources 2017," 6.

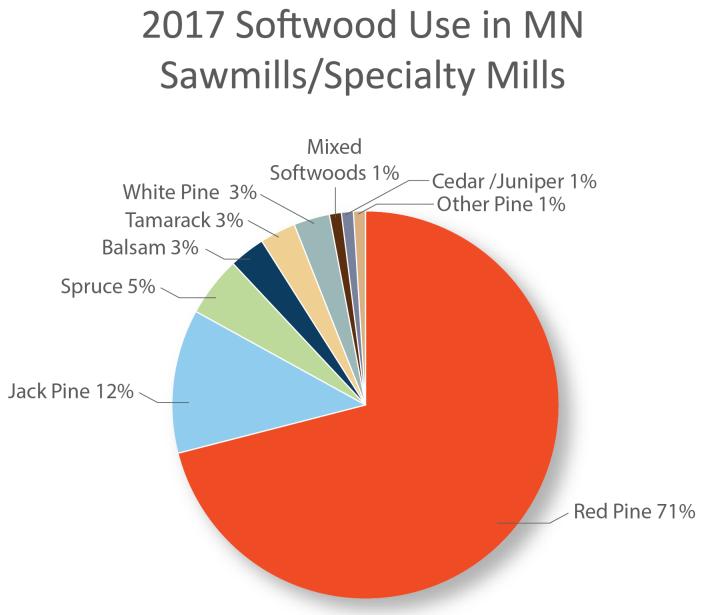
Table 2. The distribution of manufacturing facilities by industry sector in Minnesota as of January 2017

Number of Manufacturing Facilities	Industry Sector
329	Sawmills and wood products plants
328	Wood kitchen cabinets and
94	Converted paper products
62	Wood furniture and custom architectural woodwork
4	Primary pulp and paper mills
3	Recycled pulp and paper

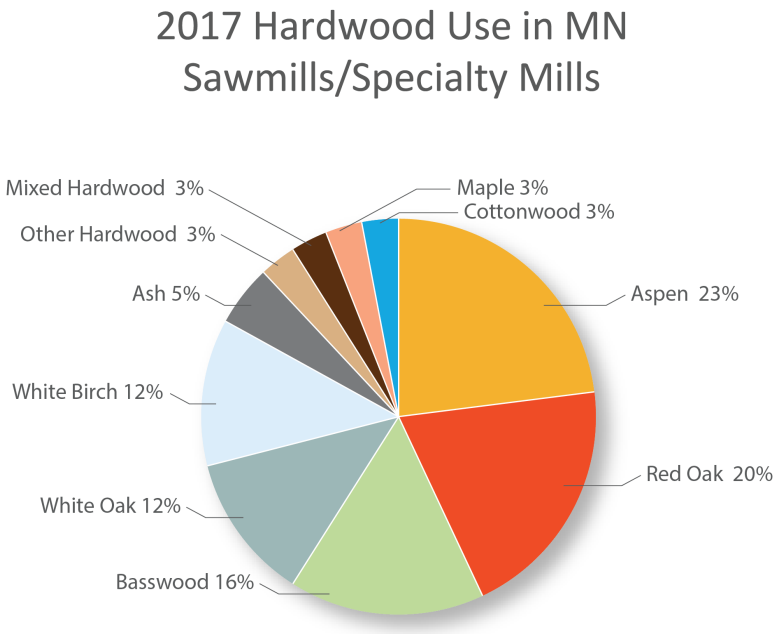
Source: Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017", Minnesota Department of Natural Resources Forestry Division, 6.

Figure 1. Minnesota timber uses in sawmills in 2017

2017 Softwood Use in MN Sawmills / Specialty Mills



2017 Hardwood Use in MN Sawmills / Specialty Mills



Source: Data from Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017," Minnesota Department of Natural Resources Forestry Division, 9. Figure authored by GPI, 2018.

PULP AND PAPER

Despite the decline in demand for traditional paper products, pulp and paper manufacturers continue to utilize Minnesota wood. Some of these manufacturers adjusted to current market demand trends by producing items that are more in demand such as packaging paper and chemical cellulose. Table 3 shows how the pulp and paper industry is utilizing Minnesota's wood species.

Table 3. Pulp and paper products by manufacturer in Minnesota

Wood Used	Product	Manufacturer
Aspen, balsam fir, basswood, spruce	Lightweight coated publication paper	UPM- Blandin Paper Mill
Aspen, balsam, pine, spruce	Office papers, label and release papers, base sheets, business, and specialty printing grades	Boise White Paper
Balsam fir, spruce	Uncoated, lightweight supercalendered magazine, and publication papers	Verso, Duluth
Aspen, maple, minor amounts of birch and ash	Specialized cellulose, coated freesheet fine printing and publication paper, market pulp	SAPPI North America

Source: Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017," Minnesota Department of Natural Resources Forestry Division.

ENGINEERED WOOD PRODUCTS

Some engineered wood products present an opportunity to utilize all types of available wood, as well as some wood residue. Engineered wood products include plywood, oriented strand board (OSB), glued laminated timber (Glulam), I-joist, laminated veneer timber (LVT), as well as medium-density fiberboard (MDF) and particle board. Some technologies are suitable for Minnesota's wood supply today such as cross-laminated timber (CLT), but some other opportunities would require additional research and development to be suitable for Minnesota's wood supply. Table 4 shows which Minnesota wood species produce OSB.

Table 4. Engineered wood products by manufacturer in Minnesota

Wood Used	Product	Manufacturer
Aspen, balsam, birch	Engineered Siding Panel – OSB	Louisiana Pacific
Aspen, balsam, birch, maple, pine	Engineered wood–OSB	Norbord

Source: Hillard, S., Bergstrand, K. Deckard, D. "Minnesota's Forest resources 2017," "Minnesota's Forest Resources 2017," Minnesota Department of Natural Resources Forestry Division.

SAWMILLS AND SPECIALTY MILLS

Although there are over 300 sawmills in Minnesota, the top 12 mills by production volume account for 70 percent of the total consumption. The largest softwood mill accounts for 40 percent of the total volume utilized.[10] Table 6 shows how Minnesota's wood species are being used by the industry.

[10] Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest resources 2017," 8.

Table 6: Examples of Products Produced by MN Sawmills/Specialty Mills

Wood used	Product	Manufacturer
Aspen, jack pine, red pine, white pine, mixed hardwoods, black ash, balsam fir, basswood, paper birch, black spruce	Cants, lumber	Cass Forest Products, Hawkins Sawmill, Rajala Timber Co.
Red pine, jack pine, spruce, balsam fir	Lumber	Potlatch Deltic
Aspen, jack pine, red pine, white pine, white spruce	Lumber	Hedstrom Lumber Co
Black ash, aspen, basswood, paper birch, hard maple, red oak, white oak, red pine, white pine, white spruce, tamarack, elm, green ash, hickory, walnut	Cants, lumber, veneer	Root River Hardwoods Inc., Rajala Mill Co.
Aspen, basswood, jack pine, red pine, mixed pine	Shavings	Woodline Sawmill
Red pine	Poles, pilings, and posts	Bell Lumber and Pole Inc., Pliny Post & Pole, McGrath
Black ash, aspen, basswood, paper birch, mixed hardwoods, red oak, pine	Boxes or crates, pallets/skids, hardwood lumber	Savanna Pallets

Source: Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017," Minnesota Department of Natural Resources Forestry Division.

Minnesota Industry Trends

FACILITY CLOSURES

Minnesota has lost numerous forest products industry facilities in the past 20 years, including three oriented strand board facilities operated by Ainsworth, a Verso paper mill in Sartell, a Georgia-Pacific Hardboard plant in Duluth, and a Weyerhaeuser laminated strand lumber plant in Deerwood.

UPM, the Finland-based graphic paper production giant, finalized closing paper machine #5 in its Blandin mill in Grand Rapids Minnesota in April 2018, leaving paper machine #6 as the sole operating machine. The permanent closing reduced UPM's annual capacity by 125,000 tons of coated magazine paper, as well as by 150 jobs. The reduction occurred as a result of the diminishing demand for paper in an increasingly digitalized world in contrast with overcapacities in North America.11 The Boise paper mill in International Falls, Minnesota, downsized its operations and laid off 265 employees.12 Another International Falls business, Bildrite International Inc, ceased operations in April 2018 due to "market conditions and commodity prices."[13] The family-owned plant, which employed 43 full-time employees, manufactured fiberboard sheathing for exterior wall application, high-density roof board, and sound deadening board for interior use.

Xcel Energy terminated its power purchasing agreements with three wood biomass facilities under The Laurention Energy Authority and Benson Power, significantly changing the wood energy and wood biomass market in the state.14 Further declines in wood harvest occurred as a result of the shutdown of a biomass electricity plant in Benson, Minnesota that was decommissioned in 2018.

Minnesota retains a diversified forest products industry, but plant closings have led to a steady decline in wood harvest and created challenges in finding a market for mill residuals and underutilized species, as well as a loss of biomass wood waste power/heating markets.

Global Industry Trends and Opportunities for Minnesota

BIOENERGY

Bioenergy is renewable energy derived from biomass and renewable sources, such as food and feed crops, organic wastes, wood, and forestry and forest residuals. The demand for bioenergy has been increasing worldwide, largely because of increasing concerns about energy security and the environment, which is leading countries to seek alternatives to fossil fuels. Applications for bioenergy include transportation, electricity, and heating. The market for bioenergy has witnessed increasing investments, advances in enzyme technologies, and the emergence of alternatives to conventional transportation fuels. One of the challenges to the bioenergy market

[11] Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017," Minnesota Department of Natural Resources Forestry Division, 7.
[12] Jennifer Vogel. "Last Days for Many at the Boise Paper Mill in International Falls." Ground Level. September 27, 2013. Accessed June 25, 2019. https://blogs.mprnews.org/ground-level/2013/09/last-days-for-many-at-the-boise-paper-mill-in-international-falls/.
[13] Gedde, E. (2018, April 24). "Bildrite ceases operation". Accessed November 15th, 2019, from https://www.ifallsjournal.com/news/local/bildrite-ceases-operation/article_1001b7e1-0426-5c10-8568-cdf43b6bdc48.html.
[14] Hillard, S., Bergstrand, K. Deckard, D., "Minnesota's Forest Resources 2017," Minnesota Department of Natural Resources Forestry Division 7.

is the volatility in global crude oil prices. Despite the challenges, the global bioenergy market is expected to grow at a compound annual growth rate of 5.89 percent between 2018-2022.15

Bioenergy accounts for 3 percent of global electricity demand, and while growing more slowly than the power sector, the heat sector is expected to claim the largest share of renewable energy demand by 2023.

Most significant climate mitigation studies have found a large and expanding role for bioenergy (including the use of biomass in all sectors) to achieve deep decarbonization of the economy. A review of major national decarbonization studies found that on average, by the end of the 21st century, bioenergy represented 25 percent of global energy in a decarbonized world with higher-end estimates above 40 percent.[16] A recent report from the Minnesota Pollution Control Agency and Department of Transportation on strategies for decarbonizing the transportation sector recommends a portfolio approach that includes aggressive transportation electrification along with displacement of remaining gasoline and diesel with biofuels. A regional transportation electrification roadmap similarly found that even with aggressive assumptions about electrification of transportation, biofuels and other low carbon fuels are still essential.

BIOFUELS

Biofuels demand is driven in the United States by the federal renewable fuel standard (RFS) and state low carbon fuel standard/clean fuel standard policies. Minnesota has seen several proposals for advanced biofuel projects using wood. A significant barrier to these projects is a lack of clarity on whether biofuels produced from Minnesota's wood resource are eligible for incentives under the RFS.

The RFS allows production of biofuels from plantation-grown wood but not from wood produced on federal land or from natural forests. Much of Minnesota's wood resources are from natural forests that experience natural regrowth after harvesting. A Minnesota advanced biofuel project using wood will likely require either clarification of rules from the US Environmental Protection Agency, changes in statute to the RFS, or new state policy in Minnesota like the low carbon fuel standard/clean fuel standard. Most biofuel production today supplies the gasoline and diesel markets.

Many longer-term climate mitigation assessments looking out to 2050 and beyond project that biofuels are most needed in sectors that are difficult to decarbonize by other means, such as long-haul trucking, aviation, and ocean shipping. Another important factor is the growth in electric vehicles, which are projected to offer cost saving in light-duty vehicles and short and

[15] Markets and Research, "Global Bioenergy Market Report 2018 - Forecasts to 2022." PR Newswire: Press Release Distribution, Targeting, Monitoring and Marketing. June 27, 2018. Accessed June 26, 2019. https://www.prnewswire.com/news-releases/global-bioenergy-market-report-2018---forecasts-to-2022-300635282.html

[16] Bruce E Dale et. Al, "Take a Closer Look: Biofuels Can Support Environmental, Economic, and Social Goals," Environmental Science and Technology 48, no. 13 (2014): 7200-7203, https://pubs.acs.org/doi/full/10.1021/es5025433

medium-haul trucking within to next 10 years, eventually cutting into gasoline and diesel demand.

The market for aviation biofuel needs significant development, since biofuel only accounted for less than 0.01 percent of aviation fuel demand in 2018; however, global airlines have made commitments to incorporate lower carbon biofuels into their fuel supply. Nearly 200 countries have committed to increase global biofuel under the Sustainable Development Scenario outlined by the International Energy Agency to tackle the Sustainable Development Goals set forth by the United Nations in 2015.[17]

Minnesota has a state biodiesel mandate requiring 5 percent blending from October–March and 20 percent blending from April–September. Biodiesel is defined as renewable, biodegradable, mono alkyl ester combustible liquid fuel derived from agricultural plant oils or animal fats and meeting ASTM specifications. Wood-derived diesel fuel would not qualify. Minnesota has a biofuel blending requirement for gasoline as well, requiring either 10 percent ethanol or 10 percent of another biofuel. A wood-based biofuel could qualify for the biofuel blending requirement. Minnesota has a petroleum replacement goal of 25 percent by 2020 and 30 percent by 2025 that it is not on track to meet. Wood-derived biofuels would qualify for Minnesota's Bioincentive Program and could receive up to $60 million over 10 years in incentives. The Bioincentive Program is currently underfunded, and full funding would be necessary to attract new projects such as this.

Despite the lack of clarity on incentives, Minnesota has seen several project proposals that would utilize wood to produce advanced biofuels. These projects are challenging due to high capital cost, policy risk, and sometimes technology risk. Depending on the technology used, these projects are likely to be able to use underutilized wood and wood residuals. If the difficulties can be overcome, this is a promising strategy for the state.

In summary, attracting new wood-based biofuel projects in Minnesota would require policy and regulatory changes. Securing incentives under the federal RFS would require a statutory change or engagement with US Environmental Protection Agency to secure eligibility for Minnesota wood as a biofuel feedstock. A new state policy such as a clean fuel policy or low carbon fuel policy could provide an alternative to RFS incentives to help make wood-based biofuel projects economically viable. Biofuel production would help support state petroleum replacement goals and be eligible for existing state incentives from the Bioincentive Program.

BIOMASS, HEAT, AND ELECTRICITY

[17] Pharaoh Le Feuvre, "Transport Biofuels." International Energy Agency. May 27, 2019. Accessed June 24, 2019. https://www.iea.org/tcep/transport/biofuels/; "Sustainable Development Scenario." International Energy Agency. 2019. Accessed June 24, 2019. https://www.iea.org/weo/weomodel/sds/

A study by the National Renewable Energy Laboratory[18] determined that a combination of forest residuals, mill residuals, and urban wood waste could produce enough biomass electricity to provide 10 percent of Minnesota's electricity demand.

In 2010, Minnesota operated 12 biomass combined heat and power facilities with more than 135 MW of capacity. Biomass electricity generation doubled from 2002 to 2010.[19] An important driver was legislation passed in 1994 (subsequently amended multiple times) requiring biomass electricity generation by Northern States Power (now Xcel Energy). Legislation in 2017[20] allowed Xcel to renegotiate and end power purchase agreements for biomass electricity from power plants in Benson, Virginia, and Hibbing, effectively ending the state's biomass electricity requirement and reducing demand for woody biomass in the state. Two additional combined heat and power facilities in St. Paul and Shakopee are still operating, but future demand for electricity from these facilities is unclear.

Demand for wood pellets for international renewable electricity markets, in particular the United Kingdom, European Union, and Japan, is a strong and growing market, and other regions of the US have become major wood pellet exporters. Minnesota is at a disadvantage on price due to the cost of shipping pellets out of the state to a coastal port for expert overseas or moving pellets through the Great Lakes. While the higher cost of transportation is a challenge, technology risk is low, the market is growing, and the ability to use underutilized species and mill residuals is high. There may be advantages to producing torrefied pellets for export, and Minnesota has research expertise in torrefaction technology.

Domestic pellet demand is small but growing, and mostly consists of pellets for home and commercial heating. There is pellet production for domestic use in neighboring states. Technology risk is low and the ability to use underutilized species and mill residuals is high. The major challenge to establishing pellet production for domestic use is increasing demand for wood heating.

Commercial-scale wood heating with chips is a niche opportunity that could grow with dedicated market development. Long-standing projects at District Energy St. Paul and Koda Energy continue to operate, new projects like a wood heating project at Grand Rapids Community College opened recently, and additional projects are under consideration.

Minnesota should take steps to avoid further declines in biomass electricity production and seek to expand biomass thermal energy production. One important step is fully funding the Bioincentive Program. The state should take additional steps to support domestic demand for heating pellets and support exporting of industrial pellets. Bioenergy is a core market for forestry

[18] "Minnesota Biomass – Hydrogen and Electricity Generation Potential," National Renewable Energy Laboratory, February 2005. https://www.pca.state.mn.us/sites/default/files/MNbiomass-NREL.pdf

[19] Minnesota Department of Commerce. Accessed October 29, 2019 https://mn.gov/commerce/industries/energy/bioenergy/

[20] Tom Meersman. "New law allows much of Minnesota's biomass industry to be shut down". Star Tribune. June 6, 2017. http://www.startribune.com/new-law-allows-much-of-minnesota-s-biomass-industry-to-be-shut-down/426537051/

and mill residuals and bug-kill wood. It is important to maintain and expand the market for biomass heat and electricity.

BIOENERGY AND CARBON CAPTURE AND STORAGE

Bioenergy with carbon capture and storage (CCS) is a group of different technologies (referred to together as BECCS) that produce energy from biomass, capture the carbon dioxide (CO_2) emissions, and store the captured CO_2 in geologic formations. BECCS could be applied through combustion or gasification of biomass, or through capture of CO_2 from fermentation processes. The CO_2 produced during these processes is either captured and stored or compressed and stored with no need for capture. CO_2 can also be utilized to produce products.

There are currently five facilities in operation around the world using BECCS technologies which collectively capture approximately 1.5 million tons of CO_2 per year.[21] The production of bioethanol with carbon capture and storage is the largest and most commercially attractive application of BECCS, with the individual technologies to use biomass to produce energy or fuel being mature and used in commercial facilities around the world. The cost of implementing BECCS technology varies between US $15-400 per ton of CO_2 avoided depending on the sector. The CO_2 avoided cost in pulp and paper mills is estimated to range between $20-70 per ton of CO_2[22] which is in the range of existing incentives.

By combining biogenic carbon storage with geologic carbon storage, BECCS offers a unique opportunity for carbon-negative energy production. It offers the opportunity to not just reduce today's emissions, but the reduce yesterday's emissions as well. The Intergovernmental Panel on Climate Change mitigation reports project a large role for BECCS in most scenarios that avoid exceeding 2ºC of warming by 2100.

Although Minnesota lacks appropriate geology for CO_2 storage, it has abundant biomass resources and appropriate technologies for biogenic carbon capture (e.g., ethanol, pulp, and paper). The state should consider the potential role of BECCS projects using forestry biomass in planning its long-term climate mitigation strategy. BECCS is a bioenergy strategy, and thus in many cases will be an appropriate market for mill and forestry residuals and bug kill wood. Future bioenergy and biofuel projects could also be designed with CCS in mind.

Low carbon fuel standards offer attractive incentives for very low-carbon biofuel production, sufficient to cover the incremental cost of CCS. Additional incentives are offered by the federal CCS tax credit (Section 45Q), offering from $35-50 per ton of CO_2 stored (beneficial use projects must achieve an equivalent emissions reduction on a lifecycle basis). Public and private efforts to plan regional CO_2 pipeline networks are underway and several proposed pipelines reach Minnesota. The state could play a proactive role to make sure that pipelines can support both current producers of biogenic CO_2 and support potential future BECCS projects.

[21] Christopher Consoli, 2019. "Bioenergy and Carbon Capture and Storage". Global CCS Institute. https://www.globalccsinstitute.com/resources/publications-reports-research/bioenergy-and-carbon-capture-and-storage/

[22] Fuss et al., 2018. Negative emissions—Part 2: Costs, potentials and side effects. Environmental Research Letters, 13(063002).

TORREFACTION AND THERMAL PROCESSING

Minnesota has an established research program to develop new products from thermal processing of wood. Most of these opportunities seek to establish new markets rather than directly serving an existing market. There are various degrees of thermal processing.

Thermally modified wood involves heat treating to drive off some volatile compounds but retains the structural integrity of the wood. Thermally modified wood may have some advantages in terms of moisture resistance and warp resistance and could make Minnesota wood resources accessible to new markets (for example siding, decking, and outdoor furniture.

Another promising opportunity is biochar, a charcoal that is also produced by thermal processing of wood. Biochar holds potential as a soil amendment for improving the productivity of soils, preventing nutrient loss and water pollution, and storing carbon in soils. Biochar may enable carbon storage for centuries or longer. As markets develop and place increased value on these environmental services, this could present a significant opportunity for Minnesota forestry.

As mentioned above, torrefied wood pellets may offer advantages over conventional wood pellets given their ability to behave like coal in a coal-fired power plant and resist falling apart during shipping.

ACTIVATED CARBON

Activated carbon is a category with a wide variety of applications and is worth exploring. Activated carbon is made from carbonaceous source materials and converted through thermal and physical modification to increase its surface area per unit volume and create a network of submicroscopic pores. Some of the most important product forms of activated carbon include cylindrical pellets, powder, honeycombs, and fibers and fiber mats. These products, among others, cover a wide range of applications, including gas and air cleaning, water purification, and energy storage.[23]

Demand for the various forms of activated carbon is driven by its increased use in water and air purification in clinker cement industries and coal fired plants, as well as in municipal and domestic water treatment. It is also used in the pharmaceutical industry and the food industry respectively as an antidote to toxins and for removing unwanted color and odor from food products.[24] Activated carbon fibers are used as electrodes in energy storing devices such as batteries, capacitors, and supercapacitors. Activated carbon fibers are advantageous due to their low cost, high electrical conductivity, high packing density, and improved specific capacity.[25]

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[23] " Activated Carbon and its Application," Donau Carbon. Accessed June 27, 2019. https://www.donau-carbon.com/getattachment/76f78828-2139-496f-9b80-6b6b9bdc6acc/aktivkohle.aspx

[24] "Activated Carbon Market Worth $14.66 Billion by 2025 | CAGR: 17.5%." Market Research Reports & Consulting. May 2016. Accessed June 27, 2019. https://www.grandviewresearch.com/press-release/global-activated-carbon-market.

[25] A. Javaid, " Activated Carbon Fiber for Energy Stotage," Activated Carbon Fiber and Textiles (2017): 281-303. Accessed June 27, 2019. https://www.sciencedirect.com/science/article/pii/B9780081006603000110

Many of these thermal modification opportunities can utilize underutilized species and mill residuals and deserve further research and development.

BIO-BASED CHEMICALS

The global market for bio-based chemicals is expected to reach $97.2 billion by 2023. According to 2018 data, Europe accounted for 33.75 percent of the market share, while China accounted for the largest market share by country. Strategies for the key players in the global bio-based chemicals market include expansions, acquisitions, joint ventures product launches, and technology transfer. Some of the products included under the umbrella term 'bio-based chemical' include bio-alcohols, bio-based acids, bioplastics, bio-lubricants, bio-surfactants, and bio-solvents. [26]

A key player in the global bioplastics industry—Natureworks LLC—is based in Minnetonka, Minnesota, and produces polylactic acid biobased plastic at a facility in Nebraska. Polylactic acid plastic, like other prominent bioplastics and biobased chemicals, is sugar derived. Producing bioplastics and biobased chemicals from wood depends on first perfecting the conversion of wood to sugars at low cost. Other pathways to produce renewable chemicals (and fuels) involve gasification and chemical conversion, gasification combined with fermentation of syngas, or other novel conversation technologies.

Minnesota has attracted interest from several biobased chemical facilities in recent years, and some projects are still taking shape. Biobased chemical facilities are difficult to establish because of likely technology risk, capital intensity, and difficulty in financing the project. Biobased chemical plants may or may not be good markets for underutilized wood; the wood species used will depend on the specific technology.

PULPING, PAPER, AND PACKAGING

Pulp and paper plants vary in their ability to use underutilized species and mill residuals, but expanded production presents an opportunity for the state.

The graphic paper market has witnessed declining demand that is projected to continue worldwide. This decline should be balanced by the increase in demand for packaging and tissue products. Possible packaging materials could include both hardwood and softwood fiber. However, demand for plastic packaging continues to grow higher than demand for fiber-based packaging.[27]

Considering the receding demand for some of the more traditional wood products, such as printing paper, the pulping industry is adjusting by manufacturing products that are more in demand. Worldwide demand for chemical cellulose, for example, has increased by around 50 percent between 2013 and 2017. Sappi Fine Paper in Cloquet, Minnesota, made a $170 million

[26] "Bio-Based Chemicals Market Research Report - Forecast to 2023| MRFR." Research Report - Forecast to 2023| MRFR. March 2019. Accessed June 24, 2019. https://www.marketresearchfuture.com/reports/bio-based-chemicals-market-5706

[27] Peter Berg, "Pulp, Paper, and Packaging in the next Decade: Transformational Change." McKinsey & Company. 2019. Accessed June 14, 2019. https://www.mckinsey.com/industries/paper-and-forest-products/our-insights/pulp-paper-and-packaging-in-the-next-decade-transformational-change

conversion to making chemical cellulose in 2013 and has since been producing around 1,050 tons per day. Chemical cellulose, also called dissolving pulp, is increasingly being used to make fabric, especially as the world supply of cotton decreases.[28]

There are further opportunities for innovation in fractionating wood into higher-value constituents that could be explored within existing pulp and paper plants or new facilities.

Additionally, there is active research into developing high-value products from lignin, and some production of products already in existence. Lignin is typically a waste product from pulp and paper production and is generally burned for energy, despite it being a low-grade fuel. Researchers have found ways to derive lignin from wood and convert it into chemical building blocks that can be used in paint, insulation foam, and other products.[29]

Reinvesting in existing pulp and paper facilities in order to sustain them for the long term as economic and community assets should be a critical priority for the state.

WOOD EXTRACTIVES

There is additional opportunity to extract high-value chemicals from wood. Extractives are non-structural wood constituents that differ in composition between tree species. Extractives can be isolated from wood using water distillation and organic solvents. Some possible extractives from wood include lignins, phenols, and arabinogalactan.[30] Lonza in Cohasset, Minnesota extracts arabinogalactan from tamarack trees, which can be used in food and dietary supplements in both human and animal nutrition. [31] There are also potential opportunities to extract additional products from different Minnesota tree species. Cedar has been mentioned as one potential source of valuable compounds.

BUILDING MATERIALS

The building industry provides an important market for softwood lumber and engineered wood products, especially as furniture manufacturing in the United State declines. New housing construction accounted for 31% of all sawn consumption (hardwood and softwood, including solid lumber and laminated veneer lumber) and 41 percent of all structural panel consumption (including plywood and oriented strand board) in 2015. Another 23 percent and 22 percent,

[28] Adam Belz, "Cloquet Paper Mill Shifts Its Focus to Textiles.," Star Tribune. November 01, 2013. Accessed June 25, 2019. http://www.startribune.com/minnesota-s-largest-paper-mill-shifts-its-focus-to-pulp-for-clothing/230139431/?refresh=true

[29] KU Leuven, "Turning Paper Industry Waste into Chemicals.," Phys.org. June 08, 2015. Accessed June 27, 2019. https://phys.org/news/2015-06-paper-industry-chemicals.html

[30] Guangyu Yang," Wood Chemistry and Isolation of Chemistry from Wood," Saimaa University of Applied Sciences" (December 2011): 3-47. Accessed June 27, 2019. https://pdfs.semanticscholar.org/8da6/397e7b858c44bf53fcf11de9f0b4682c04fa.pdf

[31] Lisa Rosemore, "Lonza to Launch First Consumer Product.," Grand Rapids Herald-Review. September 28, 2012. Accessed June 27, 2019. https://www.grandrapidsmn.com/business/lonza-to-launch-first-consumer-product/article_609b49f2-08ae-11e2-a035-0019bb2963f4.html.

respectively, of the total volume are consumed by the repair and remodeling sectors.[32] Additionally, as the green building market increases, sustainable building materials, such as reclaimed wood and bamboo flooring, are also expected to witness higher demand.[33] Future wood products demand will depend on housing demand, but new wood products related to construction, such as thermally modified wood products and cross laminated timber show a lot of promise.

ENGINEERED WOOD PRODUCTS

Engineered wood product offer more opportunity to utilize different species of wood and wood residues. Engineered wood products include plywood, oriented strand board (OSB), glued laminated timber (Glulam), I-joist, laminated veneer timber (LVT), as well as medium-density fiberboard and particle board.

- **Mass timber/ cross-laminated timber (CLT):** The Bureau of Business and Economic Research (BBER) at the University of Minnesota Duluth recently published a report investigating the Economic Feasibility of Mass Timber Manufacturing in Minnesota, more specifically, cross-laminated timber (CLT) production, which is an engineered wood product. The global market for CLT was valued at $558.6 million at 2016 and is expected to grow to $2.07 billion by 2025. In North America specifically, demand for CLT was at $118.8 million in 2016, and is expected to grow in the region. In addition to CLT, mass timber includes nail-laminated timber (NLT), dowel-laminated timber (DLT), glue-laminated timber (GLT), and structural composite timber (SCT). These types of mass timber along with engineered wood are typically used in construction as well as prefabricated buildings. The number of new mass timber projects has increased from around 20 in 2014 to around 230 in 2018, indicating a growing interest and investment in the potential that mass timber shows, especially as the demand for more sustainable construction increases. Minneapolis' T3 building, standing seven stories high, is a prime example of how mass timber can be used for large projects that reduce the carbon footprint of the built environment. Overall, the growing trend for mass timber and especially CLT because of its durability, low cost, thermal regulation, and ease of construction, makes it an exciting emerging opportunity for Minnesota.[40] [41] While the most immediate opportunity for Minnesota in this area is secondary manufacturing relying on lumber sourced from in and the region, there is a longer-term opportunity to develop mass timber wood products and other innovative engineered wood products from Minnesota resources.

[32] Urs Buehlmann." Recent Developments in US Hardwood Lumber Markets and Linkages to Housing Construction". Cross Check, April 22nd, 2017. Accessed June 27th, 2019. https://www.fs.fed.us/nrs/pubs/jrnl/2017/nrs_2017_buehlmann_001.pdf[33] Joe Gargiulo. "Five Trends in the 2018 Building Materials Industry: Pt 1." Five Trends in the 2018 Building Materials Industry: Pt 1 (September 11, 2018). Accessed June 27, 2019.https://www.cross-check.com/blog/five-trends-in-the-2018-building-materials-industry-pt-1

[33] Joe Gargiulo. "Five Trends in the 2018 Building Materials Industry: Pt 1." Five Trends in the 2018 Building Materials Industry: Pt 1 (September 11, 2018). Accessed June 27, 2019.https://www.cross-check.com/blog/five-trends-in-the-2018-building-materials-industry-pt-1

- **Oriented strand board (OSB)** is a type of engineered wood made by adding adhesives to layers of wood strands and then compressing them in specific orientations. It is a versatile type of wood, particularly suitable for construction, taking up 66 percent of the structural panel market in 2018, with an expected compound adjusted growth rate of 6.2 percent between 2019-2024. The largest market for OSB is currently North America, while the fastest growing market is South America. Five key players dominate the global OSB landscape: Norbond Inc., Louisiana-Pacific Corporation, Kronoplus Limited, Georgia-Pacific, and Weyerhaeuser Company.[34] OSB's increasing market share could be credited to its low price, efficient production, and product development that made it stronger and well-suited for construction. OSB board production can utilize small, fast-growing trees such as aspen and poplar (although it cannot use small wood), and utilizes the entire tree, reducing its environmental impact compared to plywood.[35] Many OSB plants are able to utilize a small percentage of a variety of wood species. Expanded production could present an opportunity.
- **Glued laminated timber**, also referred to as Glulam, is composed of individual wood laminations glued together by moisture-resistant adhesive. Glulam is the only engineered wood product that can be produced in curved shapes. Its structural flexibility allows it to be made into unlimited shapes and sizes, while maintaining durability. The global glued laminated timber market was valued at $4.76 billion in 2016 and is expected to grow at a compound adjusted growth rate of 5.9 percent between 2018-2025. The demand for Glulam has risen due to its durability and ease of construction, as well as its increasing acceptance as a low-cost and sustainable replacement to steel and concrete.[36]
- **I-joists** are "I"-shaped engineered wood structures, used in residential floor and roof construction. The joists are made by binding together sawn or composite lumber flanges and OSB webs, bonded together with exterior-type adhesives. The global I-joist market, also called I-beam or composite wooden joist, reached a value of $2.5 billion in 2018, and is growing at a compound adjusted growth rate of 13.8 percent during 2011-2018. The market is further expected to reach a value of $4.30 billion by 2024. North America is the largest market for I-joist, followed by Europe, Asia-Pacific, and Latin America.[37]
- **Laminated veneer lumber (LVL)** is made from peeler logs veneered and glued together under heat and pressure, using fully waterproof glue. Panels are typically made from

[34] "Oriented Strand Board | Growth, Trends, and Forecast (2019 - 2024)." Market Research - Consulting, Reports. https://www.mordorintelligence.com/industry-reports/oriented-strand-board-osb-market
[35] Bertrand Marotte, "Toronto's Norbord Riding the Rising Wave of OSB Sales." The Globe and Mail. May 17, 2018. Accessed June 26, 2019. https://beta.theglobeandmail.com/report-on-business/forest-products-firm-norbord-riding-the-rising-wave-of-osb-sales/article30985989/
[36] "Glue Laminated Timber Market Size, Share | Industry Report, 2018-2025.," Grand View Research. December 2017. Accessed June 27, 2019. https://www.grandviewresearch.com/industry-analysis/glue-laminated-timber-market
[37] " I-Joist Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2019-2024.," Accessed June 27, 2019. https://www.imarcgroup.com/i-joist-market

smaller trees, efficiently utilizing wood fiber. All veneers are lined up, so the grain direction is the same in all veneers. LVL is light weight yet durable with the ability to span long distances, making it particularly useful for beams, lintels, purlins, joists, concrete formwork, and scaffold boards. The LVL market reached a value of $2.33 billion in 2018 and is expected to reach a value of $4.23 billion by 2024.[38] [39]

- **Medium-density fiberboard (MDF)** is a type of engineered wood product made from hardwood or softwood fibers fused together with glue, pressure and heat. Low-density fiberboard, also called particle board, is made from even smaller wood fiber particles than MDF. MDF is an advantageous product because it is inexpensive to manufacture, uses recycled wood and wood residue, and doesn't expand and contract in the heat and humidity, making it suitable for furniture and high humidity applications such as bathrooms and laundries.[40] The market for MDF reached a value of $22 billion in 2016 and is expected to reach $34 billion by 2022.[41]

OPPORTUNITIES FOR MINNESOTA

Input from the stakeholder engagement process and results from the literature review point to several opportunities for economic and environmental benefits from Minnesota's forest resources.

1. **Support the existing industry.** Stakeholders expressed a desire for a state strategy that supports the existing forest products industry while attracting new investments and new facilities.

   Traditional industry priorities remain important. Minnesota's forest products industry competes in a global market. Continued health of the industry and reinvestment in the future depends on having low-cost energy, availability of wood, a healthy workforce, and regulatory certainty.

   Energy costs are a particularly important consideration. Industrial electricity rates have increased in the last 20 years in Minnesota, and Minnesota has higher rates than other US competitor states, creating a competitive disadvantage for Minnesota's industry. This is an important issue to address if we want to see future investment in existing facilities.

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[38] Reportlinker. "Laminated Veneer Lumber Market Is Expected to Reach a Value of US$ 4.23 Billion by 2024." PR Newswire: Press Release Distribution, Targeting, Monitoring and Marketing. June 21, 2019. Accessed June 27, 2019. https://www.prnewswire.com/news-releases/laminated-veneer-lumber-market-is-expected-to-reach-a-value-of-us-4-23-billion-by-2024--300872915.html.

[39] "Vertically Laminated Veneer Lumber (LVL) Panels | Engineered Wood." StructureCraft Builders. Accessed June 27, 2019. https://structurecraft.com/materials/mass-timber/laminated-veneer-lumber

[40] Scott LeGros. "What Is MDF Wood?" Forest Plywood California. November 27, 2018. Accessed June 27, 2019. https://forestplywood.com/blog/what-is-mdf-wood/

[41] " $22 Billion Medium-Density Fibreboard (MDF) Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2017-2022 - Research and Markets | Business Wire. May 31, 2017. Accessed June 27, 2019. https://www.businesswire.com/news/home/20170531006131/en/22-Billion-Medium-Density-Fibreboard-MDF-Market-Global

Sappi North America's recent activities demonstrate the potential for reinvestment and innovation at existing plants. The company announced that it had invested $25 million in their pulp and paper mill in Cloquet, Minnesota. This investment is meant to increase the mill's capacity to better serve their dissolving wood pulp customers by increasing the mill's pulp production capability by 30,000 tons a year.[42] Sappi's example demonstrates the potential for reinvestment in an existing facility.

Minnesota should continue to address issues of energy cost, wood cost, wood availability, regulatory certainty, and other competitiveness issues while encouraging new investment in existing plants.

2. **Market for residues, underutilized species, and diseased and damaged wood.** Building on theme one above, stakeholder input makes clear that identifying new markets for wood residues is a critical priority for the state to ensure the continued health of existing forest products industry facilities, especially sawmills. Sawmills are currently facing a challenge as demand for residues from the pulp and paper industry, and biomass electricity production has declined in recent years. As trade-exposed industries competing globally in a commodity market with tight margins, mill operators must maximize revenue from residues and avoid disposal costs to remain viable.

   In addition to the economic and community importance of Minnesota's lumber mills, these industries could support new secondary manufacturing industries. Furthermore, studies demonstrate that building materials can store carbon for long periods of time, displace more carbon-intensive building materials, and offer attractive greenhouse benefits relative to other uses of wood.

   Table 7 identifies several growing markets that could utilize residues, underutilized species, and disease and damaged wood, and strategies to pursue them through policy development, market development or research and development. The state should select priorities and pursue them.

3. **Market is management.** Management of Minnesota's forests depends on markets for wood, and the underutilization of many species today means that there is not an ability to put loggers in the woods to manage those forests. Hazards for the state from the lack of management include forest fires, loss of carbon storage potential, inability to remove and rehabilitate stands of trees killed by insects, risk of losing water quality benefits from sustainably managed forests, and conversion of privately-owned forested land to agriculture or other uses due to the lack of a market for wood.

   Table 7 identifies several growing markets that could utilize underutilized species and strategies to pursue them through policy development, market development, or research and development. The state should select priorities and pursue them.

[42] News Tribune. "$25 Million Investment for Cloquet Sappi Mill." Duluth News Tribune. May 07, 2019. Accessed June 24, 2019. https://www.duluthnewstribune.com/business/4609457-25-million-investment-cloquet-sappi-mill.

4. **Social license to operate—tell the story.** A recent op-ed in *The Hill* by forestry experts Robert Bonnie and Jad Daley made a clear case for the importance of forests in fighting climate change. As they explained, the 1.3 million square miles of forests in the United States annually store 15 percent of the nation's carbon dioxide emissions. But they expressed concern about the impact of urbanization, wildfires, pests, and climate change. They recommended several strategies to increase the ability of forests to actively remove carbon from the atmosphere, including a federal program to plant more trees, private landowner incentives to keep land in forestry, and better management on public lands to selectively harvest and reduce risk from fire and pests. One of their core recommendations related to markets for wood. They said, "public dollars won't meet the challenge. To be successful, we must expand markets for wood products in buildings, bioenergy, and other applications. While this might seem counterintuitive, private landowners respond to higher wood prices by planting trees and maintaining forests." And furthermore that, "we need to move forward despite a vocal minority who argues that we must curtail forest management and the use of wood products to protect the climate. This approach would risk much greater carbon emissions from climate-induced forest mortality and wildfire."[43] This echoes the sentiment expressed by many Minnesota stakeholders that we heard from as part of this project when they expressed the view that there is no management without markets.

   The academic debate on how to evaluate the greenhouse gas (GHG) impact of forest utilization is shifting. There have been numerous studies that ask an oversimplified and unrealistic question: Is bioenergy better or worse than fossil energy? These studies assume that bioenergy projects exist in a vacuum as the only product coming out of a forest. Studies like this give conflicting results, leaving policy makers and the public to question the potential role of forests in addressing climate change.

   The most innovative research takes a different and more realistic approach and asks a different question: How can forests and forest products industries in their totality contribute to carbon emissions reductions (keeping in mind forest management and the impacts of different industries)? When asking this question, bioenergy is one product from a forest products industry that is managing forests for multiple products.

   Such research acknowledges that bioenergy is likely to utilize mill residuals, harvesting residuals and underutilized species that other industries cannot use. This research also acknowledges that many forest products become long-term carbon sinks (building materials) or displace very carbon-intensive materials (steel and concrete). Research like this can also recognize the potential for emerging opportunities like BECCS and biochar to enable enhanced biogenic carbon removal and long-term storage alongside traditional bioenergy projects.

[43] Robert Bonnie and Jad Daley, "Putting America's Forests to Work on Climate Change," The Hill, June 23, 2019, https://thehill.com/opinion/energy-environment/449917-putting-americas-forests-to-work-on-climate-change?amp

Furthermore, a healthy forest products industry sustains demand for wood, provides incentives for private landowners to keep land in forestry rather than converting to other uses like agriculture, and supports better management on both public and private lands. Studies that take a more holistic approach tend to find that there is a role for bioenergy alongside other uses of wood, and that the most carbon benefits come from producing a mix of products rather than bioenergy on its own.

An example of a study that uses this methodology and reaches this conclusion is a study by Robert Matthews with United Kingdom Forestry.[44]

There was a clear recommendation from stakeholder interviews on the importance of telling a positive story about the environmental benefits of increased wood utilization, and a concern that increased wood utilization could face public backlash without laying the groundwork with education and outreach. A study demonstrating the carbon benefits of wood utilization and laying out a vision for maximizing the GHG benefits, other environmental benefits, and economic benefits is critical to building public support for a wood utilization strategy for the state.

[44] Robert Matthews, Nigel Mortimer, Ewan Mackie, Charlotte Hatto, Anna Evans, Onesmus Mwabonje, Tim Randle, Will Rolls, Marc Sayce, and Ian Tubby, "Carbon Impacts of Using Biomass in Bioenergy and Other Sectors: Forests, Final Report: Parts A and B," Report URN 12D/085, The Research Agency of the Forestry Commission, (January 2014).

Table 7: Matrix of opportunities

This matrix of opportunities emerged from stakeholder engagement and literature review. This is a high-level summary of opportunities that Minnesota could pursue, many of which offer opportunities to utilize mill and forestry residuals, bug-kill wood, and underutilized species.

Technology Area	Opportunity for Minnesota	Market Status	High Level Barriers	R&D
Thermal energy: deriving energy for heating or electricity generation	Commercial heating—wood chips	Small, modest growth	Market development, policy	Wood pellets from torrefied wood Analysis demonstrating the GHG and environmental benefits of wood energy in Minnesota
	Residential heating—cord wood	Small, stable	Market development, policy	
	Pellets—exports	Large, growing	Infrastructure, economics	
	Pellets—domestic heating	Small, growing	Market development, policy	
	Domestic electricity generation	Shrinking	Lack of domestic market, lack of supportive policy	
Thermochemical processing: converting woody biomass into fuels and power through thermochemical processing	Bio-based diesel fuel, bio jet, and bio-based gasoline from gasification or pyrolysis	Policy-driven demand for low-carbon fuels	Policy/regulations Technology risk Economics/financing	R&D to lower cost and improve economies of scale from syngas cleanup Syngas fermentation Analysis demonstrating the GHG and environmental benefits of wood energy in Minnesota
	BECCS, applied to bioenergy or biofuel project	Policy-driven demand for low carbon fuels, federal tax credit for carbon capture and storage	Infrastructure, R&D	R&D to demonstrate carbon capture from a range of bioenergy and biofuel projects
Torrefaction and thermal modification: A mild form of pyrolysis to better the quality of fuel for combustion and gasification applications	Thermally modified wood products	Small, potential to grow	Market development, product development	New product development
	Biochar as a soil amendment	Small, growing	Policy	Consistent data on benefits in agricultural soils
	Activated carbon	Stable, potential to grow	Technology development, market development	New product development

Technology Area	Opportunity for Minnesota	Market Status	High Level Barriers	R&D
Wood Fractionation/pulping A process that separates wood into its main compounds, including sugars, fiber, lignin, and extractives	Conventional pulping	Growing for packaging and biobased materials, shrinking for paper	Investment, financing, new product development	New products from lignin, pulp
	Biofuels and bio-based chemicals from sugars, extractives	Large and growing	Investment, financing, technology and product development, policy	New materials from sugars, lignin, extractives CCS from pulping
Wood Products Materials derived from wood, either through traditional or non-traditional methods	Traditional wood products, lumber	Large and growing – residential and commercial building	Economic competitiveness, market for residuals	Product Development Application of engineered wood technologies to Minnesota's wood resource
	Engineered and specialty wood products	Market development, technology development	Investment Market Development Policy supporting substitution of concrete and steel with wood construction Building codes that favor wood construction	

RECOMMENDATIONS TO SUPPORT EMERGING MARKET OPPORTUNITIES IN MINNESOTA

The following recommendations emerged from stakeholder engagement and the literature review. Following these recommendations will help the state pursue the emerging market opportunities presented in the matrix above.

Research, Development, and Analysis

- Conduct analysis to demonstrate the environmental and GHG impact of expanded energy, fuel, and materials from wood.
- Facilitate production of biofuels from wood by lowering the cost of syngas clean-up and exploring syngas fermentation.
- Develop new products from torrefied wood and thermally modified wood.

- Conduct agricultural trials with consistently produced biochar to demonstrate benefits for carbon storage, water quality, and agricultural productivity.
- Develop high-value products from activated carbon produced from Minnesota wood.
- Develop new products from pulping, lignin, sugars, and extractives.
- Demonstrate the suitability of Minnesota wood species for engineered wood products and tall timber.
- Demonstrate carbon capture and storage from existing and potential future wood uses.

Policy

- Fully fund Minnesota's Bioincentive Program and consider expanding eligibility for wood pellet production as a thermal energy product.
- Provide policy support to avoid further declines in biomass electricity production in Minnesota and support large-scale biomass heating projects.
- Communicate to Minnesota's US congressional delegation the importance of changing EPA rules to allow Minnesota's wood resource to be used for biofuel production.
- Consider a low carbon fuel policy/clean fuel policy to create incentives for wood-based biofuel production that are not dependent on EPA rules or markets in other states.
- Establish policies that support market development for domestic residential and commercial heating with efficient wood pellet stoves to support pellet production in Minnesota and expand commercial heating with wood chips.
- Identify approaches for reducing the cost of energy for trade-exposed large industrial energy users.
- Support market development for biochar by establishing incentives for agricultural soil carbon storage.
- Establish policies supportive of increased mass timber construction in Minnesota.
- Support inclusion of Minnesota forest industry facilities in plans for regional/national carbon dioxide pipelines.

Other

- Put forward a vision for the role an expanded forest products industry can play in reducing state GHG emissions, supplying clean water, and maintaining and enhancing wildlife habitat and recreation.
- Educate the state government about the value of a healthy forest products industry in delivering environmental and economic benefits.
- Explore the development of renewable natural gas from wood.

CONCLUSION

GPI gathered information on emerging wood markets for Minnesota through literature review, expert interviews, and stakeholder engagement. This white paper revealed the importance of reinforcing viable existing markets, as well as investing in product and market research and development. Identifying markets for mill residuals, logging residuals, underutilized species, and bug-kill wood are particularly important for the state.

This white paper also identified several technologies worth pursuing and listed specific steps for the state. The growing interest in sustainability by consumers and businesses presents an opportunity for the forest products industry. Possible new markets include engineered wood construction materials, wood pellets for heating and electricity generation, advanced biofuels, biobased chemicals, and chemical extractives from wood.

GPI recommends fully funding the Bioincentive Program, considering a low carbon fuel policy to create incentives for wood-based biofuel production, establishing policies that support market development for domestic heating with efficient wood pellet stoves, and supporting increased mass timber construction in Minnesota. GPI also recommends examining the role an expanded forest products industry can play in reducing state GHG emissions, supplying clean water, and maintaining and enhancing wildlife habitat and recreation.

Glossary

Black liquor is a byproduct of the Kraft process, which is where wood is converted into wood pulp and then into paper. It is a renewable biomass fuel that helps increase the quality of combustion.

CAGR stands for compound annual growth rate.

Coniferous trees are any trees that reproduce via cones.

Cords measure f feet high by 4 feet wide by 8 feet long (4ft. X 4ft. X 8ft.) and have a volume of 128 cubic feet. The amount of solid wood in a cord varies based on the size of the pieces.

Cross-laminated timber is engineered wood paneling made up of layers of dimension lumber stacked in alternative directions and bonded with structural adhesives to form a solid rectangular panel.

Dissolving wood pulp is bleached wood pulp used in textiles, pharmaceuticals, and food.

Engineered wood, also called composite wood, is manufactured by binding the strands, particles, fibers, or veneers together with adhesives, or other methods of fixation to form composite materials.

Fiber furnish is the fiber used to manufacture paper and paperboard. This includes recovered paper (wastepaper), other fiber pulp, and the wood pulp used to make paper.

Forest type is a classification of forest land based on the species forming a majority of live tree stocking.

Grade stamps indicate important information about a piece of lumber, such as the grading association, the species of lumber, the mill identification name or number, the grade itself, and the treatment.

Industrial roundwood is any roundwood used for anything other than energy. It includes pulpwood, saw logs, and veneer logs.

Paper and paperboard includes graphic papers (newspapers, printing, and writing paper), wrapping and packaging paper, and household and sanitary paper.

Petroleum resins are aromatic hydrocarbon used in industrial applications, specifically for paint, rubber, and adhesive, because of their tackifying effect.

Sawn wood are planks, beams, boards, laths, etc., that exceed 5 mm in thickness. It includes sawn wood that is planed, unplaned, grooved, chamfered, beaded, etc., but it does not include wooden flooring

Short ton is a measurement equal to 2000 pounds, as opposed to the long ton which equals 2240 pounds, and the metric ton (referred to as a ton) which equals 1000 kilograms (or 2204 pounds).

Torrefaction of wood (or other forms of biomass such as grain) is a mild form of pyrolysis to better the quality of fuel for combustion and gasification applications.

Wood fuel is roundwood used as fuel for power production, heating, or cooking, including wood used to make charcoal and pellets. This does not include wood residuals from the forest processing industry, black liquor, or recovered wood waste. Wood fuel can be subdivided by source: coniferous and non-coniferous species.

Wood pulp is the lignocellulosic material separated from wood mechanically or chemically and used to make paper. Chemical wood pulp could also be divided into bleached or unbleached and sulphite or sulphate wood pulp.

Wood residuals are wood materials recovered from municipal solid waste (MSW), construction and demolition debris, and primary timber processing.

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