

**State of Wisconsin
Department of Administration
Division of Energy**

Environmental Research Program

Final Report
November 2006

Bioenergy in Wisconsin: The Potential Supply of Forest Biomass and Its Relationship to Biodiversity

Prepared by:
Cassandra J. Willyard and Susan M. Tikalsky
Resource Strategies, Inc., Madison, Wisconsin

This report in whole is the property of the State of Wisconsin, Department of Administration, Division of Energy, and was funded through the FOCUS ON ENERGY program.



Executive Summary

Wisconsin's forests, long regarded as one of the state's most valuable natural resources, are now being recognized for their potential to serve as a source of renewable energy and new jobs for rural residents. With its unique set of natural and cultural resources, Wisconsin possesses abundant potential to generate energy from this clean-burning, local fuel. In fact, of the fifty states, Wisconsin ranks among the highest in its potential to produce forest biomass for bioenergy.

Developing the promise of an innovative bioenergy industry faces market challenges and the need to accommodate other state goals. Of particular importance is Wisconsin's tradition of commitment to environmental quality. Further, because electric utilities produce nearly all of the state's electricity, any substantial growth in energy independence will require that electric generating facilities play a significant role. One way to assist utilities' capacity to accomplish this goal is to establish an adequate supply of forest biomass—one that is reliable, economical, and ecologically sustainable.

This report explores existing and potential sources of forest biomass in Wisconsin, and the relationship between biomass production and forest health. Nearly 150 papers and scientific articles were reviewed in order to prepare this document. In addition, interviews with regional experts provided a local perspective.

Wisconsin Forest Resource Potential

Wisconsin fosters a billion tons of woody biomass, and forested acreage is increasing. Harvesting biomass for energy is compatible with many other forest uses. Because it must be competitive with other fuels, only the lowest-value biomass is used to produce bioenergy. The only two economical sources are: 1) residues—waste materials from wood-processing facilities and from wastes that remain on private woodlands after logging or other forest management activities—and 2) energy plantations—trees grown as crops specifically for energy production. Currently, there are no energy plantations in Wisconsin, and therefore, the sole source of bioenergy from forest biomass is derived from waste residues.

Today, Wisconsin's forest-derived bioenergy hinges solely on gleaning wastes from others' harvesting and processing operations. Yet, available residues are in high demand and energy companies must compete with a growing number of other interests. Further, Wisconsin's abundance of residues is largely unrealized because most are never harvested.

Changing patterns of land ownership are also contributing to reduced harvests and limited availability. Wisconsin's forests are being divided into ever-smaller parcels. Increasingly, these new owners are absentee, wealthier, and less engaged in managing their forests. This phenomenon of "parcelization" threatens the availability of biomass, while resulting in a loss of habitat that presents one of the state's greatest threats to conserving biodiversity.

In many cases, biomass removal at current market prices is simply not economical due to small quantities or insufficient local markets. In other cases, although responsible harvest of the fine woody debris, the type most used by the bioenergy industry, is not expected to present a substantial impact on forest health, some parties harbor concerns about how to integrate ecological considerations into harvest methods.

While none exists today, Wisconsin ranks fifth among the fifty states in potential production from energy plantations: with over a million acres of idle crop land and favorable agricultural conditions, the promise is excellent. Careful siting is essential for success, both in productive capacity and acceptable environmental influence. These intensively managed, even-aged woodlots are unique from a habitat perspective. Plantations will not approach the biodiversity present in well-established forests, but when compared to row crops, they offer considerable environmental benefits including improved soil conservation and greater species diversity and abundance.

Conclusions and Recommendations

Wisconsin possesses the ideal natural and cultural resources upon which to build a thriving bioenergy industry. It has abundant capacity to produce a reliable, competitively priced, and ecologically sustainable supply of forest biomass. Developing a fraction of the state's potential would increase the amount of energy produced from forest biomass more than tenfold. Establishing a new industry requires commitment and support: a Wisconsin bioenergy industry will not develop on its own. Thus far, its progress has been hindered by changing priorities and demographics, and a lack of market development.

A robust market for forest residues is the single most important element in a near-term strategy to initiate a bioenergy industry in Wisconsin. Residues are and will always be important: they are the sole source of forest biomass available today and, as such, must serve as the spring board from which to launch a new industry. However, forest productivity and ecologic conditions are site-dependent, and the supply chain involves many participants who hold different objectives. An enhanced forest-planning process can provide a means to reach more private forest owners. It can help them to meet their management objectives and understand their forests' specific limitations and advantages. Because the degree to which residue removal impacts species diversity is expected to be directly related to the intensity of the harvest, of particular importance is establishing the percentage of residues that can be acceptably removed from a given site. Enhanced planning can provide interested parties with the information they need to create an informed and balanced patchwork of working forests and protected areas.

Beyond residues, a serious commitment to long-term stability will require the volume that can only be achieved with energy plantations. Establishing sufficient, well-sited, well-managed energy plantations is the lynchpin to a sustainable supply.

Actively managing Wisconsin's private forest-resource potential will generate benefits for the economy and the environment. With support, Wisconsin can have productive and ecologically sound forests—and launch a flourishing bioenergy industry.

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Acknowledgements

The authors extend appreciation to those who provided interviews, suggestions, and information:

- Bill Berguson, Director of the Forestry Program, Natural Resources Research Institute, University of Minnesota, Duluth, Wisconsin
- Paul DeLong, Division Administrator and Chief Forester, WDNR
- Mike Demchik, Associate Professor of Forestry, College of Natural Resources, University of Wisconsin–Stevens Point
- Bob Gowdy, Plant Manager, Ashland, Wisconsin Bay Front, Northern States Power, a Wisconsin corporation and wholly owned subsidiary of Xcel Energy Inc.
- JoAnn Hanowski, Senior Research Fellow, Natural Resources Research Institute, University of Minnesota, Duluth, Minnesota
- Bill Horvath, Chair, Biomass Working Group, Wisconsin Council on Forestry, Madison, Wisconsin
- Keith Jacobson, Forest Products Utilization and Marketing Program Leader at the Minnesota Department of Natural Resources
- Joseph Kramer, Senior Project Manager, Energy Center of Wisconsin
- Nancy Mathews, Associate Professor, Nelson Institute for Environmental Studies and Department of Wildlife Ecology University of Wisconsin, Madison, Wisconsin
- James Meeker, Associate professor of Natural Resources, Northland College, Ashland, Wisconsin
- Mark Piatl, Plant Manager, LaCrosse, Wisconsin French Island, Xcel Energy, Northern States Power, a Wisconsin corporation and wholly owned subsidiary of Xcel Energy Inc.
- Paul Pingrey, Private Forestry Specialist, Wisconsin Department of Natural Resources, Madison, Wisconsin
- Don Riemenschneider, Research Geneticist, USDA Forest Service North Central Research Station, Rhinelander, Wisconsin
- Dick Rossman, Regional Forestry Specialist, Minnesota Department of Natural Resources
- Don Waller, Professor of Botany and Environmental Studies, Department of Botany, University of Wisconsin, Madison, Wisconsin.

A special acknowledgement and thanks are extended to Preston Schutt of Clean Tech Partners who developed the structure of the conceptual model presented in chapter 5.

This report has been prepared with funding from the Wisconsin Focus on Energy, Environmental Research Program and Northern States Power, a Wisconsin corporation and wholly owned subsidiary of Xcel Energy Inc.

Abstract

Biomass-derived energy is an increasingly attractive option for Wisconsin. Renewable and clean burning, it compares favorably to the operational characteristics of fossil fuels; it draws on Wisconsin's abundant natural resource potential and workforce; and it could help staunch the flow out of the state of over one hundred million energy dollars each year.

The purpose of this review is to explore forest biomass as a source of bioenergy. This report considers the forest resource as a source of biomass supply and as a source of biodiversity. The information presented in this report reflects the knowledge and findings of the over 150 papers and scientific articles that were reviewed. Interviews with a score of Wisconsin experts provided insight to augment the written text and offered a local perspective.

Foreword

Wisconsin's annual expenditures for energy exceed \$15.5 billion.¹ Two-thirds of this state wealth, or about \$4,600 per household, is exported from Wisconsin's economy each year. As the price of fossil fuels escalates,² renewable energy becomes an increasingly attractive alternative to nonrenewable, imported energy sources. Demonstrating the state's commitment to renewable energy, Wisconsin's governor launched the POWER (Promoting Our Wisconsin Energy Resources) Initiative in March of 2006.³ Governor Doyle emphasized his commitment to leading the nation in clean energy production and "growing an innovative new industry here that will not only help our country kick the oil addiction, but also create thousands of jobs for our citizens." [1]

Electricity accounts for about 30%, or nearly \$4.7 billion a year, of Wisconsin's overall energy bill. [2] Because electric utilities are producing 92%⁴ [3] of the state's electricity, any substantial growth in energy independence will require that electric generating facilities play a significant role. One way to accomplish this goal is to create a bioenergy industry in Wisconsin by harvesting renewable, homegrown fuel from forests.

¹ 2004 data. This new record was set by the 11.8% increase in expenditures in 2004. [2]

² Wisconsin's total energy expenditures have increased 60% since 1999. [2]

³ This initiative will include funding targeted to develop markets for biomass products by connecting owners of biomass resources with companies that are using biomass as an energy source.

⁴ April 2006 data [3]

Chapter 1

Introduction

Wisconsin's forests are one of the state's most valuable resources. They provide marketable goods, such as timber and pulpwood, but also hold aesthetic, ecological, economic, and cultural value. Forests now are being considered for yet another crucial purpose, providing a renewable source of energy for the state's residents. In fact, after careful study of the potential and existing biomass in this state, local researchers believe that Wisconsin is optimally positioned to move into bioenergy. [5]

Forest biomass⁵—a renewable, clean-burning, and local fuel—has the potential to be an environmentally sound energy choice for Wisconsin, [5] but the demand for forest resources is already high. In addition to potential energy suppliers, existing timber and paper industries, sportsmen, and outdoor enthusiasts all place demands on this resource. Any large-scale program for biomass-fueled energy will need to accommodate other state goals. Further, in order for the energy industry to commit to the investment necessary to convert biomass to energy, a reliable, long-term supply is needed.

This report focuses on Wisconsin bioenergy.⁶ It explores existing and potential fuel sources and the relationship between biomass production and biodiversity through a summary of the scientific literature and the views of local experts.

The purpose this report is to provide information about specific concerns that arise as the state moves toward biomass-fueled energy:

Can sufficient biomass be generated reliably and sustainably?

Can sufficient harvest be achieved without compromising Wisconsin's commitment to biodiversity?

⁵ Biomass is organic matter available on a renewable basis; it can include forest and mill residues, agricultural crops and wastes, fast-growing trees and plants, and municipal and industrial wastes. Forest biomass sources include tree plantations and residues from natural forests.

⁶Bioenergy is generally defined as the conversion of the complex carbohydrates in organic matter into energy. Bioenergy is useful, renewable energy produced from organic matter.

Chapter 2

Wisconsin's Forests: A Vital Resource

Today, as in the past, forests are an essential part of Wisconsin's economy and the quality of life enjoyed by its citizens. Shifting approaches to management have reflected shifting priorities for and attitudes towards this resource. Over time, these changes have produced the composition and function of today's forests. [6]

Historical Perspective

Wisconsin's residents have long relied on the forests for a wide array of products and services. Human activities have always played a role in shaping the forests; however, stewardship and sustainability are relatively recent management goals. The importance Wisconsin places on its forests today is reflected in the way the state's forests are currently managed under sustainable forest management⁷ practices—in a way, and at a rate, that maintains their biodiversity,⁸ productivity,⁹ regeneration capacity, and vitality.

One hundred and fifty years ago, European-American settlers viewed the forests largely as an impediment to farming or an inexhaustible source of wood products. In the early 1800s, forests covered between 22 and 30 million acres, between about 60% and 90% of the total land area of the state. They supported a complex array of wildlife, plants, and humans. [7] However, treaties signed in the 1800s opened up the area to intensive settlement. Initially, these settlers cleared or burned the forests in southern Wisconsin to create farmland, but by the late 1860s, timber production in the state's northern forests had also become important. [6]

In an era known as the cutover,¹⁰ some areas were clear cut, but most were high graded (only the most valuable timber was removed)

⁷ A more complete definition of sustainable forest management includes “stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and their potential to fulfill, now and in the future, relevant ecological, economic, and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.” This definition was developed in 1993 at the Helsinki Declaration of Ministerial Conference on the Protection of Forests in Europe (MCPFE) and has since been adopted by the Food and Agriculture Organization (FAO) of the United Nations.

⁸ Biodiversity is the diversity of all life at all scales—genetic, species, ecosystem, and landscape.

⁹ Productivity is the rate of biomass production.

¹⁰ The period of time during which most of the timber from the upper Lake States was removed, about 1850–1920.

leaving the less-economically desirable species to reseed. By the 1930s, most of the timber in the northern forests had vanished. The 16 million acres of forest that did exist in the 1930s was primarily young, early successional second growth, mostly quaking aspen and paper birch. The composition and structure was vastly different from what had been removed, favoring a different suite of species, including white-tailed deer. Many years passed before the forests recovered sufficiently to be suitable once again for harvest. [6]

Forests of Today

Wisconsin's forests have recovered dramatically, says Don Riemenschneider, a research geneticist at the United States Department of Agriculture (USDA) Forest Service North Central Research Station in Rhinelander, Wisconsin. [5] Once again, there are about 16 million acres of forested land, but today's forests are far more varied, complex, and dynamic in structure, composition, and function than the forests of the 1930s. The quality and quantity of this restored resource has largely been the result of an improved understanding of ecosystem¹¹ functions and from the success of multiple-use management policies. [8] However, new challenges are emerging.

Once again, changes in attitudes toward forests are creating new pressures. Although the acreage of forested land¹² and the amount of growing stock¹³ are increasing,¹⁴ [8] the state faces a forest-biomass supply shortage. Despite the state's billion wet tons¹⁵ of woody biomass, [9] Bill Horvath, chair of the Wisconsin Council on Forestry's Biomass Working Group,¹⁶ says the problem is one of accessible supply. [5] The phenomenon of "parcelization" threatens the availability of biomass, while the resulting forest fragmentation threatens biodiversity. [6]

The term parcelization describes the division of larger landholdings into smaller ones. Although parcelization has occurred on private forest lands in the US since at least the 1900s, its rate and extent have accelerated in recent decades. [10] Within the last 10 years, it is estimated that the number of private forest landowners may

¹¹ Ecosystems include the biotic organisms of a particular habitat or area, such as a savanna or forest, together with the physical environment in which they live.

¹² 15.32 million acres in 1983 to 15.96 million acres in 1996. [8] The rate of forestland growth is increasing as well, with 550,000 acres gained in the last decade. [9]

¹³ 16.5 billion cubic feet in 1983 to 18.5 billion cubic feet in 1996 [8]

¹⁴ Between 1983 and 1996, average net annual growth exceeded harvests and other removals by 158 million cubic feet. [8]

¹⁵ WDNR Inventory Analysis includes everything over one inch in diameter. [9]

¹⁶ The Wisconsin Council on Forestry was created by State Statute 26.02 in July 2002 to advise the governor, legislature, the WDNR, the Wisconsin Department of Commerce, and other state agencies on forestry-related topics.

have increased by 21%,¹⁷ with 57% of forested lands in private hands. [11] Statewide, approximately 3,400 new parcels of forest are created each year, [8] and parcel size is decreasing.¹⁸ [10]

In addition to trends of increasing numbers of landholders and decreasing parcel size, the demographics of Wisconsin's forest landowners are changing. Today, forested land is more likely to be purchased by people who have different objectives than in the past. According to a Wisconsin Department of Natural Resources Department (WDNR) assessment, "Rather than the farmer,¹⁹ who owned forest and used it primarily to supplement his income, many of today's new forest owners are from urban areas who own forest primarily for recreational use or aesthetic values." [6] Riemenschneider agrees, "We've got the resource in the hands of people that, in many cases, would prefer simply to enjoy its beauty, rather than managing it for production." [4]

This new group of private owners is "more cautious about harvesting their timber, less knowledgeable about rural areas and the forests they've moved to, wealthier than past owners, and more likely to be absentee landowners." [6] In fact, 25% of private forest owners own land that is more than 25 miles from their residence and non-resident purchases are increasing.²⁰ [11]

In addition to concerns about accessibility of forest biomass due to parcelization, this phenomenon can also create ecological concerns due to habitat loss and fragmentation. Both forest fragmentation and forest parcelization are caused by land division; however, parcelization involves the breaking up of contiguous properties, [10] whereas fragmentation is the result of breaking up contiguous habitat. As forested parcels are divided between ever-increasing numbers of landowners—many of whom may have different, competing goals—habitat can be lost and large blocks of contiguous forest become increasingly scarce. Habitat loss is one of the greatest threats to conserving biodiversity. And, biodiversity is both a common management objective and an indicator of ecosystem productivity and health.²¹ [6]

¹⁷ The last official census in 1997 showed 262,000 owners. [14]

¹⁸ For example, in the north woods of Wisconsin, average parcel size fell from 44 acres in 1986 to 41 acres in 1997. [10]

¹⁹ Statewide an average of 25% of forest land is owned by farmers, with a county high of 50%. [9]

²⁰ More than 13% have their primary residence outside of the state. [11]

²¹ Ecosystem health is determined by the functionality of natural processes.

Forests as Fuel

Wisconsin woodlands provide the largest share of the state's renewable energy resources. [2] Wood-burning is particularly favored by the residential and industrial sectors. The residential sector alone accounts for over half of the wood consumed statewide for energy (wood is 90% of residential alternative fuels), and together, they account for 93%. Electric-utility sector use comprises 5.5% of the total (wood is one-fifth of its total alternative fuel use). The only significant electric utility use of wood comes from two power plants, owned and operated by Northern States Power, a Wisconsin corporation and wholly owned subsidiary of Xcel Energy Inc., French Island (on the Mississippi River in La Crosse) and Bay Front (on Lake Superior in Ashland). Together, over the last five years, they produced an average of over 3,200 billion BTUs per year,²² [2] enough to provide the electrical energy needs for 26,400 homes.²³

Bioenergy produced from locally grown biomass is a renewable, environmentally sound alternative to fossil fuels. [13] Because biomass burns cleanly, it produces less ash waste than coal and, unlike coal, the ash and other waste products often can be returned to the soil. A transition to bioenergy would also reduce net carbon dioxide emissions as new trees temporarily sequester carbon. Further, the burning of biomass produces fewer harmful primary air pollutants (such as SO_x and NO_x) than does coal. [14]

²² 278,500 tons and BBTUs are five year averages of the years 2000-2004. [2]

²³ Assumes a 40% moisture content, 13.652 BTU/kWh (heat rate at 25% conversion) and average annual home electrical use of 9,000 KWh. With the exception of the higher moisture content used for Xcel (other figures are reported in dry tons), these assumptions are used throughout the report.

Chapter 3

Potential Biomass Supply

Although demand for forest resources and services is already high, [11] biomass harvested from Wisconsin's forests is being considered as a viable fuel for energy production. In addition, bioenergy has significant advantages over coal and other fossil fuels: it is an environmentally friendly source of energy, and it is compatible with other current forest uses, such as the paper and timber industries. But, are ample quantities available?

Harvesting biomass from Wisconsin forests is consistent with other uses. Because only the lowest-value biomass is used to produce bioenergy, there are only two economical sources: 1) waste residues—waste materials from various wood-processing facilities and residues remaining in the forests after logging or other forest management activities—and 2) energy plantations—trees or other woody crops grown for energy production. [15] Waste materials from wood-processing industries have well-developed markets and a high utilization rate; and therefore, this report explores the viability of these other sources of biomass as fuel for a bioenergy industry. This chapter presents the literature and expert opinions on current and potential availability and discusses whether sufficient biomass can be generated reliably and sustainably.²⁴

Forest Residues

Forests managed and logged for Wisconsin's thriving paper and timber industries create large quantities of residues. Although these residues—specifically defective portions of trees, unmerchantable trunks, trees removed for purposes of thinning, and other materials left behind during logging and management operations—could be used for a wide variety of purposes, including energy, much is left on the forest floor. In order for forest residues to be part of a favorable, economic component of a bioenergy industry, there must be sufficient quantity, and it must be suitably located.²⁵

²⁴ The term sustainability, when used to describe production refers to maintaining yield over time, when used to describe an ecosystem, refers to a condition in which biodiversity, renewability, and resource productivity are maintained over time.

²⁵ While there are other important contributing factors, such as accessibility, only quantity and distribution are addressed. Other factors could not be included because they are either too site-specific, were not identified by the experts interviewed, and/or were not suitably addressed in the literature.

Current

As of 2006, only two electric generating plants in Wisconsin used forest residues as a fuel source for commercial energy production. NSPW's French Island power generating plant started burning wood in 1976 and its Bay Front plant started in 1980. Mark Piatl, the plant manager at French Island, reports that about 10% (~6,000) of the 65,000 tons²⁶ of fuel burned each year at French Island are tree trimmings and forest residues salvaged after harvesting operations. [16] (Another 10-15,000 tons of the wood burned are wastes from saw mill operations.) Due to diminishing supplies, Bay Front has been burning less in the last couple of years. Currently they are burning between half and two-thirds as much as they'd like, "We could be burning 300,000 tons, if we could get enough fuel," says Bob Gowdy, plant manager at Bay Front. He adds that competition for existing supplies is intense. [17] Piatl agrees that the plants would use more if it were economically available. [16]

According to Mike Demchik, an associate professor of Forestry at the University of Wisconsin-Stevens Point, the wood supply in Wisconsin is well-utilized. Energy companies must compete for underutilized waste materials that have a growing demand by other interests, such as landscapers, paper mills, livestock operations, and makers of reconstituted products. [18] Although there are several studies on supply (see Table 1), there are no estimates available for the amount currently extracted and utilized. Of the residues that were removed, some were purchased by French Island and Bay Front. As for the rest, no comprehensive inventory exists identifying other consumers or the quantities purchased. [19]

Despite the demand, most residues are left on site. [4] An Oak Ridge National Laboratory (ORNL) study, sponsored by USDA and USDOE, estimates that nation-wide, an average of about 60% to 65% of the total generated residues are recoverable after a conventional harvest (when merchantable wood is removed and the residues remain scattered across the harvest area) due to difficult terrain and lack of roads into large tracts of forest. [20] On this basis, Wisconsin's recovery rate would be higher than the national average because it is relatively unhindered by these factors: Wisconsin's road density and topography are favorable. Nevertheless, in most cases, increased removal of generated residues at current market prices is simply not economical due to factors such as small quantities or insufficient local markets.

Residues are highly price-sensitive: [21] the higher the price, the

²⁶ NSPW's figures refer to as-burned tons. The residues burned in Wisconsin range in moisture content from 35-45%, according to David Donovan, manager of regulatory policy for NSPW. [22]

more residues can be economically removed from the forest and delivered to market. For the energy industry, pricing must be relatively stable and competitive with other fuels. [16] Because price stability is linked to supply, Bay Front pays a premium price for its wood waste. Gowdy emphasized that at this time, even-high priced biomass is still cheaper than coal in his region. [17] But, as with other industries, before the bioenergy industry can invest in growth, it must be sufficiently confident that it can meet the requirement of a secure supply at a competitive price.

Potential

The *amount* of forest residues²⁷ generated depends on the degree of logging, the types of management activities taking place, and the extent of the material left behind. The potential *supply*, however depends not only on: 1) the quantity of residues generated but also on 2) their distribution as well.

Quantity

Wisconsin ranks twelfth among the fifty states in the production of forest residues. [23] Recent analyses set the amount of forest residues generated in Wisconsin to be between 609,000 and 2,325,000 dry tons²⁸ per year (dt/yr) (up to ~147,500,000 cubic feet). Using only 15% of these residues²⁹ could provide for the power needs of 10,000 to 36,000³⁰ homes per year.

The potential “recoverability” (the fraction of residues physically available for removal) of any given parcel can be enhanced by the method of recovery that is used. Generally, merchantable wood is removed first and the residues, which are scattered across the site, are removed in a second pass. This practice reduces the potential recoverability and makes it less predictable.

Table 1 shows the estimated quantity of biomass produced each year by four separate studies and offers a brief description of the residues included in the analysis.

²⁷ For the purposes of this report, forest residues are defined as defective portions of trees, unmerchantable trunks, trees removed for purposes of thinning, and the materials left behind during logging and management operations; however, other reports exclude some of these sources, or include additional ones.

²⁸ All weights in this report are expressed in dry tons (dt) unless otherwise noted; that is, 2000 pounds of biomass dried to a low, consistent moisture level, usually less than about 20%.

²⁹ This figure assumes that only 60% of the residues are available to harvesters, and of that 60%, only 25% is harvested, with 75% of the residues remaining on site.

³⁰ Actual values calculated using 15% of residues were 9,516 to 36,332 homes.

Table 1. Estimates of the Quantity of Forest Residues Generated Annually in Wisconsin

Quantity Generated (dt/yr)	Research Project	Sources Included
2,325,000	USDA [24] ³¹	Unused portions of cut trees, trees killed by logging.
2,217,000	National Renewable Energy Laboratory (NREL) [23]	Unused portions of cut trees, trees killed by logging, thinning, or weeding, trees cleared from land not associated with timber production.
1,138,000	US Department of Energy (DOE) [25]	Not specified
609,000-1,138,000	Oak Ridge National Laboratory (ORNL) [21] ³²	Unused portions of cut trees, trees killed by logging, rough, rotten, and salvageable dead wood. Varies with price.

Only one study factored cost into the equation. ORNL estimated recoverable forest residues by delivered price. They found that when the price the consumer was willing to pay shifted from \$30/dt of biomass up to a maximum of \$50/dt,³³ the supply nearly doubled. [21] These figures align with the residues shortfall in Wisconsin, where loggers say the sale price must reach between about \$55/dt to \$60/dt in order for them to be able to harvest. [9]

When considering potential quantities of available residues, another key issue is that of changing land ownership. Over half of Wisconsin’s forested land is privately owned. Many of these landowners are not harvesting or even managing their forests; therefore, no residues are being generated. More technical assistance is necessary to convince landowners to harvest their land. “Otherwise,” Horvath observes, “we’re going to see an increasingly large gap between supply and demand.” [5]

Distribution

Proximity to market is crucial. Sources must generally be within 50 miles of the energy facility and relatively easily extracted to compete with other fuels. [20] Distribution is important because transportation

³¹ USDA estimated that there were 147,000,000 cubic feet of harvest residues (79% hardwood and 21% softwood) generated in 1999. Those numbers were converted from cubic feet to dry weight by using conversion factors from Forest Land Degradation: A global perspective [26]: 438 dry kg/green cubic meter for softwood and 525 dry kg/green cubic meter for hardwood.

³² In this scenario, the more the consumer was willing to pay for the biomass, the more became available. According to their estimates, as of 1999, 1,138,400 dt of forest residues were available for less than \$50/dt, the highest price analyzed. For less than \$40/dt, that quantity decreased to 886,000 dt. And only 609,000 dt were estimated to be available for less than \$30/dt. These numbers are far below the quantity estimated by the NREL; however, the report acknowledges that the authors included only logging residues and rough, rotten, and salvageable dead wood in their analysis. This would not include biomass gleaned from thinning or weeding, sources that were included in the NREL analysis.

³³ 1995 dollars

accounts for the largest cost component of residue price. In fact, the price of forest residues is based largely on transportation costs rather than on value. [9] The ORNL estimates that the price ranges from twenty to sixty cents per mile per dt. [20]

According to the NREL estimates, the greatest quantities of residues exist in the northern part of the state, with smaller amounts in the western and central parts of the state (see Figure 1).

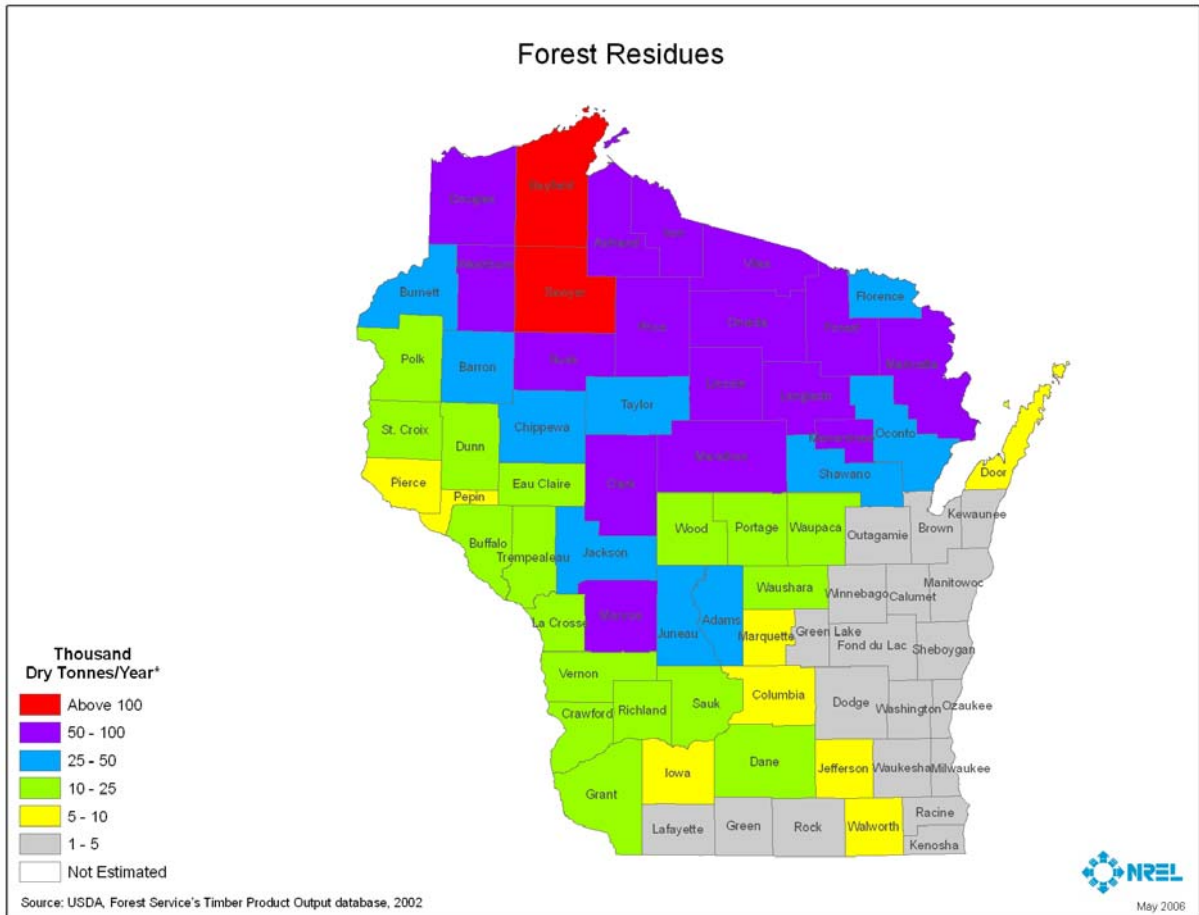


Figure 1. Estimated Quantity of Forest Residues Produced Annually by Wisconsin County³⁴

³⁴ This map reports productivity in dry metric tonnes/year rather than dry tons/year (1 tonne=1.1023 tons).

Forest residues are a valuable and available resource. Although logging practices currently generate more residues than are harvested, the quantity generated doesn't necessarily reflect the overall supply. These estimates represent only what is theoretically available. Some residues will be too costly to recover, or intentionally left to enhance soil nutrients or wildlife habitat (see Chapter 4). [20]

Energy Plantations

Energy plantations can be the most efficient and reliable source of biomass. These woody crops consist of stands of trees grown specifically as a fuel for energy production, and although perennial, they are not unlike annual row crops such as corn or beans. In general, plantations have a 7- to 10-fold production advantage over natural forests;³⁵ therefore even poor productivity on a plantation is much higher than that which can be achieved in a natural forest. [4] The degree to which biomass can serve as a viable source of energy for Wisconsin will depend on establishing productive energy plantations.

Current

There are no commercial energy plantations currently established in Wisconsin.

Potential

There is great potential for biomass production on energy plantations in Wisconsin. Production hinges on two factors: 1) the availability of land on which to establish plantations and 2) the productivity achievable on that land.

Availability of Land

Site selection is the most important determinant of potential productivity while cost is a key factor in determining where plantations will be sited. Converting existing productive agricultural lands into energy plantations would yield more biomass than conversion of marginal or degraded lands; however, biomass crops cannot compete economically with high-value crops such as corn and soybeans that are traditionally grown on the most productive soils. [27, 28] More productive soils offer better biomass yields, but those lands are also the most expensive. Because developers will be seeking the optimal balance between establishment cost and productivity, the price differential between row crops and energy crops is expected to drive development of energy plantations onto lands not used for high-intensity farming, such as marginal or degraded farm land or those

³⁵ Productivity in the natural forest is likely to be less than 1dt/ac/yr, and possibly much lower. Production on native aspen stands has been shown to be between 0.5 and 0.8 dt/ac/yr., 7 to 10 times less than estimate for energy plantations sited on marginal lands. [4]

lands suitable for government set-aside programs. On these lands, energy plantations can help farmers diversify their crop base and perhaps stabilize soil and modestly increase income. [29]

Marginal Farm Land

There is abundant idle and “marginal farm land” (lands that have marginal productivity) in Wisconsin that appears to be particularly well-suited for energy plantations. These are often degraded due to erosion, tend to be planted with lower-value crops such as hay and pasture, or are lands that are scarcely economically viable. [5] These lands, while too erosive or otherwise unfavorable for farming, may be ideal for energy plantations, which can stabilize the soil and provide other benefits. [29]

Horvath explains that these “vacant lands” were often farmed unsuccessfully in the past. [5] Riemenschneider adds that they often lie in the transition between forest and prairie. [4] According to Bill Berguson, director of the Forestry Program at the Natural Resources Research Institute, University of Minnesota–Duluth, some lands in northern Wisconsin, where farming has never been especially productive for agriculture, might be ideally suited. [30] Production on marginal lands will be lower than it would be on the most productive cropland, but the land can be obtained at a lower price.

As of 1991, there were roughly one million acres³⁶ of idle cropland in Wisconsin. [31] Paul Pingrey, a private lands forest specialist at the WDNR, notes that although some of those acres have been reforested, more farms have gone out of production since that time and speculates that the available acreage has not changed much since then. [31]

CRP Lands

Although energy plantations are not, as yet, an approved activity, USDA Conservation Reserve Program (CRP) lands have been identified as potentially suitable locations. Previously farmed lands, whether productive or marginal, are often enrolled in the CRP. This program provides landowners an opportunity to receive a fee in exchange for setting aside qualified lands. Priority is given to land where halting cultivation offers environmental benefits such as stabilizing erosive soil, improving stream quality, or enhancing wildlife habitat. However, maximum productivity on CRP lands is unlikely because they are typically more arid and offer less productive soils. [13]

³⁶ Comparing the 1974 and 1991 Wisconsin Agricultural Statistics reports, it can be calculated that there were 2,082,000 acres of farm lands in Wisconsin that were not being farmed. This figure included woodlot, pasture, and cropland (but does not include lands enrolled in CRP). The figure was calculated by taking the average percent of cropland on the idle farm lands. [31]

CRP lands are typically taken out of production under contract for 10 years. Horvath believes that because of new environmental restrictions, many of the lands that are currently in CRP will not be eligible again. “We’re going to have a large amount of land that was in CRP that is going to come back on the market,” he notes. [5] Rather than the native grasses that are typically planted, energy crops such as hybrid poplar, willow, or other woody crops could be used to serve the same purposes of erosion control or improved water quality. In Wisconsin, there are currently 618,000 acres of land enrolled in CRP (see Appendix A). [32]

Productivity

Productivity is defined as the quantity of biomass produced per acre of land per year. Productivity on any given plantation is largely determined by the characteristics of the plantation site, such as climate, soils, and availability of water. After site selection, the most important factor affecting yield is that of the tree clone³⁷ selected. Following site and clone, there lies a complex mix of many smaller factors that can affect mortality, some of which are interrelated with individual site characteristics and the clones selected, such as weed control, spacing, wildlife browse, and local diseases. [33]

Studies show (see Appendix B), a warmer climate increases productivity as long as sufficient water is available. Water is often a limiting factor, but irrigation does not appear to be economical. Weeds compete with growing trees for space, light, and nutrients; therefore, production of biomass will be higher on sites where there is good weed control. More productive soil resulted in higher yields. Fertilization has been shown to increase plantation productivity when applied every other year.³⁸ [34] Little information is available regarding the long-term impact of biomass production on soil fertility (see Chapter 4).

Researchers are in the process of developing clones that are faster-growing and more disease resistant. However, the success or failure of any particular clone is highly dependent on the site on which it is grown, and productivity on any given site for any given clone varies widely.³⁹ [35, 36, 37, 38] Nevertheless, both Riemenschneider and Berguson point out that progress is being made with new hybrids and it is expected that increases in productivity will be achieved as new clones are produced. [4, 30]

According to a 2005 report from the ORNL, annual yields from

³⁷ Clones are cuttings from an original seedling plant that maintains the identical genetic character of the original ancestor, and are used almost exclusively for plantations.

³⁸ An average growth rate of 25% was seen with an application of 120 pounds per acre of nitrogen. [34]

³⁹ For specific measurements, see Appendix B.

woody crops have been approximately 5 dry tons/acre/year (dt/ac/yr). [20] (They offer an estimated range in Wisconsin between 2.5 and 6 dt/ac/yr.; [20] also see Appendix B). This 1999 estimate is in sync with estimates given by Berguson and Riemenschneider; both experts are currently involved in poplar productivity studies. Depending on rotation interval and spacing, they estimate that hybrid poplar plantations can yield anywhere from 3 dt/ac/yr on marginal lands [4] up to 5 dt/ac/yr on the best sites using commercially available hybrids.⁴⁰ [30] [32]

Though not as heavily researched, willow is another species appropriate for energy production in Wisconsin. The ORNL estimates that willow plantations will yield anywhere between 4 and 7 dt/ac/yr. According to Riemenschneider, willow yields, assuming comparable soils and climate, should be on par with productivity of poplar. [4]

Potential Biomass from Available Lands

Using average-production figures and available acreage, it is possible to generate estimates of potential biomass production from energy plantations in the state. In fact, some research laboratories have already attempted these calculations. Table 2 identifies potential lands that could be planted with forest biomass, the acres available, the estimated productivity of those lands, and potential total production. According to one source, Wisconsin ranks fifth among the 50 states in potential production of biomass from energy plantations. [23]

Establishing productive energy plantations is a complicated undertaking under any circumstances, yet Wisconsin appears to be ideally suited. With over a million acres of idle farmland, maximum production ability is estimated between 3 and 5 million dt/yr.

The annual electrical needs of one Wisconsin home could be met by biomass from less than two acres of plantations.⁴¹ A quarter-section of land (160 acres) could provide the annual needs of over 80 homes and a full section (640 acres), over 300 homes each year. Estimating energy from plantations established on only 10% of the land identified as “idle” by DNR (100,000 of the 1,000,000 acres) [30], up to an amount equivalent to about half of that currently in CRP (300,000), produces an annual energy yield from 470,000 to 1,410,000 megawatt-hours (MWh) per year, meeting the needs of between 52,000 and 157,000 homes.

⁴⁰ Riemenschneider estimates that on the marginal lands most likely to be converted to energy plantations, hybrid poplar production would be between 3.5 and 5 dt/ac/yr. Rotations would vary between 5 to 12 years for our region, he adds, depending on spacing, soil, and other factors. [4] Berguson speculates that current production would be anywhere from 3 to 3.5 dt/ac/yr, with production on the best sites between 4.5 and 5 dt/ac/yr, based on 6 foot by 6 foot spacing and a 7-year rotation. [30]

⁴¹ Assumes production rate of 5 dt/ac/yr.

Table 2. Estimated Potential Forest Biomass Production Annually in Wisconsin

Available Lands	Acres Available	Productivity (dt/ac/yr)	Production (dt/yr)	Project
CRP	618,000 [32]	3.5-5 [4]	2,161,000–3,088,000	USDA [32]
Idle farm lands	1,000,000 [31]	3.5-5 [4]	3,500,000–5,000,000	WDNR [31]
Productive croplands, idle croplands, pastures, CRP	Not specified	2.5-7 See Appendix C	6,114,000	ORNL (includes willow and poplar plantations and switchgrass) [21] ⁴²
CRP	Not specified	Not specified	3,210,000 [23]	NREL [23]

Harvesting

Using a process where all the biomass for multiple products is harvested and processed together, known as an “integrated recovery system,” improves the total achievable recoverability significantly. [20] One study found that recovery of the standing biomass could reach 94% “when using a system to recover multiple products if the biomass from in-woods processing was actually utilized for bioenergy.” [39]

Summary

The two most economical sources of fuel derived from forest resources are waste residues remaining after logging or other forest management activities, and trees or other woody crops grown in energy plantations.

Residues

Forests managed and logged for paper and timber industries leave behind large quantities of residues. In fact, Wisconsin ranks twelfth nationally in total residues production. “Those residues that are extracted are in high demand.” says Horvath. He adds, “There is a lot of competition for wood residues among existing industries.” Despite the demand, many residues are left on the forest floor. More residues are generated than can be harvested because they are too costly to recover or intentionally left to enhance soil nutrients or wildlife habitat.

⁴² ORNL estimated the amount of potential biomass from dedicated energy crops; however, they included not only forest biomass, but also switchgrass, an herbaceous source of energy. Their analysis included croplands presently planted with traditional crops, idle agricultural land, pastureland, and CRP lands. For less than \$50/dt (1997 dollars), they estimated that 6,114,270 dt of biomass would be available in Wisconsin each year.

Although forest residues are the only existing supply of forest biomass available for a bioenergy industry in Wisconsin, it is clear that, at current market prices, the supply is not sufficient. Often other consumers are able to pay a higher price than can the energy industry. As the costs of other fuels rise, power plants may be in a position to pay more for wood waste. This would drive the removal of additional residues, but regardless of this increase in removals, some residues will be unrecoverable. Even at premium prices, supplies may not be sufficient. “The bottom line is that the existing supply of forest residues isn’t meeting current demands,” Horvath says. [5] Berguson agrees, “It’s going to take more than just the casual removal of forest harvest residues and tree trimmings to fuel a bioenergy industry in the state. The potential demand is just too huge,” but he adds that the market demand is not sufficiently well developed. [30] Further, he believes that cellulosic ethanol is becoming feasible rapidly and if natural gas prices become high enough to justify replacement with biomass, the demand will be very large. [34] “Most of the readily-available sources are just not significant enough.” [30]

Plantations

Energy plantations have the potential to serve as a reliable biomass supply. Continuing improvements in the productivity of energy crops should make plantation-grown biomass more competitive with other fuels and with traditional agricultural crops. According to Berguson, dedicated energy crops are going to be crucial to the development of a sustainable bioenergy industry. [30] Biomass production in energy plantations hinges on two factors: 1) the availability of land on which to establish plantations and 2) the productivity achievable on that land. Wisconsin is well-suited to meet these requirements. Ample marginal land is available for cost-effective conversion into energy plantations, ranking Wisconsin fifth nationally in potential productivity of biomass from energy plantations.

Chapter 4

Biodiversity and Forest Biomass Production

Forests provide significant value to the citizens of Wisconsin. Not only do they possess sufficient potential for biomass production to fuel a bioenergy industry, they also play an invaluable role in maintaining biodiversity. Before the state turns to forest biomass as a fuel source, some thought must be given to the forests' ecological sustainability, specifically to biodiversity. Can sufficient harvest be achieved without compromising Wisconsin's commitment to biodiversity?

A review of the scientific literature reveals the lack of uniformity in the characteristics used to form the concept of "biodiversity." Biodiversity is selected here as a key indicator because it is a commonly used, easily measured, and a highly appreciated ecological attribute.

Biodiversity is a broad concept that can be used to describe the diversity of life on several different scales: genetic, species, ecosystem, and landscape. [6] The term biodiversity is often interpreted as a measure of the number of different species, and it is often assumed that the greater the biological diversity, the healthier the landscape; therefore, biodiversity is a commonly used surrogate for ecosystem health. Although there is some evidence that ecosystems with a higher diversity of organisms are more efficient in carrying out biological production and retaining nutrients, [40] most scientists agree biodiversity alone is not a perfect proxy for ecosystem health. In some cases, other indicators, such as soil or water quality or nutrient cycling may be more important.

Because many factors contribute to ecosystem health, maximizing biodiversity is not necessarily desirable from a management standpoint. Mature forests, which provide necessary and increasingly scarce habitat for some rare and endangered species, often shelter a fewer number of species than intermediately disturbed sites. Nancy Mathews, a wildlife ecologist at the University of Wisconsin–Madison, explains the drawback of using biodiversity as an indicator of health, "An area can have a high level of diversity based on the classic measures of biodiversity (the number of species in an area and their abundance), but the species present could be exotic or aggressive species that don't allow more rare elements—elements that might be better indicators of ecosystem health—to flourish." [41] However, if

composition is taken into account as well, biodiversity can be an excellent indicator, says Don Waller, a professor in the Botany Department at the University of Wisconsin–Madison. Thus, when defined to take into account not only the number of species and abundance, but also species composition, “biodiversity” can serve as a much better proxy for the ecological health of any given site.

The role of scale is also important in discussions of biodiversity. Waller and his colleagues are examining the changes in plant composition on sites originally surveyed in the 1950s. Their data demonstrate that biodiversity is being lost at the landscape level. “We’re not just losing native plant diversity within each site, we’re also seeing convergence in the composition of these sites. Forest understories are becoming more similar to one another—they are homogenizing—and the rare species with specific habitat requirements are getting left behind,” says Waller. [42]

Whether or not biodiversity is an accurate measure of forest health, it has been selected as a social value and a management goal for Wisconsin’s forests. [8] The concept that each organism and each natural community has worth is deeply rooted in Wisconsin, most notably Aldo Leopold’s explanation of a land ethic “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.” [43] Even species whose life history is poorly understood may play important (though as yet unidentified) roles in ecosystem function. [44] “The challenge,” according to WDNR, “is to conserve all the working parts within a particular ecosystem in order to maintain ecosystem resilience when disturbances occur.” [8]

This chapter presents expert opinions on biomass production and biodiversity within the framework of relevant literature. It discusses the potential impacts of increasing biomass production—through increased harvest of forest residues and by conversion of non-forest lands to energy plantations—on biodiversity, and it explores whether sufficient harvest can be achieved without compromising Wisconsin’s commitment to biodiversity.

Forest Residues

Residues are generated as a result of logging or management activities. Logging disturbances can, depending on the management practices and the species under consideration, have either positive or negative impacts on the many different indicators of forest health, including biodiversity. Similarly, harvesting the leftover woody debris—whether as part of the logging process or undertaken as a second wave of resource removal—will also create a cascade of effects.

Before settlement, residues were periodically cleaned from the forest by natural fires. It is inevitable that the impact of removing residues, while perhaps minor when compared to logging or forest fires, will adversely affect some species. Residues can support a wide variety of animals, plants, insects, and microbes. These species may be those specifically adapted to taking advantage of residues or those species newly dependent on residues as a substitute for the food and shelter harvested by logging. The degree to which residue removal impacts species diversity is dependent primarily on two factors: 1) the type (size) of residues removed, and 2) the intensity of removal.

Residue Type

“Biodiversity impacts,” says Berguson, “depend on the type of material being removed.” [30] Forest residues are categorized according to size into two main types: 1) coarse woody debris (CWD)—stumps and fallen trunks or limbs of more than six-inch diameter at the large end [8]—and 2) fine woody debris (FWD)—smaller branches and twigs. The characteristics of CWD are not as amenable for energy use, and so of the two, FWD is a much more significant source of biomass for the bioenergy industry. Further, at this time, FWD is considered of less importance from a biodiversity standpoint. [30, 44] CWD provides structural diversity and decays slowly, while FWD, which decays more quickly, makes a larger contribution to soil fertility than it does to biodiversity. Nevertheless, because residue harvest reduces the amount of woody debris in managed forests and changes the physical structure and perhaps the nutrient cycling in logged areas, some changes in biodiversity can be expected with removal of either type. [41]

Coarse Woody Debris

CWD provides structural complexity that increases the number of microclimates and microhabitats. It provides moisture retention for plants and animals, refuge from environmental extremes, and nesting and denning sites. [45] In addition, it is one of the most important habitat factors for small mammals such as voles and shrews; it provides shelter in clear cut areas for flightless insects; and it offers a colonizing substrate for mosses and fungi. [46] Some soil-dwelling organisms associated with CWD have been shown to increase the availability and suitability of organic particles for decomposers. [46]

Demchik adds that CWD provides valuable habitat for reptiles, amphibians, and birds and that it can act as a nurse log for other species. [18] Mathews agrees: “If you take the coarse woody debris out of the forest, you’re going to reduce the habitat for a lot of ground-dwelling animals—from insects to small mammals to birds.” However, she adds that the degree of impact will vary according to the intensity of the removal. [41]

Numerous studies have been conducted examining the importance of CWD on biodiversity. [45] In fact, Michael Huston, a research associate at the NREL, writes, “No other manageable property of the forest environment has a greater impact on biodiversity than [harvesting] CWD.” [44] He asserts that removing coarse residues as part of the logging process has a greater negative impact on biodiversity than does logging alone. Logging as the primary harvest, without removing CWD, can actually increase the number of tree species by ‘resetting’ the process of forest succession. [44]

Large residues, such as CWD, are well utilized by many industries in Wisconsin, but due to cost and competition, energy production is not significant among them. CWD is not a significant potential source of biomass for energy production; however it is undeniably important for wildlife as a source of habitat. [30] Recognizing its importance, Wisconsin’s forest management guidelines recommend that dead standing trees and CWD are left on site to maintain habitat and ecological processes. The Wisconsin guidelines for timber harvest suggested leaving “as many snags as possible,” avoiding disturbance of downed logs, and ensuring that “at least 2–5 bark-on downed logs (diameter greater than 12 inches) are left per acre” [8] (see Appendix C).

Berguson summarizes by saying, “Because most CWD is either left on site or salvaged for other purposes, the bulk of the research on coarse woody debris is not applicable to biomass production for bioenergy.” [30]

Fine Woody Debris

Most forest biomass for bioenergy production comes from FWD. [30] The experts interviewed agree that FWD harvest is not known to present any substantial ecologic impact, yet, there is little research to supply verification.

Up to this point, the greatest ecologic concern regarding harvest of FWD, such as small twigs, branches, and leaves, according to Berguson, “has focused more on nutrient concerns and less on wildlife impacts due to the fact that the fine material decomposes rather quickly and the material is too small to provide habitat for wildlife.” [34] Unlike the trunks and large matter of CWD, FWD is high in available nutrients, especially calcium, magnesium, and potassium. This may be especially true on sites with unique moisture characteristics—outwashed sands, shallow to bedrock soils, or certain types of wetlands. [18]

Nutrient loss may be a more significant concern than species loss when discussing the ecological impacts of fine residue harvest, but the impact on flora and fauna is not insignificant. Waller anticipates that residue removal may open the understory to more intense browsing and limit the ability of trees to regenerate and more sensitive species to persist. [42] “In terms of small mammals and even birds, the fine biomass is going to provide better cover than will the coarse,” says Mathews. She also points out that any change in the forest floor will have a substantial impact on insects, but that the specific impacts and the species they will affect are largely unidentified. [41] “That’s where you fall off the deep end with respect to the literature,” says Berguson. [30] Waller adds, “The long-term impacts of fine residue removal are an unknown because no one has tracked long-term changes.” [42] James Meeker, an associate professor of biology and natural resources at Northland College in northern Wisconsin, agrees, “No one knows about long-term nutrient extraction from the soil and how that might affect soil fertility down the line.” [47]

Experts agree that it is not only the lack of research; it is not possible to generalize on the effects of residues harvest on biodiversity due to the complexities inherent in ecosystem functions. They note that effects will always be dependent on site-specific characteristics such as, forest type, the species the forest supports, surrounding landscape, and the quantity and type of residues removed. Mathews observes, “All kinds of species will be impacted, but the degree of the impact will be related to the intensity of the harvest.” [41]

Intensity of Harvest and Site Concerns

In addition to the type of residues, the quantity removed will affect the overall impact of residues harvest. It is simply not known what level of FWD harvest (percent of total debris removed) will impact biological diversity in the forest; it is not even known how it will be influenced. Some sites—depending on the species found there, the soil type, and the sensitivity of the habitat to disturbance—are more tolerant of biomass removal than others. [18] Demchik emphasizes that in some forests, especially those that are only marginally productive, residues removal will have a significant effect on the already limited soil nutrients. On other sites, “You can probably harvest about as much material as you like and have an overall limited impact on future site productivity.” [18]

The literature contains no formulas that can be used to predict the percentage of generated residues that can be removed on any given site. Such a calculation would require site-specific components. The scant available literature on the subject reports a wide range in the percentage of residues that should be left on the ground in order to avoid ecological impacts. With very little data to draw upon, Keith

Jacobson, forest products utilization and marketing program leader at the Minnesota Department of Natural Resources, believes that most harvesters are operating on “wild guesses.” He has heard a wide range of estimates reported—leaving from between 80% to 25%. [48]

According to the literature, on the high end, the ORNL, in their assessment of available biomass in the US, after taking into account long-term productivity and biodiversity issues, assumed the portion of residues left on the ground⁴³ should be no more than 15% in order “to allay concerns about site impacts.” [20] Perhaps most reliable and most applicable to Wisconsin, is the work being done in Minnesota and in Finland. The Finns have long been researching and harvesting biomass. Their regulations call for 30% of slash and tops to be left on site.⁴⁴ [49] The Finnish work aligns very closely with that of Minnesota. This field study, which sampled 125 residues-harvested sites in Minnesota, inspected the remaining residues for their efficiency of harvest and for their environmental acceptability. The results report that the remaining residue level of about 28% FWD was acceptable (averaging about 13 green tons per acre of CWD and FWD debris combined).⁴⁵ The method of harvest had little impact.⁴⁶ [50]

Riemenschneider emphasizes that generalizations regarding how bioenergy will impact biodiversity are problematical. He sums up the complexity of natural systems and the general lack of scientific information that can be practically applied, “There is no way to look at a management strategy on a large scale and determine whether it will positively or negatively impact biodiversity.” In all cases, some species will benefit from removal of fine debris and some species will lose. [4]

Energy Plantations

Energy plantations are unique from a habitat standpoint. These intensively managed, even-aged woodlots usually consist of clones of a single tree species (monoculture). They are characterized by short harvest rotations⁴⁷ and a lack of almost all of the structural diversity (for example, canopy gaps and dead wood) found in natural forests. In order to achieve high productivity, ground vegetation, which might compete with the young clones, is controlled through chemical or mechanical means. The heterogeneity that does exist in a plantation is

⁴³ This figure assumes an integrated recovery system is used (see page 22).

⁴⁴ Finnish operations call for every fifth tree processed has all the tops and branches left on site, accounting for 20%. The remaining 10% is produced through breakage.

⁴⁵ Accepted individual measurements included: Apen/Birch, 28% FWD; other hardwoods, 20%; lowland conifers, 35%; upland conifers, 10.5%. [50]

⁴⁶ Acceptable CWD and FWD remaining by harvest type: clearcut, 12.9 green ton/acre; thinning, 12.2 green ton/acre. [50]

⁴⁷ Short rotations usually refer to a 10 to 12 year cycle.

unintended. It comes from failures in weed control, dead or missing trees, or other inconsistencies. Plantations are managed to be predictable and uniform, not dynamic and variable. [51]

Because greater complexity generally is associated with greater degrees of biodiversity, [52] some wonder if conversion of land from existing uses to simplified plantations for biomass production could have serious ecological consequences and result in species loss or replacement of rare species with those that are more common. Some have even described plantations as “biological deserts.” [53] However, JoAnn Hanowski, a senior research fellow at the Natural Resources Research Institute at the University of Minnesota–Duluth, disagrees. “They’re crops,” she explains, “They may be deserts compared to a natural forest, but not compared to a field of corn.” [54]

Several comprehensive studies have been conducted to research the level of biodiversity on energy plantations relative to that found in other habitats in the Midwest (Wisconsin, Minnesota, South Dakota). [54, 55, 56, 57, 58, 59] These studies⁴⁸ generally focused on birds or small mammals, with a few studies of medium-sized mammals and deer. By studying species that differ in their mobility and habitat requirements, the researchers were able to gain more insight into the habitat provided by plantations. [57]

The Midwest studies addressed many of the key issues associated with the expanded, more comprehensive definition of biodiversity: species richness, species abundance, and species composition. The results of these studies can be understood by grouping these elements of biodiversity within the context of the plantation: 1) site, 2) age, 3) heterogeneity, and 4) the surrounding landscape.

Site

One of the objectives of the Midwest studies was to compare the abundance, composition, and number of species on different land uses—row crops, CRP land, haylands, or shrublands—to that found on hybrid poplar plantations. Overall, avian abundance and species richness were lower in plantations than in forests or shrublands, but higher than in row crops or small-grain fields. Small mammals showed a similar pattern: abundance and species richness were lower in plantations than in forests or grasslands, but higher than in traditional agricultural croplands.

⁴⁸ A group of studies, initiated in 1992, was funded by the Environmental Task Force of the USDOE’s Biofuels Development Program for the purpose of conducting research on how to plant, manage and harvest bioenergy crops to maximize environmental advantages and minimize [negative] impacts. This initiative instigated several studies conducted with the collaboration of and additional funding by many other institutions.

Addressing land type for conversion, Hanowski sees the potential conversion of CRP lands into energy plantations as one of the major environmental concerns related to biomass production. CRP lands planted with native grasses provide favorable habitat for prairie species. The Midwest studies found that, not only were species of concern⁴⁹ in the region found on CRP lands (but not on plantations),⁵⁰ [56] also fewer cowbirds, brood parasites that lay eggs in the nests of other birds, were counted there. “Converting CRP lands to energy plantations would definitely have a negative impact on biodiversity,” Hanowski concludes. [54] Mathews expressed concern as well. CRP lands that have been allowed to return to something resembling an oak barren are valuable, says Mathews, and should not be converted. [41]

It is generally agreed that converting CRP land to plantations would likely depress the level of biodiversity. However, the increasing price of energy and the intensifying demand for ethanol, intensifies the likelihood that CRP lands will be coming back into production. [34] If there is a simple choice between conversion to plantations versus row crops, plantations would be the preferred land use with regard to biodiversity.

Age

A second objective was to look at whether the species composition changed as the plantation aged—shifting from an open area, to shrubs, to larger trees. Not surprisingly, they found that as the site changed, the bird species inhabiting the area changed as well. As the plantations matured, the suite of avian species present became more similar to that found in the surrounding forests. The greatest change in composition took place between 2 and 4 years after establishment. On young plantings (1–2 years), the researchers observed open-habitat bird species.⁵¹ Species turnover, indicative of community instability, was high. [5]

Regarding species composition, the researchers report that each plantation was more similar to itself in a different year, than another plantation in the same year. So, although there was an age effect (a reflection of the changing vegetation structure), species composition depended more on the unique characteristics of the site than on the age of the plantation.

⁴⁹ The term “species of concern “ refers to a designation used by the WDNR to describe those species about which some problem of abundance or distribution is suspected but not yet proven. The main purpose of this category is to focus attention on certain species before they become threatened or endangered. [6]

⁵⁰ Three species of concern included the uplands sandpiper, the short-eared owl, and Bell’s vireo.

⁵¹ These species included Killdeer, Horned Lark, and Red-Winged Blackbirds.

Long-distance migrants, many of which are habitat specialists and therefore rare, were less abundant on plantations than in forest/shrub lands; [58] however, the researchers speculated that more specialists might use the plantation as it matures. [55] The composition of small mammals changed as the plantation matured as well, but the change seemed to be more closely related to heterogeneity than to plantation age. [59]

Heterogeneity

Plantations where management practices resulted in imperfect plant monocultures (e.g., weed growth, spaces from clone failure) produced the greatest diversity of birds and mammals. Small mammals were absent from young plantations with little groundcover, but were observed in well-vegetated patches in both young and old plantations. Large numbers of small mammals were captured in areas where clones had failed, especially on weedy patches larger than 1,000 square meters. The absence of ground cover was found to be the most important factor in reduced abundance. Some heterogeneity will always be present without specifically managing for it, but “Weed control may be so effective on some plantations that heterogeneity is lacking if not specifically incorporated into management plans.” [57]

Surrounding Landscape

The Midwest studies looked at a range of species—including birds, small mammals, and large mammals—in order to investigate the impact of plantations on different niches in the ecosystem.

Plantations located in open agricultural areas were used by birds more often than plantations located in forested areas. In general, perhaps because of their mobility, the bird species found on plantations tended to be typical of those found in the rest of the region, that is, forest species in forested areas, open habitat species in open areas. [57]

With respect to small mammals, the researchers found that the suite of species present in plantations was closest to that found in row crops. Forest-dwelling mammals were notably absent or rare in plantations sited in both forest- and agriculture-dominated landscapes. Researchers speculated that the species composition found in plantations reflects the abundance of local populations. For example, a significant number of prairie voles—a rare species in Minnesota—was captured in one plantation, leading researchers to speculate that the plantation is located near an important source population. [57]

In addition to tracking small mammals, researchers looked at winter use of plantations by white-tailed deer, a source of significant problems statewide. Plantations encounter the same types of difficulties with deer as do natural forests. From a biodiversity standpoint, large numbers of deer can lead to a reduction in ground-level plant and shrub diversity. [42] Deer can also affect tree regeneration because selective browsing can change the tree composition in the forest. [41, 42]

In the Midwest, researchers found that use of energy plantations by deer is variable. Deer and moose browse was a major source of tree mortality on some plantations in Minnesota,⁵² [54] but researchers suggest that they will use plantations only if other local habitat factors are suitable. “Plantations do not seem to attract deer to an area,” they reported, [57] but plantations, if not properly protected, will certainly provide more browse.

Summary

Biodiversity is one of many measures that, when taken together, can be used to assess the health of an ecosystem. Most scientists agree that biodiversity alone is not a perfect proxy for forest health but it is a commonly used and highly appreciated ecological attribute in Wisconsin.

Because natural systems are complex and their characteristics site-specific, the existing research is useful, but certainly not definitive, for creating practical harvest guidelines to protect biodiversity. Many of the impacts, or lack of impacts, will become evident only as biomass production and harvest increases.

Forest Residues

The degree to which residue removal impacts species diversity is dependent primarily on two factors: 1) the type of residues removed, and 2) the intensity of removal.

Responsible harvest of the fine woody debris, the type most used by the bioenergy industry, is not expected to present any substantial ecologic impact on biodiversity. Nevertheless, there is also general agreement among scientists that there is little research to verify this position. It is simply not known what level of FWD harvest (as a percentage of total debris removed) will impact biological diversity in the forest; nor is it certain which species will be influenced.

⁵² This finding is supported by the results of a study carried out in the Pacific Northwest where researchers found that Columbian white-tailed deer, a federally listed species, used plantations extensively throughout the year. [57]

Plantations

Abundance and species richness were consistently higher on plantations than in croplands, but lower than in natural forests. Energy plantations that replace row or small grain crops are expected to have a positive impact on biodiversity; however, on plantations replacing established grassland, shrubland or land currently set aside in CRP, the level of biodiversity can be expected to decrease.

As plantations age—shifting from open area, to shrubs, to larger trees—the suite of species present became more similar to that found in the surrounding forests. Those plantations with internal variation such as weed growth and spaces from clone failure produce the greatest diversity of birds and mammals.

Chapter 5

Enhanced Forest Management Planning: A Conceptual Model

Introduction

Established energy plantations will be necessary in order to provide the quantity of biomass needed to propel a thriving bioenergy industry, but there will be no springboard for growth without an adequate supply of forest residues. Near term, residues will continue to be the sole source of bioenergy from the forest. This chapter offers a model for managing private forests—not only for improving residue availability, but also for maintaining forest health.

Despite a plentiful supply, the availability of residues is scarce. Many who could be involved in the chain of supply are reluctant to participate. Without the benefit of conclusive science to serve as a guide, forest owners, harvesters, and purchasers share concerns over acceptable forestry practices. An enhanced forest management planning process has the potential to bring more people into the process and to serve as a management guide for Wisconsin's private forest lands.

Harvesting residues for bioenergy is not expected to have a significant impact on biodiversity and forest health; however, ecological conditions vary by site. This chapter presents a six-step conceptual model, or decision framework, that can be used to create, evaluate, and incorporate ecologically sound forest management practices.

A conceptual model consists of a series of (often idealized) logical steps that form a framework for progressing from a beginning point to an end result. Conceptual models contain sets of variables that have defined relationships between and among themselves but do not require strict adherence to a set procedure. Rather, they offer an opportunity to reason and adjust each step, as necessary. Conceptual models, as the one presented here, merely provide a logical guide to a process of discovery.

Model Description

The conceptual model outlined here offers a six-step method for private landowners and purchasers of biomass for energy production to incorporate ecologically sound management practices for residues

harvest on private lands.⁵³ In addition, if additional assurances are desired, it provides a means to identify practices that can be incorporated into contractual obligations.

Step 1: Baseline Data

As with many planning processes, the first step involves an assessment of the resource in its current state with its current management activities, if any. Collecting and organizing accurate and reliable baseline data on each candidate forest serves as the basis for establishing options for its use and management.

Ideally, a general site inventory should be conducted under the direction of a professional forester⁵⁴ using the Forest Habitat Type Classification System (FHTCS).⁵⁵ This system offers a classification tool that can be uniform and accepted throughout the state. It can be used by a professional forester to identify, classify, and evaluate a forest's potential in and of itself and with regard to any unique role it may play within the larger context of the state as a whole.

A census is required for the tract's special attributes—those factors that may limit or enhance harvest options as well as any unique ecological conditions present. Declaring any special circumstances, in combination with the FHTCS classification, will enable a common understanding of potentially limiting features and their role not only within the parcel but their relative importance throughout the state. For example, a harvest plan may be curbed or abandoned if a species of interest, perhaps rare in the state, resides in the parcel and is dependent on features that would be disturbed with harvest. On the other hand, if that resident species resides in many places throughout the state or region that will remain undisturbed, plans may be designed that allow a greater level of activity.

Establish Baseline Data

1. Identify Basic Forest Attributes
 - Resource (tree and plant species, wildlife present)
 - Harvest (species composition, age of stand)
2. Classify Forest
 - Resource: cover type and habitat type (FHTCS)
 - Harvest: potential products (sawlogs, pulp logs, residues)

⁵³ Note that within the steps, items in parentheses are presented as examples.

⁵⁴ WDNR maintains an online directory of professional foresters:

<http://www.dnr.state.wi.us/org/land/forestry/private/assist/coopforesters/>

⁵⁵ The Silviculture and Forest Aesthetics Handbook, Chapter 12 pp 12-1 to 12-14

<http://dnr.wi.gov/org/land/forestry/Publications/Handbooks/24315/>

3. Identify Special Conditions

Resource

Unique landscape features (riparian zones, soils, topography)

Biodiversity (diversity, abundance of protected, nuisance species)

Conditions of local &/or statewide importance

Harvest

Assets or limitations

Land use (archeological sites, social, legal)

Practical (distance from markets, size of parcel)

Yield potential

Primary product

Residues

Establishing the relative importance of special conditions is a key outcome of Step 1. The assessment that results from this effort can serve as the harvesting and ecological bounds for a landowner's long-term management planning.

Step 2: Landowner Objectives

The second step is intended to identify, or to help a landowner clarify, management objectives. Many of today's landowners are not managing their forested lands or they are not managing them in a manner consistent with their objectives. [60] For some, an unmanaged forest is an objective. For others, this step can help bring into focus the possibilities and responsibilities associated with active forest stewardship.

Establish Landowner Objectives—short- and long-term

1. Determine Resource-use Priorities: social, environmental (hunting, habitat), economic
2. Define Desired Economic Return: value, timing

These objectives will provide the basis for future management practices and provide the insight necessary to identify options for an enhanced management plan.

Step 3: Menu of Options

The third step is an iterative investigation of enhanced management strategies whereby a landowner is presented with alternatives to the present management system. These alternatives take into account the outcomes from Steps 2 and 3, and provide the basis for Step 4.

Develop Menu of Options for Enhanced Forest Management Plan

Considering:

- Landowner's primary and secondary objectives
 - Baseline information, including limitations:
 - Resource: ecological sensitivities within parcel and relative to local/state importance
 - Harvest: land-use, physical obstacles
1. Identify Alternative Uses (pulp, saw logs, hunting, non-consumptive, wildlife)
 - Primary
 - Secondary
 2. Identify Potential Management Activities
 - Resource Program
 - Improvements (erosion control, water retention, species succession)
 - Maintenance (selective thinning, invasive species control)
 - Harvest Program
 - Locations
 - Schedule
 - Techniques: methods, timing, frequency
 - Limitations: acceptable % residues harvest

Step 4: Evaluate Options

This step produces a matrix of the costs and benefits associated with a landowner's chosen uses and activities. This step can provide clarity by connecting the attributes of the physical resource with the economic return and the effort required to achieve the stated objectives. It also imparts information on the monetary and non-monetary aspects of each prospective option. This step provides the landowner with a means to evaluate the management plan options under consideration.

Matrix to Evaluate Menu of Enhanced Management Plan Options

1. Estimate Monetary Benefits—amount and timing
(income from sales of thinnings, primary, and secondary uses)
2. Estimate Monetary Costs—amount and timing
(payments associated with maintenance, harvest, land-improvement activities)
3. Identify Nonmonetary Benefits
(enhanced biodiversity, increase in preferred species, improved ecological functions)
4. Identify Nonmonetary Costs
(loss of aesthetics, nuisance species, conflicts with neighbors)

Step 5: Enhanced Forest Management Plan

This step's goal is for the landowner to decide on and commit to a management plan that can include scheduled thinning, harvests, protection of biodiversity, and incorporation of management activities that meet landowner objectives balanced by the property's habitat type.

Enhanced Forest Management Plan

1. Define Goals and Responsibilities—contractor, purchaser, landowner
2. Resource Improvement Program
3. Resource Maintenance Program
4. Harvest Program

Step 6: Contract Specifications

The goal of this step is to establish an understanding and commitment between the landowner and the purchaser of biomass-for-energy on the issues that are important to each party.

Identify Contract Specifications

1. Establish Conditions of Sale (harvest methods, price, quantity, timing)
2. Establish Provisions of Contract (terms, remedies)

Summary

Enhanced forest management planning can provide benefits for producers, purchasers, and for those charged with protecting and enhancing Wisconsin's forest resource. When refined, this approach can provide a basis from which to develop a system that incorporates preserving biodiversity while also increasing the supply, predictability and reliability of available residues. A systematic approach will provide a degree of certainty for landowners who have residues to produce and market.

It is important for both the private landowners and large-volume purchasers of biomass, such as utilities, to understand what precautions can be taken to protect biodiversity and other indicators of forest health, and how these precautions will affect the supply and price of biomass. And finally, this method can offer an accepted, established process by which to incorporate these precautions into biomass purchase agreements. Large-scale biomass harvesters and purchasers who undertake these precautions will demonstrate a good faith effort to protect biodiversity and to sustain the resources they consume.

Chapter 6

Policy Implications: A Need for Market Development

Wisconsin has the capacity to produce renewable, clean-burning, local fuel and to fulfill the promise of a thriving bioenergy industry. In fact, it can be said, unequivocally, that of the fifty states, Wisconsin ranks among the highest in its potential to produce forest biomass for bioenergy. Yet, establishing a new industry requires commitment and support: a Wisconsin bioenergy industry will not develop on its own.

Wisconsin is uniquely suited with the means for success:

- Capacity for high-volume, reliable production
- Logistics for economical production, and
- Conditions for an ecologically sustainable supply.

Wisconsin possesses ideal natural resources and cultural conditions. There are abundant private forests and another million acres of idle lands. Wisconsin has favorable roads, soils and growing conditions. And, government, citizens, and utilities have a committed interest in developing renewable energy and preserving natural resources.

Forest Residues

Developing a robust market for forest residues is the single most important element in a near-term strategy to initiate a bioenergy industry in Wisconsin. Residues serve as an excellent source of biomass. Residues are plentiful and in demand, and as waste products, their harvest is compatible with other uses and generally of low economic value. Residues will always be a component of the long term supply, and more importantly, they are the only fuel available in Wisconsin today. However, an irregular market has strained the relationship between demand and supply.

Many of the same impediments exist on both the demand and supply sides. Landowners tend to limit the volume of available supply due to price signals, demographic trends, and ecological concerns. On the other hand, uncertain or high prices and uncertain supply (both with respect to expected volume and interest in supplies produced from ecologically sound harvest methods) tend to be limiting factors for utility demand. In turn, the lack of market signals hold down availability and exert price pressure back to suppliers. Even Northern States Power, located in the heart of Wisconsin's forested land, is challenged to secure an adequate and economical supply of forest biomass.

Wisconsin's forests form a diverse assemblage. Cooperative forest management planning can help landowners define and reach their objectives for their forest lands—whether for production, habitat or beauty. Management practices that present little consequence at one site may pose a significant impediment to the ecological balance at another. Due to natural variability and the lack of scientific evidence on the subject, some guidance is needed in order to insert a reasonable level of precaution into forest management practices—especially harvesting forest residues.

A logical process that incorporates economics, yield, multiple uses, forest health, and statewide ecological goals can serve as a guide for responsible residues harvesting. Additionally, if desired, such a process can provide a basis for contractual obligations to ensure that the harvester has committed to managing the forest property in a manner consistent with the goals of the purchaser.

Attentive management is the key to developing markets. Enhanced forest management planning can ensure a reliable volume of residues—and result in an ecologically sustainable supply.

Energy Plantations

A stable bioenergy industry in Wisconsin must include sufficient, well-sited, well-managed energy plantations to supply the demand. Only energy plantations can offer a sufficiently reliable, economical, and sustainable supply over the long term. Given that the woody crops grown on these plantations cannot be harvested for 5 to 7 years or more, establishing multiple energy plantations in the very near term is essential.

Providing power fueled by forest biomass requires a long-term investment by the private-forest owners who will supply the resource and by the energy companies that will produce the power. Prudent investors require a level of security before undertaking a long term commitment. Without support, it is unlikely that energy plantations will be established. And without them, a bioenergy industry is unlikely to develop.

Chapter 7

Conclusions

This review explores the available forest resource as it pertains to bioenergy. Its purpose is to consider Wisconsin's forests as a source of biomass for energy and to examine how biomass harvest will affect biodiversity.

Can sufficient harvest be achieved without compromising Wisconsin's commitment to biodiversity?

Despite the quantities of biomass necessary to fuel a large-scale bioenergy industry, accommodations for preserving biodiversity are not expected to present a significant difficulty; however, some precautions will be required. With regard to residues, the proportion and type of material available for harvesting will be limited by the ecological sensitivity of the forest site. For energy plantations, management practices and careful site selection can enhance ecologic conditions. In general, energy plantations will not approach the diversity present in well-established natural forests, shrublands or grasslands, but they will provide considerably more complexity and structural diversity, and support a greater number of species, than traditional agricultural annual row crops.

Can sufficient biomass be generated reliably and sustainably?

Wisconsin has abundant potential to produce a reliable and sustainable supply of forest biomass. Wisconsin's forest resources—the current production of forest residues and the potential production from residues and energy plantations—are significant. This potential bodes well for establishing an adequate supply to fuel a viable bioenergy industry. Developing Wisconsin's potential new sources of available biomass will be necessary in order to fulfill this potential and to sustain Governor Doyle's vision of an innovative new bioenergy industry in Wisconsin.

Biomass Supply

Forest residues—likely greater quantities than are currently being harvested—are important today and will become even more important in the near future because they involve less risk and are already available. Longer term, residues are better suited to serve as a supplemental source of biomass, rather than as the primary fuel source. To develop a sustainable bioenergy industry in Wisconsin, the state

must look beyond forest residues. A greater commitment is required for long-term stability. Establishing sufficient, well-sited, well-managed energy plantations is the lynchpin to achieving a reliable, sustainable supply of biomass for a Wisconsin bioenergy industry.

Developing only a fraction of this potential would increase Wisconsin's energy produced from forest biomass by tenfold. Today's forest biomass-based utility energy production stands at less than 0.3%⁵⁶ of Wisconsin's annual utility energy production. Energy plantations on less than one third of the land identified by the DNR as idle farm lands and harvests of only 15% of the potential available forest residues could increase this contribution to over 3% of Wisconsin's annual electric utility energy production.⁵⁷

Limitations in the Supply Chain

Demographic changes in forest ownership present the greatest threat to biodiversity and add complexity to the harvesting of residues. Smaller parcel sizes contribute to fragmentation and loss of habitat. Decreasing parcel size reduces economies of scale for harvesters while greater numbers of landholders increase transaction costs. Further, increasingly affluent and aesthetic-seeking absentee landholders are limiting the material available for harvest.

Wisconsin has abundant under-utilized land. Plantations are significantly more environmentally friendly than row crops, but the improving agricultural demand due to increasing ethanol production is expected to push more land into cultivation for corn production.

Farmers looking to enhance the productivity of their land may determine that converting land into an energy plantation would be too risky. Farmers can generate revenue from row crops every season, whereas energy crops are left in the field anywhere from 5 to 12 years. Without an operating history to serve as a guide, it would be difficult to determine if future demand will ensure profitability.

Suppliers are uncomfortable about investing in energy plantations without a certain market. At the same time, the electrical utility industry is reluctant to invest in bioenergy when fuel price trends are unclear, and when there is no certainty of a reliable biomass supply.

⁵⁶ 2004 figures. [2]

⁵⁷ The current 0.27% plus the increase calculated as the range of 0.9% to 2.9%. Calculations used the range of plantation land from 100,000 to 300,000 acres and 15% of the estimated potential ranges cited for residues in Table 1.

A thriving bioenergy industry can meet many of the state's objectives. It can create rural jobs, improve Wisconsin's energy independence and assist utilities' obligations to include renewable energy in their generation mix.

However, despite the interest, supplies have not developed sufficiently for utilities to be able to rely on forest biomass as a viable source of renewable energy. Thus far, the market has not developed, and left on its own, it is doubtful that it will. Without support, it is unlikely that more residues will be available or that energy plantations will be established. And without them, this promising bioenergy industry cannot develop.

Appendix A

Estimated Productivity on Available CRP Lands in Wisconsin by County⁵⁸

<i>County</i>	<i>Tree Type</i> <i>P=poplar</i> <i>W=willow</i>	<i>Median</i> <i>Production (dry</i> <i>tons/acre/year)</i>	<i>CRP</i> <i>acreage</i>	<i>High</i> <i>Production</i> <i>Estimate</i>	<i>Low</i> <i>Production</i> <i>Estimate</i>
Adams County	P	4.5	1,823	5.0	2.5
Ashland County	W	5.0	0	6.5	4.0
Barron County	P	4.5	4,296	5.0	2.5
Bayfield County	W	5.0	no info	6.5	4.0
Brown County	W	6.0	2,857	7.0	4.5
Buffalo County	P	5.0	13,377	6.0	3.0
Burnett County	W	5.0	276	6.5	4.0
Calumet County	P	5.0	2,028	5.5	3.0
Chippewa County	P	4.5	8,433	5.0	2.5
Clark County	P	4.5	1,554	5.0	2.5
Columbia County	P	5.0	9,831	5.5	3.0
Crawford County	P	5.0	18,509	6.0	3.0
Dane County	P	5.0	31,591	5.5	3.0
Dodge County	P	5.0	13,318	5.5	3.0
Door County	W	6.0	7,163	7.0	4.5
Douglas County	P	4.5	0	5.0	2.5
Dunn County	P	4.5	23,236	5.0	2.5
Eau Claire County	P	5.0	18,023	6.0	3.0
Florence County	W	5.0	63	6.5	4.0
Fond du Lac County	P	5.0	15,523	5.5	3.0
Forest County	W	5.0	no info	6.5	4.0
Grant County	P	5.0	44,479	6.0	3.0
Green County	P	5.0	20,126	5.5	3.0
Green Lake County	P	5.0	7,479	5.5	3.0
Iowa County	P	5.0	44,286	6.0	3.0
Iron County	W	5.0	0	6.5	4.0
Jackson County	P	5.0	8,916	6.0	3.0
Jefferson County	P	5.0	8,560	5.5	3.0
Juneau County	P	4.5	8,666	5.0	2.5
Kenosha County	P	5.0	1,614	6.0	3.0
Kewaunee County	W	6.0	6,264	7.0	4.5
La Crosse County	P	5.0	6,868	6.0	3.0
Lafayette County	P	5.0	27,252	6.0	3.0
Langlade County	W	5.0	227	6.5	4.0
Lincoln County	P	4.5	no info	5.0	2.5
Manitowoc County	W	6.0	9,030	7.0	4.5

⁵⁸ Productivity estimates were generated by the ORNL in 1996.

Marathon County	P	4.5	2,118	5.0	2.5
Marinette County	W	5.0	1,250	6.5	4.0
Marquette County	P	4.5	4,043	5.0	2.5
Menominee County	P	4.5	no info	5.0	2.5
Milwaukee County	P	5.0	392	5.5	3.0
Monroe County	P	5.0	13,783	6.0	3.0
Oconto County	W	6.0	2,696	7.0	4.5
Oneida County	W	5.0	no info	6.5	4.0
Outagamie County	W	6.0	8,830	7.0	4.5
Ozaukee County	P	5.0	5,395	5.5	3.0
Pepin County	P	5.0	4,937	6.0	3.0
Pierce County	P	5.0	20,826	6.0	3.0
Polk County	P	4.5	12,809	5.0	2.5
Portage County	P	4.5	1,946	5.0	2.5
Price County	P	4.5	47	5.0	2.5
Racine County	P	5.0	2,626	6.0	3.0
Richland County	P	5.0	21,382	6.0	3.0
Rock County	P	5.0	14,883	5.5	3.0
Rusk County	P	4.5	609	5.0	2.5
St. Croix County	P	4.5	29,662	5.0	2.5
Sauk County	P	5.0	15,046	6.0	3.0
Sawyer County	W	5.0	117.5	6.5	4.0
Shawano County	P	4.5	4,774	5.0	2.5
Sheboygan County	P	5.0	3,714	5.5	3.0
Taylor County	P	4.5	470	5.0	2.5
Trempealeau County	P	5.0	34,229	6.0	3.0
Vernon County	P	5.0	12,399	6.0	3.0
Vilas County	W	5.0	no info	6.5	4.0
Walworth County	P	5.0	6,195	5.5	3.0
Washburn County	P	4.5	237	5.0	2.5
Washington County	P	5.0	2,757	5.5	3.0
Waukesha County	P	5.0	3,769	5.5	3.0
Waupaca County	P	4.5	6,290	5.0	2.5
Waushara County	P	4.5	1,781	5.0	2.5
Winnebago County	W	6.0	9,572	7.0	4.5
Wood County	P	4.5	2,111	5.0	2.5

By combining the available CRP acreage with the productivity estimates for each county, the NREL was able to generate a map (see below) depicting the production (dt/yr) of woody biomass on CRP lands.

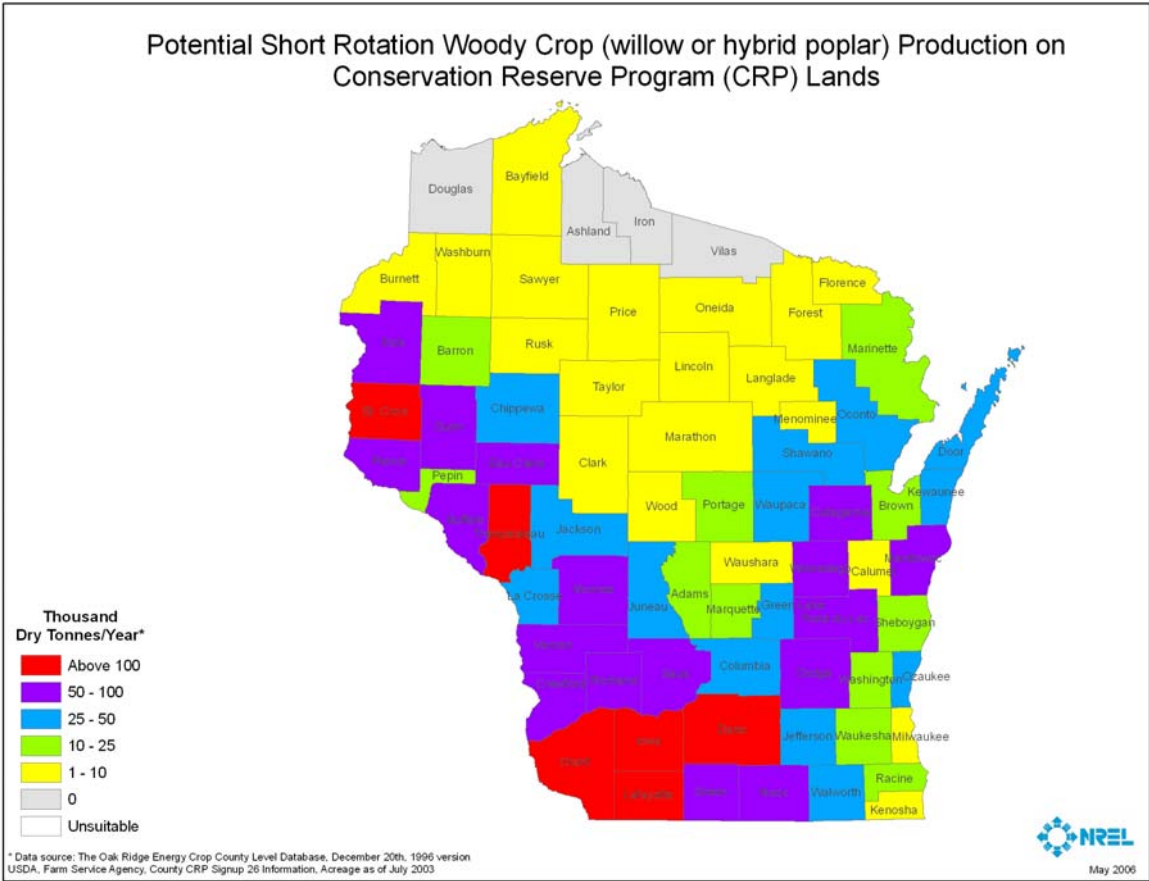


Figure 2. Estimated Plantation Productivity Annually by Wisconsin County

Appendix B

Research on Hybrid Poplar Productivity in Wisconsin

Research Group	Productivity (dry tons/acre/yr)	Brief Study Description	Location	Site	Important Factors Affecting Productivity
USDA Forest Service 1992 [35]	3 (average yield of the fastest growing clone) 1.2–2.2 (average yields of the five best clones, all sites) 2.66 (average productivity of the 5 best clones at Mondovi, WI after 5 years growth) 1.52 (average productivity of the 5 best clones at Ashland, WI after 5 years growth).	10–20 acre plots, 8 x 8 spacing. Each plot was divided into 10 subplots so that 13 different poplar clones could be grown. Weight of dry biomass was measured after 4 and 5 years of growth.	Wisconsin, Minnesota, and North and South Dakota	Not specified.	Tree mortality was high (42% in 1987, 37% in 1988) and yields would have improved with greater survival. New, faster-growing clones might have improved yields as well. Water seemed to be a key factor affecting productivity, and the author notes that water was a limiting factor in many of the sites studied. Fertilization was not required on most sites. Regarding temperature, warm weather positively affects growth as long as water is available.
University of Wisconsin–Madison, USDA Forest Service 1999 [36]	3.6 (highest accumulation after 4th season on conventionally managed plots planted with clone NM6).	40 plots—10 for each of the 2 clones and 10 for each of the 2 weed control practices (mechanical and chemical control or plastic mulch laid in strips).	Southern Wisconsin	Plantations established in a fertile, low lying area previously planted with alfalfa.	Experiments did not include fertilization or irrigation. Overall, after 4 seasons, the difference in productivity between conventionally managed and plastic mulch plots was not significantly different. The clone type significantly impacted productivity, but the authors caution that productivity can vary widely depending on local environmental conditions. They also found a large difference in yield between plots, which strongly suggests other factors (besides plant material and soil) impacted productivity. “Failure to achieve greater yields even on this very good site with good growing conditions, and the rather large amount of plot to plot variation indicate that we know relatively little about the really important biological determinants of productivity.
USDA Forest Service 2002 [37]	> 3 (average yields with harvest between 7–10 years) 4 (yields on better sites) 4.1 (productivity on the 2 best sites, Granite Falls, MN and Mondovi, WI).	Same plantations as the Hansen USDA study (see above).	Wisconsin, Minnesota, and North and South Dakota	Former agricultural land that had been in row crops, small grain, or hay the year before.	Competing weeds are the most important stress factor in decreasing poplar plantation success. Good site preparation is critical. Deep fertile sandy-loam to clay-loam soils that are well-drained but not droughty are best. Weed control and disease susceptibility played a large part in overall productivity and

					survival of the clones. The authors speculate that clonal breeding and selection, mid-rotation fertilization, and improved weed control could increase yields. They emphasize the importance of matching the clone to the site.
ORNL, USDA Forest Service 2001 [38]	7.7 (best clone tested in Wisconsin after 6 years of growth). Growth at the Wisconsin site exceeded growth at all other sites. 6.7 (average productivity of the best 5 clones).	60 rooted clones were planted in 4 test sites. Spacing was 9.8 x 9.8 ft and the harvest rotation was 6 years.	Minnesota, Iowa, Wisconsin, and Michigan	The site in Wisconsin, near Arlington, had very fertile, high quality soil.	The researchers point out that they used small experimental plots and rooted cuttings (rather than un-rooted). This in combination with other factors could have resulted in an overestimation of growth potential. Their yield estimates likely represent an upper limit.

Appendix C

Current guidelines for logging residues [8]

Type of Residue	Importance	Best Management Practices
Snags--dead standing trees	As many as 30 birds, 30 mammals, and several reptiles and amphibians use snags as breeding sites.	Leave as many snags as possible standing in harvest areas unless there are concerns about the surrounding landscape (e.g., adjacent sites to Sharp-tailed Grouse management areas) or forest insects and diseases
Reserve Trees--live trees left unharvested	Snags and reserve trees may also provide microsites for plants. These residues are important for cavity-dependent species such as the Barred Owl, Pileated Woodpecker, and Black-capped Chickadees.	Retain clumps, strips, or islands of live trees in distributed throughout each harvest unit, or leave scattered individuals. On clearcut sites, leave 6-12 trees standing per acre. On non-clearcut sites, ensure that there are at least 6 cavity trees or potential cavity trees per acre
Coarse Woody Debris	Coarse woody debris and slash provide cover, food, and growing sites for a diverse group of organisms. Small mammals dependent on this cover feed raptors and carnivores such as the Pine Marten and the Broad-winged Hawk.	Avoid disturbing pre-existing large downed logs, stumps and uprooted stumps. If snags must be cut, leave them where they fall if possible. Ensure that there are at least 2–5 bark-on downed logs (diameter greater than 12”) on each acre. Scatter logs across the site.

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