Assessment of Biomass Energy Opportunities
Red Lake Band of Chippewa Indians
FINAL REPORT

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ABSTRACT

A biomass energy feasibility study was conducted for the Red Lake Band of Chippewa Indians. The resource assessment identified approximately 120,000 green tons produced annually and can be delivered at a cost of $26-49/green ton to various sites on the reservation. An analysis of the potential for power generation determined there is a limited market for biomass power, generally because competing sources of power are more cost-effective. Interestingly the tribal biomass resource base (i.e., capable of supporting a 5MW power plant) and the tribal power demand are nearly the same. Tribal thermal demands for space and water heating are significant due to the long, cold winters. Most of the buildings are heated with propane or fuel oil. There have been two successful biomass heating applications on the reservation (i.e., Humanities building and Tribal greenhouse) and one high-profile failure (the High School). No opportunities were identified for retrofit to accommodate a biomass system. Several new buildings are good candidates for biomass heating including the new High and Middle School complex and the new (proposed) greenhouse. An analysis of the market for bedding material derived from Tribal forestry resources, including a complete financial evaluation for a potential business, suggests the potential for a small-scale new venture. New technologies, specifically bio-oil, offer some promise for space heating purposes.

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Finally, despite our best efforts at editing and revisions, mistakes may still remain within this document. Any mistakes or omissions are the sole responsibility of the authors. Any questions or comments should be addressed to McNeil Technologies Inc., 143 Union Blvd., Suite 900, Lakewood, CO 80228. McNeil staff members who worked on this project are Scott Haase, Tim Rooney, Jack Whittier, Angela Crooks and Kristy Moriarty. Energy CENTS Coalition Staff who worked on the project are Pam Marshall and Chris Duffrin.

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AAC	annual allowable cut
BD	bone-dry, or containing 0% moisture content; also referred to as oven-dry
BFB	bubbling fluidized bed
BLM	U.S. Bureau of Land Management
Btu	British thermal units
CCF	hundred cubic feet (ft^3)
CF	cubic feet (ft^3)
CFB	circulating fluidized bed
CFR	Code of Federal Regulations
CHP	combined heat and power
CO	carbon monoxide
CO_2	carbon dioxide
CRP	Conservation Reserve Program
CTIC	Conservation Technology Information Center
CVS	continuous vegetation survey
DBH	diameter breast height
DEQ	Department of Environmental Quality
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
E10	gasoline containing 10% ethanol by volume
E95	gasoline containing 95% ethanol by volume
EIA	U.S. DOE Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act
ETBE	ethyl tertiary butyl ether
EVG	existing vegetation
GT	green tons
H_2	hydrogen
HHV	higher heating value
IAC	indicated annual cut
IFB	inclined fluidized bed
kW	kilowatt
kWh	kilowatt-hour
lb	pounds
LHV	lower heating value
MBF	thousand board feet
MC	moisture content
mi^2	square miles
MMBF	million board feet
MMBtu	million British thermal units
MSW	Municipal Solid Waste
MTBE	methyl tertiary butyl ether
MW	megawatt

MWh	megawatt-hour
NASS	National Agricultural Statistics Service
N	nitrogen
NO_x	oxides of nitrogen
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory
OD	oven-dry, or containing 0% moisture content; also referred to as bone-dry
ODT	oven dry tons
psi	pounds per square inch
PURPA	Public Utility Regulatory Policy Act
RBEP	Regional Biomass Energy Program
REPA	Renewable Energy Production Incentive
RFG	reformulated gasoline
ROI	Return on Investment
SDI	Stand Density Index
SO_x	oxides of sulfur
SSCF	simultaneous saccharification and cofermentation
S	sulfur
TPA	trees per acre
TSI	Timber Stand Improvement
TVA	Tennessee Valley Authority
U.S.	United States of America
USA	United States of America
USDA	United States Department of Agriculture
USFS	United States Forest Service
VOC	volatile organic compound
WRBEP	Western Regional Biomass Energy Program
wt %	weight percent
yr	year

EXECUTIVE SUMMARY

The Assessment of Biomass Energy Opportunities for the Red Lake Band of Chippewa Indians was funded by the US Department of Energy's Tribal Energy Program. The purpose of this study was to examine the feasibility of producing energy or other value added products from the biomass resources available on the Red Lake Reservation. Research and analysis was conducted by McNeil Technologies, Inc. and Energy CENTS.

The biomass resources available on the Red Lake Reservation are abundant. Nearly 60% of the reservation's 805,093 acres is forested. Most of the trees are located in the area known as the Diminished Lands (73%). The Ceded Lands comprise 18% and the Northwest Angle contains the remaining 9% of the Tribal forests. Thirty-four percent of the trees on the reservation are aspen/birch, and 31% are swamp conifer. The remainder of the forests is comprised of swamp hardwood, upland hardwood, red and white pine, northern white cedar, upland spruce/fir and jack pine. Biomass residues were estimated at 38,291 green tons (GT) per year, with an additional 2,394 GT available from red pine restoration activities.

The tribe currently harvests wood to be used as sawlogs, pulpwood and firewood. Given suitable market conditions for various end uses, the tribe could use a larger percentage of its forest resources. The Allowable Annual Cut for the Reservation is approximately 41 million board feet, but the tribe has typically harvested less than half this amount. The tribe is also reforesting up to 1,000 acres per year with pine, which will ultimately lead to a greater resource base. In addition, changes in silvicultural practices could increase growth and yield in the forests. It is possible that additional materials could be available from state, local, private and federal lands in the surrounding areas. If all biomass generation is included, then 118,642 GT/yr could be available.

The cost to harvest, process and deliver biomass was estimated at $26-49 per GT, depending on haul distance and rates charged by forest thinning contractors. Wood chips are the least expensive energy source available in the area, as shown in the table below:

Table ES-1. Comparative Costs of Regionally Important Energy Forms, 2005

Source	Units	Value	Efficiency	Btu/unit	$/MMBtu
Biomass chips	$/wet ton	$ 35.00	70%	8,000,000	$ 6.25
Pellets	$/ton	$ 86.00	75%	16,000,000	$ 7.17
Electricity	$/kWh	$ 0.03	100%	3,413	$ 8.79
Fuel Oil	$/gallon	$ 1.78	80%	135,000	$ 16.48
Propane	$/gallon	$ 1.20	75%	91,600	$ 17.47
Electricity	$/kWh	$ 0.062	100%	3,413	$ 18.17

Red Lake is part of the Mid-Continent Area Power Pool (MAPP), which provides services to a large portion of the Midwest, including tribal lands. Since MAPP is currently five percent below its reserve margin due to increasing growth, it is likely that it will seek to increase the supply of electricity it can provide. Since nearby regions are also below their excess supply requirements, it is anticipated that utilities within MAPP will be seeking to increase their own supplies rather than import power.

The Tribe currently buys its power from the Beltrami Electric Cooperative, a rural provider. Based on a survey conducted for this report, Beltrami's average residential rate is about $0.062/kWh or approximately 5% lower than regional competitors and 26% lower than the national average. The Tribe pays $0.054/kWh for its power, and its demand is estimated at 5 MW. Minnkota Power Cooperative is Beltrami's wholesale power provider. Minnkota has plans to expand its capacity through new construction and power purchase options. Minnkota already offers an optional green pricing program to its customers, based on wind power in North Dakota. Discussions with Beltrami and Minnkota reflected a lack of interest in the green power attributes of Red Lake's biomass power. Discussions with Beltrami and Minnkota seemed to confirm that the Redby substation might be able to absorb 5MW of biomass power supplied from Red Lake. However, McNeil staff learned that the buy-back rates for electricity were $0.02021/kWh for electricity and $21/kW/yr for capacity.

If 87% of the tribal biomass supply or 60% of the regional supply were used, a 5MW combustion unit using stoker technology could be supported. Based on these costs and other factors, an analysis was conducted to determine the economic feasibility of using biomass for electricity production. The economic analysis performed in the study calculated the levelized cost of production from biomass at $0.07/kWh. Given that the selling price is only $0.02, Red Lake would lose $0.05 for every kWh sold to a utility in Minnesota. Even supplying its own power results in a loss of more than $0.03/kWh. Ultimately, the high cost of gathering and processing the biomass for fuel makes the power plant unfeasible.

In terms of heating, biomass is often cost competitive with other fuel sources such as propane. The cost of propane at Red Lake is lower than in other parts of the country, but the Department of Energy expects prices to continue to rise throughout the country. Red Lake has had mixed results with attempts to use wood pellets and chips in the past. Although details about the system are unavailable, there were difficulties with blockages and freezing in the system installed at the High School. Municipal solid waste pellets were a poor substitute; it was less expensive, but the smell was not tolerable. In contrast to the High School system, a pellet system in the Humanities Building has been operating successfully for 10 years but few people are aware of the system. In order to overcome the reservation's mixed track record with biomass technology, the study attempted to find a superior opportunity.

Seven school buildings and 11 other non-residential facilities on the reservation were considered as possible biomass heating sites. Most of the buildings were not viable sites due to the relatively low cost of propane and the fact that many of the existing boilers and heating systems are not in need of repair or replacement.

Although none of the buildings offered a good opportunity, the Middle School may be suitable depending on future retrofit activities. If the Middle School is not linked to the High School, the retrofit of its HVAC system may make this building suitable for a biomass system. Similarly, the greenhouse for the Forestry Department could be a viable site; it would also be an appropriate location, since the Department of Natural Resources could show leadership in the sustainable use of forestry resources by setting up a biomass system. Heating the new greenhouse with biomass should be investigated in further detail.

The study also looked at using forest resources to make products instead of energy. Bio-oil, wood plastic composites and pellets were considered. It was decided that bio-oil will be considered in greater detail in a follow-on study. The wood plastic composites could be explored in more depth, although the markets for these products are relatively new. The market for pellets is saturated with low-cost suppliers, and it was concluded that this product did not represent a good opportunity for the Tribe at this time.

The development of a wood shavings operation was analyzed, and financial analysis was conducted to determine the profitability of selling shavings to turkey farmers in the local area to use as bedding. Given the existence of established supply relationships, the challenge of selling this product would be to take market share from existing producers. Since quality cannot be meaningfully improved for this product, Red Lake would need to gain market share by offering the shavings at a lower price. The economics of the project do not work for several reasons. The high capital costs of the equipment and high recurring costs of the wood inputs cannot be recovered by selling shavings at a lower than market price on such a small scale. It is recommended that Red Lake consider a higher value-added product, such as shavings for small pet bedding and/or laboratory animals. These products would also capitalize on the fact that a high proportion of the tribe's trees are aspen, which are more highly valued by the small pet and laboratory animal industries than the turkey farming industry.

There are a variety of end uses for biomass which could help meet the tribe's economic development goals. This study demonstrated that biopower is not economically feasible under the current local market conditions, but thermal applications for biomass may be a cost effective solution for heating new facilities on the reservation. The feasibility of heating a greenhouse using biomass resources and the viability of developing a bio-oil product will be explored in a future report. The development of a wood shavings enterprise deserves further consideration, but a different target market should be selected (e.g. small pet or laboratory animal bedding).

1 PROJECT OVERVIEW

The Red Lake Indian Reservation, home to the Red Lake Band of Chippewa Indians (Red Lake) is located in the northwest corner of Minnesota, about 160 miles from the Canadian border. The reservation is 1,259 square miles in area. It is rural, containing forests, wetlands, brush and grasslands, and two large connected freshwater lakes: Upper and Lower Red Lake. Along the southern shore of the lower lake are the communities of Little Rock, Red Lake and Redby. Thirty-five miles north, on the peninsula between the two lakes, lies a fourth community, Ponemah. The scope of the project covers the entire Red Lake Reservation, and will also focus on potentially available biomass resources from nearby public and privately owned forest lands within an economic hauling distance of the Reservation.

Red Lake is a "closed" reservation, meaning all of its land is owned in concert by all of its enrolled tribal members. Its elected government, the Red Lake Tribal Council, is the sole governing authority on the reservation. The Council is made up of two representatives from each of the four communities, plus a Treasurer, a Tribal Secretary and a Tribal Chair. Red Lake Reservation has its own criminal justice system, police force, schools, hospital, and fire department. The people of Red Lake are Ojibwe Indian. Their community retains its old language, religion, customs, and traditions while at the same time functioning in modern America. The population of Red Lake stands at over 7,000. Sixty-five percent of households earn less than $12,000 a year.

1.1 Project Need and Purpose

The Red Lake logging industry and reforestation projects generate a significant amount of by-product fuel wood. Red Lake currently harvests 35,000-40,000 cords of wood each year (78,000-90,000 tons green weight). There are 20 Red Lake member owner loggers on the reservation, each of whom employs an average of 3-4 workers. Red Lake Forest Products employs one person who acts as a broker between loggers and pulp and lumber mills. About 10% of the total weight harvested is left behind on logging sites. The tribe also reforests as much as 1,000 acres a year to pine. Current harvest levels are less than half of the allowable annual harvest volume. The Red Lake Department of Natural Resources Forestry Department relies upon the Forest Inventory Analysis (performed by the BIA's Branch of Forest Resource Planning) to determine the annual allowable harvest volume. Red Lake may also entertain hybrid planting and whole tree biomass production.

The sustainable use of forest resources on the reservation can help the Red Lake tribe meet its goals of energy autonomy and economic development. The purpose of this study is to evaluate the technical and economic feasibility of using Red Lake's biomass resources for energy generation or production of other value added products.

1.2 Study Area

Figure 1-1 shows a map of the Red Lake reservation and surroundings. The Diminished Lands border the large Red Lake, make up the majority of the land area and are home to the majority of the reservation population. The Ceded Lands consist of noncontiguous parcels north of the Diminished Lands. The Northwest Angle is located north of the Diminished Lands straddles the border with Canada. The Ceded Lands and Northwest Angle make up approximately 27% of the total land area of the reservation and a smaller proportion of total forest land. The entire reservation consists of 805,093 acres. The reservation land area is 60% forested. Water covers 230,000 acres, or 29% of the reservation surface area.

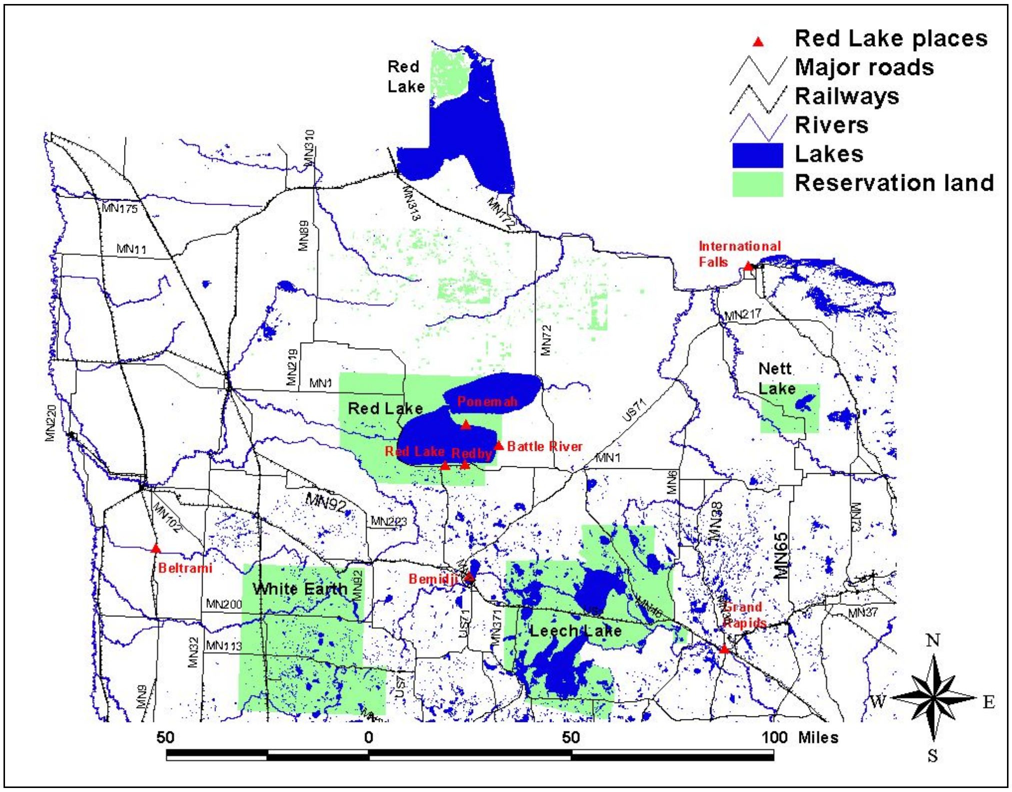


Figure 1-1. Map of Reservation

Table 1-1 shows the breakdown of reservation land between wetland forest, non-wetland forest, non-productive land for the Diminished Lands, Ceded Lands and Northwest Angle. Approximately half the forested area is made up of wetland forests.

Table 1-1. Breakdown of Reservation Land Area

Area	Wetland Forests (Acres)	Non-Wetland Forests (Acres)	Total Forests (Acres)	Non-Productive (Acres)	Total Land (Acres)	% of Total Forest	% of Total Land
Diminished Lands	117,466	142,635	260,101	158,925	419,026	76%	73%
Ceded Lands	21,680	22,344	44,024	60,738	104,762	13%	18%
Northwest Angle	30,635	8,695	39,330	11,975	51,305	11%	9%
Total	169,781	173,674	343,455	231,638	575,093	100%	100%
% of Total Forest	49%	51%	100%	100%	NA	NA	NA
% of Total Land	30%	30%	60%	40%	100%	NA	NA

Note: NA = not applicable. Source: Red Lake Forest Management Plan (FMP)

Table 1-2 shows the breakdown of the forest resource on Red Lake land by cover type.

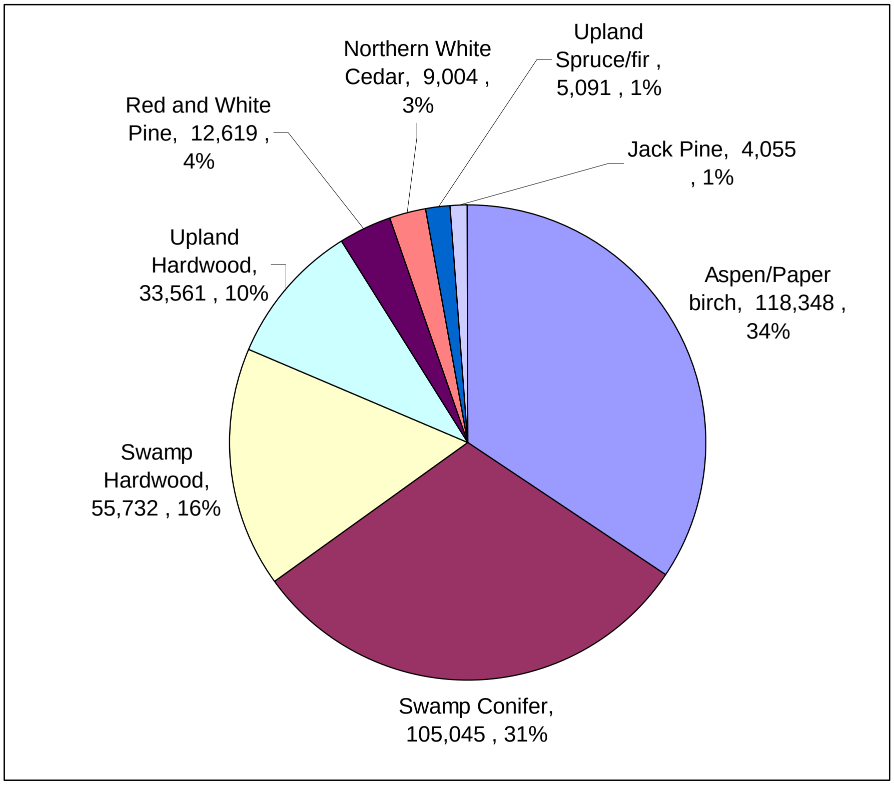
Table 1-2. Forest Resources – Overview of Major Forest Cover Types

Area	Forested Acres	% of Total
Diminished Lands		
Aspen/Paper Birch	98,710	38%
Red and White Pine	10,364	4%
Swamp Conifer	66,630	26%
Swamp Hardwoods	50,836	20%
Upland Hardwoods	33,561	13%
Total Forested Acres	260,101	100%
Ceded Lands		
Aspen/Paper Birch	12,918	29%
Red and White Pine	2,255	5%
Jack Pine	4,055	9%
Swamp Conifer	17,596	40%
Swamp Hardwood	1,727	4%
Upland Spruce/Fir	3,116	7%
Northern White Cedar	2,357	5%
Total Forested Acres	44,024	100%
Northwest Angle		
Aspen/Paper Birch	6,720	17%
Swamp Conifer	20,819	53%
Swamp Hardwoods	3,169	8%
Northern White Cedar	6,647	17%
Upland Spruce/Fir	1,975	5%
Total Forested Acres	39,330	100%
Total	343,455	NA

Note: NA = not applicable. Source: Red Lake Forest Management Plan (FMP)

Aspen/paper birch is the most common cover type on forests in the Diminished Lands. Swamp conifer is the most significant cover type on the Ceded Lands and Northwest Angle lands.

Overall, four cover types, aspen/paper birch, swamp conifer, swamp hardwood and upland hardwood together make up 90% of the forest cover type on the reservation (Figure 1-2).



Source: Red Lake Forest Management Plan (FMP)

Figure 1-2. Forest Cover Types on the Reservation

1.3 Project Team

The U.S. Department of Energy, Tribal Energy Program provided funding for this effort. For Red Lake, the project was coordinated by the Department of Natural Resources, Forestry Program, and the Tribe's Biomass Energy Task Force. The Tribe Red Lake signed hired McNeil Technologies, Inc (Denver, Colorado) and Energy CENTS Coalition (located in Minneapolis, MN) for technical assistance related to this project.

1.4 Goals and Objectives

The goal of the project was to conduct analysis leading to the development of a tribal biomass enterprise. The project objectives and subsequent accomplishments were:

- Conduct a detailed biomass resource assessment
- Evaluate local and regional utility issues
- Evaluate biomass energy technologies and markets
- Conduct a preliminary biomass facility siting study, focus on power and heating
- Assess social, environmental and economic impacts
- Prepare pro-forma financial analyses
- Conduct a business plan analysis for a biomass enterprise

2 BIOMASS RESOURCE ASSESSMENT

This section discusses the regional forest resource, forest management planning, forest management activities and forest products infrastructure in the study area. The study also presents the data sources, methods and results of the forest biomass resource assessment.

2.1 Forest Resource Conditions

This section summarizes forest resource conditions based on the most recent Forest Management Plan (FMP) for the reservation. The Red Lake Reservation has a long history of logging, but significant changes have occurred in the last three decades that have resulted in a reduction in Annual Allowable Cut (AAC) volumes. In 1980, the AAC for the reservation was approximately 69 million board feet (MMBF) per year. The AAC (based on the indicated annual cut, or IAC) for 1992 – 2001 for Diminished/Ceded lands and 1991 – 2000 for the Northwest Angle lands was approximately 41 MMBF, a significant reduction in the amount of timber available on a sustained basis. The most recent forest management plan for the Red Lake Reservation attributed reduction in AAC volumes on the Reservation to variety of past disturbances, including:

1) Intensive aspen harvest between 1970 – 1992 on Diminished Reservation lands;
2) Wildfire in aspen on the Diminished lands that reduced availability and growing stock;
3) Better growth and yield but also increases in mortality for the Ceded and NW Angle;
4) Accelerated harvest in the Northwest Angle in the 1960s that reduced the timber supply available. Northwest Angle stocking levels in the current measurement period (1991) now equal stocking levels in 1961;
5) More refined statistical analysis, accounting of cover type acres and calculation of AAC procedures more accurately define the present AAC;
6) Jack pine has essentially been liquidated from the Diminished lands reducing the AAC by 158 mbf (1980 CFI) from previously levels; and
7) Massive mortality in the swamp hardwoods cover type on Diminished lands.[1]

The reductions in AAC reduce the amount of annual timber harvesting available and also suggest that an array of different silvicultural treatments may be used to improve growth and yield, reduce mortality and address wildfire issues on the Reservation. Stand improvement activities may also help even out the age distribution of forest stands in different species groups. This can help push the forest resource towards a sustainable yield condition, in which each forest stand age class is represented equally, facilitating stable annual outputs of timber and other forest products and services.

[1] FMP, 67

2.2 Forest Management Process

It is crucial to understand how the forest management planning process operates at the Red Lake Reservation if a reliable biomass feedstock supply system is to be developed. The Red Lake Band holds all tribal lands in common; no individual member owns tribal land. Access to the Reservation is limited for non-tribal members. The Red Lake Band assumed full management duties of forest land in 1997. Prior to that time and dating back to the early 1900s, the BIA directly managed forest management activities on the reservation.[2]

The forest management system on the reservation is governed by several documents, the first of which is the Red Lake Band of Chippewa Indians Integrated Resource Management Plan (IRMP 2000), developed by the Red Lake Department of Natural Resources (RLDNR) and the BIA Branch of Forestry. The RLDNR developed a draft Forest Management Plan (FMP), completed in December 2002 which addresses issues specific to forest management that are not addressed in detail in the IRMP. The FMP includes estimates of annual allowable cut volumes based on 1998 re-measurement of continuous forest inventory (CFI) plots that are part of the Red Lake Forest Inventory Analysis completed in March 2002. The Red Lake Land Use Plan (LUP) completed in 1999, provides information on fire prevention through forest management and the use of fire in managing natural resources on the Reservation.

The RLDNR Forestry Program management staff includes an inventory forester, presale forester, timber sale administration forester, Forest Development Forester, Ceded Lands forester and a Fire Management Officer, all of whom report to the program director. In addition, a Greenhouse Manager reports to the Forestry Program Director. A tribal timber policy committee provides input to forest resource management policy decisions, including setting stumpage prices.

Two forest inventory systems are in place. The CFI plot system consists of 1/5 acre plots that are re-measured periodically to provide information on forest species composition and tree diameter distribution. The OPINV system describes forest stand locations. A GIS system links the spatial and tabular data along with other GIS coverages.

Even-aged silvicultural systems are used primarily, with rotations ranging from 50 years for aspen to 130 years for red and white pine. Some uneven-aged management systems are used on hardwood stands. Tribal logging contractors do all the timber harvesting. Felling is conducted primarily using mechanical shears, and logs are forwarded tree-length to landings using cable or grapple skidders. Tree-length logs are then cut to l00-inch bolts or trimmed and topped tree-length. Some hardwood timber stand improvement activities are also conducted. A greenhouse produces 619,000 containerized seedlings/year, mostly pine, in support of reforestation efforts.[3]

2.3 Red Lake Tribal Forestry

Timber harvesting on the Red Lake Reservation is conducted exclusively by tribal logging companies, although these companies can subcontract to outside firms to some extent. There are 20 Red Lake member owner loggers on the reservation, each of whom employs an average of 3-4 workers. Red Lake Forest Products employs one person who acts as a broker between loggers and pulp and lumber mills. About 10% of the total weight of merchantable timber harvested is

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[2] SmartWood Certification Report, 6, Must clear release with tribe

[3] SmartWood Certification Report, 12, Must clear release with tribe

left behind on logging sites due to poor species or poor markets. The tribe also reforests as much as 1,000 acres per year with pine. A significant amount of biomass is generated in the conversion process to pine. Current harvest levels are less than half of the allowable annual harvest volume. The Red Lake Department of Natural Resources (RLDNR) Forestry Department relies upon the Forest Inventory Analysis (performed by the BIA's Branch of Forest Resource Planning) to determine the annual allowable harvest volume.

The Red Lake logging industry and reforestation projects produce sawlogs, pulpwood and firewood. Red Lake currently harvests 35,000-40,000 cords of firewood each year (78,000-90,000 tons green weight). Table 2-1 shows the major markets for Red Lake forest products. Red Lake also has a custom homes facility which manufactures pre-fabricated homes. This business generates wood waste that could be utilized. Red Lake Builders is a construction business on the Reservation which also generates construction debris and wood removed for home sites and road construction. Red Lake Forest Products (Tribal sawmill) is currently shut down, however, if that were to re-open, slab wood, edgings, and planer shavings all could be utilized as biomass. Future forest products business areas that Red Lake may also entertain include hybrid plantations and whole tree biomass production.

Table 2-1. Regional Markets for Red Lake Forest Products

Company/User	Location	Species	Raw Material from Red Lake	End Product
Residential firewood	Reservation	Paper birch, red maple, burr oak	Firewood	35,000 to 45,000 cords/year
Ainsworth	Bemidji	Red and white pine, aspen	Pulpwood, sawlogs	OSB (535 million sf 3/8" capacity) specialty products
Potlatch	Bemidji	Pine, aspen	Sawlogs	studs, finger-joint, dimension lumber
Northwoods Panelboard Corp.	Bemidji	Aspen	Sawlogs	OSB (440 million sf 3/8" capacity)
Boise Cascade	International Falls	Aspen	Pulpwood	Office paper
Blandin Papermill	Grand Rapids	Aspen	Pulpwood	Advertising, catalog & magazine papers
Sappi	Cloquet	Red and white pine	Pulpwood	Coated papers (410,000 tpy capacity)
International Paper	Sartell	Aspen	Pulpwood	Coated, supercalendared papers (310,000 tpy capacity)

Source: BIA, Red Lake Forest Inventory Analysis. 22-23

2.4 Biomass Resource Locations

This section describes forest biomass availability from Red Lake tribal forestry, federal government, state government, county and local government and private landowners.

2.4.1 Tribal Forest Biomass

Biomass is generated on the Reservation through timber harvesting and forest stand conversion to red pine. Timber harvest residues include tops and branches and unusable portions of the stem and dead/damaged trees often referred to as logging slash. Because even-aged management is common for forest management on the Red Lake reservation, timber harvest residues also includes trees smaller than commercially viable timber that are removed during the harvest.

Timber harvest locations and volumes vary each year, which makes it difficult to predict harvest volumes that will be generated. Estimates of annual allowable cut volume provide an upper bound on the volumes that could be generated from forest management activities, if market prices are sufficient to make timber harvesting profitable. Actual timber harvest levels on the Red Lake Reservation have consistently been below annual allowable cut levels. Current and historical timber harvest levels from the Red Lake Reservation are tracked by the RLDNR using a mill ticketing system. The mill places a deposit on a timber permit and receives a ticket. When a log load is received at the mill it is scaled and recorded by ticket number. The mill provides a record of the wood scaled by ticket number to the RLDNR each week. Estimating biomass generation based on a range of values for annual timber harvest provides a conservative basis for estimating forest biomass generation from timber harvest residues.

Biomass yields from forest management depends on a variety of factors, including:

- Diameter distribution of harvested materials;
- Species of harvested materials;
- Technically recoverability of materials (i.e. how much is needed to be left on-site, how much material is lost during handling and which harvest methods are being used); and
- Economic availability of materials

To estimate timber harvest residue volumes we broke residues into two components: tops, branches and unmerchantable stem portions of trees harvested; and volumes of unmerchantable trees removed as a byproduct of even-aged management. We estimated biomass generation from tops, branches and the unmerchantable portion of logs from timber harvesting using tree volume equations by Briggs,[4] assuming a log diameter at breast height (dbh) of 12 inches and a top diameter of 4 inches. This log diameter assumption results in estimates of residue volumes as a proportion of timber harvest that range from 20% for aspen and paper birch and as high as 38% for spruce/fir forests. Timber harvest volumes were provided by the Red Lake Forest Management Plan. We compared timber harvest residues generated based on historical timber harvest levels and biomass based on calculated AAC levels for the reservation. To estimate the volume of unmerchantable trees removed as a byproduct of management, we multiplied the average number of acres harvested between 1992 and 2001 from the Red Lake forest management plan by the volume of tree biomass less than six inches in diameter based on a query of USFS Forest Inventory & Analysis (FIA) data for counties in the study area.

Biomass generation from red pine restoration has not been measured. However, most red pine conversion is taking place on previously harvested aspen stands. Therefore, a conservative estimate may be made by estimating the quantity of material less than six inches dbh remaining

[4] Briggs citation

on aspen stands to calculate the quantity of material per acre that may be recovered. USFS FIA data showed that this quantity ranges from 1.1 to 2.7 GT per acre, after converting from volume to weight using an assumed density value of 0.024 GT per cubic foot (average for paper birch, maple, spruce/fir and pine).

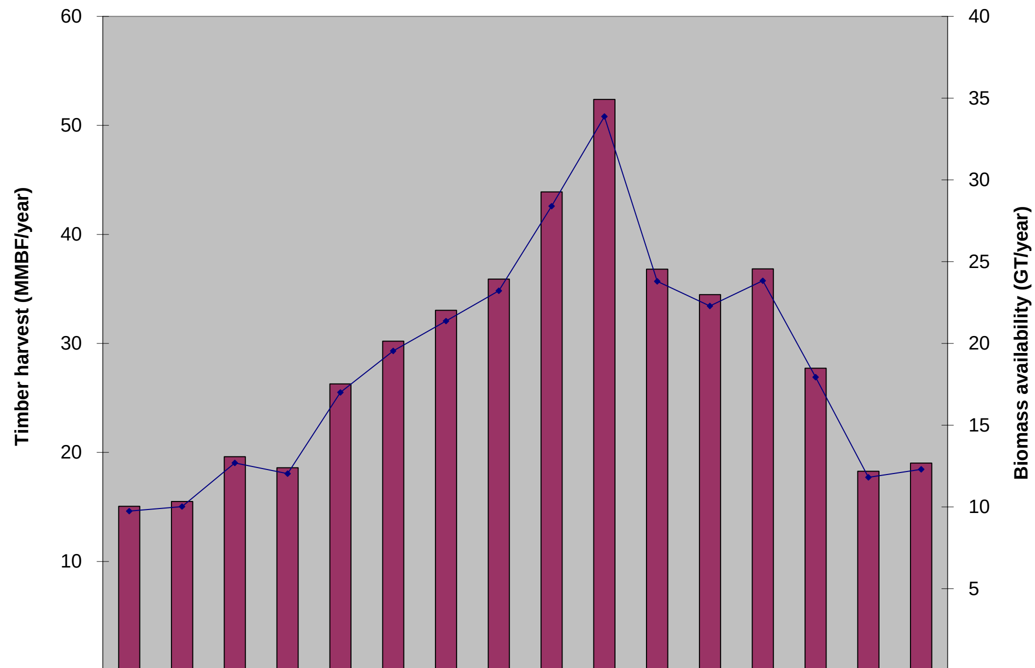
Biomass availability from forest management sites is inherently a site-specific variable. Because site-specific conditions on the Red Lake reservation for forest management projects cannot be predicted, we relied on a U.S. Department of Energy evaluation of logging residue availability throughout the U.S. that took into account slope and other technical variables and economics. This methodology suggests that on average, approximately 50% of logging residue can be removed at costs of less than $40 per ton. One issue specific to Red Lake is that timber harvesting is increasingly occurring in aspen stands that are not easily accessible except in the winter months, when vehicles can cross frozen ground.

Table 2-2 shows estimated biomass generation and availability, based on AAC levels described in the Red Lake FMP. Total biomass availability from tribal land is an estimated 38,291 GT per year, with 94% of the total coming from timber harvest residues and the remainder from red pine restoration.

Table 2-2. Estimated Biomass Generation and Availability Based on Reservation AAC

Cover Type	Acreage	Annual Allowable Cut (Cords)	Biomass Generation (GT/Year)	Biomass Available (GT/Year)
Timber Harvest Residues				
Diminished Land				
Aspen/Birch	98,710	36,625	33,352	16,676
Red & White Pine	10,364	3,253	1,865	932
Swamp Conifer	66,630	11,274	8,796	4,398
Swamp Hardwood	50,836	9,875	9,969	4,984
Upland Hardwood	33,561	1,698	1,714	857
Total Forested Acres	260,101	62,725	55,696	27,848
Non-productive Acres	158,925	NA	NA	-
Water	230,000	NA	NA	-
Subtotal Diminished Land	649,026	62,725	55,696	27,848
Ceded Land and Northwest Angle Land				
Forested Acres	83,354	17,727	8,205	4,102
Non-Productive Acres	72,713	NA	NA	-
Subtotal Ceded and Northwest Angle Land	156,067	17,727	8,205	4,102
Biomass < 6 inches dbh	NA	NA	12,681	6,341
Subtotal Timber Harvest Residues	343,455	80,452	76,582	38,291
Red Pine Restoration	NA	NA	4,788	2,394
Total	805,093	80,452	81,371	40,685

Timber harvest residue availability will be lower if actual harvests are lower than AAC values. Historically, timber harvests have been lower than AAC. In the mid to late 1990s, estimated biomass availability based on timber harvest residue volumes ranged from 12,300 to 23,800 GT per year not including biomass volumes less than six inches dbh (Figure 2-1). Including materials less than six inches dbh and biomass from red pine restoration, total biomass availability from tribal land between 1995 and 2001 would range from 21,035 to 32,175 GT per year. The highest annual biomass availability from timber harvest residues was in 1994, 33,400 GT per year, which is similar to estimates of timber harvest residue availability based on AAC levels. Including materials less than six inches dbh and biomass from red pine restoration would bring total annual biomass availability from tribal land to 41,775 GT per year.



Year	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Timber harvest (MMBF)	15.06	15.50	19.62	18.60	26.29	30.21	33.04	35.90	43.90	52.38	36.80	34.47	36.84	27.73	18.27	19.02
Available biomass (thousand GT)	9.7	10.0	12.7	12.0	17.0	19.5	21.4	23.2	28.4	33.9	23.8	22.3	23.8	17.9	11.8	12.3

Source: Timber harvest data from annual forestry reports, cited in Red Lake FMP, p. 22

Figure 2-1. Timber harvest and estimated biomass availability based on past tribal harvest

Prior to 1992, the AAC level for the reservation was 69 MMBF per year. For the Red Lake FMP covering 1992 – 2001 the AAC was 41 MMBF per year. Harvest levels were consistently below this level except for 1993 and 1994.

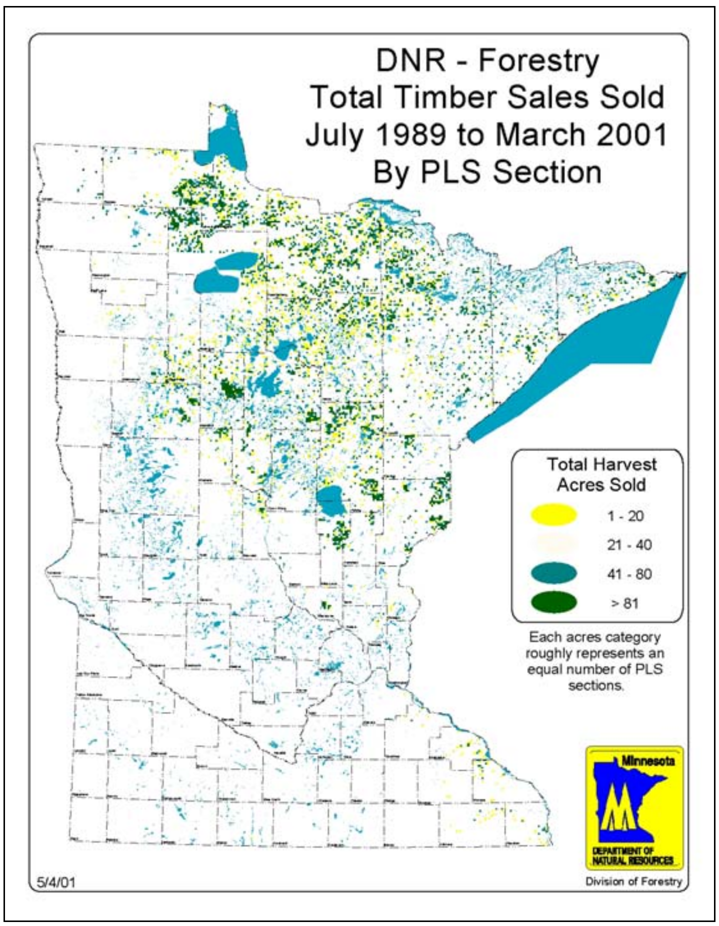
2.4.2 State Lands

The Minnesota Department of Natural Resources (DNR) sells timber from state-owned forest land throughout Minnesota. A large number of timber sales from 1989 to 2001 have been geographically concentrated around the study area (Figure 2-2). A partial list of state forest land in and near the study area includes:

- Red Lake
- Pine Island

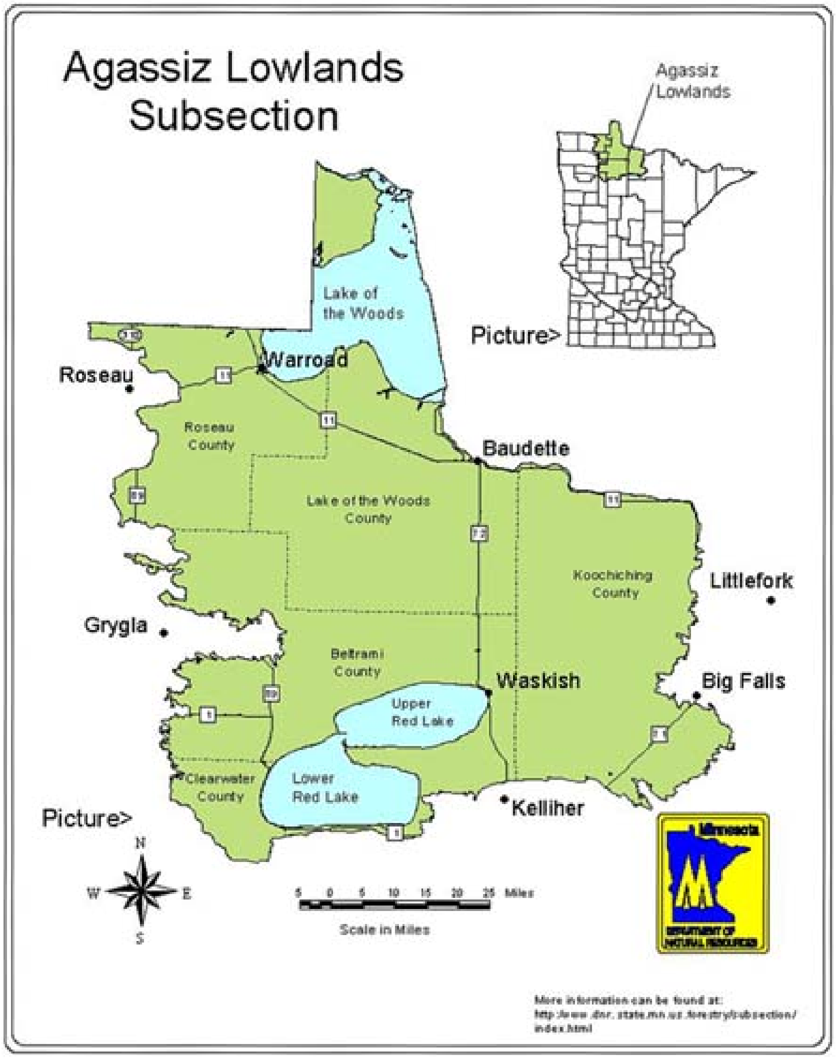
- Beltrami Island
- Big Fork
- Koochiching
- Northwest Angle
- Lost River

The DNR has adopted a new process for planning forest management projects. Rather than five to 10 year forest management plans, the DNR is basing management planning on subsections of its ecosystem classification system (ECS) and identifying stands to be treated over a seven year planning horizon, allowing for public input in treatment decisions. The Red Lake Reservation and surrounding area falls within the Agassiz Lowlands subsection (Figure 2-3). The draft plan for this subsection is in the final stages of preparation. As of January 2004, the planning efforts focused on identifying and prioritizing stands for treatment and obtaining public input. These planning data provide the most reliable information on future harvest activities in the region and thus were used as the basis for estimating biomass generation and availability from state land.



Source: Minnesota DNR, http://www.iic.state.mn.us/finfo/luse/harvest.htm

Figure 2-2. Past timber sales on Minnesota DNR land: 1989 - 2001



Source: http://www.dnr.state.mn.us/forestry/subsection/agassiz/map.html

Figure 2-3. Agassiz Lowlands subsection of DNR administration

The Agassiz Lowlands do not include material from several state forests south and southeast of the reservation. However, timber harvesting has focused to a greater extent on areas north of Red Lake. There is no planning activity in those areas that would support assessment of future harvest levels that would aid in estimating quantities of timber harvest residues. Additional materials may be available from some state-owned land in these areas.

The draft plan for the Agassiz Lowlands maintains recent historical timber harvest levels until 2020. After 2020, the management focus changes to preserving the age class structure that will result from increasing harvest of mature timber stands in several cover types between now and 2020. Therefore the timber harvest acreage from state land is expected to decline following 2020.

Table 2-3. Minnesota DNR Timber Harvest Acreage – Draft Agassiz Lowlands Plan

Cover Type	Management Pool (Acres)	Planned Annual Harvest Area (Acres)		
		Until 2010	2011 - 2021	> 2021
Aspen/Balm	227,232	7,200	4,235	1,840
Jack Pine	27,205	680	487	192
Lowland Black Spruce	142,643	1,450	1,336	960
Lowland Tamarack	122,593	721	721	-

We evaluated timber harvest acreage by species and age class provided in the draft Agassiz Lowlands forest management plan, then coupled those data with USFS FIA data on sawtimber volume per acre by age class to provide an estimate of annual harvest volume by species and age class. Then we estimated timber harvest residue generation and availability based on the conservative assumption that 20% of the volume of timber harvested would become residues. An estimated 16,212 GT of biomass would be available from state lands in the Agassiz Lowlands (Table 2-4). The majority would be harvested from mature and over-mature aspen/balm. Some material is likely to come from older lowland tamarack stands that will be harvested to improve stand productivity.

Table 2-4. Biomass Generation and Availability from State Lands in the Agassiz Lowlands

Species Group	Biomass Generation By Age Class (GT/Year)							Total Generation (GT/Year)	Total Availability (GT/Year)
	51-60	61-70	71-80	81-90	91-100	101-110	111-120		
Aspen/Balm	6,000	16,781	4,647	920	392	-	-	28,740	14,370
Jack Pine	-	2,552	822	-	-	-	-	3,374	1,687
Lowland Black Spruce	-	-	-	-	8	6	59	73	36
Lowland Tamarack	-	-	-	-	-	239	-	239	119
Total	6,000	19,332	5,469	920	400	245	59	32,425	16,212

Additional quantities of material may be available from state-owned lands south of the Agassiz Lowlands, but the majority of the timber harvested from state lands in the study area historically has come from the Agassiz Lowlands.

2.4.3 Federal, County & Local Government and Private Lands

The USFS FIA provided estimates of timber removals from federal, county and local government and private land. The most recent FIA data were from 2002 cycle 12.[5] The Chippewa National Forest is the primary federal timber supplier in the region, though a small

[5] Patrick D. Miles. Oct-18-2004. Forest Inventory Mapmaker 1.7. St. Paul, MN: USFS, North Central Research Station. www.ncrs2.fs.fed.us/4801/fiadb/i Counties: Beltrami, Cass, Clearwater, Hubbard, Itasca, Koochiching, Lake of the Woods, Mahnomen, Pennington, Polk, Red Lake

portion of Superior National Forest is in Koochiching County in the study area. To estimate biomass generation from federal land, we multiplied removals by a residue factor of 20%, a conservative assumption based on the log volume equations used for tribal and state biomass estimates. Volumes were converted to weights using density factors for each species group (i.e., aspen/paper birch, spruce/fir, pine and maple). Table 2-5 shows removals for the study area for these landowner classes. More than 35 million cubic feet of timber were removed from timberland managed by these landowner classes in 2002. County governments in the study area play a significant role as timber suppliers in the region. A significant amount of timber under stewardship by counties is owned by the state due to forfeiture for tax reasons. County and local government removals were nearly nine million cubic feet in 2002.

Table 2-5. Timber Harvest by Species Group and Landownership for Federal, County/Local, Private and Other Landowners (Cubic Feet)

Species Group	Federal	County/Local	Private	Other	Total
Aspen	2,488,980	5,676,452	8,830,332	-	16,995,764
Paper Birch	238,379	209,484	1,389,471	-	1,837,334
Jack Pine	-	1,088,882	357,785	-	1,446,668
White Spruce	-	-	1,272,089	-	1,272,089
Red Pine	743,665	-	525,213	-	1,268,879
Hard Maple/Basswood	510,744	-	1,498,182	-	2,008,925
Mixed Upland Hardwoods	-	-	1,633,993	-	1,633,993
Black Ash/American Elm/Red Maple	257,559	-	1,116,001	-	1,373,560
Other Hardwoods	212,428	1,085,772	1,312,903	-	2,611,103
Other Softwoods	-	332,646	502,035	-	834,681
Other	-	-	-	5,277,198	5,277,198
Total	4,451,754	8,393,236	18,438,005	5,277,198	36,560,193

Source: Patrick D. Miles, Forest Inventory Mapmaker 1.7: St. Paul, MN: USFS, North Central Research Station. www.ncrs2.fs.fed.us/4801/fiadb/i

Table 2-6 shows estimated biomass generation and availability from federal, county/local, private and other landowners in the study area based on USFS harvest removals in 2002. Total biomass availability is estimated to be 71,220 GT per year.

Table 2-6. Estimated Biomass Generation and Availability by Species Group and Landownership for Federal, County/Local, Private and Other Landowners (GT/Year)

Species Group	Federal	County/Local	Private	Other	Total
Aspen	3,542	40,385	62,823	-	120,915
Paper Birch	339	298	1,977	-	2,614
Jack Pine	-	975	320	-	1,296
White Spruce	-	-	1,551	-	1,551

Table 2-6. Continued

Species Group	Federal	County/Local	Private	Other	Total
Red Pine	666	-	470	-	1,137
Hard Maple/Basswood	806	-	2,363	-	3,168.70
Mixed Upland Hardwoods	406	-	1,760	-	2,167
Other Hardwoods	335	1,713	2,071	-	4,119
Other Softwoods	-	298	450	-	748
Other	-	-	-	4,726	4,726
Total Generation	6,094	43,669	73,785	4,726	142,440
Total Availability	3,047	21,834	36,893	2,363	71,220

Private landowners generate the most biomass of these landowners, followed by county and local government. Federal land and "other" landowners generate small proportions of total biomass.

2.4.4 Summary of Biomass Availability – All Sources

An estimated 118,642 GT of forest biomass per year are available from all landowners in the study area (Table 2-7). This assumes that tribal foresters meet the AAC level each year. If future harvest levels are similar to those observed from 1995 through 2001, where tribal timber harvests were well below total AAC levels, then tribal biomass availability would range from 21,000 to 32,200 GT per year instead of 40,685 GT per year. In this scenario, total availability would range from approximately 99,000 to 110,000 GT per year rather than 119,000 GT per year.

Table 2-7. Total Harvest Volume, Biomass Generation and Availability

Biomass By Landowner	Harvest Volume (Thousand Cubic Feet)	Biomass Generation (GT/Year)	Biomass Available (GT/Year)	Percent (%) of Total
Tribal				
Timber Harvesting				
Diminished Land	8,029	55,696	27,848	23%
Ceded Land & Northwest Angle	2,269	8,205	4,102	3%
Biomass < 5.5 Inches dbh	NA	12,681	6,341	5%
Subtotal - Timber Harvesting	10,298	76,582	38,291	32%
Red Pine Restoration	NA	4,788	2,394	2%
Subtotal - Tribal	10,298	81,371	40,685	34%
State	NA	32,366	16,183	14%
Federal	4,452	6,094	3,047	3%
County & Local	8,393	43,669	21,834	18%
Private Land	18,438	73,785	36,893	31%
Total	41,581	237,284	118,642	100%

We believe that both the values in Table 2-7 and estimates based on actual past harvest levels are conservative estimates of biomass availability because of the assumption of 50% biomass availability from forest management projects.

Typical harvest methods in the region for small diameter trees are similar to pulpwood harvesting in Minnesota, with the additional costs of chipping at the forest landing site. Biomass utilization will require the use of full-tree harvesting systems, in which whole trees (small and large diameter) are transported to a landing site where they are sorted and processed. Tops and unmerchantable materials are then chipped at landing sites. Bundling systems are an alternative to chipping at the landing sites, and can harvest and bundle small diameter unmerchantable trees. Such systems can also bundle slash at the landing. Tree bundling is less commonly used in the U.S. than in northern Europe, so it will not be the focus of this discussion.

Full-tree yarding is compatible with even-aged management, which represents the majority of the harvesting in Minnesota and on the reservation. A comprehensive logging survey of silvicultural systems in Minnesota in 1992 showed that overall, 92% of the harvest volume was done by clearcutting; of that total, 52% was clearcutting areas greater than 5 acres and 40% was clearcutting with standing residuals.[6] Loggers reported felling mostly by feller buncher in aspen and northern pine, whereas central hardwoods are mostly felled by chainsaw. Grapple skidding is predominant in aspen and northern pine, while cable skidding is more common in central hardwoods. An additional logger survey in 2004 supported the predominance of feller buncher felling coupled with cable and grapple skidders.[7] Full-tree harvesting using mechanical felling with transport by cable and/or grapple skidding is the norm for tribal loggers on the Red Lake reservation. Tribal loggers use the Minnesota BMPS (the MFRC's "Voluntary Site-Level Guidelines") as standards for harvesting. However, full-tree yarding is not the predominant practice for all landowners. Statewide, about one-third of the volume is topped and limbed at the landing site for aspen and northern pine, while almost all hardwoods are topped and limbed at the point of felling. Approximately 82% of all log bucking for aspen and 72% of bucking for northern pine is done at a roadside landing. For central hardwoods, an estimated 40% of bucking is done at the felling location and 52% is done at a roadside landing.

The most significant issues with collecting and processing forest biomass for energy or other value-added product manufacturing are associated with changes in operations required to collect the materials and cost. Costs are discussed in the subsequent section. Tribal forestry operations are not likely to require significant changes because current systems can easily be adapted to chipping biomass materials at the landing site. Logging on federal, state, county/local or private land may require more changes because tops and branches are more often left on-site. Logging on aspen and pine is the most compatible with using full-tree harvest systems.

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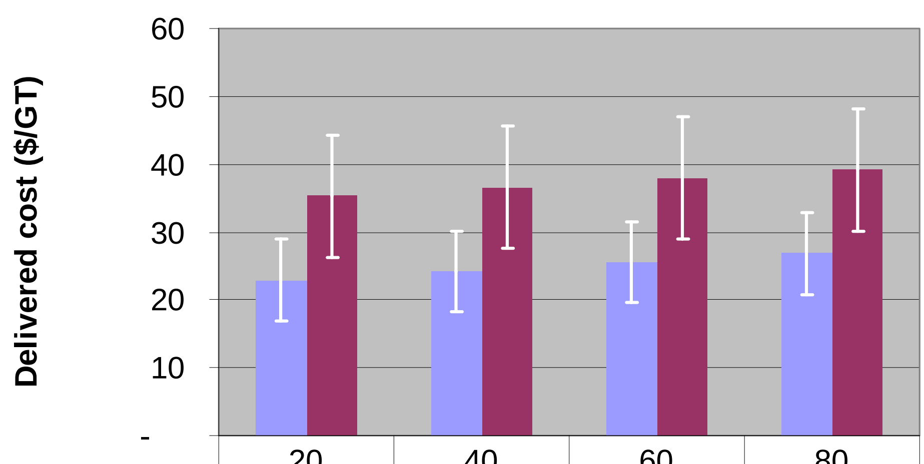
[6] Minnesota Environmental Quality Board, Maintaining Productivity and the Forest Resource Base, Table A, December 1992, http://www.iic.state.mn.us/download/geis/product/ekrose_app.pdf

[7] Blandin Foundation, Survey of Minnesota Logging Operators in 2004, December 21, 2004, http://www.blandinfoundation.org/html/documents/2004%20Logger%20Survey%20Report_Final.pdf

2.5 Costs of Gathering and Supplying Biomass Feedstock

Costs for collecting, processing and supplying biomass vary with biomass yield, tree size, harvest method, skid distance and transportation distance. Recent harvest cost modeling efforts for Minnesota that modeled the impact of these and other variables on harvest costs showed logging costs at the landing that range from $16 to $32 per cord ($7 to $14 per GT assuming 2.3 GT/cord) for even-aged management and $23 to $43 per cord ($10 to $19 per GT assuming 2.3 GT/cord) for thinning.[8] This does not include the cost of chipping and transportation. These estimates employed the harvesting cost component of the RXWRITE Prescription Writer. The harvesting cost modeling was coupled with additional modeling efforts that calculated transport costs and transport costs to one of six market centers located in the state. The choice of allocating harvest volumes to specific market areas was based on cost-effectiveness. Transportation cost assumptions were $0.15 per cord-mile plus $4.75 per cord handling.

To estimate delivered costs, we assumed chipping costs of $6 to $12 per GT based on published sources of chipping and grinding costs. Adapting these costs to the current study area and assuming haul distances up to 80 miles provided the range of delivered biomass costs in Figure 2-4. Average delivered biomass costs range from $23 to $27 per GT for clearcuts depending on the haul distance. Variation in harvest and chipping costs can widen that cost range to $16 to $33 per GT depending on the site. Costs for biomass from thinning average from $35 to $39 per GT. However, variation in harvest and chipping costs can widen that range to $26 to $49 per GT.



	20	40	60	80
Clearcut	23	24	26	27
Thinning	35	37	38	39

Figure 2-4. Range of Delivered Biomass Costs for Clearcut and Thinning Projects Assuming Haul Distances Ranging from 20 to 80 Miles

[8] Minnesota Environmental Quality Board, Maintaining Productivity and the Forest Resource Base, Table A, December 1992, http://www.iic.state.mn.us/download/geis/product/ekrose_app.pdf. Note: adjusted from 1992 values to 2005 assuming 3% inflation rate.

For biomass generated as a byproduct of other harvesting operations, removal of other biomass products can help subsidize the cost of biomass removal, since a portion of the costs can be attributed to the harvest of the higher value-added material. The extent to which other operations would cover biomass removal costs depends on the operator, but the cost would have to be sufficient to provide a profit incentive for the operator. The biomass chipping and transportation costs alone would range from $10 to $20 per GT.

2.6 Fuel Characterization of Available Biomass

There are a wide variety of published chemical property data available for biomass. This section presents published information available for some common tree species in the study area. There are no testing data available for a variety of species in the area including tamarack, many swamp conifers, many swamp hardwoods and others. A main reason is that there has been little regional effort to utilize these species for energy or fuels. For these species, it would be advisable to perform ultimate and proximate analysis, heating value analysis and ash analysis prior to usage.

The amount of usable thermal energy that can be obtained from fuel is known as the higher heating value (HHV). HHV is interchangeable with the following terms: heat content, energy content, latent heat, latent energy, and the heat of combustion. The practical heating value of biomass, as received, varies considerably due to differences in the ash-forming mineral and fuel moisture content. Table 2-8 provides chemical and heating value properties for several common tree species based on dry biomass. Forest biomass moisture content typically varies from 40 to 60% by weight (wet basis), and can be higher, especially if exposed to precipitation.

Table 2-8. Chemical And Heating Value Properties For Several Common Tree Species

Species	Fixed C	Volatiles	Ash	C	H	O	N	S	HHV	
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	kJ/g	Btu/lb
Aspen	30.1	65.8	4.1	NA	NA	NA	NA	NA	20.41	8,960
Beech	NA	NA	0.65	51.64	6.26	41.45	0	0	20.38	8,947
Birch	NA	NA	0.29	49.85	6.72	42.54	0.1	0.5	20.06	8,806
Douglas-Fir	17.7	81.5	0.8	52.3	6.3	40.5	0.1	0	21.05	9,241
Hickory	NA	NA	0.73	47.67	6.49	43.11	0	0	20.17	8,855
Maple	NA	NA	1.35	50.64	6.02	41.74	0.25	0	19.96	8,762
Ponderosa Pine	17.17	82.54	0.29	49.25	5.99	44.36	0.06	0.03	20.02	8,789
Poplar	NA	NA	0.65	51.64	6.26	41.45	0	0	20.75	9,109
Red Alder	12.5	87.1	0.4	49.55	6.06	43.78	0.13	0.07	19.3	8,473
Redwood	16.1	83.5	0.4	53.5	5.9	40.3	0.1	0	21.03	9,232
Spruce	NA	NA	0.77	51.06	5.75	42.29	0.11	0.01	19.97	8,767
Western Hemlock	15.2	84.8	2.2	50.4	5.8	41.1	0.1	0.1	20.05	8,802
White Fir	16.58	83.17	0.25	49	5.98	44.75	0.05	0.01	19.95	8,758
White Oak	17.2	81.28	1.52	49.48	5.38	43.13	0.35	0.01	19.42	8,525

Notes: wt % = percent of dry matter weight, C= carbon, H= hydrogen, O= oxygen, N= nitrogen, S = sulfur, kJ = kiloujoules, g = grams, lb = pounds, Btu = British thermal units

Sources: WoodGas, http://www.woodgas.com/proximat.htm except birch and spruce, source: Hermann Hofbauer, University of Technology - Vienna, Institute of Chemical Engineering, Fuel and Environmental Technology, Biobib: A database for biofuels, Vienna, Austria, http://www.vt.tuwien.ac.at/biobib/wood.html

Analysis of alkali content can also indicate the likelihood that a given fuel may cause boiler slagging and fouling. The value pounds of alkali per million Btu (lb/MMBtu) can be used as an indicator to estimate the risk of boiler slagging and fouling problems. Research indicates that biomass fuels with alkali contents below 0.4 lb/MMBtu are not likely to cause slagging problems.[9] Consequently, biomass feedstocks with high alkalinity are often blended with other fuels to reduce alkali concentrations and control fouling and slagging problems.

[9] T.R. Miles, et al. *Alkali Deposits Found in Biomass Boilers*, Vol. II, Sandia National Laboratory and National Renewable Energy Laboratory, NREL/TP-433-8142 and SAND96-8225, February 1996, 198-200.

3 REGIONAL AND LOCAL POWER MARKET ANALYSIS

One of the options for biomass utilization is the production of electricity. In this section we provide a brief overview of regional electricity utility considerations. We depict the Mid-Continent Area Planning Pool infrastructure, supply / demand balance and reserve conditions. We then provide a profile of the local electricity supplier (Beltrami Electric Cooperative) and finally we characterize electricity demand on the Red Lake Reservation. The focus is to assess the market potential for a new biopower facility in or around the Red Lake Reservation using tribal resources.

3.1 Mid-Continent Area Power Pool

The Red Lake Reservation falls within the jurisdiction of the Mid-Continent Area Power Pool (MAPP), which is an association of electric utilities and other electric industry participants. MAPP was organized in 1972 for the purpose of pooling generation and transmission. MAPP is a voluntary association of electric utilities who do business in the Upper Midwest. Its 107 members are investor-owned utilities, cooperatives, municipals, public power districts, a power marketing agency, power marketers, Regulatory Agencies, and independent power producers.

The MAPP organization performs three core functions: it is a Reliability Council, responsible for the safety and reliability of the bulk electric system, under the North American Electric Reliability Council (NERC); a regional transmission group, responsible for facilitating open access of the transmission system; and a power and energy market, where MAPP Members and non-members may buy and sell electricity.

MAPP was created to safeguard the region's bulk electric system. One of its main responsibilities is protecting the electric power network, commonly referred to as the grid, in the following states and provinces: Minnesota, Nebraska, North Dakota Manitoba, Saskatchewan, and parts of Wisconsin, Montana, Iowa and South Dakota. MAPP also has members in Kansas and Missouri.

Figure 3-1 provides a geographical overview of all of the power planning organizations in North America including MAPP, plus a general location of tribal reservation boundaries. MAPP covers a large swath of the upper Midwest and includes several tribes.

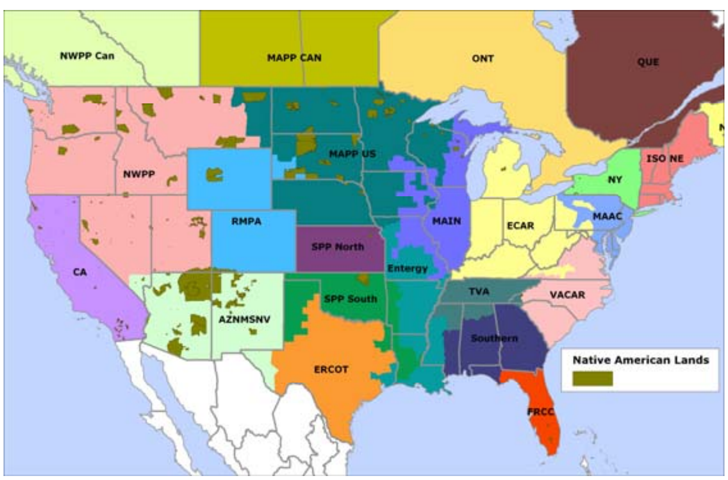


Figure 3-1. Map of NERC Regions and Native American Lands

3.1.1 Reserve Margin

North American Electric Reliability Council (NERC) regions are expected to attain levels of supply assurance to maintain the integrity of electricity supply to consumers. A key aspect of the supply assurance provision is the concept of reserve margin. There are many forms of electricity reserves (see Table 3-1). For planning purposes, utilities have historically attempted to maintain reserve margins around 15-17%. Utilities typically forecast demand and supply scenarios, often looking to the future for 20 years or more. When reserve margins drop below 15%, the utility often looks for additional supplies, either through contractual purchases or by construction of a new power plant(s).

Table 3-1 Categories of Reserves for Electricity Supply

Reserve Category	Description
Operating	That capability above firm system demand required to provide for regulation, load forecasting error, equipment forced and scheduled outages, and local area protection.
Spinning	Unloaded generation, which is synchronized and ready to serve additional demand. It consists of Regulating Reserve and Contingency Reserve.
Regulating	An amount of spinning reserve responsive to Automatic Generation Control, which is sufficient to provide normal regulating margin.
Contingency	An additional amount of operating reserve sufficient to reduce Area Control Error to zero in ten minutes following loss of generating capacity, which would result from the most severe single contingency. At least 50% of this operating reserve shall be Spinning Reserve, which will automatically respond to frequency deviation.
Nonspinning	That operating reserve not connected to the system but capable of serving demand within a specific time, or Interruptible Demand that can be removed from the system in a specified time. Interruptible Demand may be included in the Nonspinning Reserve provided that it can be removed from service within ten minutes.
Planning	The difference between a Control Area's expected annual peak capability and its expected annual peak demand expressed as a percentage of the annual peak demand.

As illustrated in Figure 3-2, reserve margins for 2012 are projected for all of the NERC regions and sub-regions in North America. The horizontal red line drawn across the figure represents the historic 15% reserve margin that many utilities use for planning purposes. Thirteen regions are below or just at 15% for the year 2012, including MAPP at approximately 10%. The five-percentage point difference suggests, if MAPP is to maintain a 15% reserve, then there will be the need for additional supply brought into the region. It can reasonably be expected that utilities within MAPP will be searching for new power supplies. Individual utilities will either attempt to obtain their own supplies or form alliances with other utilities.

Clearly one option is to import supplies from other NERC regions with reserves in excess of the 15% guideline. In this case, most of the regions with substantial reserve margins are located a great distance from MAPP and therefore it is unlikely imports of large amounts of electricity, beyond current imports, are likely.

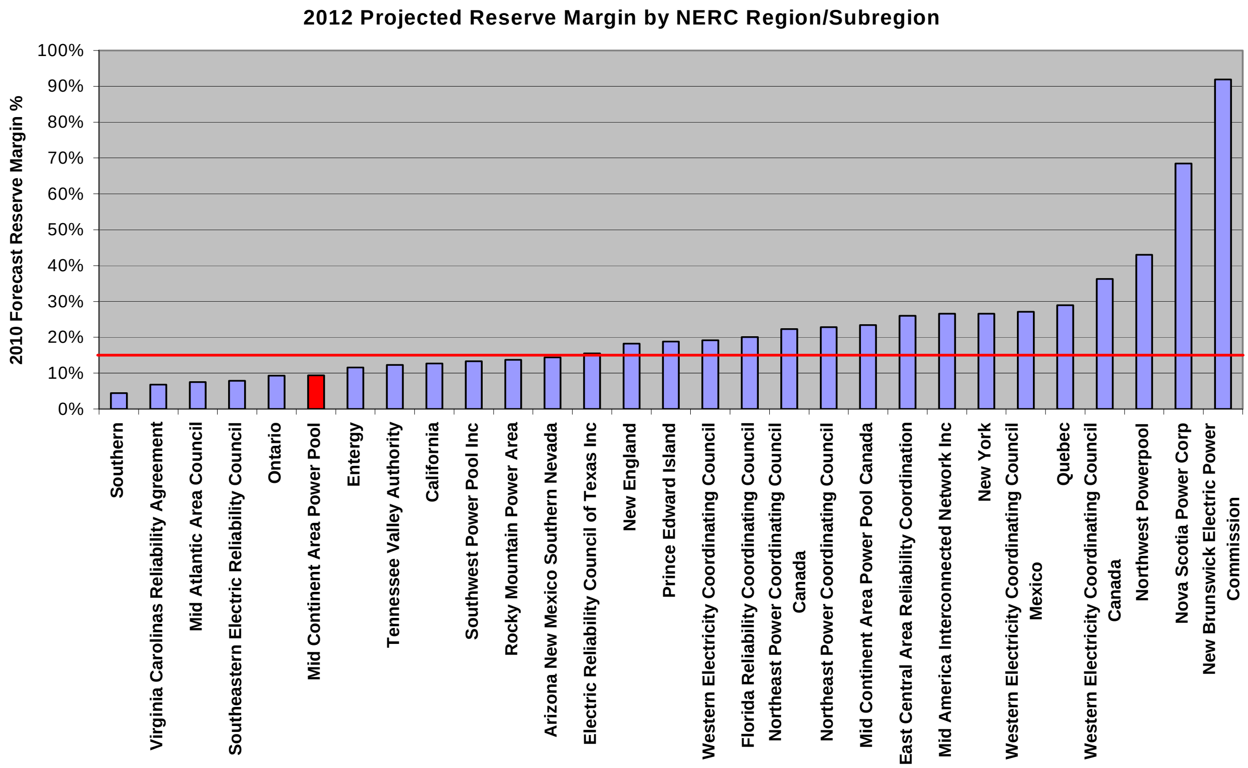


Figure 3-2 2012 Projected Reserve Margin by NERC Region/Subregion[10]

Additional detail to supplement Figure 3-2 is provided in Figure 3-3. Figure 3-3 illustrates the effect of demand growth exceeding capacity growth, leading to a decline in reserve margin. By 2012 the reserve margin is forecast to be approximately 10%, considerably less than historic operating conditions.

While a decline in the reserve margin is ostensibly an indication of the potential for new capacity additions, it is also reasonable to assume that MAPP has performed calculations to provide assurance that a 10% reserve margin may be acceptable. We are aware of a gradual relaxation of the 15% "rule of thumb" for reserve margins, due both to sophisticated modeling as well as the continued growth of electricity sales outside of traditional boundaries.

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[10] Power Development and Reservation Lands, Spatial Approaches to Finding Opportunity, Energy Velocity presentation to Council of Energy Resource Tribes, May 6, 2004.

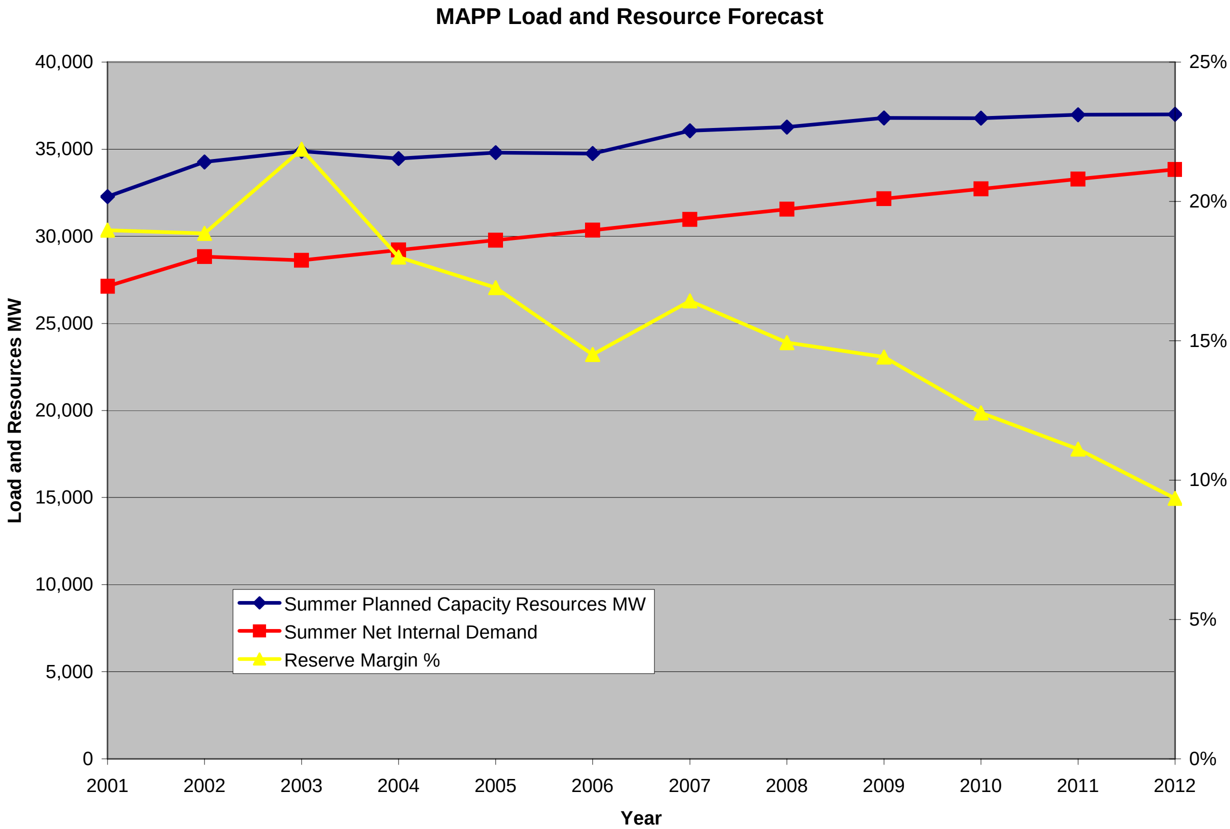

Figure 3-3 MAPP Load and Resource Forecast[11]

Another important consideration for a large power plant is access to transmission lines. As illustrated in Figure 3-4, major power transmission lines cross a small portion of the Red Lake reservation, specifically to the north and east of the Diminished lands and through the Ceded lands. While it is interesting to note the proximity of the 500kv line, it is not anticipated that this line will be important to Red Lake. Because biomass resources probably constrain power plant size to less than 10MW, it is likely that existing distribution lines can accommodate the load.

[11] Power Development and Reservation Lands, Spatial Approaches to Finding Opportunity, Energy Velocity presentation to Council of Energy Resource Tribes, May 6, 2004

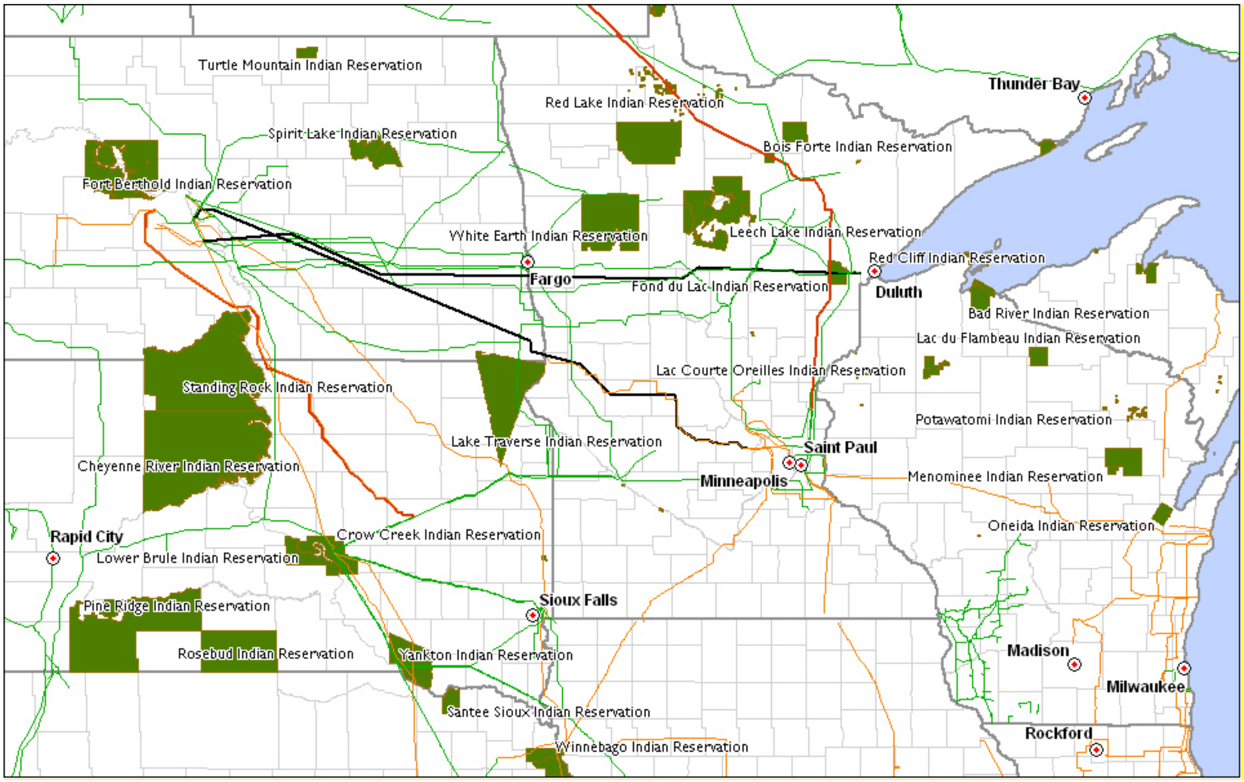

Figure 3-4 Reservation Locations Relative to Major Power Transmission Lines[12]

3.2 Red Lake Reservation Electric Service Provider

The Red Lake Reservation and all of the tribal members currently purchase power from the local rural electric cooperative, Beltrami Electric Cooperative, Inc. (Beltrami). According to the *2000 Minnesota Utility Data Book*, Beltrami had almost 17,000 electric customers in 2000 of which almost 14,000 were farms. Almost 2,000 electric customers were non-farm residential and just under 1,000 were commercial. Beltrami had no industrial customers.[13]

Beltrami is a distribution cooperative with approximately 14,500 members providing service over a 3,000 square mile area. The electric distribution system is comprised of 1,2000 miles of overhead line and over 1,700 miles of underground line.[14] Minnkota Power Cooperative is Beltrami's wholesale power provider.[15] Electricity usage for all Beltrami customers is shown in Table 3-2 for 2003.[16]

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[12] Power Development and Reservation Lands, Spatial Approaches to Finding Opportunity, Energy Velocity presentation to Council of Energy Resource Tribes, May 6, 2004

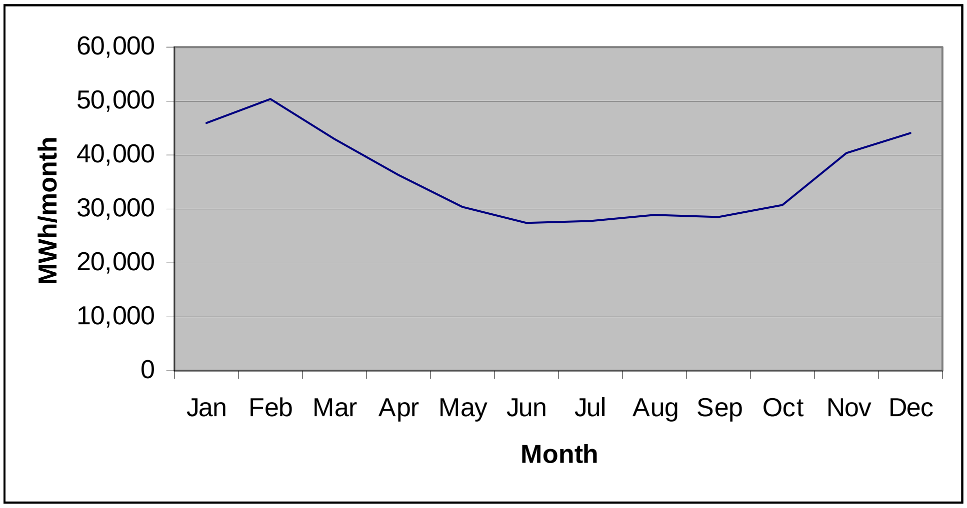
[13] *2000 Minnesota Utility Data Book*, Table 5, page 29.

[14] www.beltramielectric.com/About%20BEC.htm, accessed December 8, 2003.

[15] www.beltramielectric.com/load_management_program.htm, accessed December 8, 2003.

[16] USDA Financial and Statistical Report, 2004, Beltrami Electric Cooperative.

Table 3-2 Beltrami Electric Cooperative, Total Electricity Sales by Month, 2003



As shown in Table 3-2, the utility experiences peak consumption during winter months. The load factor is approximately 53%, reasonably typical for a rural electric utility with a high level of residential sales (see Figure 3-5).[17]

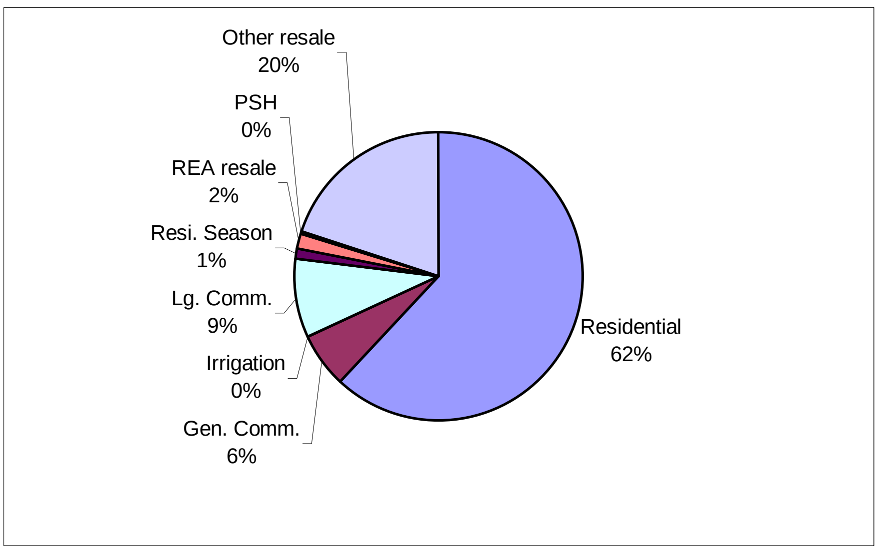


Figure 3-5 Distribution of Electricity Sales (kWh), Beltrami Electric Cooperative 2003

We performed a brief survey of 29 of the utilities in Minnesota to assess the relative position of Beltrami residential rates. Beltrami's average residential rate is about \$0.062/kWh or approximately 5% lower than regional competitors and 26% lower than the national average (see Table 3-3). Our complete results are provided in Appendix A.

[17] Load factor refers to the ratio of average-to-peak day use calculated over a specific period of time, such as a day, month, or year.

Table 3-3 Comparative Residential Electric Rates, 2004

Category	$/kWh
Beltrami	$ 0.062
MN avg.*	$ 0.065
National avg.	$ 0.084
* this study	

3.3 Minnkota Power Cooperative Inc.

The Minnkota-associated systems are a regional association of 25 electrical suppliers serving more than 114,000 customers in a 34,500 square-mile area in northwestern Minnesota and eastern North Dakota. They include 11 distribution cooperatives, 12 municipal utilities, a power agency, and a generation and transmission cooperative. Beltrami is a member of Minnkota.

The primary source of power supply is the Milton R. Young facility located at the mine mouth in Center, North Dakota. Two units comprise this lignite-fired installation, Unit #1 -- 250 MW and Unit #2 -- 455 MW. Minnkota is a winter peaking utility with a 2.2% annual growth forecast.

Over the next decade, Minnkota will satisfy increasing demand by purchase of options the firm holds in Square Butte power plant.[18] By 2009, Square Butte will provide an additional 95 MW of baseload capacity. Additional "supply" up to 340 MW will be obtained by reliance upon interruptible load control measures. Finally, the supply will be augmented by purchases of hydroelectricity from Manitoba Hydro for both peaking and firm requirements.

The *Minnkota Messenger*, a publication from Minnkota, provides some insight into the long-term plans for the utility.[19] Minnkota is pursuing the construction of a new facility by 2015. The firm estimates that it requires approximately seven years for planning, permitting and building a new plant. Talks are currently under way with Basin Electric Power Cooperative and Montana-Dakota Utilities about a possible joint venture. Another possibility is a third generating unit at the Milton R. Young Station. That project could involve constructing a 250-500 MW lignite-fired generator at the existing site.

3.3.1 Minnkota and Green Power

Minnkota Power offers its customers the opportunity to subscribe to the Infinity Wind Energy program whereby subscribers pay an extra $2.50 for each 100-kWh block of wind power. This premium is billed monthly. The wind project is located in North Dakota and the turbines are capable of producing an estimated combined annual output of 5 million kWh.[20]

3.3.2 Meeting with Beltrami and Minnkota

On June 16, 2004, a representative from McNeil attended a meeting with Mr. Roger Spiry, General Manager of Beltrami, and Mr. Wally Lang, Vice President for Transmission with Minnkota. The purpose of the meeting was to discuss renewable energy/biomass power, Red

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[18] Minnesota Public Utilities Commission, Staff Briefing Papers, April 3, 2003. Regarding Minnkota Power Cooperative and Northern Municipal Power Agency, 2002 Integrated Resource Plan.

[19] Minnkota Messenger, May/June 2004, annual meeting report, page 2.

[20] www.beltramielectric.com/Infinity%20Wind%20Energy.htm, accessed December 8, 2003.

Lake tribal interests, and the potential for small-scale generation, including access to transmission lines, on the reservation.

Based on the discussions in the meeting, it was apparent neither Mr. Spiry nor Mr. Lang have given much consideration to new power supply from biomass. While neither individual is tasked with resource planning, they are generally aware of corporate initiatives. Both Beltrami and Minnkota are not required to participate in renewable portfolio standards. The general impression was that the firm was meeting its environmental objectives with the Infinity Wind Energy program and through its purchase of 5MW of biopower through Otter Tail (see the following section).

At the time of the meeting, McNeil personnel were confident of supply sufficient to fuel a 5MW biopower facility, therefore the meeting focused on a small-scale facility. There was considerable discussion of available transmission capacity at the Redby substation. At this point in time and absent a detailed study (estimated cost by Minnkota of $5-10,000 by Minnkota representatives), the collective understanding was there was sufficient capacity at the Redby substation to effectively absorb the supply.

Mr. Spiry provided the “buy-back” rates for Minnkota under the provisions of the Minnesota small power production statute. Beltrami will purchase electricity for $0.02021/kWh and capacity for $21/kW/yr.

3.4 Otter Tail Power Company

Otter Tail Power Company serves about 127,000 customers in 423 communities in Minnesota, North Dakota, and South Dakota. The firm is headquartered in Fergus Falls, New Mexico and has an office in Bemidji, Minnesota and is active in the local community. Peak demand in 2003 was 668,703 kilowatts. Total generating capability was 696,380 kilowatts. The firm employs approximately 700 people.

Otter Tail presently purchases approximately 12.5MW of biopower from the Potlatch Corporation OSB facility in Bemidji, MN. Half of the power is then re-sold to Minnkota. We had two conversations with Otter Tail regarding additional purchases of biopower and while they indicated a general interest in further purchases, they did not believe the economics would be sufficiently attractive to allow them to integrate into their power supply mix.

3.5 Red Lake Tribe Electricity Consumption

Between June 2002 – June 2003, the tribe used 47.6 million kWh. Total tribal peak demand is not known but a simple calculation suggests the demand is approximately 5MW. Total expenditures for electricity during this time frame were $2.6 million.[21] The average rate is approximately $0.054/kWh. Monthly energy usage is shown in Figure 3-6. Electricity demand peaks in the winter.

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[21] Red Lake Reservation Biomass Energy and Biobased Product Feasibility Study Proposal in response to DOE solicitation Number DE-PS36-036093002, p.4.

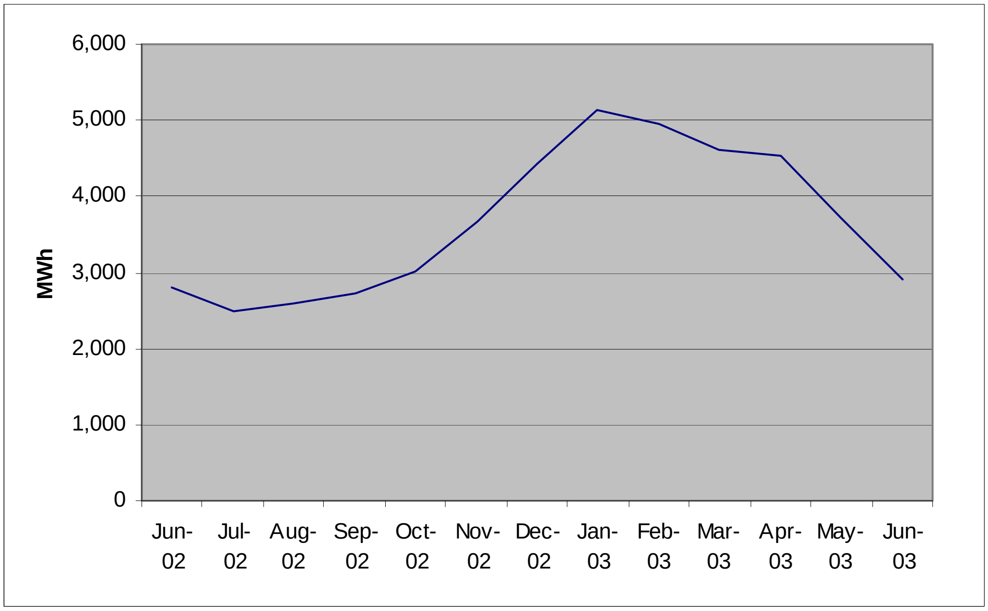

Figure 3-6 Red Lake Reservation Total Electric Consumption, 2002-2003

The largest commercial users on the reservation include the Tribal Council building, the Red Lake Casino, and the BIA agency office. Energy usage in 2002 for the three facilities is illustrated in Figure 3-7. The casino electric usage is about $100,000 per year while the other two facilities are considerably less at around $5,000 - $10,000/year.

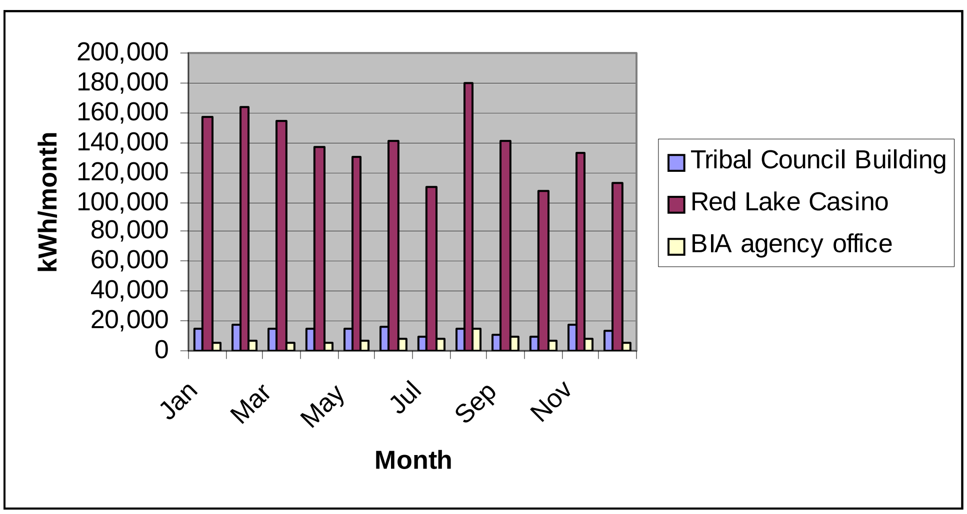

Figure 3-7 Red Lake Reservation Commercial Building 2002 Electricity Usage and Cost[22]

3.6 Biomass Power Economic Projections

Biomass power is often a relatively expensive form of electricity. The fuel is usually several times more expensive than its major solid fuel competitor, coal, and biomass fuel also has higher

[22] E-mail from Pam Marshall, Energy Cents Coalition, December 16, 2003.

moisture content and lower energy content than coal. Furthermore, capital costs for biomass systems are also more expensive than coal units, primarily because coal plants tend to be quite large and thus capture economies of scale not available to biomass power facilities.

For this report, we have prepared hypothetical pro forma economic calculations for several sizes of biomass facilities to present a general overview of the delivered cost of electricity. The economic model is from the perspective of a private developer.

3.7 Fuel Consumption

As shown in Table 3-4, we have performed a straightforward estimate of the fuel consumption (demand) requirements for a 5MW combustion unit (stoker technology). Annual demand is calculated to be approximately 43,000 dry tons per year (or approximately 72,000 wet tons/year). The biomass demand, using only timber harvest residue, represents 87% of the Tribal available supply and approximately 60% of the regional available supply. While it is clear the region has supply to satisfy demand, it is unlikely that a larger facility could be supported using only available timber harvest residues..

Table 3-4. Calculated Fuel Consumption for 5MW Biopower Stoker

Category	Units	5-MW Stoker
Capacity	kW	**5,000**
Capacity Factor	%	**85%**
Energy content	Btu/dry lb	8640
Moisture Content	%	40%
Energy content	Btu/wet lb	5184
Consumption	wet lb/hr	19,290
Consumption	Btu/hr	100,000,000
Heat Rate	Btu/kWh	20,000
Efficiency	%	17%
Consumption	dry tons/hr	5.8
Consumption	dry tons/yr	43,090

3.8 Economic Analysis

We have employed a pro forma model to determine the financial attractiveness of an investment in a biopower facility. The pro forma model simulates revenues and costs for the project horizon with the intent to determine annual cash flows. In this manner we calculate a net present value to allow us to understand if an investment is a worthy consideration by the Tribe.

3.8.1 Economic Inputs

The economic analysis employs a number of assumptions regarding economic considerations involved in a Tribal investment. Table 3-5 provides the major inputs regarding taxes, inflation/escalation rates, interest rates, incentives such as green tags, and buy/sell rates for electricity.

Table 3-5. Economic Inputs for Pro Forma Model

Category	Units	Value
Income Tax Rate	%	0
Electricity Escalation Rate	%	0
General Inflation/Escalation Rate	%	2.8
Loan Interest/Discount Rate	%	6
Down Payment on Loan	%	10
Depreciation Method		MACRS
Loan Repayment Term	years	20
Debt Coverage Ratio		1.4
Project Life	years	25
Salvage Value	%	5
Annual Plant Insurance	$/year	15,000
Annual Letter of Credit	Basis Points	50
Loan issuance fee	%	0.01
Operators/Management Fee	$/month	0.0
Fuel tax credit	$/green ton	0.00
Production Tax Credit (10 yrs.)	$/kWh	0.018
Green Tag (5 yrs.)	$/kWh	0.025
Energy	$/kWh	0.02021
Capacity	$/kW/month	21.00

3.8.2 Capital and Operating Costs

A 5MW biomass power facility is estimated to cost approximately $12.7 million dollars (see Table 3-6). The equipment represents about ½ of the total installed costs, with the balance in engineering, interconnection with the utility grid, permitting, and actual construction. Fixed costs, dominated by labor costs, are estimated to be $87.21/kW-yr. and are detailed in Table 3-7.

Table 3-6. Capital and Operating Costs, 5MW Biomass Stoker Power Plant

Category	Units	5-MW Stoker
Equipment	$	$ 6,364,918
Engineering+Interconnect	$	$ 1,862,086
Permitting/contingency	$	$ 499,626
Sitework+construction	$	$ 3,970,442
Capital Cost	$	$ 12,697,072
Capital Cost	$/kW	$ 2,539
Fixed Cost	$/kW-yr.	$ 87.21
Variable cost	$/kWh	$ 0.003

Table 3-7. Labor Requirements and Cost, 5MW Biopower Stoker

Category	5-MW Stoker
Plant Manager (#)	1
Deputy (#)	0
Operators (#)	7
Fuel Handling (#)	0
Maintenance (#)	1
Administration (#)	0.25
No. of Employees	9.25
Total payroll	$323,000
Benefits	$113,050
Annual payroll	$436,050
kW	5,000
$/kW-yr	$87.21

3.8.3 Results

We performed two analyses. The first is a base case analysis in which all of the input values are assumed to be the most conservative. By conservative we refer to the absence of any subsidies, the lack of provision of incentives, and utility buy-back rates that reflect current market conditions. The Net Present Value (NPV) for the base case is quite poor, a negative $295 million while for the “optimistic” case the NPV is a positive $85 million.

The base case is negative for a simple reason, the levelized cost of production is calculated to be $0.07/kWh and the selling price is $0.02/kWh. Thus for each kWh sold, there is a loss of about $0.05/kWh. Clearly one cannot sell at less than the cost of production.

Table 3-8. Analysis Results, Pro Forma Model, 5MW Biopower Stoker

Category	Units	Base	Optimistic
Capital Cost	$	$ 12,697,072	$ 6,374,032
Fuel Cost	$/BDT	$30.00	$15.00
PTC	$/kWh	$0.000	$0.009
Green Tag	$/kWh	$0.000	$0.025
Selling Price	$/kWh	$0.020	$0.040
Levelized Cost	$/kWh	$0.070	$0.046
NPV	$	($295,230,467)	$85,633,150

For the optimistic case, we have assumed capital costs are reduced in half. This may be possible if the Tribe were to receive a grant for 50% of the costs. Similarly, we assumed a 50% reduction in fuel costs, perhaps available if there is a subsidy for removal of timber harvest residues. We also assumed the Production Tax Credit and the Green Tag would be available to the Tribe. Finally, we increased the selling price to $0.04/kWh. The levelized cost of production drops because of the drop in the price of the fuel. Because of the combination of the incentives and the increased selling price, the NPV is positive due to the difference between the combined selling price and the levelized cost.

Figure 3-8 provides illustrative information regarding the distribution of the costs for operating a biopower facility. With fuel representing approximately ½ of operating costs, it is clear that it is essential to minimize fuel costs for profitable operations.

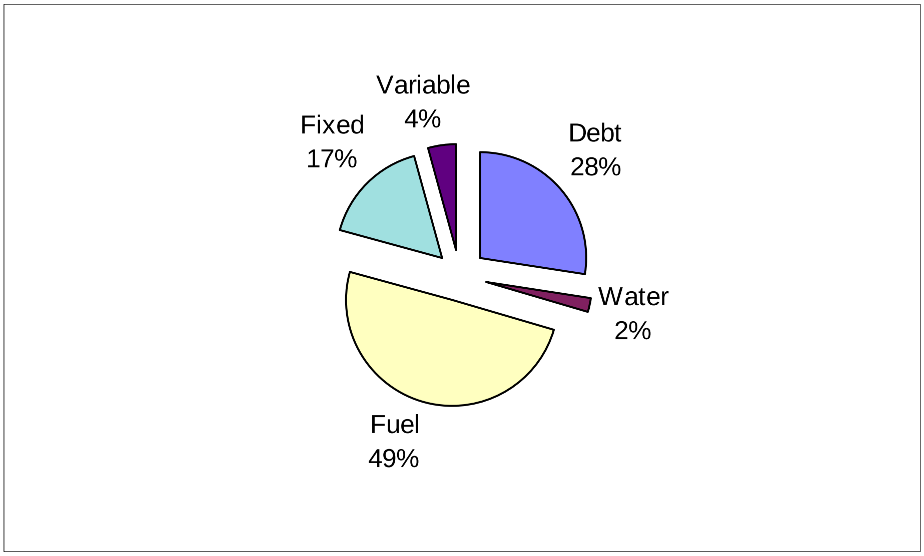

Figure 3-8. Distribution of Costs, Base Case, 5MW Biopower Stoker

4 ASSESSMENT OF BIOMASS HEATING OPPORTUNITIES

4.1 Fuel Cost Overview

Propane and fuel oil are the predominant fuels used for space and water heating for institutional and commercial buildings on the Red Lake reservation. There are various suppliers in Beltrami County that provide competitively priced energy. Propane prices tend to be lower than national averages, in part because the tribe purchases in bulk.

Biomass heating or thermal applications have merit because the delivered cost of energy is often cost-competitive with other energy forms. It is important to compare energy forms on an equivalent basis. We have performed calculations to compare energy costs on a $/MMBtu ($/million Btu) basis in order to facilitate comparisons among alternatives. As shown in Table 4-1 and Figure 4-1, wood pellets and biomass chips are the least expensive form of delivered energy for heating. Note the wide disparity in electricity costs. The low rate reflects the off-peak heating rate associated with thermal storage units. The higher rate reflects the residential service rate in effect at Beltrami. Perhaps most importantly, the cost of the predominant energy forms on the reservation, propane and fuel oil, are significantly higher than the biomass costs.

Table 4-1. Comparative Costs of Regionally Important Energy Forms, 2005[23]

Source	Units	Value	Efficiency	Btu/unit	$/MMBtu
Biomass chips	$/wet ton	$ 35.00	70%	8,000,000	$ 6.25
Pellets	$/ton	$ 86.00	75%	16,000,000	$ 7.17
Electricity	$/kWh	$ 0.03	100%	3,413	$ 8.79
Propane	$/gallon	$ 1.20	85%	91,600	$ 15.41
Fuel Oil	$/gallon	$ 1.78	80%	135,000	$ 16.48
Electricity	$/kWh	$ 0.062	100%	3,413	$ 18.17

[23] Pellet prices are derived from current prices paid by the Red Lake Tribe to Valley Forest Resource (Marcel, MN) for pellets delivered to the Humanities Center. Biomass chip prices are from this study. Propane prices reflect a brief survey of three Bemidji, MN suppliers plus an average of propane prices paid by the Red Lake High School and Middle School. Fuel oil prices reflect a brief survey of heating oil suppliers in Bemidji, MN in May of 2005. Electricity prices reflect current retail rates for Beltrami Electric Cooperative for residential service, with and without off peak pricing programs.

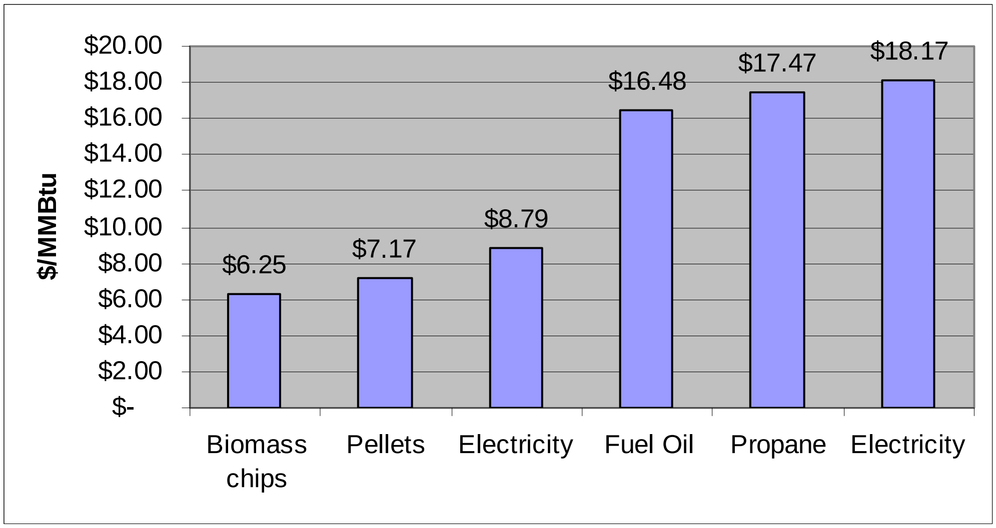

Figure 4-1. Comparative Costs of Regionally Important Energy Forms, 2005

Propane is a major fuel source on the Reservation, indeed for the surveyed buildings it is the predominant source. Propane is generally priced competitively at Red Lake, especially with regard to national prices. However, there is considerable upward pressure on propane prices. Figure 4-2 illustrates price trends for commercial customers on a national basis. The important consideration is the upward slope indicating continued real price increases forecasted by US DOE over the next ten years.

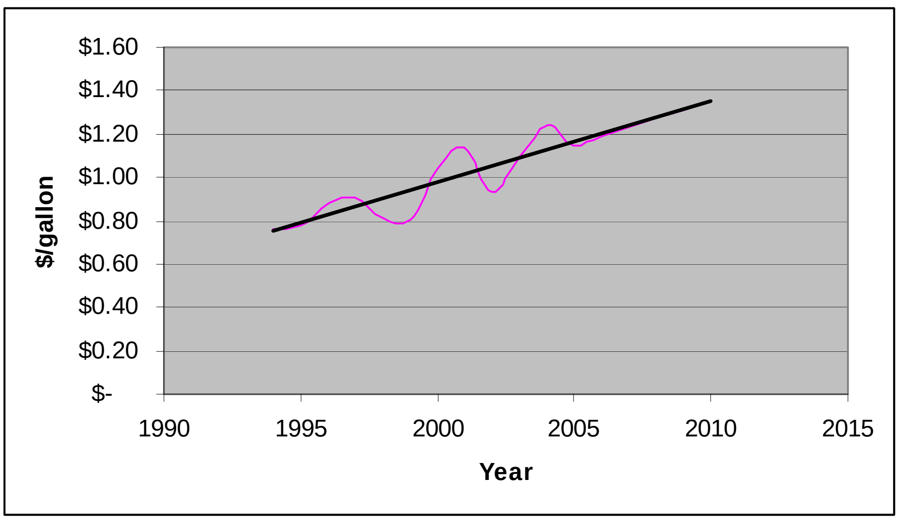

Figure 4-2. Propane Commercial Price History and Projections to 2010[24]

4.2 Biomass Heating History at Red Lake

Over the past 10-15 years at least four non-residential buildings have had biomass heating systems installed. The High School in Red Lake had a biomass chip/Municipal Solid Waste

[24] US Department of Energy, Energy Information Administration, Petroleum Marketing Monthly, January 2005.

(MSW) system, the Ponemah Elementary School had a biomass system, the Forestry Division operates a biomass-heated greenhouse and the Humanities Center presently has a bulk wood pellet system. The history of biomass usage is mixed and represents a challenge for increased use of biomass on the reservation.

The High School system was removed within the last several years due to the poor performance. McNeil personnel were not able to inspect any of the system because it had been removed and therefore the boiler manufacturer, feed handling system, and associated machinery are not known. The system was originally designed to utilize wood chips and was subsequently modified to accept MSW pellets. Both chips and MSW pellets were obtained within a 100 mile radius.

According to maintenance staff at the High School, the wood chip system had a poor feed supply technology or configuration. The chips would bind together in cold weather thereby causing a blockage and insufficient fuel supply to the boiler. While this is a common biomass fuel handling issue, many cold weather operators have successfully addressed this issue with thoughtful solutions.

Further, the wood chips would freeze on the supply line sensors, thereby sending misleading signals to the control system. In many instances operating staff were not aware if there was sufficient supply due to the inaccurate sensor readings. Additionally, the baghouse did not seem to capture the particulate matter as there were several reports of ash being deposited on the cars in the adjacent parking lot leading to complaints about the “dirty” conditions at the school.

The High School had a performance contract with GE Systems. The performance contract provides for remote monitoring of the boiler at the High School. When the sensors would report misleading fuel conditions, maintenance personnel would be called to the site via the GE operations center, often after normal work hours. Over the course of several heating seasons, it became apparent the overtime charges associated with the off-hours calls was exceeding the dollar savings associated with biomass use. Also, maintenance staff expressed annoyance with the degree of effort required to maintain the biomass system in “satisfactory” operating condition.

The biomass supply at the High School was apparently problematic. According to several individuals, the supply of chips was highly variable and of uneven quality. Our understanding is the local loggers do not have many chippers and they found the supply of chips to the High School to be only marginally profitable, especially in comparison with the provision of pulp logs.

MSW pellets were substituted for wood chips, apparently because the MSW pellets were less expensive and the supply more reliable. The MSW pellets seemed to have better handling properties than the wood chips but the smell associated with their combustion was overwhelming. Again according to maintenance personnel, the complaints from students, teachers, administrators, and adjoining building occupants were considerable. We are not certain when the biomass system was removed but it was replaced with a propane system within the past five years. The maintenance personnel are pleased with the operation of the propane system.

Although we have less information, a similar tale was relayed to us regarding the Ponemah Elementary School. In this case the biomass system was operated for less than 3 months, necessitating considerable “emergency” retrofit costs. From our understanding, the elementary school system suffered from unreliable fuel supply, poor and uneven fuel quality, and numerous maintenance problems during its short life.

Conversely, the Humanities Building has a bulk wood pellet system that is the primary heating unit for the building. This system has been in operation for at least ten years and the maintenance personnel report a high level of satisfaction with the unit. Aside from normal operating maintenance, there have been no problems with the system. Ash disposal is accomplished by dumping approximately three, 55-gallon barrels of ash per winter in the local landfill. A photo of the pellet fuel hopper is shown in Figure 4-3.

Figure 4-3. Pellet Fuel Hopper for Humanities Building

Similarly, the Department of Natural Resources, Forestry Division, has operated a small greenhouse for production of tree seedlings for many years. The primary heating source is a biomass boiler (see Figure 4-4). The biomass system consumes approximately 125-150 cords of wood per year, all derived from Tribal lands. Hot water is provided to a slab heating system to maintain interior temperatures of approximately 70ºF.

Figure 4-4. Biomass Boiler at Forestry Division Tree Seedling Greenhouse, Redby, MN

Based on our site inspection trip, it was apparent there is a disconnect between the biomass history at the schools and at the Humanities Building or Greenhouse. While there was a poor experience at the High School that many people were aware of, there was a noticeable lack of awareness that the Humanities Building even had a pellet system let alone a successful installation with a superb operating history. Similarly, the greenhouse system is not well-known and is responsible for considerable annual cost savings allowing for a successful operation selling tree seedlings. For biomass proponents, it would be advisable to "advertise" the success of the existing biomass heating system, both from a cost-saving as well as an operational perspective.

4.3 Facility Identification and Heating Load Analysis

Major thermal loads at Red Lake are represented by seven (7) school buildings and eleven (11) other larger, non-residential facilities (see Table 4-2). In cooperation with the Energy Task Force and the EnegyCents Coalition, we have assembled overview data on each of the facilities.

4.3.1 School Facilities

There are approximately 440,000 sq. ft. of building space associated with the schools. The largest two users are the High School and the Middle School. As shown in Table 4-2, some of the schools are energy efficient and some waste energy. The schools with the lowest kBtu/sq.ft./yr (kBtu refers to 1,000 Btu). are the most efficient, if one assumes all uses are nearly equivalent which they are not. The Early Childhood facility is the most efficient building but the figure is a bit misleading in that the energy requirements are reduced relative to some of the other facilities because the building is not used as much as others. The Middle School is the least efficient building and is slated for major reconstruction along with the High School.

4.3.2 Other Red Lake Buildings

For non-school buildings, the hospital represents the largest thermal user. The hospital requires 24X7 energy input for space and water heating plus required ventilation rates for health concerns. Thus it is not surprising that the energy consumption is high relative to the other buildings. However the hospital is well-managed from an energy perspective, the boilers are relatively new and there are no obvious solid fuel biomass heating opportunities. There may be reason to consider using bio-oil for replacement of the heating oil. That topic is discussed in another section.

Energy use at the greenhouse is intense on a Btu/sq.ft. basis, especially when compared with other tribal buildings. The reason for the high usage is the simple consideration is the R-value of the double polyethylene covering is quite low relative to other buildings. Because of the need for light transmission to foster plant growth, it is necessary to use a clear covering with high energy consequences. Thus it is particularly notable that the wood boiler saves, relative to oil, over $20,000/year.

Table 4-2. Major Buildings and Annual Thermal Loads, Red Lake Band of Chippewa Indians

Building	Sq. Ft.	Primary Heating Fuel	MMBtu/year	kBtu/sq.ft./yr.
Schools				
RL Middle School	77,544	Oil	7,534	97
Ponemah Elementary	59,344	Propane	2,230	38
RL High School	128,515	Propane	7,515	58
RL Elementary	89,956	Propane	4,386	49
Administration	10,451		0	0
RL Bus Garage	12,600	Oil	0	0
Early Childhood	60,860	Propane	2,622	43
Sub-Total, schools	439,270	N/A	24,287	55
Other				
Elderly Maintenance	960	Propane	61	63
Gaming Admin Office	3,020	Propane	144	48
Hospital	105,804	Oil	14,122	133
Humanities	49,519	Pellets	1,789	36
Ponemah Ambulance Station	2,400	Propane	130	54
Red Lake CAP	1,800	Oil	95	53
Red Lake Day Care	3,200	Propane	154	48
Redby Center	17,884	Oil	234	13
Redby Store	2,328	Oil	196	84
Tribal Council	11,107	Propane	1,403	126
Tribal Greenhouse	6,272	Biomass / oil	2,250	359
sub-total, other	204,294	N/A	20,578	101

4.4 Candidate Biomass Heating Opportunities

Our approach for identifying candidate biomass installations at the buildings is straightforward. We use the following criteria to screen facilities to determine if the building is a logical candidate for more in-depth analysis.

- Buildings with high heating bills. Larger facilities, typically over 50,000 square feet. The size rationale is predicated on the consideration that it is important to capture economies of scale associated with a new installation.
- Buildings with existing boilers and circulating hot water or steam systems. We have a strong preference for hot water systems because state laws generally require personnel with special certification for operation of a steam system.
- Current condition and age of existing boilers. New or well-maintained boilers are rarely candidates for retrofit.

- Future construction plans. We look for the opportunity to piggyback because a stand-alone project is often more difficult to economically justify. We especially look for construction plans that include expansion or renovation of the HVAC system.

Based on the mixed prior history of biomass utilization on the Reservation and the concerns expressed by maintenance staff over operational issues with biomass systems, we believe for biomass to be successful there must be a superior opportunity. Opposition, or even lack of support, from key maintenance personnel is a certain recipe for a poor experience with a new heating system. Therefore our application of the criteria for recommending a building for retrofit was especially rigorous. For a variety of reasons explained below, none of the existing buildings offers excellent or even good opportunities for retrofit to a biomass heating system. The Middle School may be a candidate, depending upon how future construction / retrofit is planned.

4.4.1 Heating Bills

Red Lake has a frigid climate (heating degree days of approximately 10,474 at International Falls, MN) and consequently high heating bills. Also, there are several school buildings that exceed our 50,000 sq. ft. threshold. We found competitive propane prices on the Reservation. While the delivered price of propane is about 60% higher than pellets ($7.17 - $11.50 / MMBtu), the propane price is far less than national averages. However, propane is largely an unregulated market, subject to considerable price fluctuation with a trend towards higher prices.

4.4.2 Existing Heating System

The existing building stock has a variety of hot water, steam and forced air systems. Several of the buildings, particularly the middle school, appear to be possible candidates because of the age of the system. However, most of the buildings are either new (less than five years old) or have new and/or well-maintained heating equipment that is not in need of replacement. This is especially true at the High School, the elementary school, and the early childhood facility.

4.4.3 Future Construction Plans

We identified two planned construction efforts. The first building is the High School / Middle School complex and involves major renovation of the two structures. According to the project Architecture and Engineers, the DLR Group, an $18 million effort is in late planning stages for the renovated facilities, including a central boiler plant for the heating requirements.[25] At this point propane is the preferred heating fuel. We have had one, brief conversation with the project team regarding biomass energy. The project team is mindful of the poor experience with biomass systems at Red Lake schools and members of the team have had a difficult experience with biomass at another school in Rice Lake, WI. At this writing the project team has not shown an inclination to consider biomass as a heating source although they have agreed to review the material in this report.

The second building is the proposed greenhouse for the Forestry Department. This greenhouse will be used for growing seedlings for reforestation efforts. The greenhouse will be approximately 1 acre and will be comprised of three separate buildings. For two reasons it is an ideal candidate for a biomass system. First, it is a new facility and thus retrofit costs will not be

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[25] Personal communication, Mr. Troy Miller, DLR Group, June 2005,

incurred. The absence of retrofit costs, including spacing considerations for a storage lot, will go a long way towards making the project cost-competitive with propane or oil systems. Indeed, it is likely a new system will be much less expensive than a retrofit system and thus the preferred approach to heating the building.

The second reason is a bit symbolic, it is important for the Natural Resources Department to show leadership in the sustainable use of forestry resources on the reservation. With the use of a biomass heating system, the timber harvest residues can be profitably used on the reservation to satisfy heating demand at the greenhouse. Appendix C provides additional information about biomass heating systems.

5 OVERVIEW OF BIO-BASED PRODUCTS

A range of bio-based products were considered as possible manufacturing and economic development opportunities. Due to the rural nature and agricultural output of the region, the majority of time and research was spent on animal bedding. Other novel technologies to produce bio-oil and wood-plastic composites were evaluated but are semi-commercial and require considerable capital for production. Using pellets for heating purposes was not considered in-depth, since this product is already available at a low price in the area. Below is a summary of findings for bio-oil, wood plastic composites and pellets.

5.1 Bio-oil

Bio-oils have a variety of applications which are being introduced to the market through pre-commercial demonstration projects. The primary use has been as a boiler fuel, either for heat or electricity. Bio-oil has also been used to replace fuel oil. The oils can be used to produce hydrogen, organic fertilizers, flavor chemicals, and fuel additives.

Bio-oil is manufactured through a process called pyrolysis. Pyrolysis is the irreversible, thermal degradation of organic matter to produce gas, liquid and char products. Pyrolysis occurs at lower temperatures than combustion or gasification without an oxidizing agent. Controlling the temperature and reaction rate determines product composition. Research and development in pyrolysis focuses on maximizing liquid (bio-oil) yields due to the ability to transport and store liquid fuels. Fast pyrolysis yields 75% bio-oil and occurs around 932°F at a high reaction rate, short residence time with 1 bar pressure. Rapid cooling or quenching condenses pyrolysis vapors into bio-oil.

The most common pyrolysis reactor types are fluidized beds. Biomass enters the fluid bed reactor where parameters are controlled to maximize desired product. Char particles are removed by cyclones and liquid is recovered by condensation or coalescence. Characteristics of various reactors are listed below:

<u>Bubbling Fluidized Bed</u>:

- Good Temperature Control
- Char removal by entrainment or injection and separated by cyclones
- Scalable
- Particle size <2mm

<u>Circulating Fluidized Bed</u>:

- Good Temperature Control
- Char removed by cyclones
- Can handle high volume of feedstock
- Particle size <6mm
- Complex hydrodynamics

The predominant bio-oil reactor manufacturers are Dynamotive, Ensyn and Renewable Oil International. Dynamotive's fast pyrolysis technique is termed BioTherm and utilizes a bubbling fluidized bed reactor. Ensyn's process is Rapid Thermal Processing (RTP) and the reactor type is a circulating fluidized bed. Ensyn has several reactors in commercial operation. Renewable Oil International's fast pyrolysis reactor is a linear system that does not require a gas stream to fluidize an inert material; rather, the reactions occur in an indirectly heated auger.

There are several storage issues associated with bio-oil. Due to the acidic properties, all storage materials must be made from stainless steel or another durable metal. Viscosity increases over time due to the multitude of components that compose bio-oil. Aldehydes, alcohols and acids react to form larger molecules. Adding a solvent such as ethanol or methanol alleviates these issues and allows bio-oil storage up to six months.[26]

Limited tests on industrial size boilers in Finland found corrosion occurred at a quicker rate than use of conventional heating oils. Current commercial boilers are likely able to operate on pyrolysis oil, however, burners must be adjusted or replaced with anti-corrosive parts and further testing is required to determine likely operation characteristics.

Bio-oil is a complex mixture of oxygenated hydrocarbons with high acidic and water content. Due to its chemical and physical properties, bio-oil cannot be blended with petroleum products without modification. In comparison with petroleum oils, bio-oil contains minimal or no sulfur and more oxygen leading to increased combustion efficiencies reducing overall emissions in heating or other energy uses. Viscosity increases overtime while volatility decreases. Phase separation, char deposits and gumming may also be problematic during storage. Bio-oils can be upgraded to reduce aforementioned risks. Techniques include filtrating out char particles, emulsifying with hydrocarbons, applying solvent, reacting with ethanol or other alcohols, or catalytic deoxygenation.

Most researchers consider bio-oil as a replacement for fuel oil #6 although the heating value is less than half that of petroleum #6.[27] Minnesota used 52.6 million gallons of residential fuel oils #5 and #6 in 2002. Minnesota consumption of #2 fuel oil was 732.628 million gallons in 2002 and Dynamotive conversion processes produce a bio-oil similar to fuel oil #2 for use as a turbine fuel .

Bio-oil costs 10-100% more than conventional fossil fuels.[28] Limited testing restricts consumer knowledge or likelihood of use. The issues associated with storing and utilizing bio-oil in conventional boilers limit market interest.

There are two commercial biomass pyrolysis installations in the US. Both are located in Wisconsin using Ensyn technology with a combined capacity of 90 dry tons per day. These systems produce liquid smoke used in food flavoring products such as barbeque sauce.

Dynamotive announced on July 21, 2004 that construction is in the final phases for the West Lorne Cogeneration plant located at Erie Flooring and Wood Products Corporation in Ontario. This system will pyrolyze waste wood produced by the flooring company into electricity using a

[26] Telephone interview with , Stefan Czernik, NREL, Biomass Pyrolysis Representative USA, September 2, 2004.

[27] Ibid.

[28] S. Czernik, "Review of Fast Pyrolysis of Biomass", NREL, 2002.

Dynamotive reactor and an Orenda gas turbine.[29] The plant will use 100 tons of waste wood daily to produce 70 tons of bio-oil, 20 tons of char and 10 tons of non-condensable gas. Electric capacity will be 2.5 MW utilizing 50 tons of bio-oil daily to meet demand at the plant.

5.2 Wood-Plastic Composites

Wood plastic composites (WPC) are a new family of thermoplastics. Recycled plastics and wood wastes are combined to provide durable and affordable products. These products are substitutes for wood in applications such as siding, fencing, molding, pallets, etc.

The composites are formed by compounding wood flour or other natural fibers into a thermoplastic resin with additives such as coupling agents, UV stabilizers, pigments, fire retardants or other additives to increase performance. Compounded materials can be extruded through a twin (most often used) or single-screw extruder into a final, usable form or processed into pellets for future processing. Processing temperatures rarely exceed 302 °F allowing high reaction rates without high energy consumption. Wood fiber present in composites ranges between 30-65%. Injection molding requires wood fiber to be concentrated prior to injection.

A pelletized feedstock enables a manufacturer to produce several WPC products from the same input. In addition to extrusion, pellets can be reformed in injection or compression molding to produce complicated shapes. The extrusion process consists of heating and compressing premixed raw ingredients. Shaping is accomplished by extrusion dies and cooling of the product in addition to downstream cutting, embossing, sanding and other processes.

The University of Maine has developed Woodtruder, a counter-rotating twin-screw extruder that optimizes WPC production by separating wood feeding and drying from polymer melting until a further point in the process. Selection of WPC machinery is dependent on the nature of the wood fibers, additives used and end-use of product.

Wood flour is the most common raw material in WPCs. It is finely ground wood cellulose from sawdust, planar shavings, sanding dust and scraps. The wood flour is obtained by passing wood wastes through mesh in a hammer mill. Wood flour has also been produced from pine needles, maple, oak and bamboo. Thermoplastic resins used in WPC production must by processed at temperatures below 3,632 °F. The most common feedstocks are PVC, polypropylene and polyethylene (the least expensive option). Virgin or recycled thermoplastics can be utilized in the production process cresting an excellent market for recycled.

Forestry slash and wood wastes have been used as a WPC feedstock in limited volumes at P&M signs under the trade name AllTree. John Hunt of the USDA Forest Products National Laboratory is analyzing forestry residues for use in solid wood and pressed-wood fiber composites to develop fiberboard and I-beams. He also mentioned that the laboratory has also developed a playground flooring material made of polymers and wood chips and expects to comply with the Americans with Disabilities Act. Research is also being conducted on converting residues into composites for use in the packaging and furniture industries.

Trex, a leading wood plastic composite manufacturer, experienced sales of over $200 million in 2003. [30] The company's primary customer is the construction industry, which uses the material

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[29] http://www.dynamotive.com/news/newsreleases/040721.html, last visited September 2, 2004

[30] F. Maine, "Wood-Plastic Composites – Challenges and Opportunities", PSA Composites, March 2004.

for decking. Other key manufacturers include Crane's TimberTech, US Plastic Lumber, AERT, Louisiana-Pacific, Nexwood, CertainTeed and Correct Deck. Emerging markets for wood plastic composites including railing, fencing, windows and doors. Although not yet commercial, wood plastic composite prototypes for siding are being tested and the North American siding market is estimated at $8 billion [4]. Over the past 5 years, the wood plastic composite industry has experienced growth of 100% per year [31]. The market for North America and Europe is estimated to reach $2 billion by 2007. [32]

WPCs exhibit superior physical, chemical and mechanical properties when compared with conventional wood construction materials. They are more weather resistant enabling their use in a wider range of climates. There is low risk of thermal linear expansion and warping. The increased resistance to moisture reduces decay, swelling and risk of fungal build-up.

Additional benefits of WPCs over traditional PVC-U are as follows:

- Dimensional stability
- Greater elasticity means there is no need for reinforcement
- High impact resistance
- Low flame spread
- Excellent screw and nail retention
- High slip resistance
- Recyclable
- Produced from waste wood and recycled plastics
- Broad range of finishes can be applied to tailor appearance
- Competitively priced

5.3 Pellets

Pellets are formed by drying, milling, extruding and applying pressure to densify biomass material. Pelletizing machines extrude biomass fines through a die at high pressures to increase density. The combination of high temperature and pressure breaks down the elasticity of the biomass producing pellets with a greater density than the original feedstock. Pellets are passed through a screen to ensure proper sizing.

Pelletizing machinery is based on animal feed pelletizers but require die modification. A pelletizer typically consists of a circular die with holes for pellet forming. The inside of the die contains compressions wheels that force the feedstock into the die holes. Pellet presses require specific moisture content and particle size for optimal performance.

Pellets have low moisture content when compared with cord wood or chips leading to efficient performance. The heating value is approximately 350,000 Btu per cubic foot of pellets whereas

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[31] "Wood Plastic Composites – a New Opportunity", Tangram Technology, UK, March 29, 2004.

[32] M. Babu, G. Srikanth, S. Biswas, "Thermoplastic Composites – Technology & Business Opportunities", TIFAC, June 2004.

cord wood is between 70,000-90,000 Btu for the same increment. Particulate emissions are 1.2 grams per hour -- well bellow the EPA wood burning limit of 7.2 grams.

Standards for pellet manufacturing have been established by the Pellet Fuels Institute and are displayed in Table 6-1. There are two pellet grades, premium and standard, determined by their ash content. Premium pellets make up 95% of the market and contain less than 1% ash. This type is manufactured from hardwoods or sawdust. Standard pellets may contain up to 3% ash and may be made from bark or agricultural residues. This pellet type can only be utilized in industrial equipment or stoves designed to handle higher ash content.

Table 6-1-Pellet Manufacturing Standards

Characteristic	Standard
Chlorides	minimum 40 lbs/ft^3
Dimensions	maximum length 11/2" diameter 1/4"-5 1/16"
Fines	<.5% by weight through 1/8" screen
Chlorides	<300 ppm

Source: Fuel Pellets Institute

There are 60 mills manufacturing pellets producing approximately 680,000 tons annually.[33] The Pellet Fuels Institute reports 2004 sales of 872,779 tons of pellets in the United States. North American figures for 2004 are 956,000 tons representing a 6.4% increase over the previous heating year. The central region, which includes Minnesota, had pellet sales of 67,175 tons in 2004. The central region saw a 55% increase in pellet sales between the 2002-2003 and 2003-2004 heating seasons.

There are 23 manufacturers of pellet stoves and 67,000 units were sold in 2004. There are more than 600,000 pellet-burning stoves and fireplaces in use in North America. A 40 lb pellet bag provides 24 hours of continuous heat and a typical household will utilize 100-150 bags during winter.

The Red Lake Tribe currently obtains pellets for a boiler at an excellent rate of $80/ton delivered. If the competitive environment in Minnesota changes in the future, the Tribe may want to conduct additional analysis to determine whether pellets represent a viable economic undertaking. At the present time, it would be difficult to compete based on the low prices offered by the existing companies.

[33] Pellet Fuels Institute, Pellet Heat Facts Information Sheet, www.pelletheat.org

6 BUISNESS PLAN ANALYSIS OF WOOD SHAVINGS FOR TURKEY BEDDING

McNeil Technologies assessed the potential for the Red Lake Tribe to manufacture and sell wood shavings to be used as turkey bedding. We considered shavings for turkey bedding as a possible product due to the fact that the tribe has forest resources on the reservation which could easily be delivered to an on-site processing facility. In addition, Red Lake is located near several large-scale turkey farmers who could be potential purchasers of the product. However, there are several challenges which make this a challenging business prospect. For this reason, we did not develop a formal business plan for this opportunity. All of the data presented in this chapter are backed up by detailed Excel spreadsheet analyses.

6.1 Product Overview

Wood shavings are produced by passing logs lengthwise through a shaving mill, which cuts the wood into thin shavings. Depending on the intended end-use, shavings may also be passed through a drying operation to kill bacteria and prevent mildew. Shaving mills can process wood that is 2-24 inches in diameter.

Wood shavings are useful as animal bedding for a variety of livestock, laboratory animals and small pets. Shavings have excellent absorbent properties and are softer than other types of bedding. Pine is currently the dominant tree species used for animal bedding, due to the fact that it is the least expensive wood and is relatively clean. Cedar and aspen are other popular wood types. Based on information from the biomass resource assessment (Chapter 2 of this report), aspen is the most likely feedstock for a shavings operation.

Our analysis assumes that biomass materials from current harvests on the reservation are being used in existing business operations (e.g. firewood). If we subtract out these materials, there should be an adequate supply of wood for a shavings business assuming harvesting practices are held constant or increased. Table 6-1 shows preliminary estimates of biomass availability based on estimated annual allowable cut (AAC) levels less average annual harvest. The harvest levels for the Diminished lands are the annual average for 1981 to 1992, while for Ceded and Northwest Angle Lands the data were from 1974 to 1992.

Table 6-1. Estimated Annual Availability of Biomass for Major Species Groups

Resource Type	Size/Quality Of Material	Biomass Available (Cords)
Aspen	Much in younger age classes - some larger logs but access not easy	8,753
Swamp conifer	Consists of black spruce, tamarack, balsam fir and white spruce primarily	7,843
Swamp hardwood	Primarily black ash	4,596
Aspen from red pine conversion	Quality varies in residual stands - size ranging from 2 to 8 inches dbh	2,394
	Total	23,587

Note: Aspen, swamp conifer and hardwood estimates based on 2002 Red Lake Forest Inventory & AAC calculations. Aspen from red pine conversion estimated based on volume of wood in trees less than 6 inches dbh from USFS Forest Inventory & Analysis.

Due to Minnesota's high volume of turkey farms (it is the largest producer in the US), this analysis focuses on wood shavings produced for turkey bedding. Since shavings for turkey are sold by the truckload, no packaging equipment or related labor is required. A wood shavings operation can be relatively small, employing a laborer, a manager/laborer and a part-time driver.

6.2 Market Characterization

According to statistics from the US Department of Agriculture 250 turkey farmers raised 46.5 million birds in the state of Minnesota in 2004. Table 6-2 shows that 11,616,567 turkeys were sold in the counties surrounding Red Lake. The numbers were actually greater than this, since some counties within the 150-mile did not disclose statistics on turkeys: Red Lake, Wadena, Kittson, Mahnomen, Marshall, Norman, Pennington, Hubbard, and Lake of Woods.

Table 6-2. Turkey Sales and Inventory Within 150 Miles of Red Lake

	sales		inventory		Approximate Distance (miles)
County	**# Farms**	**# Turkey**	**# Farms**	**# Turkey**	
Beltrami	5	32	10	36	30
Becker	18	1,064,605	21	307,722	100
Clay	6	371,034	8	80,038	150
Clearwater	4	4	14	71	42
Morrison	23	3,395,977	31	1,183,373	140
Ottertail	17	2,857,570	31	907,471	130
Polk	3	22	5	14	110
Roseau	12	872,000	9	271,502	100
Todd	17	3,055,249	24	804,625	150
Totals	**105**	**11,616,493**	**153**	**3,554,852**	

An additional 23 million turkeys were sold in the largest producing counties located 150-250 miles away from Red Lake. Table 6-3 displays quantity and approximate distance data for Minnesota's largest turkey producing counties.

Table 6-3. Turkey sales and inventory more than 150 miles from Red Lake

	sales		inventory		Approximate Distance (miles)
County	**# Farms**	**# Turkey**	**# Farms**	**# Turkey**	
Kandiyohi	16	6,512,003	15	2,178,806	220
Meeker	13	2,960,158	17	1,115,898	233
Morrison	23	3,395,977	31	1,183,373	157
stearns	32	4,598,129	32	1,437,090	185
swift	7	4,438,688	9	1,574,289	215
Renville	3	1,562,400	7	630,436	250
Totals	**94**	**23,467,355**	**111**	**8,119,892**	

Source: USDA NASS 2002, http://www.nass.usda.gov/census/census02/volume1/mn/st27_2_013.pdf

Wood shavings are a common and desired material for turkey bedding. According to the former President of the Minnesota Turkey Growers Association, Greg Langmo, shavings are the most frequently used and best quality turkey bedding material in Minnesota.[34] In a survey of Minnesota Turkey Growers Association members (done for this study), 28 of 32 respondents used wood shavings as their predominant source of bedding. Only three respondents used primarily sunflower hulls, and only one respondent used hay. Eighteen of the respondents used wood shavings as well as other types of bedding, such as sunflower hulls, saw dust and hay.

Farmers typically buy shavings in loads of 150 cubic yards. Shavings are also sold by the ton and by varying truckload sizes, costing $8.55/yd^3 on average. Based on these figures, each turkey requires .0216 yds^3 of bedding. Table 6-4 summarizes this data.

Table 6-4 Wood Shavings per Turkey

Farm	Yd3/Bird	Price/Yd3	Total Yd3/Year
Flann Turkeys	.014	$9.13	3,000
Glen Klaphake Turkeys	.06	$9.33	2,700
Gorton Turkeys	.012	$8.67	6,000
Hill River Farms	.0222	$7.56	2,002
Jennie O Food	.0163	$8.64	2,850
Kersting Poultry Farms, LLC	.0198	$8.54	2,770
Olson Farms	.0133	$5.90	667
P&J Turkeys	N/A	$8.99	2,937
Swan River Farm and M&N Turkeys	N/A	$9.02	2,549
T& J Turkeys	.015	$9.67	6,000
Averages	**.0216**	**$8.55**	**3,148**

It seems unlikely that consumption habits will change. According to the survey conducted for this report, wood shavings were chosen because they were considered to be the most effective bedding material. Absorbency was the most important qualitative factor for many respondents. Farmers also liked the fact that wood shavings pack down less than other bedding. A study of bedding derived from wood, particularly aspen, yielded limited bacterial growth when compared with straw and sunflower hull bedding. Bacterial growth is impacted by particle size, with larger shavings exhibiting fewer bacterial colonies.[35]

[34] Greg Langmo, turkey farm owner, former president of Minnesota Turkey Growers Association (320) 693-0226

[35] R. Bey, J. Reneau, R. Famsworth, "The Role of Bedding Management in Udder Health", University of Minnesota, St. Paul.

Wood preference was not a critical factor. Twenty one respondents listed pine as their top choice, and 11 said that the tree type does not matter. Six respondents also listed cedar as an option they would consider and four respondents listed aspen as a preference. It is possible that answers were influenced by prices for the different types of wood. Cost was listed as a key consideration for about a third of the respondents.

When asked whether they would be interested in using wood chips as opposed to wood shavings, 20 respondents said definitely not, and 11 said they would consider chips if they were dry enough and not too coarse, and only one respondent would be interested in using them.

Substitutes do not seem to be a threat, despite their lower costs. Sunflower hulls can be purchased for $20-30/ton, however, few farmers are using them. In some cases, the hulls were received free of charge. Sunflower, wild rice and corn hulls are not as absorbent and result in more time and expense in barn cleaning.

6.3 Financial Assumptions

The start-up costs of a wood shavings operation are significant. Figure 6-1 shows the breakdown of fixed and variable costs. A shaving mill and dryer are required to make shavings that are suitable for poultry bedding. The wood must be dried so that it has a moisture content of less than 12% for poultry. The installed cost of this equipment is estimated at $289,000. A front end loader is needed to move the chips into a trailer and unload them at the client site. This adds approximately $100,000 to the cost. A used truck and trailer for making deliveries can be purchased for roughly $90,000. We have assumed no building will be purchased to house the equipment or that the old sawmill building could be made available for the business. Shavings could be made as orders are placed and stored in the trailer.

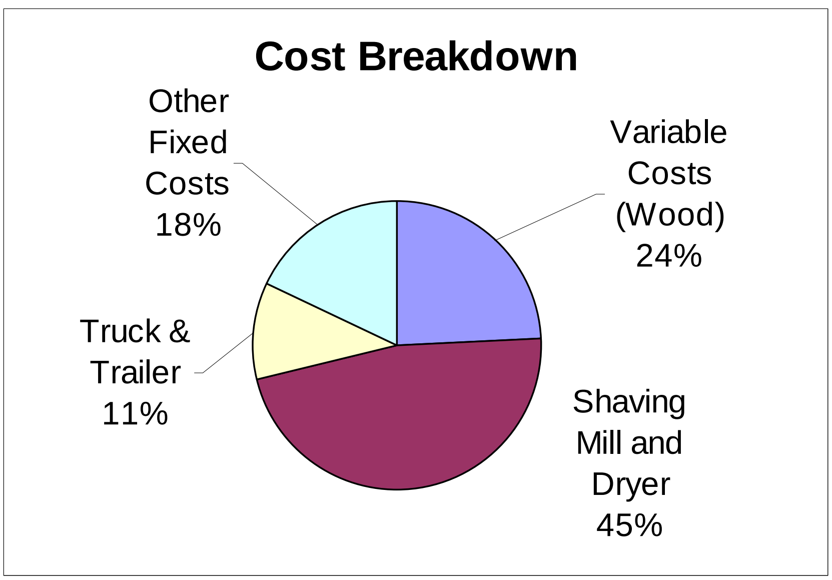

Figure 6-1. Fixed and Variable Costs for Plant

Variable costs are dominated almost entirely by wood inputs. In order to produce 60,000 cubic yards of product, the shavings mill would need to purchase 3,600 cords of wood at an assumed cost of $201,560 (approximately $56/cord delivered). This production target is based on capturing 20% of the local market (i.e. within 150 miles). This calculation is based on turkey sales as well as inventories (15 million turkeys in the area), since the total number represents the bedding required for a year. Note that this is an ambitious sales target, since it involves taking market share from established shavings suppliers.

In order to obtain market share, Red Lake will need to offer its customers a price break (since there is no practical way to differentiate the product on the basis of quality). The tribe may be able to encourage customers to switch shavings suppliers by offering the product at a price of $6.22 (10% below the going market rate before shipping is included), plus shipping at $1.75/mile. The resulting delivered price would be $7.93/cubic yard.

In order to break into the market, Red Lake would need to make personal introductions through phone calls, farm visits and/or introductions facilitated by the local farm bureaus. It is unlikely that the Tribe could succeed in markets beyond a 150-mile radius, due to the fact that the increased travel distance would raise costs for consumers – making the product less competitive. Despite this challenge, the Tribe could query potential customers at more remote locations; it is possible that some farmers are paying too much and Red Lake could make a better offer – even when factoring in the added distance.

Under the business analysis, revenues from shavings sales would be $335,700 per year, assuming sales of 60,000 cubic yards. Some revenues could also be realized through profits on transportation: approximately $110,000 after the cost of gasoline is taken into account. However, these revenues are insufficient to offset the cost of production with wood at $56/cord.

Due to the limited size of the local market and the fact that pricing must be competitive, the business is not financially viable. However, if prices for some of the inputs changed, the Tribe might be able to realize a profit. The price of wood is $56/cord, delivered to the shaving site (based on data from the Tribe's harvesting operations). At $56/cord, the NPV of the project is negative: -$326,595. However, if the Tribe could obtain wood for $35/cord, the NPV would be positive: $277,228. This is an unlikely scenario since current prices range from $50-$75/cord.

6.4 Next Steps

Producing shavings exclusively for turkey farms is not a viable business. However, the per unit price of small pet bedding and laboratory animal bedding is much higher. It is possible that these higher selling prices could make up for long distance transportation costs and packaging costs associated with packaging the product for different end users. The Tribe could also capitalize on the fact that it has a high volume of aspen trees, which are the preferred type of bedding for smaller animals. The tribe should maximize the value of its resources by obtaining the highest possible value for each species of tree. The wood shavings market for turkey does not differentiate between pine and aspen in a meaningful way.

In addition to turkey bedding, there are many other end use markets for wood shavings. The most promising markets appear to be for small pets and laboratory animals. An overview of these markets is provided, although more research would be needed to investigate the costs and possible revenues from these market segments.

Small Pet Market

The market for pet products is large, and it is growing. The American Pet Products Manufacturers Association (APPMA) 2003/2004 National Pet Owner Survey found that Americans own 16.8 million small animal pets, 17.3 million birds and 9 million reptiles. Total spending for pets was estimated at $34.3 billion with supplies and medical expenditures of $7.9 billion (this figure includes expenses for bedding).

An APPMA survey found that 86% of small pet owners purchased litter and bedding products in 1996. Small pet bedding products are most often purchased at discount stores followed by hardware/garden stores, pet stores and grocery stores. Cedar bedding is the most readily available product, with a price range between $2.50-3.50 for 1,500 cubic inches. Kiln dried pine bedding was available at discount stores for $5.00-6.00.

Aspen is considered the best bedding for small animals, although pine and cedar dominate the market for pet products.[36] There may also be the potential for cottonwood and less aromatic softwoods (spruce and fir) to penetrate the market.[37]

There are three aspen bedding companies supplying large retailers (including Wal-Mart and Petsmart). Green Pet of Conrad, Iowa produces Aspen Supreme Pellets retailing for $6.99 per ten pound bag. Kaytree of Chilton, Wisconsin sells aspen bedding for $7.69 per 3,200 cubic inch bag. Sunseed of Bowling Green, Ohio provides shredded aspen bedding retailing for $6.09 for 3000 presspak.

Small animal bedding would require bagging machinery since it is not sold in bulk as is the case for livestock bedding. However, as a higher quality product sold at a higher price, bagged shavings can be sold to a wider market. SBS Shavings ships its bagged shavings products up to 500 miles. SBS Shavings also noted that the company was not able to keep up with market demand.[38]

<u>Laboratory Animals</u>

Aspen is the most common wood used for laboratory animal bedding. An important distinction is that neither cedar nor pine are used for research animals since these woods emit aromatic hydrocarbons that can contribute to respiratory diseases.[39] The University of Minnesota purchases aspen shavings from five providers. The primary supplier is Harlan Teklad from Madison, Wisconsin. Harlan Teklad is the largest laboratory research animal diet and bedding provider. The primary campus and largest laboratories are located in Minneapolis, approximately five hours away from Red Lake. Bemidji State University is located near Red Lake and also has some laboratory facilities. However, Bemidji State's needs for animal bedding are minimal.

Hardwood trees other than aspen can be used if they are debarked; particles must be dried at a high temperature to remove moisture and kill bacteria. Reclaimed virgin wood pulp can be used, since it does not contain news print or similar waste materials. Corncobs can also be used to make laboratory animal bedding. The woody-ring portion is used to make 1/4" and 1/8"

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[36] Ibid. p. 6.

[37] Mackes p. 13.

[38] Interviewed with Glen Barrow on October 14, 2004.

[39] Kurt Mackes and Dennis Lynch, "The Use of Wood Shavings and Sawdust as Bedding and Litter for Small Pet Mammals in Colorado," Department of Forest Sciences, Colorado State University, September 28, 1999, p. 4.

products, and the pith and chaff are made into a pelleted product. Cotton fiber is used in cage liners.

Similar to the small pet bedding market, aspen bedding for laboratory animals sells at an average price $7.00-9.00 per bag.[40] Given the limited number of laboratories and lack of sales opportunities in the area, Red Lake would need to develop a sales network on a national scale or work with a distributor to find customers in this somewhat limited market segment. It is likely that Red Lake would need to identify additional target markets for shavings (such as the small pet market) rather than replying solely on sales to laboratories.

Livestock

The US Department of Agriculture statistics for 2002 count 28,448 dairy cattle on 354 farms in Minnesota (in 12 surrounding counties). Typical wood shaving or chip bedding requirements for livestock are 12.5 lbs/1000 lbs live animal weight changed once a week.[41] There were also 8,917 horses on 1,428 farms in the 12 surrounding counties.

However, shavings are rarely used for beef cattle. Straw, newspaper and sawdust are more common, according to Howard Person of the University of Minnesota Extension Service. Bedding for livestock is sold in bulk amounts and generally receives lower prices when compared with laboratory or small animal bedding.

[40] K. Mackes, D. Lynch, "The Use of Wood Shavings and Sawdust as Bedding and Litter for Small Pet Mammals in Colorado", CSU Department of Forest Sciences, September 28, 1999.

[41] Beef Cattle Housing and Feedlot Facilities, Saskatchewan Agriculture, Food and Rural Revitalization, March 2004.

7 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes conclusions and recommendations drawn from the results of the resource, technology, and economic analysis.

7.1 Conclusions

This section summarizes conclusions and recommendations drawn from the results of the resource, technology, and economic analysis.

7.1.1 Biomass Resources / Costs

Total biomass availability for energy use is estimated to be 118,642 GT per year from tribal, federal, state, county/local government and tribal land (Table 7-1).

Table 7-1. Total Harvest Volume, Biomass Generation and Availability

Biomass By Landowner	Harvest Volume (Thousand Cubic Feet)	Biomass Generation (GT/Year)	Biomass Available (GT/Year)	Percent (%) of Total
Tribal				
Timber Harvesting	10,298	76,582	38,291	32%
Red Pine Restoration	NA	4,788	2,394	2%
Subtotal - Tribal	10,298	81,371	40,685	34%
State	NA	32,366	16,183	14%
Federal	4,452	6,094	3,047	3%
County & Local	8,393	43,669	21,834	18%
Private Land	18,438	73,785	36,893	31%
Total	41,581	237,284	118,642	100%

Estimated biomass availability from tribal land assumes that the harvest levels are at the annual allowable cut (AAC) level of 80,452 cords specified in the 2002 Red Lake Forest Inventory Analysis. A reduction in the AAC would reduce the amount of biomass available from tribal lands. Also, if as in the past, past harvest levels are well below the AAC level, biomass availability will be lower. Based on harvest levels from 1995 to 2001, availability would range from 21,000 to 32,200 GT per year instead of 40,685 GT. Total availability would range from 99,000 to 110,000 GT.

However, the values in Table 7-1 and estimates based on past harvest levels are conservative estimates of biomass availability because of the assumption of 50% biomass availability from forest management. This provides a substantial buffer for technical limitations, shifts in allowable cut volumes and annual variability in harvest volumes.

Estimated delivered biomass costs, including collection, forwarding, chipping and transport depended on the forest management prescription. For clearcuts, average delivered costs ranged from $23 to 27 per GT depending on the hauling distance. Average costs for biomass from uneven-aged management ranged from $35 to $39 per GT. Costs for biomass generated as a byproduct of other harvesting activities include chipping and hauling costs, and range from $10 to $20 per GT.

In addition to overall biomass availability for energy, we investigated the potential to harvest and utilize aspen and underutilized species such as swamp conifer swamp hardwoods for the production of shavings for animal bedding. We estimated that 23,587 cords of material could be produced each year for a potential shavings operation. The cost to a potential tribal shavings operation would be $56 per cord based on tribal harvest operations, but regionally costs vary from $50 to as much as $75 per cord.

7.1.2 Electricity and Power markets

- Red Lake is served by Beltrami Electric Cooperative which is a member of Minnkota Power Cooperative. The Red Lake Reservation falls within the jurisdiction of the Mid-Continent Area Power Pool (MAPP).
- Electricity demand continues to grow within the MAPP region. Reserve margins are falling indicating a need for additional power plants.
- Integrated Resource Plans (IRP's) prepared for Minnkota and other regional electricity suppliers include significant additions to power supplies over the next decade but only limited inclusion of renewables. Renewable energy purchases identified in the IRP's are focused predominantly on wind power, biopower is not selected as a preferred resource.
- The regional purchase price for electricity from Qualified Facilities is approximately $0.02/kWh, a very low price that precludes many self-generation projects.
- The Red Lake Reservation composite residential rate for electricity is $0.062/kWh or approximately 5% lower than regional competitors and 26% lower than the national average.
- The composite peak demand for the Red Lake Reservation is approximately 5MW which is also the available capacity at the Redby substation owned and operated by Beltrami.
- A 5MW biopower facility, located at the site of the old sawmill and fueled with wood from the reservation has unfavorable economic projections. The calculated levelized cost of producing electricity is $0.07/kWh. Given a selling price of $0.02/kWh, the plant would never make money.
- Sensitivity analyses on the assumptions for the 5MW plant indicate that there would need to be implausible changes in underlying inputs to achieve economic viability.

7.1.3 Biomass Heating

- Biomass chips are the least cost fuel on the Red Lake Reservation.
- There has been a mixed history of biomass space heating performance on large facilities at Red Lake. The High School heating system performed poorly and was removed. The Humanities Center and the Forestry greenhouse have been successfully and economically heated with wood pellets and chunk wood, respectively, for many years.

- The majority of the larger facilities at Red Lake use either propane or fuel oil as their heating energy. In general, many of the facilities are new and in good operating condition.
- The newly proposed High School / Middle School complex is an ideal candidate for a biomass heating system due to the large annual load and the consideration that the building has not been built or even specified. A new building offers the opportunity to plan for the biomass system at the outset.
- Heating bills at the various schools do not appear to be a concern to the Tribe because the state of Minnesota pays a substantial fraction of the operating cost for the facility. Thus the motivation to utilize the least-cost technology does not reside at the Tribe.
- A new greenhouse to grow tree seedlings for reforestation efforts is a prime candidate for a biomass heating system.

7.1.4 Alternative Fuels

- Bio-oil produced from woody biomass via a pyrolysis process has growing significance on a national basis and Red Lake may be able to capture some of the promise. The attractive proposition is the combination of major heating loads (primarily the hospital) coupled with the resource base and the emerging technology.
- The production of wood pellets is possible but not a viable outlet for Red Lake because there are many pellet producers in the general region and their existing capacity exceeds demand. Red Lake does not have a compelling advantage that would foster market entry into wood pellet production.

7.1.5 Wood Shavings/Animal Bedding

- Based on the resource assessment, wood is available for use in additional tribal business enterprises. Pieces and logs that are 2-24 inches in diameter can be made into wood shavings and passed through a dryer to produce a final product. Due to Red Lake's remote location and the proximity of several turkey farms, we evaluated the potential to produce wood shavings to supply turkey bedding within a 150-mile radius of the reservation.
- A financial model was developed to determine whether the costs of selling to 20% of the local market would be sufficiently profitably to justify investing in the new business venture. It was learned that even selling to 20% of the market -- which would be a significant challenge in an environment with long-established buyer-seller relationships – the tribe would not be able to earn a reasonable return on its investment.

7.2 Recommendations

Two clear choices for additional biomass development emerged from this study. First, biomass heating has considerable merit for several buildings. It is recommended that the Tribe perform detailed feasibility analyses of heating the High School / Middle School campus. This facility could be a showcase opportunity for Red Lake. The Tribe could provide 100% of renewable fuel for the facility for the duration of the building life as well as provide jobs and income for Tribal members.

A similar recommendation is made for heating the proposed tree seedling greenhouse. While the greenhouse would not have the scale as the High School / Middle School complex, the DNR can promote the integrated nature of resource management by treating acres on the Reservation and utilizing the by-product of the treatment process. Because wood chips are the least expensive heating option on the Reservation, the DNR will save operating funds relative other heating sources. Funds have been made available to Red Lake Tribe from the Bureau of Indian Affairs for the detailed analysis of peak and annual heating loads at the proposed greenhouse.

The final recommendation is to continue to explore the feasibility of utilization of bio-oils for thermal applications. As heating oil prices continue to increase, Red Lake may be well-positioned to capitalize on provision of renewable energy to Tribal as well as federal facilities. Because federal facilities are required to secure an increasing portion of their energy from renewable sources, the Tribe may benefit from both its resource base as well as its proximity to a number of large federal installations. Funds have been made available to Red Lake Tribe from the Bureau of Indian Affairs for the detailed analysis of bio-oil opportunities.

Wood Shavings

It appears that manufacturing wholesale shavings for the livestock bedding market is not a good opportunity. The Tribe may wish to consider developing a high quality animal bedding product which would be sold to different market segments. Buyers of small pet bedding and laboratory animal bedding are willing to pay a premium for aspen – unlike turkey farmers, who need to keep costs low. It is likely that the higher selling price obtainable on these markets would compensate for any additional costs associated with packaging, transportation and commissions paid to wholesalers. The shavings analysis conducted under this study could be expanded to include an assessment of the bagged shaving wholesale and retail markets.

Appendix A. Comparative Minnesota Residential Electricity Rates[42]

[42] Rates were calculated on a hypothetical 1,000kWh/month load for the "basic" residential service absent taxes, surcharges, monthly fees and incentive plans.

#	Utility	Residential Rate		Ownership
1	Ada Public Utilities	$	0.047	Municipal
2	Agralite Electric			Cooperative
3	Alexandria Light and Power	$	0.061	Municipal
4	Allete (MN Power)	$	0.044	IOU
5	Alliant Energy (Interstate Power and Light)	$	0.087	IOU
6	Arrowhead Electric			Cooperative
7	Austin Utilities			
8	Barnesville	$	0.063	Municipal
9	Beltrami Electric	$	0.062	Cooperative
10	Brainerd	$	0.059	Municipal
11	Connexus	$	0.070	Cooperative
12	Cooperative Alliance Partners			Cooperative
13	Cooperative Light and Power			Cooperative
14	Crow Wing Power			Cooperative
15	Dakota Electric	$	0.076	Cooperative
16	Detroit Lakes	$	0.055	Municipal
17	East Central Energy	$	0.075	Cooperative
18	East Grand Forks	$	0.069	Municipal
19	Fairmont Public Utilities	$	0.080	Municipal
20	Fosston Public Utilities	$	0.059	Municipal
21	Hibbing Public Utilities			
22	Hutchinson Utilities Commission			
23	Lake Country Power	$	0.074	Cooperative
24	Moorhead Public Service	$	0.050	Municipal
25	Mountain Iron	$	0.063	Municipal
26	New Ulm	$	0.073	Municipal
27	Otter Tail Power	$	0.067	IOU
28	Rochester Public Utilities	$	0.075	Municipal
29	Xcel Energy	$	0.069	IOU
	Average	$	0.065	

Appendix B. Biomass Power Technologies

TECHNOLOGY OVERVIEW

Direct combustion systems are by far the most common biomass fired technologies employed today. The major types are the circulating fluidized bed (CFB) units, bubbling fluidized bed (BFB) units, inclined fluidized bed (IFB) units and stoker fired units.

Gasification units are widely believed to hold great promise for future development and several firms are presently deploying small units. In general, gasification technology allows for fuel flexibility and increased efficiency gains. However at the present time there are a limited number of installed gasifiers and thus the technology cannot be considered commercial.

Combustion Technologies

Spreader-Stoker Fired Boilers

Stokers currently used today in wood fired applications fall into two major categories, the air-cooled traveling grate and water-cooled stationary grate. With both of these types of stokers, the wood fuel is distributed across the width of the grate with metering bins on the front wall of the boiler. The fuel is then uniformly distributed over the depth of the grate by air swept spouts. Saw dust and other fines in the fuel are burned in suspension, while larger particles drop to the grate and are dried and burned directly on the grate surface. Heated low-pressure combustion air is evenly distributed through the grate surface to promote fuel drying and provide the primary source of combustion air. To further aid the combustion process, high-pressure over fire air ports are used above the grate to provide turbulence and thorough mixing of the unburned combustion gases with air.

With the traveling stoker, the grate travels from the rear of the boiler to the front with fuel being fed across the depth of the furnace to the rear wall. Ash travels to the front edge of the grate and falls into a pit. This design requires additional maintenance due to the high temperatures that the grate bars are exposed to and the abrasive nature of the wood ash due to the high silica content.

The stationary water-cooled grate is typified by the Detroit Hydro-Grate stoker. With this design, the grate bars are attached to a water-cooled tubular grid and the grate is sloped at a slight angle (approx. 6-8 degrees) and is periodically vibrated to assist the movement of the burning fuel and ash down the grate towards the ash pit. The advantage of a water-cooled grate is the reduced maintenance from the minimum of moving parts. Care must be taken in operation not to permit an ash pit fire. This will result in overheating and failure of the water supply tubes feeding the grate's support grid.

Both of these two types of stokers are commercially proven technologies that are highly flexible in the choices of fuels that can be burned, alone or in combination. Turndown and response to rapid load swings with little or no change in steam temperature or pressure are also very good. Steaming capacities of these units range in size from a steam flow of 40,000 to 700,000 lbs/hr.

Circulating Fluidized Bed Boilers (CFB)

The application of wood fired CFB units has generally been limited to waste wood products that are significantly drier than biomass from the forest. Typically CFBs use fuels such as demolition wood waste and mill residues but they can be easily designed to fire higher moisture wood fuels, alone or in combination with solid fuels.

In a CFB unit, fuel is fed into the lower part of the furnace where the fuel mixes with the fluidized bed where the solids are maintained at 1,500 to 1,600 degrees Fahrenheit (F). The fuel introduced to the bed is quickly heated until it reaches ignition temperature. As the fuel burns, the size is reduced to a point where the particles are entrained by the upward flow of combustion gases. Larger particles are removed from the gas stream before it reaches the convection surfaces of the unit by use of a cyclone or particle collector beams and they are returned to the bed for further burnout and size reduction.

The advantages of a CFB unit are the ability to burn lower grade fuels at reduced temperatures and excess air without loss of combustion efficiency. In addition to the reduced NO_x and SO_x emissions that are inherent with a CFB, these units can burn high fouling fuels without the normally associated operating problems due to the reduced combustion temperatures. CFB units will suffer from bed sintering from firing fuels that have high alkali metal content.[43] This will result in higher fouling of the bed tube surfaces and excessive above bed burning that will increase furnace exit gas temperatures and superheater fouling. Units equipped with refractory lined cyclones will also have high refractory maintenance requirements due to the abrasive nature of the ash.

Bubbling Fluidized Bed Boilers (BFB)

The application of wood fired BFB units is much more wide spread than the CFB units. Due to their ability to burn high moisture, low Btu fuels they have been uniquely suited to the needs of the pulp and paper industry to burn biomass, wood waste and bark commonly produced in large quantities at a pulp mill. These units have been used fairly extensively in this application with capacities ranging from a steam flow of 25,000 lbs/hr up to 600,000 lbs/hr.

The fuel feeding and combustion process for a BFB unit is very similar to that of a CFB except that the bed is only partially fluidized and the burning fuel is not entrained in the combustion gas flow and it remains in the bed.

The advantage of a BFB unit is its ability to burn difficult low grade wet fuels. The thermal inertia of the bed and the mechanical action of the sand and ash to break down the fuel particles make a BFB unit insensitive to fuel variations. Unlike a CFB unit, a BFB unit utilizes a non-circulating bed in the furnace bottom that is made up of sand. The wood ash and a small amount of sand are removed through a drain opening in the floor of the furnace to control the bed level. The sand acts as a thermal reservoir and it mechanically breaks down the size of the fuel to facilitate combustion. BFB units do suffer from the same bed sintering problems as the CFB, but due to the partially fluidized bed the sintering problems can be much worse and can result in high sand consumption rates due to the high bed drain rates.

Inclined Fluidized Bed Boilers (IFB)

The Inclined Fluidized Bed (IFB) technology combines aspects of the inclined grate and fluidized bed technologies. Unlike most other technologies that mechanically agitate the fuel

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[43] Bed sintering is caused from chemicals or minerals in the fuel that reduce the ash softening temperature and cause large conglomerations of bed material that restrict the bed drains or closes them off completely requiring the unit to be shut down and the bed material manually removed from the unit. In addition, sintering causes loss of bed fluidization and reduces combustion efficiency.

during combustion, the IFB uses an entirely different concept for performing this function. With the IFB technology, the fuel is fed onto an inclined grate assembly via a feed ram where controlled combustion takes place. Combustion air is provided to each portion of the grate from a combustion air fan through slots in the grate assembly.

The IFB grate utilizes hollow tubes to form the steps on the grate. Each of the tubes is equipped with a number of small nozzles that provide a passage from the tubes to the fuel bed on the grate. The tubes are connected to a common fan that recycles a portion of the exhaust gas. This gas is introduced into the fuel bed as short pressure pulses, controlled by valves on an intermittent basis, providing a burst of energy into the fuel bed. These pulses result in highly efficient agitation of the fuel. The fuel is pneumatically mixed in lieu of a mechanical means, thereby providing efficient oxidation of the fuel.

This technology uses fewer moving parts, which reduces both the equipment capital costs and the maintenance costs. IFB grates are new and have not as yet been utilized in an industrial wood fired application although pilot scale testing has been very successful.

Gasification

Biomass can be converted to synthesis gas, which consists primarily of carbon monoxide (CO), carbon dioxide (CO_2), and hydrogen (H_2), via the gasification process. Gasification technology has been under intensive development for the last two decades. Large-scale demonstration facilities have been tested and commercial units are in operation worldwide. Producer gas has been used in reciprocating engine-generator sets to generate electricity. Gas impurities have prevented the use of producer gas from gasification systems in gas turbines. Gasification coupled with the production of a higher value liquid fuel is another ongoing area of research, with several pre-commercial technologies that are capable of producing ethanol or other alcohol fuels and bio-crude, a fuel that could be used as heating oil or in low-speed diesel engines. Bio-crude can not be used in transportation applications without further refining into a biodiesel product.

Biomass gasification systems offer several advantages over direct combustion systems. Gasification reduces corrosion compared to direct combustion because of the lower temperatures in the gases. Gasifiers can convert the energy content of a feedstock to hot combustible gases at 85 to 90% thermal efficiency. Also, the fuel throughput/unit area is greater for gasification than combustion, which means that smaller gasification units can process the same amount of fuel as larger combustion units. In addition, approximately 80% of the usable energy is in the form of chemical energy in the gas. A final advantage is that, if desired, the materials that cause slagging can be removed at relatively high temperatures through a gas clean-up process. These last two statements imply that the gas can be cleaned-up and used at higher temperatures without significant loss of sensible heat, although the costs to do so can be considerable. [44,45]

Gasification can occur in one of two ways. The first method simply adds the fuel to a fixed bed, a process used in both updraft and downdraft gasification. The second gasification method

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[44] R.D. Rutherford, Calvin B. Parnell and Wayne A. Lepori, *Cyclone Design for Fluidized Bed Biomass Gasifiers*. ASAE Paper no. 84-3598, 1984.

[45] C.B. Parnell, W.A. LePori, and S.C. Capareda, “Converting Cotton Gin Trash into Usable Energy,” *Proceedings of the 1991 Beltwide Cotton Conference*, 1991, 969-972.

utilizes the fluidized bed approach. Both systems require the feedstock to be relatively dry prior to gasification. Table B-2 lists some of the characteristics of gasification systems.

Table B-2. Gasification system characteristics

Combustion process	Capital costs	Operating costs	Combustion temperature (degrees F)	Fuel MC (%)	Comments
Fixed Bed					
Updraft	Low - Medium	(Not Available)	1,950 - 2,650	< 40	A,D,F
Downdraft	Medium - High	Medium - High	Not Available	< 30	A,B,C,D,F
Fluidized Bed	Medium - High	Medium - High	<1,400	< 50	A,B,E

A = Multiple fuels can be used, B = Clean gas product, C = Feedstock in pellet form, D = Particle size limitations, E = High fuel throughput, F = Alkalis in fuel material must be considered

Feedstock requirements and power output

Feedstock requirements for a biomass power facility are dependent upon the capacity of the facility and, to a lesser extent, the efficiency of a specific technology. Dramatic reductions in demand, on a normalized basis, are achievable with increased size of the facility. A small direct combustion (stoker) power plant, on the order of five MW, has a much higher heat rate than a larger facility. Indeed the larger plant may be approximately 50% more efficient than the smaller installation. The major reason for the higher efficiencies at larger sizes is the increased temperature and pressure that can be economically accommodated in the big facilities to supply larger turbines.

It is interesting to note the difference between a calculated heat rate (shown in Figure) and reported heat rates from operating facilities (see Figure). In practice heat rates appear to be better than what one would calculate from a heat/mass balance perspective. However the actual results mask differing combustion technologies, varying fuels, plant age, and potential differences in operator practices including data reporting.

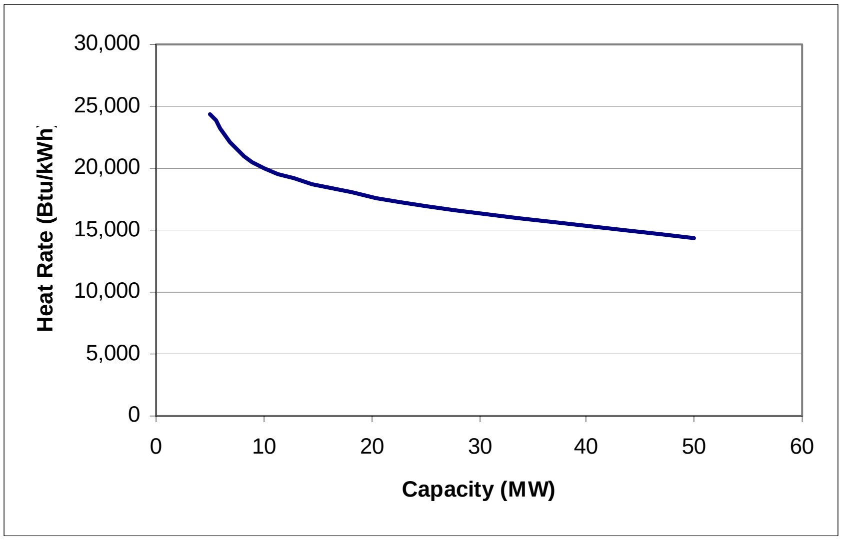

Figure B-1 Representative efficiencies, biomass power direct combustion

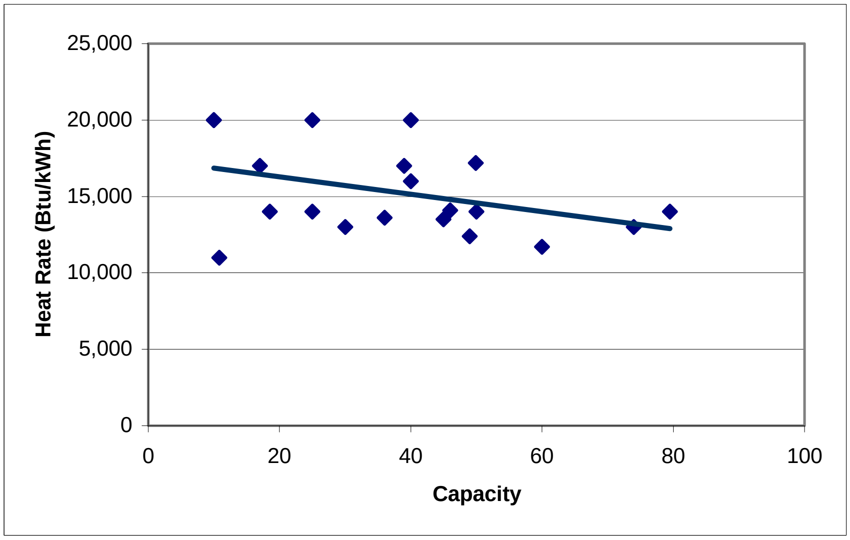

Figure B-2 Reported heat rate for 20 operating biomass plants[46]

Plant efficiency, fuel characteristics, and operating schedules dictate fuel consumption. As illustrated in both Figure and Figure , fuel consumption is approximately 15 GT/hour for a small facility and roughly 90 GT/hour for a 50MW facility.

[46] George Wiltsee, *Lessons Learned from Existing Biomass Power Plants*, Golden, Colorado: NREL/SR-570-26946, December 2000.

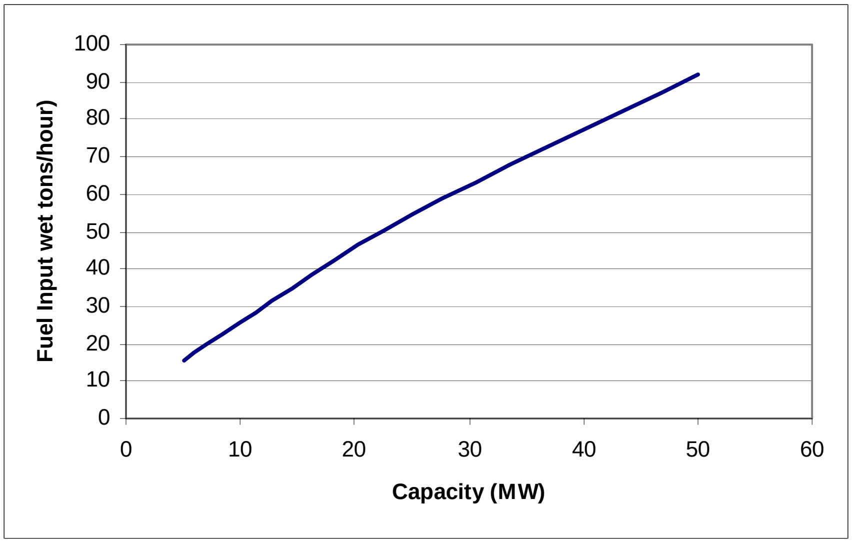

Figure B-3 Calculated biomass fuel consumption as a function of capacity and heat rate, direct combustion

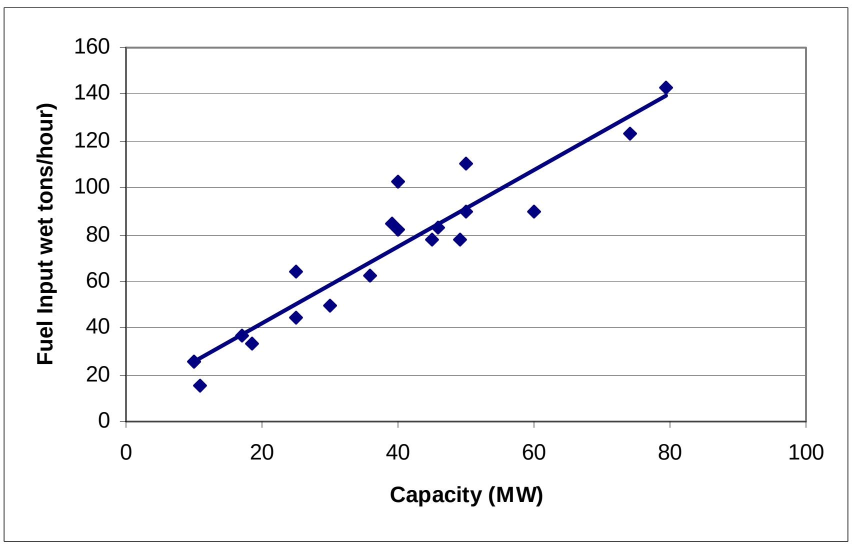

Figure B-4 Biomass fuel consumption based on 20 operating facilities[47]

Fuel characteristics greatly affect the combustion process and therefore the decision process for choosing combustion technologies. The most common problems associated with the direct combustion of wood are boiler slagging and fouling, erosion and corrosion, combustion instability, and particulate carryover. Fuel characteristics that should be analyzed include heating value, MC, ash content, sodium and potassium quantities, particle size distribution, ash fusion temperature and sulfur content.

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[47] George Wiltsee.

Physical fuel characteristics, such as density and particle size, affect combustion as well as material handling considerations. Changes in fuel density could cause combustion to occur in the wrong place in the boiler, upsetting the heat transfer scheme and therefore the boiler efficiency.

Appendix C. Biomass Heating System Components

Biomass System Components

This appendix provides information on various biomass heating system components that may be applicable for Red Lake applications. Even though we do not recommend current retrofit of any particular building on the reservation to a biomass system, it is important to have appropriate information on technologies and costs associated with the various system elements.

Three separate vendors of biomass combustion systems were contacted and asked to provide information on their systems and estimates of system price including installation and commissioning. Vendors A and B have many years of experience with the design, fabrication, and installation of conventional wood-chip combustion systems and Vendor C designs and installs wood pellet combustion systems. Here, a description of the main components and how they function is presented. Figure C-1 shows a representative diagram of the overall wood handling and combustion system.

The main system components are comprised of the following:

- fuel storage,
- fuel feed,
- burner-fuel combustion,
- boiler,
- fans,
- stack cyclone,
- water feed and return subsystem – pumps, tanks, supply line, fittings inside building,
- electronic controls, and
- supply piping (ditch plus pipe)

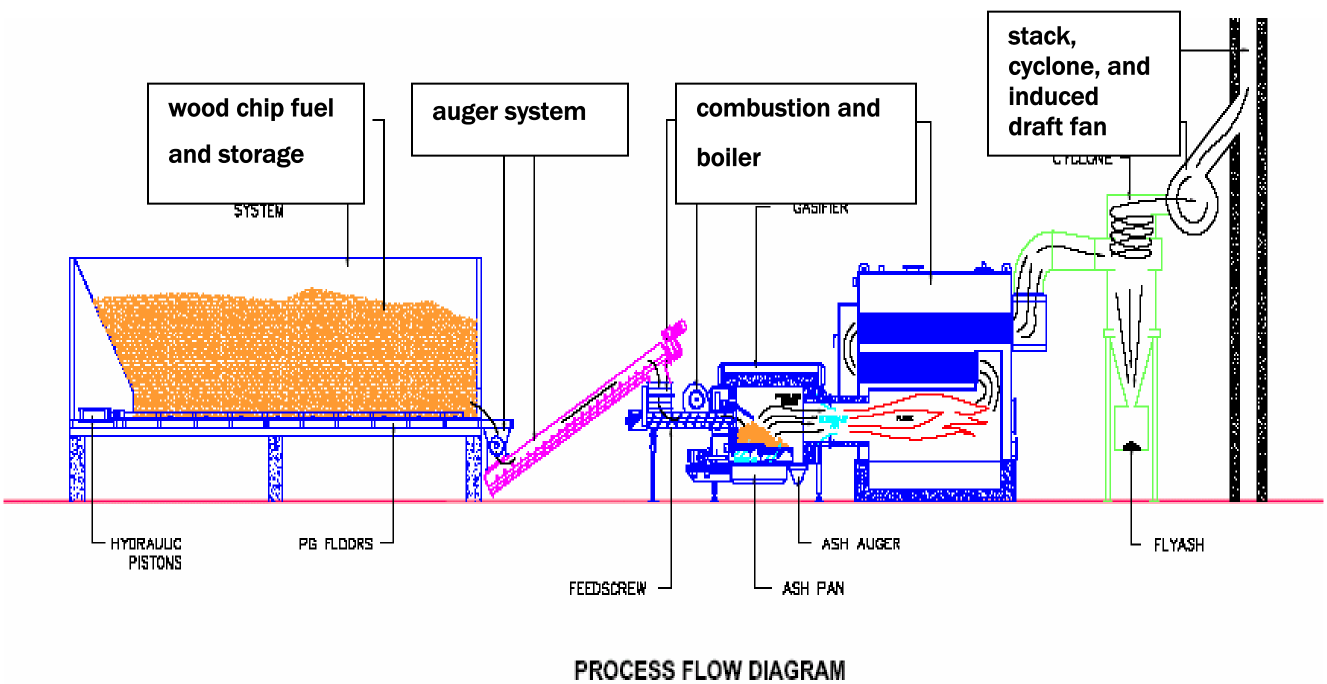

Figure C-1 Representative process flow diagram

Figure C-2 shows a possible layout of a biomass plant building and gives the reader an overall idea of how the component equipment is configured.

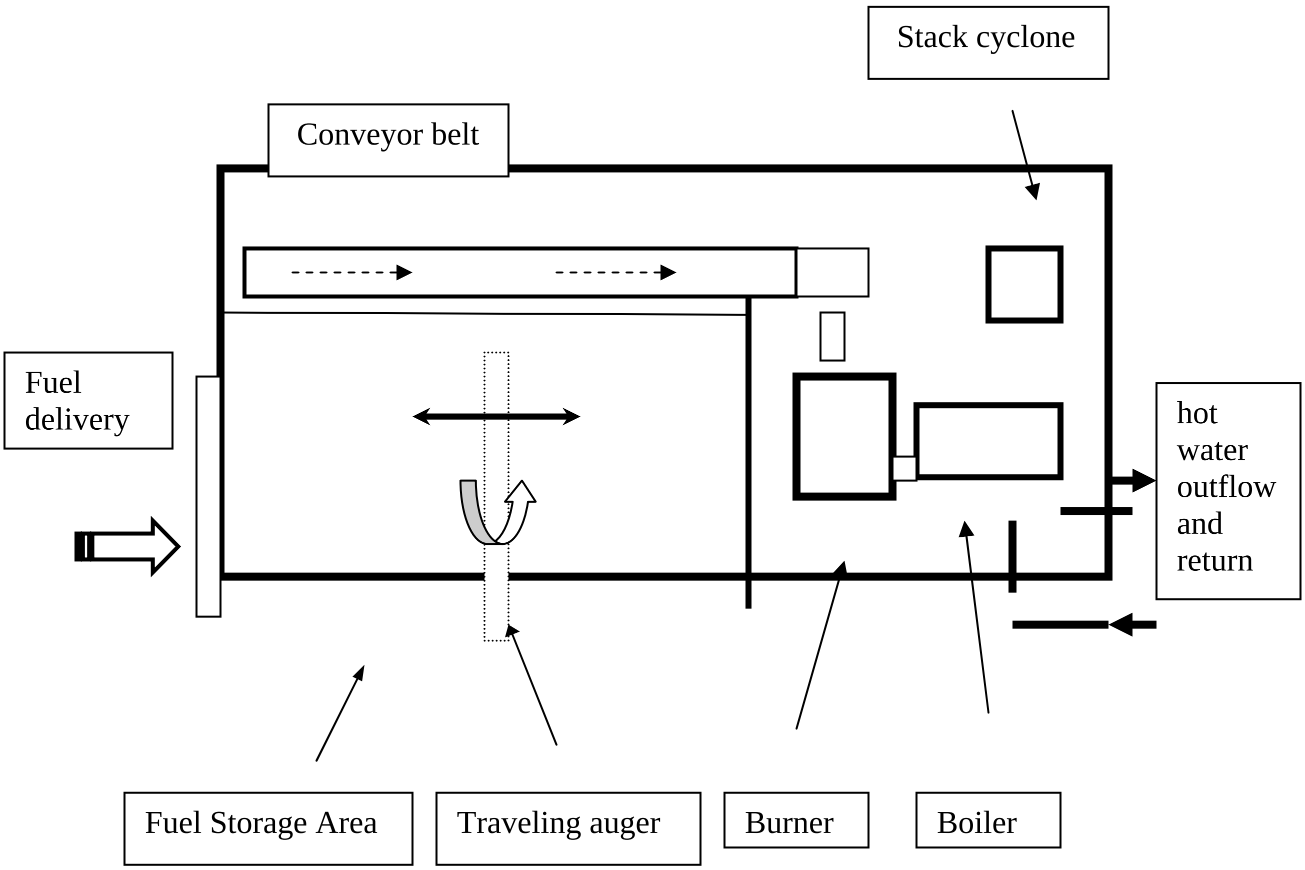

Figure C-2. Representative traveling auger building configurations

STORAGE VOLUME REQUIREMENTS

At the institutional or commercial level of heating activity, adequate storage is critical. If storage is too small, truck deliveries are too frequent, resulting in undesirable traffic and increased hauling costs. Furthermore, increased monitoring subtracts from the automatic and self sufficient aspects when compared with other heating systems, such as propane, fuel oil, or natural gas. If the storage is too large, it reflects in greater under-roof facility and equipment costs. A rule of thumb is to allow 3-5 days under-roof storage of biomass fuel for maximum use, peak loading conditions. Typically this means taking the peak firing fuel consumption and calculating the storage at that rate over 3-5 days. This ensures that during the coldest heating season the system can run full fire over a long holiday weekend or over an entire work week. The following formula was used to determine storage volume.

Vol = qpeak / H / Ds / eta x 27 x 24 x nday

where qpeak = 1M Btu/hr, the peak design heat load

H = 5,000 Btu/lbm, average wood heating value

Ds = 480 lbm/yd^3, typical fuel aggregate storage density (this can vary from 450 to 500, depending on fuel type and moisture)

eta = .7, typical overall wood-fired combustion (compared to .8 for gas-fired systems)

27 = conversion from yd^3 to ftY

24 = conversion to 24 hour (1 day) consumption

nday = 5, number of days chosen for unattended full system use

= 1,920 ft^3

The following describes individual components and is a combination of (mostly) Vendor A and some Vendor B descriptions plus McNeil modifications where needed.[48]

WEDGE FLOOR STORAGE

The 12 ft. wide x 20 ft. deep x 8 ft high side wall 1,920 cubic foot wedge floor receiving system is designed to receive and store the wood fuel and feed the required amount to the boiler system. The entire system operates automatically with the combustion control processor. The unit is fabricated from heavy gauge steel plate for years of continuous use. The special shaped custom fabricated tapered sectional box beams are one of the design features that makes this system rigid and stable, allowing the use of standard design hydraulic cylinders, low power pumps, and a modular floor design (see Figure C-3).

The wedge flights are electrically fusion welded to a heavy wall square tube for strength and low operating weight. These tubes ride in self lubricating precision bored bronze bushings at each end and a special polymer compound along the entire length. These features provide lubrication and rigidity. The wood fuel is loaded at one end of the floor and pulled to the discharge auger at the other end. Each ram assembly pulls material forward in sequence until all the rams are forward then each is cycled back to pick up more material. The operation continually moves the wood pile forward into the discharge auger. This type of system has proven to be reliable for a wide range of wood material. At the time of installations, the wedge floor arrives in two or three sections and is reassembled on site. After the final hydraulic connections to individual cylinders are made, and the power pack turned on, the system is ready. These types of systems are pre-assembled and run in the vendor’s shop minimize startup problems.

[48] McNeil does not promote any specific design or technology and uses specific equipment or processes only as representative of good design and operational practices.

Figure C-3. Wedge Floor Storage

TRAVELING AUGER ON STORAGE FLOOR

The alternate design to the wedge floor is the traveling auger method, used by Vendor B and one that also has many years of design use, particularly in New England. The beam-mounted, automated traveling auger system transfers wood fuel laterally from the storage area and moves it onto a conveyor belt for delivery to the boiler. The traveling auger is typically 10 – 15 ft long and 6-8 in diameter and sits approximately 6 in above the concrete floor of the storage area. Figure C-4 shows the storage area – the auger is underneath the wood chip pile. Figure shows the motor-driven side of the auger and wood chips falling onto the conveyor. The conveyor has an open pan design that provides extra capacity and reduced belt friction for lower power requirements.

Figure C-4. Representative Slab Floor Storage

Figure C-5. Representative Traveling auger and Conveyor

Belt wheels stabilize conveyor movement and their bearings are precision, long-life, sealed, and able to be greased for trouble-free, continuous duty. Galvanized steel, bolt-together conveyor sections resist rust and the formed frame is heavy-gauge steel for durability. All conveyors have convenient adjustment for belt tension and tracking. The conveyor delivers the wood chips to the metering bin that in turn delivers the fuel to the stoker auger at the firebox.

TRANSFER SCREW AUGER

The transfer screw auger is a large, industrial duty screw auger that is designed for the transfer of large amounts of wood chips (see Figure C-6). The U-Trough design, along with the proper speed control and drive system, eliminates any bridging of chips.

Figure C-6. Transfer Screw Auger

FUEL SUPPLY, SUMMARY

In summary, there are many types of biomass-fueled systems available in the United States and Canada. It is strongly recommended that a fully automated system, such as those described in this report, be selected. Typically, adding a biomass system requires several hours per week of O&M that is normally not associated with conventional gas-fired heating systems. O&M would in all likelihood be borne by the school's maintenance personnel and a fully automated system would require the least additional labor and time - and for small systems keeping the O&M costs at a minimum is crucial so that all of the savings associated with fuel cost differences (propane vs wood) can be obtained. For small systems, there is a sensitivity in fuel savings to the burdened O&M costs. Semi-automated systems, on the other hand, cost somewhat less but can require considerably more weekly labor to run, particularly in the winter when wood fuel must be fed into the system very regularly. The 5+ day running time on a full fuel supply for the automatic systems discussed in this report is based on peak winter requirements and will be much longer in the off-peak heating system, so personnel requirements will be kept at a minimum.

TRANSITION AND DROP TUBE

The connecting transition from the transfer screw auger and the drop tube to the stoker are constructed from heavy gauge structural steel sheet and plate, and can withstand hard use in a continuous feed environment. A neoprene bladed rotary air lock is mounted to the top of each stoker. This airlock design passes over-sized fuel "chunks" without jamming. A two horsepower TEFC high efficiency motor moves an industrial gear reducer that drives the airlock and infeed screw, which meters material to the firebox combustion area. The stoker is controlled by the PLC to feed the boiler fuel material as needed. "Off the shelf" Honeywell & Danfoss type temperature switches and water control valves along the stokers prevent a back fire condition by spraying water into the stoker tube upon detection of potential combustion in the stoker tube.

Figure C-7. Stoker and Airlock

PRECAST 3,100ºF REFRACTORY FACE COMBUSTION CHAMBER

The combustion chamber (or firebox) is custom manufactured for each customer and is complete and ready on-site for installation (see Figure). Typical total system installation time is on the order of 3 to 5 days. The wood fuel designed fireboxes are constructed with a large gasification area to completely combust the fuel. The fuel is burned on a sloped floor grate area to produce a high quantity of wood gases whose combustion is a major component of the overall heat produced. This design allows for more of the wood ash to remain out of the air stream, which greatly helps in reducing particulate emission and increases combustion efficiency since 2/3rd of the available heat energy is in the combustion of the wood gas. An efficient system is designed to closely monitor the combustion through process time, temperature, and turbulence. Oversized combustion volume allows for large gasification turbulence area in the secondary combustion area of the boiler vessel and the over-fire air control system takes advantage of the turbulence and helps reduce emissions. High quality cast refractory is used in the firebox and has proven track record of long service life. The fire boxes also have a double skin design which first preheats the combustion air and also makes the fire box skin cool to the touch.

Figure C-8. Combustor

30 HP BOILER (1.0M BTU/HR)

The 30 Hp 15 psi design hot water boiler vessel has 206 square feet of heating surface and delivers the hot water, with a delivery temperature of 160-180ºF (see Figure). The fire tube design wood-fired boiler vessel has been manufactured and used in Canada and the U.S. for almost 100 years. This series of vessels is designed exclusively as a wood-fired vessel and is not converted from any other fuel-designed system. This design philosophy has yielded a good reputation for craftsmanship and dependability. The boilers have approximately 7 square feet of heating surface per horsepower, which is a conservative value in the industry, and provides the customer with a vessel that will make the rated output continually with varying fuel quality. This also allows a more gentle boiler load which adds longevity to the system and allows for some growth in demand without having to replace or continually update the system.

Figure C-9. Boiler

Figure C-10. Integrated Combustor/Boiler Configuration

UNDER FIRE AIR (UFA) & OVER FIRE AIR (OFA) FAN ASSEMBLY

The UFA system is a radial blade draft fan. The drive portion of the system consists of a TEFC, high efficiency type motor and high quality sheaves and belts. This fan system pushes preheated combustion air through the fuel pile aiding in combustion of high moisture wood (see Figure C-11).

Figure C-11. Under fire fan assembly

The OFA system is a radial blade draft fan. The drive portion of the system also consists of a TEFC, high efficiency type motor and high quality sheaves and belts. This fan system adds preheated combustion air to the wood gas (gasification) section of the fire box allowing complete combustion of the wood fuel and transferring the maximum Btu’s to the boiler vessel (see Figure C-12).

Figure C-12. Over fire fan assembly

EXHAUST BREECHING

The exhaust breeching connects the boiler vessel to the particulate collector assembly or stack cyclone. This breeching is constructed of heavy gauge steel and bracing designed to withstand the high heat in this area. The breeching is primed and painted with two coats of heat resistant paint.

PARTICULATE COLLECTION

This system has a high efficiency 3 tube particulate collector. This is a 3 tube multi-cyclone separator designed to efficiently remove the excess fly ash in the exhaust stream. The collectors use a special "bell shaped" inlet design that eliminates the sharp edge gas inlet condition and thereby reduces turbulence in the inlet vane. Removing turbulence increases the energy available to impart centrifugal force to the dust particles. This greatly improves collection efficiency. Inlet vanes have an airfoil cross-section which also increases efficiency over uniform thickness designs. The airfoil-designed inlet vane area results in 50 percent larger openings for gas and dust passage greatly reducing collector plugging. The inlet vanes are independently removable for easy maintenance and low down time. These collectors are constructed of heavy gauge steel plate and angle iron. The collector tubes are precision rolled and fitted into each collector and receive high temperature primer and two coats of heat resistant paint.

INDUCED DRAFT FAN SYSTEM

The induced draft fan is a large radial blade high temperature draft fan. The drive portion of the system consists of a TEFC, high efficiency type motor and high quality sheaves and belts. This system pulls a variable draft through the fire box and boiler depending upon heat demand.

EXHAUST STACK

The exhaust stack is connected to the discharge side of the draft fan and channels the exhaust gases to the outside environment. Stacks are typically constructed from heavy gauge steel and need to be sized correctly for proper back pressure and dispersion characteristics in the system. If they are too small in diameter too much back pressure will develop, causing increased horse power draw on the induced draft system. If their length is too short, the proper exhaust dispersion will not develop resulting in a possibly unsafe work environment. Total length from ground level will be approximately 20-25 ft. with an internal diameter of 12-14 in. Exhaust stacks are primed and painted with two coats of heat resistant paint (see Figure C-13).

Figure C-13. Representative Exhaust Stack

BOILER CONTROL SYSTEM

Operation of all mechanical parts of the plant are dependent on the control management system. There have been great strides made in boiler combustion control techniques as part of industry-wide practices to correctly, reliably, and efficiently run an entire system. These control management systems can monitor plant conditions off site and can be configured to control off-site if necessary. A PC configured for this application can be connected to the PLC and used to modify the programming. By using variable frequency drives on all the combustion fans the system is controlled and adjusted continually to maximize efficiency and minimize emissions. The control panel is powered by a single source of power and contains off -the-shelf starters and variable frequency drives for the electric motors.

FITTINGS, CONNECTIONS, PIPING, EXISTING HYDRONICS

This section briefly discusses equipment outside of the plant building. Once the approximately160ºF hot water from the boiler leaves the plant building, it is pumped through the buried 3 inch insulated steel. Typical insulation is polytherm or exotherm (with fiberglass), though there are many pipe insulation products on the market. There is much detail in fittings and connections that is beyond the scope of this report. Embedded in the approximate $145/ft cost of the pipe, insulation, and trenching is 30% for fittings, valves, and connections that a conventional plumbing company would need for system installation.

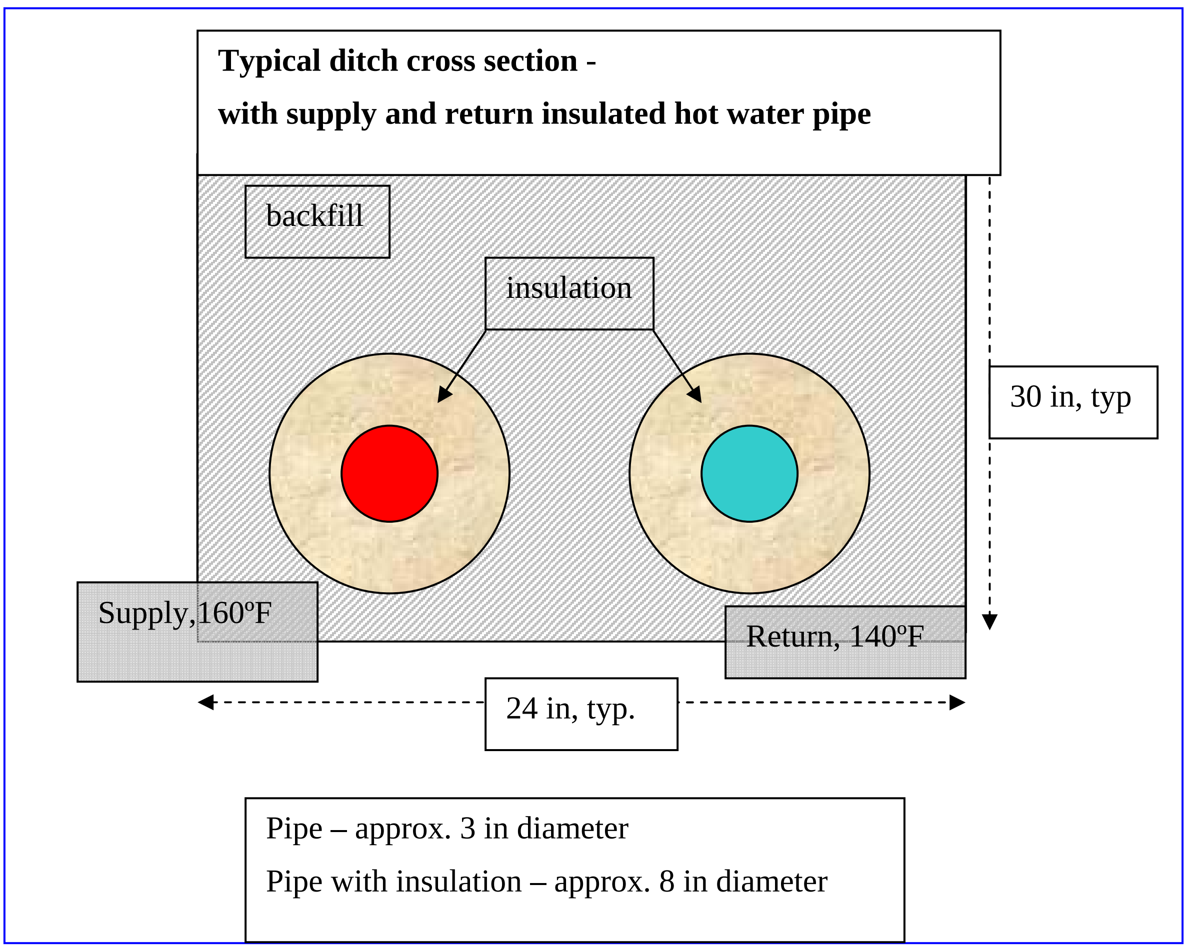

Figure C-14. Representative Buried Pipe Installation and Dimensions

Appendix D. Biofuels Production

Ethanol

Minnesota is the only state to mandate the use of ethanol and biodiesel. The state pays 11 to 20 cents per gallon to ethanol facilities with a capacity of less than 15 million gallons per year.

Several technologies can convert cellulose feedstocks into ethanol including the following:

- Concentrated acid hydrolysis,
- Dilute acid hydrolysis,
- Enzymatic hydrolysis and
- Biomass gasification and fermentation.

<u>Concentrated acid hydrolysis</u>

This process is based on concentrated acid decrystallization of cellulose followed by dilute acid hydrolysis to sugars at near theoretical yields. Separation of acid from sugars, acid recovery, and acid reconcentration are critical unit operations. Fermentation converts sugars to ethanol.

A flow diagram, shown in Figure D-1 is one example of how a process based on concentrated acid might be configured. The heart of the process is the decrystallization followed by dilute acid hydrolysis. The original Peoria process, developed by USDA researchers in World War II and a modified version proposed by Purdue, carry out dilute acid pretreatment to separate the hemicellulose before decrystallization.[49] The biomass would then be dried to concentrate the acid absorbed in the biomass prior to addition of concentrated sulfuric acid. Purdue proposed recycling sulfuric acid by taking the dilute acid/water stream from the hydrolysis reactor and using it in the hemicellulose pretreatment step.

In Arkenol's process, decrystallization is carried out by adding 70%-77% sulfuric acid to biomass that has been dried to 10% moisture. Acid is added at a ratio of 1.25:1 (acid: cellulose + hemicellulose), and temperature is controlled at less than 50 degrees Celsius (C). Adding water to dilute the acid to 20%-30% and heating at 100 degrees C for an hour results in the release of sugars. The gel from this reactor is pressed to remove an acid/sugar product stream. Residual solids are subjected to a second hydrolysis step. The use of a chromatographic column to achieve a high yield and separation of acid and sugar is a crucial improvement in the process that was first introduced by the Tennessee Valley Authority (TVA) and researchers at the University of Southern Mississippi. The fermentation converts both the xylose and the glucose to ethanol at theoretical yields of 85% and 92%, respectively. A triple effect evaporator is required to reconcentrate the acid. Arkenol claims that sugar recovery in the acid/sugar separation column is at least 98%, and acid lost in the sugar stream is not more than 3%.[50]

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[49] Ibid

[50] Ibid

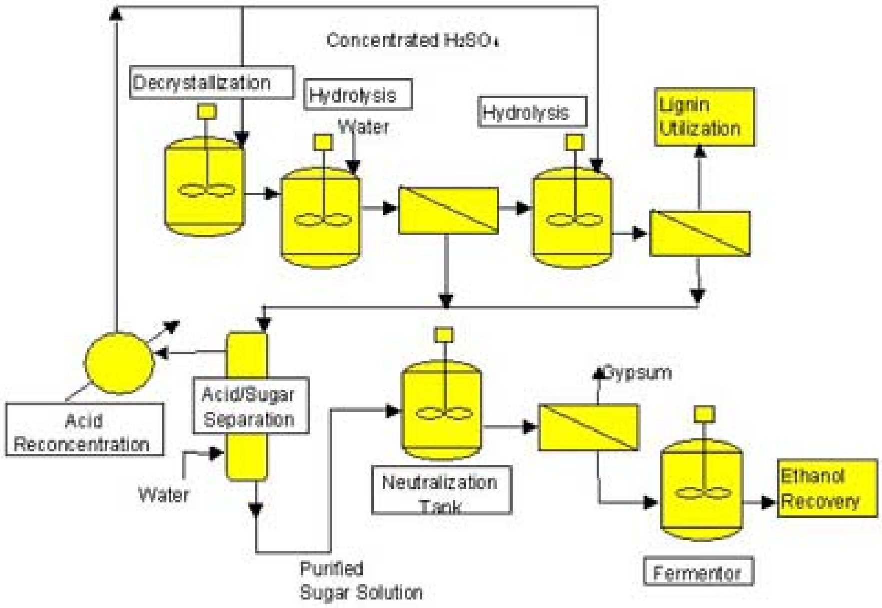

Figure D-1. Example process flow, concentrated acid hydrolysis

The concentrated sulfuric acid process has been commercialized in the past, particularly in the former Soviet Union and Japan. However, these processes were only successful during times of national crisis, when economic competitiveness of ethanol production could be ignored. Conventional wisdom in the literature suggests that the Peoria and TVA processes cannot be economical because of the high volumes of acid required. Improvements in acid sugar separation and recovery have opened the door for commercial application. Two companies in the United States, Arkenol and Masada Resources Group, are currently working with DOE and NREL to commercialize this technology by taking advantage of niche opportunities involving the use of biomass as a means of mitigating waste disposal or other environmental problems.

Dilute acid hydrolysis

Dilute acid hydrolysis of biomass is, by far, the oldest technology for converting biomass to ethanol. Hydrolysis occurs in two stages to maximize sugar yields from the hemicellulose and cellulose fractions of biomass. The first stage is operated under milder conditions to hydrolyze hemicellulose, while the second stage is optimized to hydrolyze the more resistant cellulose fraction. Liquid hydrolyzates are recovered from each stage, neutralized, and fermented to ethanol.

While a variety of reactor designs have been evaluated, the percolation reactors originally developed at the turn of the century are still the most reliable (see Figure D-2). Though more limited in yield than the percolation reactor, continuous co-current pulping reactors have been proven at industrial scale. NREL recently reported results for a dilute acid hydrolysis of softwoods in which the conditions of the reactors were as follows:

- Stage 1: 0.7% sulfuric acid, 190 degrees C, and a 3-minute residence time
- Stage 2: 0.4% sulfuric acid, 215 degrees C, and a 3-minute residence time

Figure D-2. Example process flow, dilute acid hydrolysis

These bench scale tests confirmed the potential to achieve yields of 89% for mannose, 82% for galactose and 50% for glucose. Fermentation with *Saccharomyces cerevisiae* achieved ethanol conversion of 90% of the theoretical yield.

There is quite a bit of industrial experience with the dilute acid process. Germany, Japan, and Russia have operated dilute acid hydrolysis percolation plants off and on over the past 50 years. However, these percolation designs would not survive in a competitive market situation.

<u>Enzymatic hydrolysis</u>

The first application of enzymes to wood hydrolysis in an ethanol process was to simply replace the cellulose acid hydrolysis step with a cellulase enzyme hydrolysis step. This is called separate hydrolysis and fermentation. The most important process improvement made for the enzymatic hydrolysis of biomass was the introduction of simultaneous saccharification and fermentation (SSF), as patented by Gulf Oil Company and the University of Arkansas. This new process scheme reduced the number of reactors involved by eliminating the separate hydrolysis reactor and, more importantly, avoiding the problem of product inhibition associated with enzymes. In the SSF process scheme, cellulase enzyme and fermenting microbes are combined. As sugars are produced by the enzymes, the fermentative organisms convert them to ethanol. The SSF process has, more recently, been improved to include the cofermentation of multiple sugar substrates. This new variant of SSF, known as SSCF for Simultaneous Saccharification and CoFermentation, is shown schematically in Figure D-3.

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Figure D-3. Enzyme process configured for simultaneous saccharification and cofermentation (SSCF)

Cellulase enzymes are already commercially available for a variety of applications. Most of these applications do not involve extensive hydrolysis of cellulose. For example, the textile industry applications for cellulases require less than 1% hydrolysis. Ethanol production, by contrast, requires nearly complete hydrolysis. In addition, most of the commercial applications for cellulase enzymes represent higher value markets than the fuel market. For these reasons, there is quite a large leap from today's cellulase enzyme industry to the fuel ethanol industry. DOE’s partners in commercialization of near-term ethanol technology are choosing to begin with acid hydrolysis technologies because of the high cost of cellulase enzymes. U.S. DOE Biofuels Program researchers see the current high cost of cellulase enzymes as the key barrier to economical production of bioethanol from lignocellulosic material, the Biofuels Program has been working with the two largest global enzyme producers, Genencor International and Novozymes Biotech Incorporated. The objective of this collaboration is to achieve a tenfold reduction in the cost of these enzymes.

In Canada, Iogen Corporation is currently completing construction on the first commercial scale-up cellulose ethanol plant in the world, using an enzymatic process. The plant is already producing fermentable sugars from 50 tons of wheat straw in 900 lb bale form per week, and is finishing construction on its distillation towers, which should be operational in 2004.[51]

Biomass Gasification and Fermentation

A gasification system may be employed in conjunction with fermentation technology to produce ethanol. After gasification (see 0), anaerobic bacteria such as *Clostridium ljungdahlii* are used to convert the CO, CO_2, and H_2 into ethanol. Higher rates are obtained because the process is limited by the transfer of gas into the liquid phase instead of the rate of substrate uptake by the bacteria. Marc Rappaport is developing the ethanol project that is proposed in La Grande. His firm plans to use gasification to produce power and later add a system to produce ethanol from the gas. Currently the firm owns an industrial site outside of town and is working on project financing.

Feedstock Requirements and Yield

[51] Tania Glithero, Iogen Corporation, personal communication with Tim Rooney, McNeil Technologies, Inc., November 21, 2003. More information on Iogen Corporation can be obtained on-line: http://www.iogen.ca.

The quantity of feedstock required by an ethanol conversion facility is primarily determined by the size of the facility and the ethanol yield/ton of feedstock. Different conversion technologies have different yields and are at different stages of commercial development. The relationship between yield and feedstock requirement is linear. Figure D-4 illustrates the relationship for four different ethanol yields from 50 to 100 gallons/ton of feedstock and for facilities with capacities up to 60 millions gallons/year. To get some perspective on the quantity of feedstock required, a large pulp mill requires 2,000 tons of feedstock/day or 730,000 tons/year. That quantity of feedstock could produce between 36 and 73 million gallons of ethanol as yield increased from 50 to 100 gallons/ton.

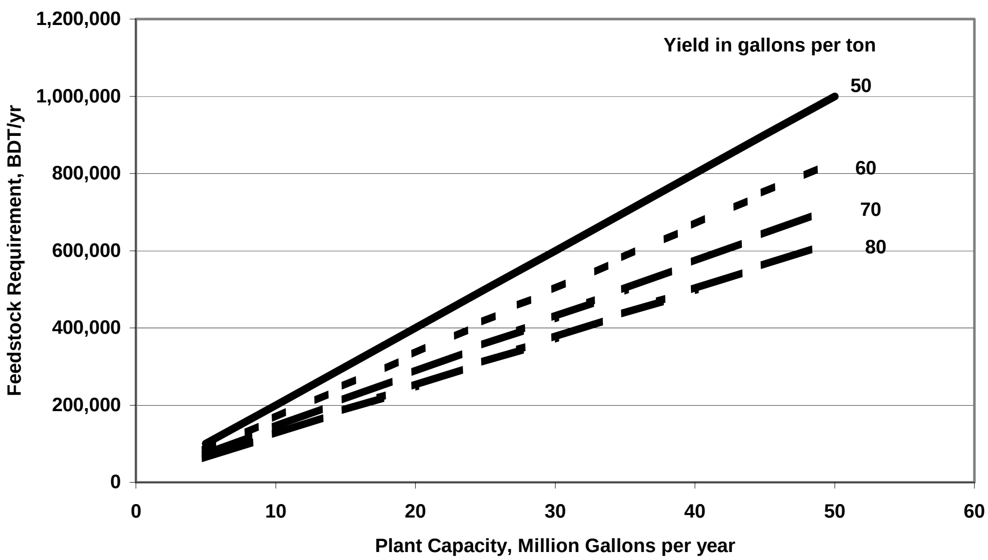

Figure D-4. Ethanol yield and feedstock relationship

The cost of converting cellulose materials to ethanol is determined by three main cost elements; feedstock, capital, and operating. Capital costs include both costs for equipment, engineering, installation, and financing. Operating cost elements include maintenance and operating labor, marketing, utilities and chemicals, and maintenance supplies. Chemical process industries, like ethanol, are known to have economies of scale. Capital and operating costs/gallon of capacity decline as the capacity increases. Figure D-5 shows the capital cost/gallon of production, assuming a capital recovery factor of 20%. This illustrates the dramatic increase in capital cost per gallon when facility size drops below 10 million gallons/year. The capital cost data for facilities 20 million gallons and larger came from the California Energy Commission report[52] and the Merrick report[53] provided data for facilities less than 20 million gallons.

[52] California Energy Commission, *Evaluation of Biomass-to-Ethanol Fuel Potential in California*, Sacramento California: California Energy Commission, December 1999

[53] Merrick & Company, *Alaska Softwood to Ethanol Feasibility Study*, Aurora, Colorado, 1999

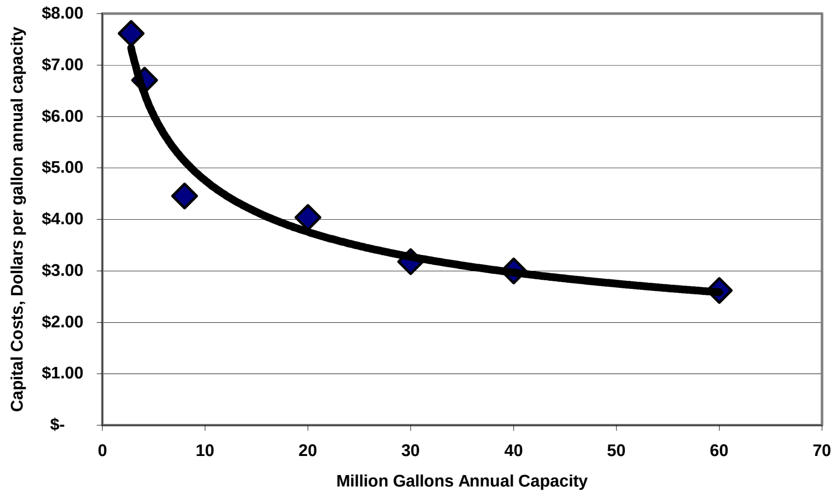

Figure D-5. Economies of scale for cellulose ethanol facilities

The optimum plant size will depend on the relationships between capital cost, feedstock cost and operating costs. Figure D-6 shows these relationships using data from the CEC report. The volumes correspond to facilities sized 20, 30, 40, and 60 million gallons of annual capacity. The feedstock costs were assumed to be from forest residues with a subsidized cost of $30/ODT. Yields were assumed to be 77 gallons/ton and maintenance cost of $0.15/gallon. The figure shows that capital costs/gallon decrease and feedstock costs/ton increase as the plant size increases and more material is needed. The shape of these curves will change for each facility depending on supply costs, conversion yields, and operating and maintenance costs. However, in most cases there will be an economic optimum where the production costs are at a minimum.

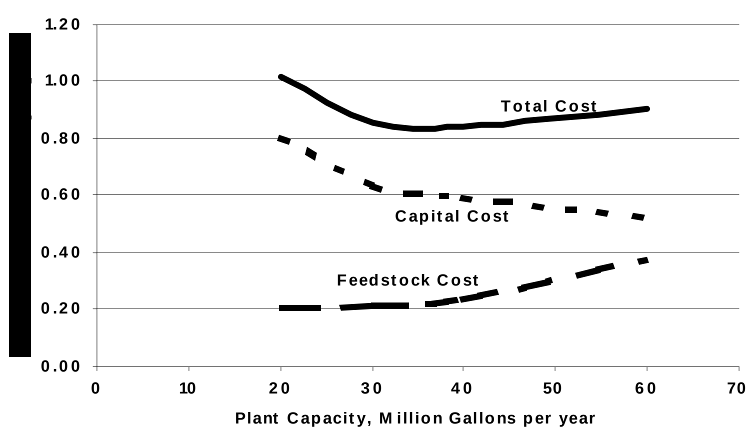

Figure D-6. Ethanol production costs

Siting Requirements

Make-up water estimates depend on the conversion technology. NREL estimated water requirements for their enzymatic processes and the approximate relationship is: Gallons/min = 12 x ethanol capacity in million gallons/yr. For example a 50 million gallon/yr facility would require 600 gallons/minute of make-up water. Wastewater discharge depends on what technologies are employed. The trend in the design of cellulose ethanol facilities is to have zero discharge. All wastewater is reprocessed and used within the facility. The solids from the wastewater treatment are sent to the biomass boiler. Merrick & Company investigated wastewater disposal options and provided a detailed report.[54] Larger cellulose ethanol facilities are assumed to generate power in excess of their needs and sell the surplus. Power needs are therefore minimal and only required for cold start conditions.

Ethanol can only be economically transported long distances by pipeline, rail, or ship. An ethanol conversion site will require on-site storage sufficient to store 15 days of feedstock, assuming that most residues are to be stored off-site at the supply locations. At the candidate capacity approximately 60,000 tons of residues are collected so roughly 2,500 tons would be stored at the conversion facility. If the bale is 16 inches wide, 16 inches high and 48 inches long and weighs 64 lb then the storage capacity/acre of land is 871 tons. This area includes space for access and handling. Thus, about three acres of land would be required to store 15 days worth of field residues.

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[54] Merrick & Company, *Wastewater Treatment Options for the Biomass-to-Ethanol Process*, NREL Subcontract AXE-8-18020-01 Final Report, Aurora, CO, October 1998.

Appendix E. Incentives for Biomass Utilization

RENEWABLE ENERGY POLICIES IN MINNESOTA

There are a variety of policies which encourage renewable energy production in Minnesota, including specific measures for biomass. The policies listed below were current as of September 2004.

Voluntary Renewable Portfolio Standard

In 2001 and 2003, Minnesota established voluntary targets for electric utilities to generate or procure a percentage of power from renewable energy technologies. By 2005, at least 1% of power should come from renewables. This amount should increase by 1% per year, reaching 10% in 2015. At least 0.5% of electricity should come from biomass sources by 2005, and 1% should come from biomass by 2010. The requirement that all hydrogen be generated from renewable sources by 2010 could also boost the usage of biomass.

The Minnesota Public Utilities Commission is also authorized to establish a credit trading program to help utilities comply with the targets. Utilities are required to develop formal plans detailing how they will meet the 10% renewables objective.[55]

Prairie Island Bill

The 1994 "Prairie Island Bill" required Xcel to acquire 125 MW of closed-loop biomass generation from farm sources. This bill was later amended to encompass other types of biomass. To meet this mandate, Xcel agreed to buy 25 MW of waste-wood generation from St. Paul Cogeneration, 50 MW from EPS/Beck for whole-tree generation, and Fibrominn for 50 MW of poultry litter generation.

In 2003, the mandate was reduced to 110 MW and adjustments were made to the strategy for meeting the biomass target. Among the changes, the Commission required Xcel to enter into a PPA with Itasca as part of an effort to meet the renewable energy objectives outside of the biomass mandate.

In amendments to Minnesota Statute 216B.2424, Xcel was required to enter into a PPA for 10-20 MW of bioenergy capacity at an all-inclusive price not to exceed $55 per MWh. Since the passage of this legislation, Xcel and Itasca have been attempting to negotiate a biomass power purchase agreement.

Minnesota enacted legislation in May 2003 requiring Xcel to pay $16 million annually into the Renewable Development Fund (RDF). This will continue as long as Xcel Energy's Prairie Island plant is in operation. The RDF originated in 1994 as an outcome of 1994 legislation concerning spent fuel storage at the Prairie Island nuclear power plant.

In 2001, the RDF selected 19 research projects to receive $16 million in funding. The second funding cycle began in the fall of 2003 and will split funding between renewable energy generation projects and research and development.[56]

Cogeneration and Small Power Production

[55] http://www.dsireusa.org/library/includes/incentive2.cfm

[56] http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=MN09R&state=…

Minnesota has also enacted a cogeneration and small power production statute with the express purpose of encouraging cogeneration and small power production consistent with protection of the ratepayers and the public (Chapter 216B, section 164). The section applies to all Minnesota electric utilities, including cooperative electric associations and municipal electric utilities. The law requires the utility to which the qualifying facility is interconnected to purchase all energy and capacity made available by the qualifying facility and such capacity and energy shall be purchased at full avoided cost. Such full avoided cost shall be established as the utility's least cost renewable energy facility or the bid of a competing supplier of a least cost renewable energy facility, whichever is lower. If the host utility does not wish to purchase the power, or if the qualifying facility requests, the host utility shall provide wheeling or exchange agreements wherever practicable to sell the qualifying facility's output to any other Minnesota utility planning expansion of its generation. The qualifying facility would then be paid at the full avoided cost of the utility actually receiving the output. The host utility is required to provide an interconnection, although the cost of that interconnection would in all likelihood be the qualifying facility's responsibility.[57]

Net Energy Billing

Net energy billing has been established by Minnesota Statute and is available only to qualifying facilities with capacity of less than 40 kW that choose not to offer electric power for sale on either a time-of-day or a simultaneous purchase and sale basis. In such a case, the utility is required to bill the qualifying facility for the excess of energy according to the utility's applicable retail rate schedule.[58]

Itasca Power Biomass Project

The Northome Biomass Plant, located in the Northome Industrial Park, Northome, Minnesota, is a 15 MW biomass plant capable of providing steam, hot water, pressurized hot water, compressed air, chilling and cooling directly to future commercial users at the industrial park. Itasca Power Company signed a power purchase agreement with Great River Energy, a wholesale energy provider to 29 member cooperatives in Minnesota and Wisconsin.[59] Construction of the plant required Great Energy to build approximately 11 miles of 69-kV transmission from an existing substation near Alvwood, Minnesota to the vicinity of Northome. North Itasca Electric Cooperative, located in Bigfork, Minnesota, will provide transmission distribution services to the facility.[60]

Complaint Against Beltrami Electric Cooperative

In January 2002, the Energy CENTS Coalition, a non-profit that promotes affordable utility service for low-income Minnesotans, filed a complaint against Beltrami at the Minnesota Public Utilities Commission (PUC) alleging that Beltrami had engaged in unfair and illegal practices. Generally cooperatives are not subject to the same level of government scrutiny as investor-

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[57] Minnesota Statutes, Chapter 216B, Section 164 "Cogeneration and small power production."

[58] Minnesota Rules, Chapter 7835, 7835.3300 Net Energy Billing Rate.

[59] Itasca Power Company, www.itascapower.com, accessed December 15, 2003. Great River Energy, www.greatriverenergy.com/HTML/company/com.html, accessed December 15, 2003.

[60] 'Great River Energy supports wood waste plant near Northome," Press Release, Great River Energy, May 5, 1999, www.greatriverenergy.com/HTML/press/pres_99_wasteplant.html, accessed December 15, 2003.

owned utilities before the PUC, but Energy CENTS argued that state laws governing service standards to apply to cooperatives. The PUC agreed and ordered an investigation into the Energy CENTS complaint. Beltrami allegedly cut off service even when low-income individuals were working to become current on their payments, charged high fees for service reconnection, and installed "service limiters" (devices that allow electricity to only flow for a half-hour at a time) on a disproportionate number of homes on the Red Lake Reservation.[61]

The complaint is still ongoing at the PUC. The initial complaint was filed January 23, 2002. An Order Asserting Jurisdiction and Directing the Department to Investigate was issued by the PUC on April 25, 2002. An Investigation Report was provided to the PUC on August 18, 2003 and briefing papers have been filed.[62]

FEDERAL BIOPOWER INCENTIVES

Healthy Forests Restoration Act of 2003 (signed into law on December 3, 2003)[63]

Title II – Biomass

(1) Findings; Definitions

The House bill contains Congressional findings that that show high risk of wildfires across many acres due to the accumulation of heavy fuel loads from insect infestations and disease, and defines the terms: Biomass, Person, Preferred Community, and Secretary Concerned. (Sections 201, 202)

The Senate amendment has comparable provisions with minor differences. (Sections 201, 202)

(2) Grants to Improve the Commercial Value of Forest Biomass; Reporting requirement

The House bill establishes biomass commercial use and value-added grant programs to benefit anyone who owns or operates a facility to produce energy from biomass, as well as a monitoring program for participants, while complying with existing endangered species protections; authorizes appropriations of $25,000,000 for fiscal years 2004 to 2008; and requires that the Secretary concerned submit a report of the grant programs no later than October 1, 2010. (Sections 203, 204)

The Senate amendment has a comparable amendment with minor differences. (Sections 203, 204)

With respect to sections 201 and 202 of the House bill and sections 203 and 204 of the Senate amendment, the Conference substitute adopts an amendment that authorizes the Secretary to provide biomass purchase grants to owners and operators of biomass facilities that use such materials for production of wood-based products or other commercial purposes. (Section 203)

(3) Improved Biomass Use Research Program

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[61] Kokmen, Lelya, "Lights Out: Residents of the Red Lake Indian Reservation fight the power company," *City Pages*, www.citypages.com/databank/23/1116/article10338.asp, accessed December 8, 2003.

[62] Case File Control Sheet, Docket No. E103/C-02-105, www.puc.state.mn.us/docs/log_files/02-105.htm, accessed December 8, 2003.

[63] http://capwiz.com/wwipo/webreturn/?url=http://thomas.loc.gov/cgi-bin/bdquery/z?d108:h.r.1904:

The Senate amendment amends the Biomass Research and Development Act of 2000 by adding a silviculture component to the program. (Section 205)

The House has no provision on this subject.

The Conference substitute adopts the Senate provision. (Section 201)

(4) Rural Revitalization Through Forestry

The Senate amendment establishes a program to facilitate small business use of biomass and authorizes appropriations of $5,000,000 for fiscal years 2004 to 2008 to carry out the program. The program is established by amending the Food, Agriculture, Conservation, and Trade Act of 1990. (Section 206)

The House bill has no provision on this subject

The Conference substitute adopts the Senate provision. (Section 202)

Section 45 - Renewable Energy Production Tax Credit

Taxpayers are allowed a credit of 1.5 ¢/kWh for electricity generated from "closed-loop biomass" projects under Section 45 of the Internal Revenue Code. In the fall of 1999, Congress amended Section 45 to let more facilities take advantage of the 1.5 ¢/kWh tax credit. The new rule extends the "placed-in-service" date for qualifying facilities to 2002 and includes poultry waste as a qualifying energy resource. Under this rule, qualifying facilities are defined as wind, closed-loop biomass, and poultry waste facilities. These plants will be eligible for the 1.5 ¢/kWh tax credit if they are placed in service before January 1, 2002. The previous rule required facilities to be placed in service before June 30, 1999 and did not include poultry waste as an acceptable energy resource.

The federal energy bills currently (as of September 2003) passed by the House and Senate includes a provision that would open the biomass credit to allow existing and new biomass plants to claim the credit for using biomass resources such as forest thinnings and mill residues. The bills are presently in conference committee.

Renewable Energy Production Incentive (REPI)

Additional information on REPI can be found at: http://www.eere.energy.gov/power/repi.html

Section 1212 of the 1992 Energy Policy Act allows DOE to make payments of 1.5 ¢/kWh, adjusted annually for inflation, for electricity generated and sold by qualifying facilities. Eligible electric production facilities are those owned by State and local government entities (such as municipal utilities) and not-for-profit electric cooperatives that started operations between October 1, 1993 and September 30, 2003. Qualifying facilities are eligible for annual incentive payments of 1.5 cents/kilowatt-hour expressed in 1993 dollars and indexed for inflation for the first ten year period of their operation, subject to the availability of annual appropriations in each Federal fiscal year of operation.

Criteria for qualifying facilities and application procedures are contained in the rulemaking for this program. Qualifying facilities must use solar, wind, geothermal (with certain restrictions as contained in the rulemaking), or biomass (except for municipal solid waste combustion) generation technologies. The production incentive authorizes direct payments to project owners from annual congressional appropriations. Payment depends on availability of funds.

The regulations for the administration of the REPI program are contained in Title 10 to the Code of Federal Regulations, Part 451 (10 CFR 451). The final rulemaking, which contains clarifying supplementary information, is contained in 60 CFR 36959

Renewable resources are divided into two tiers: Tier 1 includes wind, solar and closed loop biomass and Tier 2 includes "open loop" biomass such as landfill gas, digester gas and plant waste material. Tier 1 projects receive incentive payments first before any payments are made to Tier 2 projects. Over the past several years, there has not been sufficient money appropriated by Congress to fully fund all of the Tier 2 requests made against the program. In 2002, only 7% of the total credit requested by Tier 2 projects was paid.

Although the REPI is comparable in amount to the Section 45 production tax credit, congressional appropriations have not been adequate to fully fund payments to qualifying facilities. Because of this uncertainty, developers have been cautious in counting on REPI payments when assessing project economics and have regarded REPI payments more as a "bonus." The incentive expires September 30, 2013.

FEDERAL ETHANOL INCENTIVES

The Clean Air Act of 1970 authorized the EPA to promulgate regulations regarding the quality of conventional fuels. In 1990, the Act was amended to include establishing air quality standards related to vehicle emissions. The EPA subsequently established the National Ambient Air Quality Standards covering carbon monoxide, nitrogen oxides, particulate matter, ozone and lead. Urban areas were required to use cleaner burning fuels if they did not meet the minimum clean air standards. This can be achieved by adding oxygen to gasoline, which improves combustion efficiency; ethanol contains 35% oxygen. Substituting regular fuel with ethanol results in a reduction of carbon monoxide, volatile organic compounds and nitrogen oxides.

State oxygenated fuels programs have been developed in response to the national Clean Air Act Amendments of 1990. According to a recent study, "The majority of the increase in ethanol demand in the past 10 years has resulted from these programs. Since 1990, the nation's ethanol production capacity has more than doubled from 850 million gallons/year to 1.779 billion gallons in total production capacity in 1999."[64]

If an area was classified as non-attainment of ozone, it was required to use reformulated gasoline to lower volatile organic compounds. Mixing ethanol with gasoline increases the volatility of the fuel, releasing more VOCs. However, the EPA recently ruled that the CO reduction benefits outweigh the increased VOC emissions.

The fuel additive methyl tertiary butyl ether (MTBE) is being phased out in California, which could increase demand for ethanol. If ethanol were to fully replace MTBE, the demand for ethanol in California could reach 550 million gallons/year.[65] However, the oxygen requirement in

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[64] Angela Graf (Bryan & Bryan, Inc.) and Tom Koehler (Celilo Group), *Oregon Cellulose-Ethanol Study: An Evaluation of the Potential for Ethanol Production in Oregon Using Cellulose-Based Feedstocks*, Portland, Oregon: Oregon Department of Energy, June 2000, 71.

[65] Angela Graf (Bryan & Bryan, Inc.) and Tom Koehler (Celilo Group), 5.

gasoline may be eliminated instead, since California is seeking an exemption from the oxygenated fuel requirement.

Federal Excise Tax Exemption for Gasohol

The Energy Tax Act of 1978 established a tax exemption of 5.4 cents/gallon for blends of 10-percent grade ethanol (or 54 cents/gallon of pure ethanol. Blends of less than 10% ethanol (7.7% and 5.7%) are prorated. These credits to fuel blenders will sunset in 2007, declining to 5.2 cents in 2001, 5.2 cents in 2003, and 5.1 cents in 2005. An income tax credit of 54 cents/gallon was also introduced, and this credit can be applied to the manufacture of ETBE.

Motor fuels are otherwise taxed at 18.3 cents/gallon, so this tax break should help ethanol be more cost competitive and increase demand. The DOE Energy Information Administration (EIA) predicted that an extension of the tax exemption would increase the ethanol production capacity from grain and cellulose biomass to 2.8 billion gallons/year.[66] Current ethanol production capacity is actually 2.9 billion gallons/year.[67]

Under the Crude Oil Windfall Profits Action of 1980, it became possible to receive an income tax credit instead of the excise tax forgiveness. The blender must have a tax liability to which the credit can be applied.

A 10-cent/gallon tax credit was established under the Budget Reconciliation Act of 1990 to encourage the development of new ethanol production facilities. Plants with an annual production capacity of 30 million gallons or less are eligible to deduct 10 cents/gallon from the first 15 million gallons produced annually. This small producer tax credit is scheduled to end December 31, 2007.

In 1992, the Energy Policy Act (EPACT) required government and private fleets (having 20 or more vehicles in metropolitan areas with more than 250,000 people) to include alternative fuel vehicles in their fleets. The requirement ranges from 30% to 90% of fleet vehicles. The requirement may be met by using fuels containing at least 85% alcohol by volume. Other possibilities include: natural gas, propane, hydrogen, liquid fuels from coal, and electricity.

Deductions for Clean-Fuel Vehicles and Refueling Property

Individuals and businesses are eligible for tax deductions of $2,000 for cars and up to $50,000 for certain types of trucks and vans. The deduction will be gradually phased out by 2005. Property used to store or dispense clean fuel is deductible up to $100,000.[68]

Corporate Alcohol Fuel Credit

Businesses that sell or use alcohol fuels or fuel blends may qualify for an income tax credit. Credits range from $.3926 to $0.60/gallon, depending on the proof and type of alcohol. [69]

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[66] Angela Graf (Bryan & Bryan, Inc.) and Tom Koehler (Celilo Group), 9.

[67] Renewable Fuels Association, *U.S. Fuel Ethanol Production Capacity,* http://www.ethanolrfa.org/eth_prod_fac.html

[68]North Carolina Solar Center, *DSIRE: Incentives by State,* http://www.ies.ncsu.edu/dsire/library/includes/incentive2.cfm?Incentive_Code=US30F&State=Federal&currentpageid=1

Accelerated Depreciation

Certain equipment in an electric generating plant that uses biomass for fuel qualifies for accelerated depreciation over five years, provided the plant is a "qualifying facility" as defined by the Public Utility Regulatory Policy Act (PURPA).[70]

OTHER INCENTIVES

Renewable Energy Certificates

Renewable Energy Certificates (RECs) represent the non-electricity attributes, particularly the environmental benefits, of renewable energy generation. RECs are sold to people and organizations with an interest in supporting the development of new renewable capacity. RECs are also used in several states as a means for utilities to comply with Renewable Portfolio Standards. Project developers can sell RECs as a way to help qualify for financing or reduce project costs.

Sulfur Dioxide Emission Allowances

The Clean Air Act Amendments of 1990 includes incentives to reduce sulfur dioxide (SO_2) emissions. Public utilities may receive one emission allowance for each ton of SO_2 avoided through efficiency or renewable energy projects. The emission allowance program includes the conservation and renewable energy reserve, which is a bonus pool of emission allowances to reward utilities for new renewable energy projects. Utilities may reduce SO_2 emissions by curtailing generation from facilities that emit SO_2 if the curtailments are offset by efficiency or renewable energy projects.

The program of SO_2 emission allowances is an incentive for the development of renewable energy projects, including biomass energy projects. Fuel-switching is one way for utilities to reduce SO_2 emissions at coal-fired power plants. At generating facilities using high-sulfur coal, co-firing with biomass can reduce SO_2 emissions.

Carbon Offsets

Under section 1605 (B) of the Energy Policy Act of 1992, public utilities may voluntarily report actions undertaken to reduce or sequester greenhouse gas emissions. Industry participants in the U.S. Climate Challenge Program, sponsored by the U.S. EPA, have made non-binding commitments to reduce or sequester these emissions. The Chicago Climate Exchange facilitates a voluntary trading of carbon dioxide credits.

Special Depreciation Rules for Biomass Energy Facilities

Short depreciation lives are available for certain biomass energy facilities. A five-year tax life applies to property qualifying as a "small power production facility," which includes facilities that produce electricity from biomass and have a capacity of 80 megawatts or less. A seven-year

[69]North Carolina Solar Center, http://www.ies.ncsu.edu/dsire/library/includes/incentive2.cfm?Incentive_Code=US30F&State=Federal&currentpageid=1

[70] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Biopower Program, *Biopower – Policy – Federal Tax Credits*, http://www.eere.energy.gov/biopower/policy/po_ftc.htm#ftc1

tax life applies to property used in the conversion of solid waste and biomass into a solid, liquid or gaseous fuel.

Tax-Exempt Financing

Assuming that the facility has more than 10% private business use, a biomass project can qualify for tax-exempt financing if it fits into one of two categories: 1) the project supplies gas or electricity to an area no larger than two contiguous counties or one city and a contiguous county; or 2) the facility is a solid waste disposal facility.[71]

PROGRAMS FOR PROMOTING BIOMASS AND BIOFUELS

The federal government supports the advancement of biobased products and bioenergy in order to further the goals of strengthening farm income, creating new jobs in rural communities, enhancing energy security and reducing pollution. The goal is to triple the use of biobased products by 2010.[72] The USDA and the U.S. DOE sponsor programs to support research and development, commercialization, and public education efforts. Moreover, programs have been developed to provide technical and financial assistance for producers of bioenergy products.

USDA budgeted $268 million in 2001 for its Biobased Products and Bioenergy Initiative. Under this umbrella program, the Commodity Credit Corporation made incentive payments available to encourage the production of fuel grade ethanol and biodiesel from grain; $100 million was budgeted for 2000 and $150 million for 2001. Payments are based on bioenergy production increases from eligible commodities. To qualify, companies must produce and sell ethanol commercially and be in good standing with the EPA. Raw materials must be grown in the United States for the purpose of producing fuel grade ethanol or biodiesel. Eligible commodities for 2001 included: barley, corn, grain sorghum, oats, rice, wheat, soybeans, sunflower seed, canola, crambe, rapeseed, safflower, sesame seed, flaxseed, mustard seed, and cellulosic crops.[73]

In April, a Memorandum of Agreement was signed between USDA and Colson Services Corp, a subsidiary of JP Morgan Chase Bank. This agreement expands the scope of the Biobased Products program, enabling investors to purchase certificates for guaranteed portions of Rural Development business loans.

An additional $10 million is available through USDA's Value-Added Agricultural Product Market Development Grants program.[74] However, it is necessary to draft a regulation to govern the program before funds can be awarded.

Note that there are a handful of programs that broadly support the development of rural businesses. Fiscal year 2003 funding for the Rural Business-Cooperative Service is as follows:

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[71] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Biopower Program.

[72] *Liquid Fuels from Biomass: North America, Impact of Non-Technical Barriers on Implementation*, (S&T)2 Consultants, Inc., Canada, September 15, 2000, 44.

[73] Farm Service Agency, *Commodity Credit Corporation Announces Bioenergy Program Sign-up*, Release 1654.00, http://www.fsa.usda.gov/pas/news/releases/2000/11/1654.htm

[74] USDA Rural Business Cooperative Services, *Value-added Producer Grants*, http://www.rurdev.usda.gov/rbs/coops/vadg.htm.

- Business and Industry Guaranteed - $900 million plus $309 million carryover
- Intermediary Re-lending Program - $40 million
- Rural Business Enterprise Grant - $47.99 million
- Rural Economic Development Loan - $15 million
- Rural Economic Development Grant - $4 million
- Rural Business Opportunity Grant - $4 million[75]

Loan guarantees for biomass conversion into bioenergy are available under the Business and Industry Guaranteed Loan Program. The objective is to create employment in rural areas by expanding the lending capacity of commercial lenders. Up to 90% of a loan made by a commercial lender can be guaranteed, and the maximum loan size is $25 million.[76]

The Intermediary Relending Program provides financing to business facilities and community development projects through intermediaries. The Intermediaries establish revolving loan funds for this purpose.[77]

The Rural Business Enterprise Grant program provides funds to public bodies, nonprofits, and Indian Tribal groups to finance small business enterprises in "urbanizing areas" outside cities with populations of over 50,000. Grant funds are not provided directly to the business.[78]

Rural Economic Development Loans can be provided at zero% interest to electric and telephone utilities. The utility must re-lend the money at zero% interest to a third-party for the purpose of job creation. Priority is given to areas with populations of less than 2,500 people.

Rural Economic Development Grants are available for rural economic development purposes. Grants are provided to electric and telephone utilities and are used to establish revolving funds. The utility must contribute 20% of the funding for each grant administered.[79]

The Rural Business Opportunity Grant program seeks to promote sustainable economic development in rural communities with exceptional needs. Grants cover the costs of economic planning, technical assistance for rural businesses, and training for rural entrepreneurs or economic development officials.[80]

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[75] USDA Rural Business Cooperative Services, *Business Programs,* http://www.rurdev.usda.gov/rbs/busp/bprogs.htm.

[76] USDA Rural Business Cooperative Services, *Business & Industry Guaranteed Loans,* http://www.rurdev.usda.gov/rbs/busp/b&I_gar.htm.

[77] USDA Rural Business Cooperative Services, *Intermediary Relending Program,* http://www.rurdev.usda.gov/rbs/busp/irp.htm.

[78] USDA Rural Business Cooperative Services, *Rural Business Enterprise Grants,* http://www.rurdev.usda.gov/rbs/busp/rbeg.htm.

[79] USDA Rural Business Cooperative Services, *Rural Economic Development Grants,* http://www.rurdev.usda.gov/rbs/busp/redg.htm.

[80] USDA Rural Business Cooperative Services, *Rural Business Opportunity Grants,* http://www.rurdev.usda.gov/rbs/busp/rbog.htm.

The USDA Climate Change Technology Initiative seeks to develop and demonstrate technologies that reduce greenhouse gas emissions from agriculture and forestry. It is expected that $9.5 million will go to the Forest Service to do research on small diameter and short-rotation trees, and $4.5 million will go to the Agricultural Research Service to support biomass conversion technology development.[81]

USDA's Renewable Energy Systems and Energy Efficiency Improvements programs assist farmers, ranchers and rural small businesses in developing renewable energy systems and making energy efficiency improvements to their operations. Grant funding is available in the amount of $23 million for projects that derive energy from wind, solar, biomass, geothermal or hydrogen.[82]

The USDA manages several programs designed to increase the use of agricultural crops as feedstocks for biofuels. The Bioenergy and Energy Alternatives Program (under the Agricultural Research Service) conducts research in ethanol, biodiesel, energy alternatives for rural practices and energy crops. Emphasis is on developing or modifying technologies, developing energy crops and improving process economics.[83]

The USDA Cooperative State Research, Education and Extension Service (CSREES) advances research and development in new uses for industrial crops and products through its Agricultural Materials program, National Research Initiative, Small Business Innovation Research Program, and other activities. Areas of interest include paints and coatings from new crops, fuels and lubricants, new fibers, natural rubber, and biobased polymers from vegetable oils, proteins and starches.[84]

The Department of Energy sponsors the Regional Biomass Energy Program (RBEP). This program seeks to increase the production and use of bioenergy resources. It supports information dissemination and demonstration projects which might foster the creation of new industries and jobs."[85] There is a network of regional offices throughout the United States. Each RBEP region conducts activities in two areas. Cooperative initiatives are pursued, through which the state government matches local opportunities with resources to address area-specific problems. This provides the opportunity to integrate the work of energy, forestry, air quality and other officials. Region-wide technical projects are also pursued to address issues common to the majority of member states. Cooperation and cost sharing occurs amongst participating states, private industry, trade associations, private farm owners, universities, and other federal agencies.

The Clean Cities Program fosters the development of a sustainable alternative fuels market through the public/private partnerships formed around the country. It includes initiatives such as:

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[81] *Liquid Fuels from Biomass: North America, Impact of Non-Technical Barriers on Implementation*, (S&T)2 Consultants, Inc., Canada, September 15, 2000, 45.

[82] USDA, *Veneman Announces $44 Million in Grants for Renewable Energy Initiatives*, http://www.usda.gov/news/releases/2003/04/0111.htm.

[83] USDA, Biobased Products and Bioenergy Coordinating Council (BBCC), *BBCC Member Agencies*, http://www.ars.usda.gov/bbcc/USDA_BBCC.htm.

[84] USDA CSREES, http://www.reeusda.gov/

[85] U.S. DOE Office of Transportation Technologies, *What is the Regional Biomass Energy Program,* http://www.ott.doe.gov/rbep/what.html.

the purchase of alternative fuel vehicles; vehicle demonstrations; infrastructure development; the reduction of greenhouse gas emissions through increased use of renewable fuels and advanced vehicle technology, and the development of Clean Cities organizations.

The Biomass Research and Development Initiative is a joint endeavor of several agencies, headed by DOE and USDA. The purpose of the initiative is to develop a comprehensive national strategy that includes research, development, and private sector incentives to "stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in national and international markets."[86] The initiative was started under an Executive Order of the Clinton Administration in support of the goal of tripling U.S. use of biobased products and bio-energy by 2010.

The Healthy Forests Initiative, initiated by the Bush Administration in 2002 seeks to:

- Significantly step up efforts to prevent the damage caused by catastrophic wildfires by reducing unnecessary regulatory obstacles that hinder active forest management;
- Work with Congress to expedite procedures for forest thinning and restoration projects; and Fulfill the promise of the 1994 Northwest Forest Plan to ensure the sustainable forest management and appropriate timber production.[87]

The BLM is developing a program in support of the National Energy Policy, the National Fire Plan and the President's Healthy Forests Initiative to use the thinnings as biomass feedstock.

The Forest Service, private forestry groups, non-profits, states and universities are cooperating under the Small Diameter Utilization Program. The objective is to provide information in areas such as technology transfer, logging systems, forest products and manufacturing, biomass and marketing.[88]

The Economic Action Program provided a range of assistance to rural communities. Program areas included: fuel reduction and utilization projects; bioenergy feasibility studies; wood product utilization and market feasibility studies; support to modify or develop long-range fuels hazard reduction; and community economic development planning that expands and diversifies the use of forest products. More than 1,070 projects were completed in FY 2002. In addition, the

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[86] U.S. Office of the White House, *Executive Memorandum – Subject: Biobased Products and Bioenergy*, August 12, 1999, http://www.bioproducts-bioenergy.gov/about/ememo.asp.

[87] U.S. Office of the White House, *Healthy Forests Initiative,* http://www.whitehouse.gov/infocus/healthyforests/.

[88] National Fire Plan, accessed September, 2003, http://www.fireplan.gov/reports/perf_rpt_2002/9-16.pdf.

Forest Products Laboratory Technology Marketing Unit obtained $2 million to encourage the use of small diameter material and low-valued trees.[89]

[89] National Fire Plan, accessed September, 2003, http://www.fireplan.gov/reports/perf_rpt_2002/1-6.pdf

Appendix F. Environmental and Socioeconomic Impacts

Environmental and Socioeconomic Impacts

There are a variety of technologies used to process biomass and convert it into energy. Each application has different impacts on the local community, the economy and the natural environment. For example, using biomass in a power plant is different than using it to produce ethanol. Therefore, we will briefly examine the major positive and negative consequences of both biomass power as well as biofuels. The economic viability of using biomass is largely determined by policy barriers and incentives, which are also described in this section.

Air Quality Improvement

Biomass energy has several benefits compared to alternative forms of power generation -- primarily due reduced air pollution and improved watershed management. In addition to displacing more polluting forms of energy, biomass energy is an environmentally preferable means of utilizing forest thinnings from forest fire mitigation treatments. Although air pollution emissions will vary by feedstock, operating characteristics and emission control technology, the use of biomass power has a generally positive impact on air quality.

In terms of sulfur, biomass contains 0.05 to 0.20 wt % sulfur on a dry basis and has a higher heating value at about 8,500 Btu/lb. This compares with coal at 2-3 wt % sulfur on a dry basis. NO_x emissions are usually lower for biomass than for coal, due to lower fuel nitrogen content and the higher volatile fraction of biomass versus coal. However, this difference may not have much influence on the selection of the technology (i.e., coal or biomass) as the compliance costs are relatively insignificant given the small difference in NO_x emissions.

Some argue that biomass is "CO_2 neutral" because the plants or trees used as inputs absorb carbon dioxide from the atmosphere while they are growing and release it into the atmosphere when burned. In practice the picture is more complicated. Other carbon flows are involved in the picture, including CO_2 emissions associated with fuel use in harvesting, processing, and transportation operations that diminish the effectiveness of biomass energy use as a CO_2 sequestration strategy. Vehicle use creates carbon monoxide, hydrocarbons, nitrous oxides, carbon dioxide and particulate matter. Although a biomass plant has lower net CO_2 emissions than a fossil plant, it is also certain that biomass power generation is not a net zero CO_2 process.

Due to the air emissions created from burning biomass, the US Environmental Protection Agency (USEPA) has established guidelines for siting biomass power facilities. In many cases, data specific to a particular wood-burning appliance are not readily available. In such cases, the USEPA provides emissions factors that can be used to estimate emissions from wood-fired boilers as part of efforts to estimate effects of specific combustion sources and determine applicability of relevant permitting programs. The document "Air Pollution Emission Factors, 5th Edition, Volume I for Stationary Point and Area Sources," or AP-42 Emissions Factors, lists emissions factors for combustion systems that use mechanical particulate collection devices for emissions controls.[90] Emissions factors are specified in terms of pounds of emittent per million

[90] U.S. EPA Technology Transfer Network, *Air Pollution Emission Factors*, 5th Edition, Volume I for Stationary Point and Area Sources, http://www.epa.gov/ttn/chief/ap42/index.html

Btu (lb/MMBtu) of fuel burned. The table below shows the emission factors specified in AP-42. These factors are neither emissions limits nor standards.[91]

Table F-1. U.S. EPA AP-42 emission factors for wood boilers

Pollutants	Emissions factors (lb emittent/ MMBtu fuel input)
Total Particulates*	0.22-0.3
Oxides of Nitrogen	0.49
Carbon Monoxide	0.6
Total Organic	0.06
Sulfur oxides	0.025

Source: U.S. EPA AP42 http://www.epa.gov/ttn/chief/ap42/ch13/
* Emission factors for systems utilizing mechanical particulate collection devices

Ethanol Plant Emissions

Because no cellulose ethanol facilities exist, data on air emissions is limited to studies that have modeled expected results. It is likely that emittent pollutant levels will be similar to or less than biomass power facilities. Indeed, the capture of CO_2 may be more likely due to the confined nature of the fermentation process thereby allowing for more cost-efficient CO_2 recovery.

Avoided Emissions

In addition to reducing emissions from burning fossil fuels, forest thinning may help prevent emissions from forest fires. Recent work conducted by the Canadian Forest Service indicates forest fires emit substantial quantities of CO_2 as well as methane, carbon monoxide, NO_x, particulate matter and other trace gases.[92] As a result, fires impact not only carbon sequestration but emit greenhouse gases.[93] The magnitude of the emissions is noteworthy. The Canadian study found that direct carbon emissions by forest fires ranged from 2 to 75% of CO_2 emissions from all Canadian sources, averaging 18% of the country's total CO2 emissions.

Scientists at the National Center for Atmospheric Research (NCAR) have found that as much as "... 800 tons (more than 19 times the amount the EPA estimates is emitted annually from U.S. power plants) of mercury previously deposited on leaves, grasses, twigs, and other forest

[91] U.S. EPA, *Introduction to AP-42*, Volume I, Fifth Edition, Washington, DC. January 1995, http://www.epa.gov/ttn/chief/ap42/c00s00.pdf, 2

[92] B.D. Amiro, et al, "Direct Carbon Emissions from Canadian Forest Fires, 1959-1999," *Canadian Journal of Forest Research*, 31, 512-525.

[93] General Bioenergy, *Bioenergy Update*, September 2003, Vol. 5, No. 9.

vegetation around the world may be re-emitted into the atmosphere each year as the result of forest fires and the burning of other vegetation."[94]

Mercury and other toxic materials are emitted whether a fire is low intensity or high intensity, but considerably more is emitted in a catastrophic fire because more vegetation is burned. Thinning can reduce the extent and intensity of wildfire, therefore reducing forest fuel consumed and any resulting emissions of toxic materials.

Biomass power generation may provide air quality benefits in rural settings where forest fuels reduction activities result in open-burning of piled biomass. Burning biomass in a controlled environment can reduce smoke and particulate matter emissions by 95% to 99% over open burning. The overall impacts of biomass combustion on ambient air quality, taking into account potential benefits associated with reduction in open burning, may be a positive factor in the permitting process for a biomass plant.

Watershed Benefits

Fuels management practices can help preserve the quantity and quality of water resources. Reducing the risk of catastrophic wildfire prevents long-term impacts on riparian area water quality associated with increased debris and sedimentation. Wildfire removes vegetation and exposes mineral soils, which decreases the ability of soil to absorb water. This contributes to the potential for massive soil movements and mudslides following wildfires; it also affects soil productivity for years to come.

Forest thinning improves forest aesthetics and prevents forest stands from becoming overly dense. Excessive forest density can restrict the amount of water yield from forests to riparian areas and reservoirs, in addition to limiting forest productivity and diversity in flora and fauna. In socioeconomic terms, excessive forest density can impact the availability of water, sustainability of timber production and recreational opportunities associated with streams and lakes.

Economic Benefits

Economic benefits of either a biomass power facility or an ethanol plant result from feedstock handling and processing activities, plant construction and operation, and product marketing. All contribute income to the economy, due primarily to employment. In this section we discuss the following topics: job creation, tax revenue, and insurance implications for biomass utilization. Fiscal policies and incentives are discussed in Appendix B.

Employment

Biomass benefits include creation and retention of local jobs in a rural economy. For each MW of installed capacity, six people are employed to maintain the plant and operate the biomass supply infrastructure.[95]

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[94] "Mercury and the Forest," *Forest Products Equipment*, February 2002, 10.

[95] For California bio-power facilities, in 2003, there are 3,600 direct jobs that support 588MW of capacity. California Biomass Energy Alliance, *Benefits of California's Biomass Renewable Energy*, http://www.calbiomass.org/technical4.htm .

For a cellulose ethanol facility, the levels of employment are not as well documented because of the lack of data. In this report we provide an estimate of direct employment by comparing the corn ethanol industry and the biomass power supply industry to a potential cellulose ethanol facility. For the purposes of the employment estimate it is assumed the plant has a capacity of 15 million gallons/year and the feedstock requirements are 600,000 GT/yr (yield of 25 gallons/GT).

Based on experience with corn-based facilities, we assume it will require 30 people to operate a15 million gallon/year cellulose ethanol facility. Additional staff are required to support the fuel infrastructure. For fuel processing and delivery, a 6-person crew can deliver approximately six full chip vans/day (this includes felling, skidding, chipping, and three daily round trips/driver). At 23 GT/van and assuming a daily consumption of about 1,640 GT for a 15 million gallon/year facility, then the direct jobs associated with feedstock supply would be about 70 depending upon the level of mechanization and the travel distance. Thus total direct employment at the plant and for fuel supply would be on the order of 100 jobs for a 15 million gallon/year facility. Note that our approach does not include jobs associated with sale and distribution of ethanol.

For comparative purposes, the California Energy Commission estimates that 1,600 direct jobs would be created to support a cellulose ethanol industry producing 200 million gallons/year.[96] On a job/gallon basis, a 15 million gallon capacity plant would create approximately 120 jobs, which could include marketing and other functions.

Tax Revenue

Economic impacts from biomass power facilities and ethanol plants can be assessed in terms of the immediate effects associated with construction of a facility and the long-term impacts attributable to operations. From a socio-economic point of view, these impacts are characterized in terms of employment, income and taxes paid. Further, a multiplier effect creates additional jobs, income and taxes in the local community to support those who are working in the ethanol or power sector. The indirect effects, and are important and are a key aspect of economic impact analysis.

Furthermore, many of the expenditures of a specific project will “leak” away from the immediate area. Examples of leakages include purchases of equipment, fuel, and specialized services in areas outside the vicinity of the construction area.

Construction-related impacts include income to personnel working on the project, taxes on wages of various personnel associated with engineering, procurement and construction of the plant, as well as property taxes on new equipment. Typically the short-term impacts are considerable and may result in both individual/corporate economic gain and community economic loss and displacement. While the gain is straightforward to measure, the community loss may be more difficult to estimate. Community loss is largely a function of impacts on local services (e.g., schools, health care, public safety, transportation infrastructure) as well as opportunity losses foregone by the new facility.

Long-term impacts tend to be much higher than immediate impacts if the business is a sustainable operation. Two separate revenue streams dominate economic impacts. The first is the purchase of biomass and the subsequent re-sale of the product, either electricity or ethanol. In

[96] California Energy Commission, *Costs and Benefits of a Biomass to Ethanol Production Industry in California*, P500-01-002, March 2001.

each case the direct costs and revenues are taxable events that can be modeled with some precision. The other significant impact is the taxable income of the wages for personnel associated with biomass processing and plant operations. Finally, the multiplier effect is marked but varies from site to site due to the specific circumstances of each project.

Results for ethanol economic impact analysis suggest net positive gains associated with a cellulose ethanol facility.[97] In this study a hypothetical 10 million gallon/year facility constructed in five separate states results in the impacts presented in Table F-3.

Table F-3. Average income, jobs, and state taxes per million gallons of ethanol produced[98]

Category	Value
Gross	
Income	$919,000
Jobs	14
State taxes	$53,000
Net	
Income	$889,000
Jobs	14
State taxes	$51,000

Insurance Impacts

It is difficult to say with certainty the effect wildfires have on property insurance rates. While it is clear the industry factors in the risk associated with a wildfire, it is also clear there are more important factors such as a site's proximity to firefighting resources and historical claims for a geographic area versus proximity to overstocked forests. According to a State Farm Insurance spokesman, "Insurance rates are based on historic trends of 10 to 15 years. So far we haven't had

[97] Resource Systems Group, *Economic Impact of Fuel Ethanol Facilities in the Northeast States*, Washington, DC: Northeast Regional Biomass Program, December 2000, http://www.nrbp.org/

[98] Resource Systems Group, 21.

enough history with wildfires to determine a trend" (in reference to the impacts of increasing wildfire activity in the wildland-urban interface).[99]

Currently, there is no talk of reduced rates for properties that clear combustible vegetation from near structures to create a "defensible space" that reduces the risk of damage, but there is talk that insurance companies will raise the rates or drop coverage for homeowners who do not create defensible space, or place moratoriums on new policies in fire prone areas.

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[99] James Dietrich and Laura Lewis. "Homeowner Insurance Rates Will Increase Independent of Wildfire Costs**,"** *Southwest Colorado Fire Information Clearinghouse*, accessed September 15, 2003, http://southwestcoloradofires.org/articles/article16.htm.

Appendix G. Equipment Quote from Jackson Lumber Harvester

PHONE: (715) 926-3816
FAX: (715) 926-4545

Jackson LUMBER HARVESTER COMPANY, INCORPORATED

830 N. STATE ROAD 37 • MONDOVI, WISCONSIN 54755 U.S.A.
E Mail: info@jacksonlbrharvester.com

June 3, 2005

QUOTATION

QUOTE NO. 050603a

FOR: Ms. Angela Crooks
143 Union Blvd Suite 900
Lakewood, CO 80228

Ph:303-273-0071
Fx:303-273-0074

(1) New Jackson Two Strand Electric Drive Log Deck - for Shaving Mills

Two strand deck is 20 feet long with easy rolling large roller conveyor chain, deck strands fabricated from heavy-duty 12" rectangular tubing, 5 HP 400v 50 Hz 3-phase electric motor gearbox drive.

F.O.B. Mondovi, WI -- Installation Not Included.....................$ 10,500.00

(1) New Jackson Wood Shaving Mill - Model 30D-10HL

The cutter heads are specially designed and engineered by Jackson for the purpose of producing wood shavings. Minimum diameter of material used should not be less than two inches (5 cm), with maximum diameter being 24 inches (60 cm). Allowable wood length is 7' to 8'8" (213 to 274 cm). When solid wood is transformed into shavings, the expansion results in an increased volume ratio of 3:1 up to 4:1. (This varies depending upon the species of wood and knife setting used.) Softwoods may be shaved with bark or with bark removed: i.e.. round wood, pulpwood, low-grade logs, etc., green or dry. This machine typically produces up to 550 ft^3 (15.6 m^3) per hour (depending on species and moisture content, and setting of knives - production is generally less with dry wood). The shaving mill has two heads which are 10" (25.4 cm) diameter, with eight knives per head (extra set of knives included) with v-belt drives; cutting surface of the heads is approximately 27" (70 cm). Main frame is equipped with replaceable box travel track and mounting brackets for conveyor to discharge shavings at floor level. Includes (1) 75 HP (56 kW) 400v 50 Hz 3-phase electric motor drive with all belts, sheaves, and guards (starter and wiring not included). Hydraulic box drive package includes hydraulic power system w/30 GPM (1.9 liters/sec) pump, 25 HP (18.3 kW) 400v 50 Hz 3-p hase electric motor, 8' cooler. Overall size is 7' (2.1 m) wide x 22'8" (6.9 m) long x 3-1/2' (1.1 m) high 555 ft3 (15.9 m3). Approximate weight is 8,300 lbs (3,780 kg). OIL NOT INCLUDED.

F.O.B. Mondovi, WI -- Installation Not Included.....................$ 69,100.00

(1) New Jackson Knife Cartridge System for 10" Heads (patented)

This unique Jackson-designed option includes cartridges which hold the knives, specially manufactured 10" (25.4 cm) cutter heads to accept these cartridges, and the matching gibs to secure them in the heads. The knives are installed in the cartridges and adjusted for cutting depth using the setting jig on the workbench, then installed in the machine. This makes changing knives much more convenient, and provides precise, consistent setting of knives to maximize the quality of shavings.

F.O.B. Mondovi, WI .... *$ 4,772.00*

(1) New Spare "Floater" Set of Cartridges for 10" Heads

Extra set of 16 cartridges maximizes the efficiency and advantages of the Knife Cartridge System by allowing the operator to keep a complete set of cartridges "on hand" with resharpened knives already installed and adjusted. When the machine is shut down for maintenance the cartridges can be replaced quickly and easily, thus getting the Shaving Mill ready to go again with the least amount of downtime possible. Typically saves as much as 1/3 or more of the time usually spent changing knives.

F.O.B. Mondovi, WI .... *$ 3,800.00*

(1) New Elevated Base for 2000 Series Shaving Mills

Elevated mounting base for shaving mill is designed for applications where it is desirable for the shavings conveyor to discharge above floor level. Constructed of welded steel rectangular tubing. Standard height is 2' (0.6m); contact factory for pricing on other heights.

Delivery and installation not included .... *$ 4,350.00*

(1) New 20' Jackson Belt Conveyor - For Under Shaving Mill

Trough-type belt conveyor is 24" wide x 20' long and runs under shaving mill. Includes drive package consisting of: bearings, wing pulleys, belt tighteners, mounting brackets, and 1 HP 400v 50 Hz 3-phase electric motor.

F.O.B. Mondovi, WI -- Installation Not Included .... *$ 5,320.00*

(1) New Approximately 30' Jackson Belt Conveyor - to Dryer

Trough-type belt conveyor is 24" wide x approximately 30' long and runs to dryer. Includes drive package consisting of: bearings, wing pulleys, belt tighteners, mounting brackets, and 2 HP 400v 50 Hz 3-phase electric motor. Also includes adjustable legs for elevating shavings into a semi trailer, truck, or bin.

F.O.B. Mondovi, WI -- Installation Not Included .... *$ 8,450.00*

(1) New Dryer Infeed Hood

F.O.B. Origin -- Installation Not Included .... *$ 2,500.00*

(1) New 12,000,000 BTU Webb™ Sawdust Burner

Includes all duct work, sawdust system, blower to burner, and all controls.
F.O.B. Origin -- Installation Not Included .... $ *62,000.00*

(1) Used 8'x24 Dryer

With cyclone, blower, 400v 50 Hz motors, and drive for drum.
F.O.B. Origin -- Installation Not Included .... $ *51,000.00*

(1) New 6'x6' Screen

Includes 2-deck screen with proper screen size & 5 HP motor.
F.O.B. Origin -- Installation Not Included .... $ *12,020.00*

(1) New Fines Blower

Includes 26" fan and 10 HP motor.
F.O.B. Origin -- Installation Not Included .... $ *4,250.00*

(1) New Approximately 50' Jackson Belt Conveyor - from Screen to Storage

Trough-type belt conveyor is 24" wide x approximately 50' long from screen to storage. Includes drive package consisting of: bearings, wing pulleys, belt tighteners, mounting brackets, and 3 HP 400v 50 Hz 3-phase electric motor.
F.O.B. Mondovi, WI -- Installation Not Included .... $ *11,350.00*

(1) New Automatic Knife Grinder

Sharpens knives up to 30" with automatic cooling & sharpening. 2 HP single phase motor, stand.
F.O.B. Origin -- Installation Not Included .... $ *5,900.00*

Installation

Technician(s) to install equipment and familiarize employees with operation and maintenance. Customer responsible for site preparations such as grading, cement work, building construction & modifications; for providing machine (such as fork lifts and cranes) and operators to unload and place equipment; and for electrical wiring and starters for motors.
.... $ *25,532.00*

Freight

Four loads from Mondovi, Wisconsin to Lakewood, Colorado.
.... *Estimate* $ *8,800.00*

TOTAL* .... $ *289,644.00

Customer is responsible for cyclone for dryer, fuel bin, pipe for dryer and pipe for fines bin.

Freight subject to change without notice.

This Quotation Firm for 60 Days -- Used Equipment Subject to Prior Sale

You will need to contact an electrician for the wiring.

As of today, delivery schedule would be approximately 60 days.

Customer responsible for site preparations such as grading, cement work, building construction & modifications; for providing machine (such as fork lifts and cranes) and operators to unload and place equipment; and for electrical wiring and starters for motors.

TERMS

Minimum deposit of 30%. Interim payment and final payment to be determined at time of order. Balance due prior to shipping in the form of Cash, Bank Money Order, or Cashier's Check. Orders are considered firm and non-cancellable, down payments non-refundable. Warranty applies to equipment paid for in full.

Prepared By:

William C. Becker/vmw

William C. Becker
Executive Vice President

WCB:vmw