Biofuel Feasibility Study

Bois Forte Band of Chippewa

Nett Lake, Minnesota

SEH No. A-BOISF0702.00

January 2009

SEH

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Executive Summary

The Bois Forte Band of Chippewa (Bois Forte) has completed a detailed feasibility study of the technical and economic viability of developing a renewable energy biofuel demonstration facility on Bois Forte Reservation land in Northeastern Minnesota. This study has been funded, in large part, via a grant from the State of Minnesota.

The primary goals of the project are to make more efficient use of resources of the Bois Forte Reservation and surrounding area, increased employment opportunities for tribal members, and production of domestic biofuels to reduce our energy dependence on fossil fuels and foreign sources.

The results of this study indicate that local sources are adequate to support a sustainable thru-put from 50 to 200 dry tons per day (dtpd) of forestry residual biomass. Production of bio-oil (via pyrolysis) in this range appears to be technically feasible and economically viable if petroleum crude oil prices are above $100/barrel (bbl). The USDOE's Energy Information Administration (EIA) 2009Annual Energy Outlook predicts that by 2014, crude oil prices will return to prices exceeding $100/bbl and continue to steadily rise for the next twenty years.

This study initially recommends implementation of a smaller scale demonstration scale facility to process up to 5 to 10 dry dtpd of forestry residual biomass. The demonstration facility design, installation and startup would be implemented in 2009-2010 with operations planned for 2011. This will allow current low crude oil prices (<$50/bbl) to return to higher costs (>$100/bbl), opportunity for process improvements to increase bio-oil quality, and provide an acceptable timeframe to increase familiarity for the community, workforce, bio-oil users, and regulatory agencies. The long term project envisioned will process up to 200 dtpd biomass to create a sustainable renewable fuel or energy.

Bois Forte retained the services of Short Elliott Hendrickson Inc. (SEH) and the University of Minnesota Duluth- Natural Resources Research Institute (NRRI) to assist the Renewable Energy (RE) Planning Committee with this study. The RE Planning Committee includes members from Bois Forte Development Corporation and the Bois Forte Natural Resources Department (including Forestry and Environmental Services Departments).

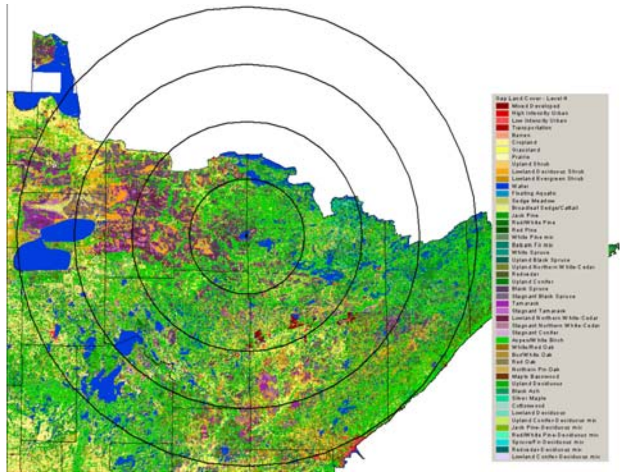
Activities conducted since July 2007 included:

- biomass resource assessment to identify feedstock availability;
- multiple meetings with various technology developers, researchers, and vendors;
- multiple meetings with potential customers;
- meetings with other local bands (White Earth, Red Lake, Fond Du Lac and St. Croix) engaged in similar activities;
- participation in quarterly Agricultural Utilization Research Institute (AURI) Energy Roundtable meetings; and
- community and legislative updates.

Biomass Resource Assessment

The biomass resource assessment evaluated various sources including: forestry low-valued roundwood resources (within the allowable cut), logging residue, pine thinnings, sawmill waste, debris from forest/brushland clearing and roadway maintenance, and weed harvesting from Nett Lake. Forestry residual biomass estimates accounted for the Biomass Harvesting Guidelines for Forestry, Brushlands, and Open Lands (December 2007) recommended by the Minnesota Forest Resources Council.

The assessment evaluated availability of biomass (roundwood, residue, thinnings, etc) within distances of 25, 50, 75 and 100 miles from the Bois Forte Reservation lands surrounding Nett Lake.



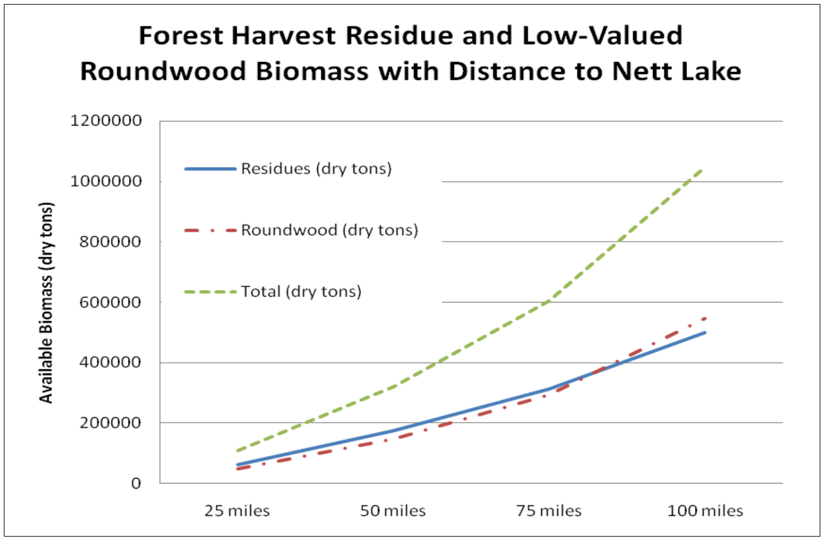
Available biomass within the distance ranges was compared to two potential harvest levels:

- 50 dtpd (equivalent to 18,250 dry tons/year);
- 200 dtpd (73,000 dry tons/year).

The table and figure below summarizes the ratios of biomass (low-valued roundwood and residue) available compared to the harvest levels. For example, the amount of low-valued roundwood and residue within a 25 mile radius provides 1.5 times the amount of biomass required to support a 200 dtpd operation.

Forest Harvest Residue Biomass and Low-Valued Roundwood Biomass Availability and Ratio of Available:Demand with Distance from Nett Lake

Distance from Nett Lake	25 miles	50 miles	75 miles	100 miles
Residues (dry tons)	61,842	173,990	313,357	499,713
Low-Valued Roundwood (dry tons)	48,610	148,221	292,428	547,173
Total (dry tons)	110,452	322,211	605,785	1,046,887
Coverage Ratio				
Minimum Demand - 50 dtpd	6.1	17.7	33.2	57.4
Maximum Demand - 200 dtpd	1.5	4.4	8.3	14.3



It appears that the available biomass proximal to Nett Lake is more than adequate to support the range of harvest levels proposed.

The assessment also evaluated biomass availability on only tribal and allotted lands managed directly by Bois Forte. The total sustainable biomass available on lands managed directly by Bois Forte could supply 100% of the lower harvest level, 50% of the mid level, and 25% of the higher level.

Considering the availability of biomass within a 25 mile radius, and also within areas directly managed by Bois Forte, it appears reasonable to conclude that competition for the resource by other potential biomass-to-energy projects within a 100 mile radius should not be detrimental to this project's long term sustainability.

Harvesting Methods

A significant factor in determining availability of harvest residues is the logging infrastructure. While resources are important, the logging industry will ultimately affect the ability to bring the resource to market. There is a variety of equipment that can be used to process forest harvest residues including chippers, grinders and potentially, slash bundlers. There is a need for the Bois Forte project to evaluate the equipment owned by local logging contractors, particularly tribal logging operations. In most cases, the lowest-cost option is to purchase a small chipper to be used to chip tops and limbs at the same time that roundwood is being produced. Integration of a chipper with the current roundwood production system is relatively straightforward. However, purchase of new equipment requires a steady market with a known revenue stream. Therefore, it may be necessary for active participation of Bois Forte in assisting tribal loggers with markets and financing for additional equipment. The report includes an evaluation of the costs and capital requirements for a typical logging operation to incorporate harvest and chipping of residues.

Biomass to Energy Technology Assessment

In Fall 2007, Bois Forte released a general solicitation to innovative biomass to energy technology developers, and subsequently initiated exploratory meetings with various companies. Potential options considered included:

- Solid (wood chips, pellets, briquettes)
- Liquid (ethanol, bio-oil)
- Gas (gasification for combined heat and power; and gasification with further processing to produce dimethyl ether, methanol or diesel)

As part of the technology assessment Bois Forte met with several potential local customers for the various renewable energy products including: regional power companies, taconite mines/processing companies, and petrochemical industries in the Duluth/Superior area. Applications for heat and power on the Bois Forte Reservation were also evaluated.

The study included evaluation of:

- Process (level of complexity)
- Inputs, outputs and scale (demonstration or commercial)
- Market for product (robustness, competition, sensitivity)
- Technology Assessment (level of development, vendors, R&D interest)
- Environmental Resources (feedstock, water, site selection, discharges, toxicity)
- Economics (jobs, capital, OM, funding support)
- Business Issues (ownership, access, royalties, branding, improvements)
- Regulatory (CAA, CWA, RCRA, OSHA, BATF) and
- Social Issues (24/7 operations, safety, noise, other).

Technology Comparison and Selection

The table below provides a comparison of the biomass to energy technologies evaluated with respect to the objectives of the study.

Biomass Fuel Options	Production Technology Maturity	Product Ability to Compete on Price (based on expected production costs at BF scale)	Number and Flexible Use for the Products	Commercial Scale Magnitude compared to BF Sustainable Harvest	Opportunity for Demonstration to Prove Technology at BF Scale and Market	Local Jobs Impact at 100 dtpd Scale	Water Resource Required	Potential Social Issues	*Average Score (lowest is best)
Wood Pellets or Briquettes	1	1	4	1	5	5	1	1	2.4
BioOil and Char	3	2	1	1	1	3	2	2	$\boxed{1.9}$
Cellulosic Ethanol	4	5	3	4	4	1	5	4	3.8
Gasification for CHP	2	3	5	3	2	4	2	3	3.0
Syn Gas Processing to DME, Methanol or Diesel	5	5	2	5	3	2	3	5	3.8

*Rating on relative scale of 1 to 5. 1 is best score and 5 worst score based on comparison to the objectives and site specific limitations of the Bois Forte project.

Based upon the above comparison, bio-oil was selected as the most appropriate technology for the Bois Forte project.

Bio-oil

Bio-oil production from woody biomass includes drying, grinding, and gasification via fast pyrolysis. A major fraction of the gas created is condensed into bio-oil. A by product of the process is char, a solid material that can either be used as a stand alone fuel, mixed back in with the bio-oil, or used as a soil amendment for agriculture.

Bio-oil has several uses. It may serve a replacement for bunker fuel and may be used as a fuel supply in industrial kilns or compatible boilers or gas turbines. Bio-oil may serve as a feedstock for ethanol or hydrogen production, and also may be potentially be further refined into higher end transportation fuels via catalytic cracking equipment typically located at petrochemical refineries. Bio-oil is used in production of the food flavoring Liquid Smoke®. Bio-oil may also be used in asphalt production.

There are few active commercial scale woody biomass bio-oil plants in operation in North America as uses for the fuel are still being developed. Bio-oil is currently considered to be suitable for storage for periods of up to 6 months, before stabilization issues begin to occur. The federal government has indicated a strong interest in bio-oil and is spending significant funds on research and development to improve fuel stability issues and improve its properties to allow easier refining.

The manufacturing process does not require significant water inputs, does not require significant air pollution controls, creates a relatively safe combustible product, and does not create significant waste byproducts.

Demonstration Phase

The next phase of this project is recommended to be a pilot scale demonstration phase. The demonstration phase will include three major components:

- Residual woody biomass harvesting and harvesting;
- Construction of a 10 dtpd demonstration scale bio-oil production facility; and
- Testing of bio-oil at local industrial target customers.

The pilot demonstration phase is recommended in order to:

- Establish local workforce operations for residual wood harvesting and preliminary processing (chipping, drying);
- Develop familiarity and support of the local community for the bio-oil technology;
- Further improve the technology for bio-oil production and quality;
- Increase market interest for improved bio-oil products;
- Build confidence in potential industrial customers for use of the bio-oil and char as fuel or other uses;
- Build a baseline for regulatory permitting approvals for both production and use of the biofuels; and
- Allow local and national economic situation to stabilize (fuel prices, market).

Engineering, procurement, and implementation of the pilot demonstration program is targeted for 2009 and 2010, pending availability of project financing. A 10 dtpd system would produce approximately 400,000 gallons of bio-oil and 600 tons of char on an annual basis at full production. Combined costs of capital and five years net operating costs for the 10 dtpd system are estimated to cost approximately seven million dollars.

Preliminary negotiations are currently ongoing with two bio-oil technology providers. The demonstration plant is proposed to be located at the Nett Lake Sector of the Bois Forte Reservation. The University of Minnesota Duluth NRRI staff and resources would likely be involved with setup and testing of the demonstration program.

Jobs and Economics – Commercial Scale Plant

A 200 dtpd system would produce approximately 8,000,000 gallons of bio-oil and 12,000 tons of char on an annual basis at full production. Capital costs for the 200 dtpd system are estimated to cost approximately thirty million dollars and would create more than 100 short-term construction jobs and 35 long-term jobs. The jobs would likely be classified as medium to high skilled labor.

The study evaluated short term capital, and long term operations costs for three levels of sustainable, full scale commercial production (50 dtpd, 100 dtpd, 200 dtpd). The economics for this technology at “commercial scale” appear to look positive if field-chipped and delivered biomass feedstock costs are below $30/green ton and crude oil costs are above $100/barrel. Return on investment appears to be most promising at the higher end of the sustainable scale (200 dtpd).

In 2008, crude oil prices drastically fluctuated from greater than $140/bbl to less than $50/bbl. Factors that affect the short-term market are global economic outlook, hurricanes, decreased oil demand and terrorism.

While the price of oil will remain volatile over the next few years, the USDOE EIA 2009 Annual Energy Outlook predicts that by 2014 crude oil prices will return to prices exceeding $100/bbl, and continue to steadily rise for the next twenty years, exceeding $110/bbl by 2018.

Mandated carbon dioxide emission reduction programs may be an additional factor that may positively impact the value of the bio-oil. Replacement of fossil fuels with bio-oil would likely qualify the end user for carbon credits. Although federal legislative mandates are not currently in effect for carbon reduction, a lively market exists. The value of carbon dioxide reduction credits ranges between $1/ton and $10/ton dependant on the application. The value may exceed $30/ton dependant on when/if/and how federal carbon reduction programs are promulgated.

Funding Approach and Business Plan

The report includes detailed business plan and economic analysis for use in definition of project financing options, current grant/funding assistance opportunities and other potential incentives (green tag renewable energy credits, carbon credits, production credits, etc).

Several potential funding sources exist or are being set up to promote both the demonstration phase and commercial phases identified in this study. Several funding opportunities are associated with the National Biofuels Action Plan, the Farm Bill, and the Energy Independence and Security Act. Administration of the funding mechanisms is being executed by various entities within the USDOE, USDA, and USFS. Matching monetary and/or in-kind contributions from the State of Minnesota, local governments, and/or private sources will likely be required to secure overall funding.

Conclusions and Recommendations

The results of the study conclude that:

- Adequate woody biomass is available for a sustainable 50 to 200 dtpd process
- Production of bio-oil is technically feasible but the process can be improved to lower costs and improve bio-oil quality
- A local market exists for bio-oil use provided petroleum crude oil costs exceed $100/bbl
- A 50 to 200 dtpd commercial scaled bio-oil production facility would result in significant jobs and economic benefit for the Nett Lake Community, and
- a smaller scale 5 to 10 dtpd pilot demonstration facility is recommended to allow system improvements, increase familiarity, and prepare for a future market with higher crude oil prices and mandated carbon reduction programs.

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

List of Tables

Table of Contents (Continued)

List of Figures

List of Appendices

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Acknowledgements

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Abbreviations

AEO	Annual Energy Outlook
ASTM	American Society of Testing Materials
AURI	Agricultural Utilization Research Institute
bbl	barrel (42 gallons)
BIA	Bureau of Indian Affairs
Bois Forte	Bois Forte Band of Chippewa
BTU	British thermal unit
C	degrees Celsius
CERTS	Clean Energy Resource Teams
cft	cubic feet
CH4	Methane
CHP	combined heat and power
CO	Carbon Monoxide
CO2	Carbon Dioxide
CTL	cut to length
DME	Dimethyl Ether
DNR	Department of Natural Resources
DOE	United States Department of Energy
dtpd	dry tons per day
EIA	Energy Information Administration
F	degrees Fahrenheit
FIA	Forest Inventory and Analysis
FS	Feasibility Study
gpm	gallons per minute
gtpd	green tons per day
kW	kiloWatt
IRRB	Iron Range Resources Board
IRMP	Integrated Resources Management Plan
lbs	pounds
LEA	Laurentian Energy Authority
MFRC	Minnesota Forest Resources Council
MMBtu	Million British thermal units
MNDNR	Minnesota Department of Natural Resources
MSDS	Material Safety Data Sheet
MW	MegaWatt
NEPA	National Environmental Policy Act
NREL	National Renewable Energy Lab
Nett Lake	Nett Lake Sector of Bois Forte Reservation
NRRI	Natural Resources Research Institute
RTC	Reservation Tribal Council
SBIR	Small Business Innovation Research
SEH	Short Elliott Hendrickson Inc.
State	State of Minnesota
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service

Biofuel Feasibility Study

Prepared for Bois Forte Band of Chippewa

1.0 Introduction

The Bois Forte Band of Chippewa (Bois Forte) (or Band) has completed a detailed feasibility study of the technical and economic viability of developing a renewable energy biofuels demonstration facility on Bois Forte Reservation land in Northeastern Minnesota. This study was funded, in large part, via a grant from the State of Minnesota (State). This report summarizes the results of the study.

1.1 Goals of Study

The project envisioned will process up to 50 to 200 dry tons per day (dtpd) of forestry biomass to create a sustainable renewable fuel or energy. The primary goals of the project are to make more efficient use of resources on the Reservation - Nett Lake sector (Nett Lake) and surrounding area, increasing employment opportunities for tribal members, and production of domestic biofuels to reduce our energy dependence on fossil fuels and foreign sources.

The proposed facility offers the real potential of beginning a dynamic new industry at Nett Lake which could provide a number of jobs at several levels of pay and expertise for many Band members, which would allow them to make significant wages, develop technical and scientific careers, while remaining on or near the ancestral homeland. These economic benefits would also extend off the Reservation to surrounding communities in the form of new employment and increased purchases of local goods and services.

The project, when operational, will help the Bois Forte achieve the transition to a more renewable energy economy, putting them in the forefront of Minnesota Tribes making the transition to a sustainable energy independent economy.

1.2 Scope of Services

The following tasks were conducted to meet the objectives of the feasibility study:

- review types, quantities and prices of cellulosic biomass sources;
- analyze logistics of source supply and handling;
- evaluation of existing renewable energy technologies;
- technology selection;
- discuss optimal characteristics of production facility site;
- specify environmental review and site permitting parameters;
- determine potential customers and market;
- prepare preliminary Business Plan;
- analyze need for additional funding; and
- report preparation.

1.3 Project Background

In March 2007, the Bois Forte Multisource Cellulosic Biofuel Production Facility Scoping Report (SEH, March 2007) was prepared to begin examination of the feasibility of producing biofuels, energy, or other value-added products from cellulosic biomass resources available on the Nett Lake Reservation in Northern Minnesota. The Scoping Report, funded by Iron Range Resources, was completed by Short Elliott Hendrickson Inc. (SEH®) with assistance from the Bois Forte Reservation Tribal Council (RTC) and the University of Minnesota Natural Resources Research Institute (NRRI). The next step outlined in the report included this Phase 2 Technical and Economic Feasibility Study (FS) for a Phase 3 Renewable Energy Biofuels Demonstration Facility.

In May 2007, the Minnesota Agriculture and Veterans Omnibus Bill passed, and included a provision for a $300,000 grant to the Bois Forte Band of Chippewa to support the FS. A copy of the announcement is included in Appendix A, “Relevant Correspondence”.

Bois Forte retained the services of SEH and NRRI to assist the Renewable Energy Planning Committee with this FS. The Planning Committee includes members from Bois Forte Development Corporation and the Bois Forte Natural Resources Commission (including Forestry and Environmental Services Departments.)

Activities conducted since July 2007 included:

- biomass resource assessment to identify feedstock availability;
- multiple meetings with various technology developers, researchers, and vendors, and analysis of various technologies;
- multiple meetings with potential customers and analysis of markets;
- meetings with other local bands (White Earth, Red Lake, Fond Du Lac and St. Croix) engaged in similar activities;
- participation in quarterly Agricultural Utilization Research Institute (AURI) Energy Roundtable meetings;
- community and legislative updates to aid in technology selection; and
- FS report preparation.

1.4 Cellulosic Biofuels

The use of fossil fuels (petroleum, natural gas, and coal) as an energy feedstock is widely believed to be exacerbating global warming. In addition, our nation’s current dependence on petroleum imports has made our economic stability and military security vulnerable to the volatility of unstable regions of the world. In response to these concerns, our Federal and State governments are increasingly focused on funding research and development of fuels made from renewable cellulosic biomass (such as wood).

Plant matter (biomass) is the only known sustainable resource for the production of organic fuels and other biochemical resources that have become essential to modern life. Cellulose exists in vast quantities, widely dispersed all over the Earth in every form of plant matter. There are many deposits of cellulose-rich material which are now regarded as waste materials, in addition to the annual production of plants in our forests and fields. The cost and availability of many forms of cellulosic biomass offer the potential of making valuable fuels and chemical products at prices competitive with using oil and other fossil fuels.

Approximately one quarter of the nation's readily available cellulosic biomass resources is in the form of under-utilized forest and woody biomass and unused residue from forest industry such as saw dust, unusable trimmings, and forest thinning waste. A large quantity of this forest residue is found in northeastern Minnesota.

1.5 Bois Forte Reservation

The Bois Forte Band of Chippewa is located in Northern Minnesota and is one of six member Bands of The Minnesota Chippewa Tribe. Although organized under a single constitution, each of the six Bands operates quite independently in exercising governing authority over respective lands and communities. Bois Forte is governed by an elected Tribal Council comprised of 5 members elected to four year, staggered terms.

Over the past two decades, the Reservation Tribal Council has increasingly assumed its inherent authority to manage its own affairs. This is evident today as Bois Forte is a self-governance Tribe having assumed nearly all BIA and IHS functions including natural resources, roads construction and maintenance, law enforcement, civil and criminal jurisdiction and medical services. The Band operates a resort destination casino and hotel, Fortune Bay Resort. In addition, the Band owns and operates two convenience stores, a radio station, car wash manufacturing business and golf course. Bois Forte plays an important role to the economy of the region as a major employer of 500 persons and with the attraction of the resort, casino and golf course operations.

By treaty of 1866, and two subsequent Executive Orders, three parcels of land were set aside for the people. The Bois Forte Reservation is comprised of the Nett Lake, Lake Vermilion and Deer Creek sectors. Today some 600 Band members reside at the 103,000 acre Nett Lake sector and another 200 live at the 2,000 acre Lake Vermilion sector.

The Bois Forte Reservation encompasses approximately 105,000 acres of land in Koochiching and Saint Louis counties including the entire area around Nett Lake. Of this total, approximately 43,000 acres is Indian trust or U.S. Government land.

The reservation is almost entirely forested and isolated from population centers. The major industries are forestry and tourism. The Bois Forte Reservation at Nett Lake is a natural area of deep woods, wetlands and Nett Lake. Maintaining the visual and aesthetic quality of this area is an important factor to the Bois Forte people.

The Nett Lake community has a long history in the area dating back thousands of years. There is a widespread respect for traditional cultural values. Land Use practices include: low impact hunting of deer, fish, fowl, and other small game, and gathering of wild rice and other edible plants. The gathering of wild rice from Nett Lake in the traditional fashion is an extremely important element of this band's cultural identity.

In 2000, Bois Forte developed an Integrated Resource Management Plan (IRMP) to guide the preservation and development of all resources within their jurisdiction. This plan looks at all the resources important to the Bois Forte people including, forests, wildlife, wetlands, water quality, cultural resources and all plants and animals. The intention was to include all resources in a single unified plan that would identify potential conflicts, so these could be resolved through planning and cooperation. The IRMP is intended to be a management guide for the Bois Forte resource managers. It provides goals and objectives for present and future activities and decision-making. The IRMP provides general policies to guide the Tribal Council and resource managers in evaluating any specific project. The purpose of the plan is to delineate key natural resources of the Bois Forte Reservation and to prepare guidelines for management goals and objectives. This plan covers the ten year planning period from 2000 to

2010. The plan does not authorize any specific action, but any project must comply with the policies set forth in this plan. Any plan to use the forest resources of the Bois Forte must be consistent with the IRMP.

Most of the volume harvested each year on the reservation comes during the winter when frozen ground allows access to lowland sites or areas where the soil is sensitive to excessive compaction. There are some pine areas along Minnesota Highway 65 that can be logged during the summer months, but summer logging is limited by very wet weather and seasonal constraints to avoid insect infestations and to protect wildlife, lakes, ponds and wetlands.

There is an abandoned sawmill site at Nett Lake with a large accumulation of sawdust. This site is centrally located and could be a possible collection and/or processing point for wood wastes.

1.6 Report Layout

Chapter 2 provides a quantitative assessment of the biomass resources in the vicinity of Nett Lake, and addresses harvesting techniques for forestry biomass residuals.

Chapter 3 provides a brief summary of evaluation of opportunities for conversion of Bois Forte cellulosic biomass into various renewable energy options including, but not limited to, wood pellets, ethanol, bio-oil, and power. The chapter concludes with a recommendation to proceed with further evaluation of bio-oil production.

Chapter 4 outlines preliminary design considerations for moving forward with a bio-oil production facility including system components, staffing needs, and regulatory considerations.

Chapter 5 presents various business planning components required to move forward with execution. Planning including economic projections, market evaluation, funding options, business plan outline, and a community plan.

Chapter 6 presents a summary of conclusions and discussion of next steps.

Chapter 7 provides a list of reference and resources that were reviewed during the compilation of this report.

2.0 Resource Analysis

2.1 Introduction and Background

The purpose of this analysis is to evaluate the physical and economic availability of biomass for delivery to a potential energy facility operated by Bois Forte. Owing to the location of the Bois Forte Reservation in northern Minnesota, the primary source of biomass available for this project is assumed to be wood biomass derived from a variety of local sources. These potential sources include low value roundwood of various species, forest harvest residues, stand thinnings, and brushland. The purpose of this analysis is to quantify available resources and estimate transportation distance for wood biomass material delivered to the Nett Lake Sector of the Bois Forte Reservation, the assumed location for the processing plant. Figure 1, “Location of Nett Lake and Four 25-Mile Distance Bands Surrounding Nett Lake” below shows the location of Nett Lake with cover types and 25-mile distance bands surrounding Nett Lake.

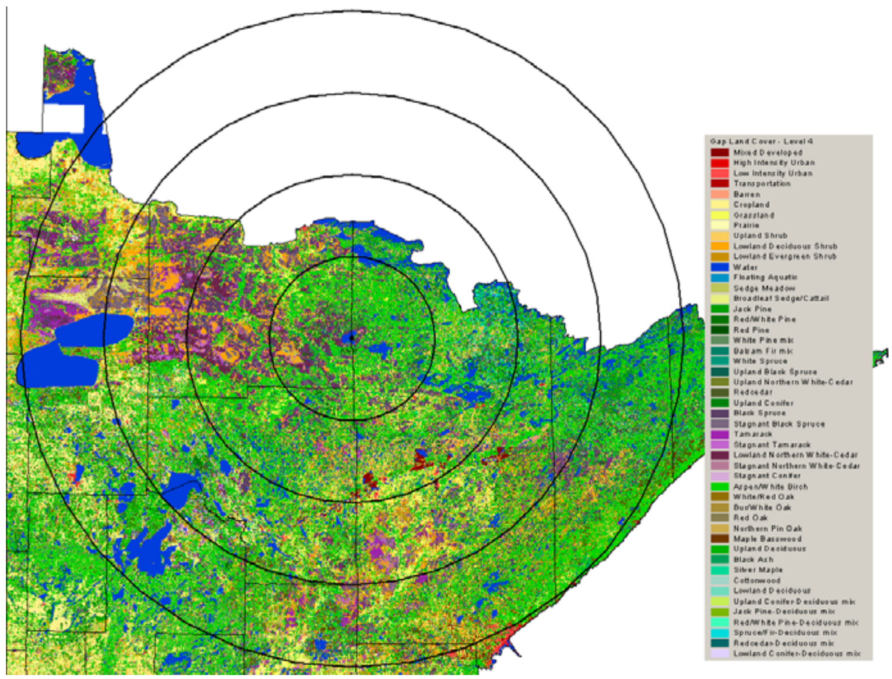

Figure 1 – Location of Nett Lake and Four 25-Mile Distance Bands Surrounding Nett Lake

In the past, using wood to replace fossil fuels was not an economically realistic proposition due to the fact that most fossil fuels were much less expensive than wood fuel. However, depending on the specific fossil fuel, there may be opportunities to replace fossil fuel with wood sources, particularly in those applications where heating oil and propane is used as the heat source. Also, the low mercury content may make wood an attractive alternative to coal in some applications. Table 1, “October 2008 Cost Comparison of Fossil Fuels to Various Wood Fuels Factoring in Estimated Combustion Efficiency” shows some common fuels and the current estimated cost per million British Thermal Units (MMBtu) factoring an expected combustion efficiency. The unit of MMBtu is a common way of expressing energy content of fuels in the United States. It should be noted that energy costs vary considerably and these costs are current as of October of 2008. It should be noted that energy prices are volatile and will vary dependant on date. In the case of the wood resource, two prices are assumed to be representative of a range of expected delivered costs for both roundwood and forest harvest residues.

Table 1
October 2008 Cost Comparison of Fossil Fuels to Various Wood Fuels Factoring in Estimated Combustion Efficiency

Fuel	$/unit	unit	$/MMBtu	efficiency	net cost
Natural Gas	$8.00	MMBtu	$8.00	0.9	$8.88
Heating Oil	$3.70	gallon	$28.46	0.85	$33.48
Propane	$2.39	gallon	$26.55	0.9	$29.50
Round Wood	$75.00	cord	$3.83	0.6	$6.38
Round Wood	$100.00	cord	$5.11	0.6	$8.52
Wood Chips	$20.00	gr. ton	$2.35	0.6	$3.92
Wood Chips	$30.00	gr. ton	$3.52	0.6	$5.88
Wood Pellets	$180.00	dry ton	$10.58	0.8	$13.23
Coal	$60.00	ton	$3.00	0.6	$5.00

As shown in the table above, wood may be considered an economically realistic energy source particularly when compared to heating oil or propane. Natural gas, where available, is the least expensive form of energy for residential and commercial energy needs. However, in those rural areas where natural gas is not available, transportable fuels such as heating oil and propane are the most common fuel. As a result, rural areas are affected to a greater degree by high fuel prices than urban areas due to the fact that space heating costs using oil or propane are three to four times that of natural gas. It is not uncommon for older oil-burning furnaces to have combustion efficiencies near 65% which results in a net cost of $44 per MMBtu nearly five times that of natural gas. As a result, wood pellet stoves and outdoor wood boilers are becoming more common than has been the case in the past. Pellet-derived energy is roughly half of the cost of propane and about forty percent of heating oil.

2.2 Resource Analysis

The analysis of biomass availability involves a combination of factors including physical availability as well as economic availability. The physical nature of the resource includes such factors as location, species composition and volumes being harvested in the state. The price of the biomass is affected by trucking distance, the type of harvesting system, new equipment needed to process biomass, volume available and form of the material. The major wood sources for the project are assumed to be comprised of roundwood and forest harvest residues with a minor component of brushland biomass. These sources are described below.

2.3 Roundwood Sources

The majority of wood harvested in the state is harvested in “roundwood” form which is comprised of the larger-sized portion of the main tree stem or bole. Most forest products manufacturers require that tree bark be separated from wood prior to being used in the manufacture of paper or building products. Because of the requirement for debarked wood in these processes, only the larger portion of the stem is able to be used due to the fact that debarking technology can only effectively remove bark from stems that have a minimum diameter of approximately three inches. The remaining portions of the tree consists of bark produced by debarking larger-diameter sections in the mills and “forest harvest residue”, typically the smaller-sized material such as tree tops and limbs which are available at the harvest site. Bark is commonly used as an energy source in all forest products mills and is not generally available for purchase on the open market. Thus, roundwood derived from species not desired in manufacturing forest products and forest harvest residues are expected to be a significant part of woody biomass that could potentially be used for energy production. Because of the more strict requirements of forest products mills, most of the available roundwood of desired species such as Aspen and many other species is expected to continue to be used by the paper and building products mills. However, there may be opportunities to use roundwood of those species that are less valuable in current markets for energy production.

A section of the report will evaluate expected prices for wood material, both in roundwood and residue form. The price to purchase the right to harvest forests is referred to as “stumpage price” and represents the price per unit volume of wood, typically a cord comprised of 128 cubic feet of space (roughly 79 cubic feet of solid wood). Due to the need to produce debarked wood mentioned above, a minimum top-diameter is assumed for the main bole of the tree. This main stem volume to a given minimum top-diameter is considered merchantable wood. All other non-merchantable portions of the tree (e.g. tops and limbs) and small diameter trees that may be present on the site are potentially harvestable for biomass to produce energy. The term “potentially harvestable” is used to indicate that not all biomass that is available will actually be harvested due to considerations for wildlife and site impacts. This issue will be discussed in greater detail further in the report.

Wood is bought and sold through private negotiations with non-industrial private landowners or, in the case of public lands, prices are set through the process of public auction. This system of marketing wood results in an efficient means to determine the price of a variety of species and products due to the fact that the prices are set through open bidding by many loggers and timber buyers. The stumpage price is only one component of the delivered wood cost. In addition to stumpage prices, logging and transportation costs combine to produce a delivered price to a wood-using facility.

Available statewide forest inventory data was used to estimate locally available wood supplies. Forest resources are monitored continuously by the U.S. Forest Service under the USDA’s Forest Inventory and Analysis (FIA) Program. The FIA inventory is conducted by placing a series of measurement plots across the entire state in the forested regions and information on forest stands at those locations is collected. Data collected as part of this inventory program includes land use, ownership, species composition, tree size, tree condition as well as tree growth. The FIA is the most extensive inventory program of its kind in the United States and is useful to determine the amount of timber potentially available for new markets such as energy production.

For purposes of this analysis, we used the FIA timberland acreage information for stands surrounding Nett Lake, Minnesota. Although the total amount of forested acreage statewide is approximately 16.3 million acres, 14.9 million acres are considered “timberland”. Timberland acreage is that portion of the total forested acreage that is considered potentially available for harvest. The remaining acreage is specifically restricted from harvest due to recreational use (ex. Boundary Waters Canoe Area Wilderness) or other set-asides. The acreage of timberland surrounding Nett Lake was calculated in 25-mile distance bands out to 100 miles to evaluate the amount of timber potentially available and estimate trucking costs associated with procuring a greater amount of resource. Obviously, the scale of the project will affect the size of the procurement zone for a given facility. The greater the amount of wood required, the greater the area that will be required to meet the needs of the processing facility. We assumed two levels of consumption for the assumed facility, 50 dtpd and 200 dtpd which equates to 18,250 and 73,000 dry tons, respectively, on an annual basis.

Timberland acreage surrounding Nett Lake was determined using the FIA data by forest covertype, or dominant species. The amount of harvested timber in the four distance bands is estimated by combining the timberland acreage and the total statewide harvest, currently assumed to be approximately 3.7 million cords. The current statewide harvest was allocated proportionately based on timberland acreage in each distance band around Nett Lake assuming a uniform harvest level statewide. It is important to note that current harvest is lower than the harvest level of 3.7 million cords annually due to reduced demand associated with production cutbacks in the oriented strandboard industry. As a result, the longer-term harvest level of 3.7 million cords used in this analysis may be slightly higher than current actual harvest. Also, the sustainable productivity potential of Minnesota's forests is estimated to be 5.5 million cords, roughly forty five percent higher than the 2005 harvest level of 3.7 million cords annually.

Table 2, "Timberland Acreage Surrounding Nett Lake by Distance Band and Forest Covertype" shows the estimated amount of timberland acreage by forest covertype in distance bands surrounding Nett Lake. The total percentage of statewide timberland by distance band is 6.9, 19.5, 35 and 56 percent within the 25-, 50-, 75- and 100-mile distance bands, respectively. The total statewide harvest of 3.7 million cords is then allocated according to these percentages. For example, the total amount of cordage expected to be harvested annually within 50 miles of Nett Lake is 19.5 percent of the statewide total or 720,455 cords. The estimated cordage harvest is converted to dry tons using a conversion factor of 1.15, roughly 2,300 dry pounds per ton. All data shown below are expressed in dry tons available annually.

Table 2
Timberland Acreage Surrounding Nett Lake by Distance Band and Forest Covertype

Cover Type	25 Mile radius	50 Mile radius	75 Mile radius	100 Mile Radius	Statewide Total
Jack Pine	22,031	76,842	131,459	188,546	356,355
Red Pine	27,146	96,804	176,961	307,653	562,656
Eastern White Pine	9,170	37,362	51,788	97,257	151,107
Balsam Fir	39,253	94,593	178,790	320,531	393,381
White Spruce	10,833	22,941	32,787	67,120	111,063
Black Spruce	130,190	474,592	844,914	1,181,783	1,335,033
Tamarack	32,625	170,726	432,236	715,641	868,215
Northern White Cedar	109,079	226,691	377,178	502,941	571,915
Eastern Red Cedar	0	0	0	0	25,623
Other Softwoods			796	796	5,665
Oak	787	3,385	5,775	45,211	724,512
Northern Hardwoods	22,375	83,914	203,340	561,367	2,050,457
Lowland Hardwoods	86,202	211,807	375,158	569,609	1,104,834
Cottonwood/Willow	4,571	12,263	27,192	41,737	107,074
Aspen	435,011	1,086,094	1,820,164	2,833,076	4,849,747
Birch	49,778	156,510	306,550	545,194	999,186
Balsam Poplar	46,998	111,352	195,085	267,614	464,007
Non Stocked	10,520	51,904	95,406	135,518	228,235
Other	796	796	796	796	79,694
Total	**1,037,364**	**2,918,573**	**5,256,375**	**8,382,390**	**14,988,759**

For purposes of this analysis, the total wood resource was compared to two assumed annual demand values corresponding to 50 and 200 dtpd. This equates to 18,250 and 73,000 dry tons annually for the two demand levels, respectively. As a means of comparison, it is not unusual for an average sized forest products mill to consume 350,000 dry tons of roundwood annually. Therefore, even at the maximum assumed demand level of 73,000 tons, the potential demand of a new facility is roughly one fifth that of an average existing mill. The maximum and minimum values of 50 and 200 dtpd are shown in the analyses to include the upper and lower bounds of this range of potential demand.

Having estimates of total forest acreage and harvested amounts with distance is a necessary starting point but does not provide information on important aspects of the resource, namely, species-specific availability and prices. When evaluating the roundwood resource, it is important to consider the relative demand and price on a species-specific level to evaluate opportunities to procure biomass in roundwood form for a prospective energy project. Ideally, new industrial expansion in the energy area should not compete with the established forest products industry in order to maintain and increase overall employment and economic opportunities in the region. Trading one job for another does little for the communities dependent on logging and employment in forest product mills. Also, competition for a limited resource is unnecessary if energy applications are not limited to using species which are already in high demand. For this reason, our analysis focuses on low-demand roundwood species as well as forest harvest residues.

2.3.1 Low Stumpage-Value Roundwood Resource

Species currently used for papermaking and building product manufacturing such as Aspen, spruce and balsam fir have unique wood properties that make them preferable in these applications. As such, these species have been in relatively high demand historically and continue to be the mainstay of the forest products industry. However, as shown in Table 3, Statewide Harvest in 2005, Allowable Cut by Covertype Category", some species have relatively low demand such as northern hardwoods (maple, basswood), lowland hardwoods (black ash, cottonwood) and tamarack relative to statewide allowable cut published by the Minnesota Department of Natural Resources (MNDNR). Overall, the difference between the 2005 harvest and the statewide estimated allowable cut is approximately two million cords with the bulk of this available cordage be found in the low-demand species mentioned. Table 4, "Cumulative Covertype Acreage, Percentage of the Statewide Total and Incremental Available Cordage with Distance from Nett Lake of Selected Low-valued Forest Types" summarizes the available cordage in vicinity of Nett Lake.

Table 3
Statewide Harvest in 2005, Allowable Cut by Covertype Category

Forest Type (MNDNR covertype)	2005 Harvest (cords)	Allowable Cut (cords)	Harvest/Allowable (percent)	Difference (cords)
Jack Pine	303,900	118,375	256.7%	-185,525
Red Pine	159,700	340,000	47.0%	180,300
Eastern White Pine	8,000	86,950	9.2%	78,950
Spruce/Fir	401,800	705,500	57.0%	303,700
Tamarack	64,700	114,800	56.4%	50,100
Northern White-Cedar	8,000	8,000	100.0%	0
Oak	120,200	499,300	24.1%	379,100
Northern Hardwoods	194,900	709,900	27.5%	515,000
Lowland Hardwoods	82,000	353,600	23.2%	271,600
Aspen/Balsam Poplar	2,011,400	2,358,000	85.3%	346,600
Birch	332,500	371,500	89.5%	39,000
	3,687,100	5,665,925	65.1%	

Note: allowable harvest for jack pine is estimated on a 50 year rotation and statewide harvested volume of 18 cords/acre.
Source: MNDNR Forest Resources - 2007 and harvest intensity expressed as percent and absolute difference

Table 4
Cumulative Covertype Acreage, Percentage of the Statewide Total and Incremental Available Cordage with Distance from Nett Lake of Selected Low-valued Forest Types

Cover Type	25 Miles	50 Miles	75 Miles	100 Miles	Statewide Total	Cords Available
Cover Type Acreage (cumulative)						
Red Pine	27,146	96,804	176,961	307,653	562,656	180,300
Tamarack	32,625	170,726	432,236	715,641	868,215	50,100
Northern Hardwoods	22,375	83,914	203,340	561,367	2,050,457	515,000
Lowland Hardwoods	86,202	211,807	375,158	569,609	1,104,834	271,600
Covertype % (cumulative)						
Red Pine	4.8%	17.2%	31.5%	54.7%		
Tamarack	3.8%	19.7%	49.8%	82.4%		
Northern Hardwoods	1.1%	4.1%	9.9%	27.4%		
Lowland Hardwoods	7.8%	19.2%	34.0%	51.6%		
Estimated Available Cords (incremental)						
Red Pine	8,699	22,322	25,686	41,880		98,586
Tamarack	1,883	7,969	15,090	16,354		41,296
Northern Hardwoods	5,620	15,456	29,995	89,923		140,995
Lowland Hardwoods	21,191	30,877	40,156	47,802		140,026
Total Incremental	37,392	76,624	110,928	195,958		420,903
Total Cumulative	37,392	114,016	224,944	420,903		

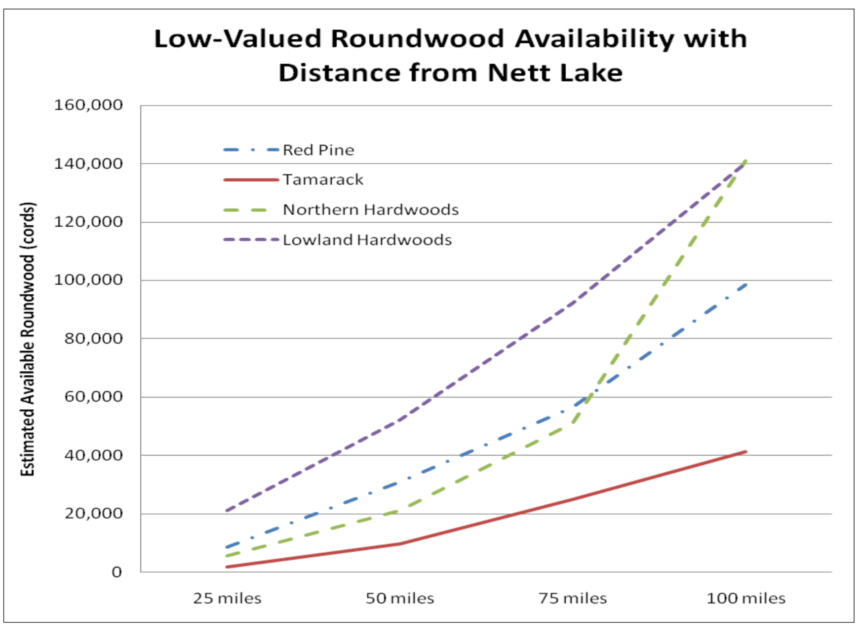

Figure 2 – Estimated Cumulative Low-Valued Roundwood Volume Available in 25-mile Distance Increments from Nett Lake, Minnesota

From the above tables and graph, approximately 400,000 cords of low-valued roundwood is potentially available surrounding Nett Lake with the majority of this volume being made up of the lowland and northern hardwood covertypes. The cumulative volume of all low-valued species with distance shown in Table 4 indicates that the total high-demand scenario of 73,000 dry tons (200 dtpd) could be met within a 50 mile radius. Obviously this assumes that all available material will be available exclusively to the Bois Forte project which is likely not the case. However, there appears to be roundwood material of species that are not in high demand currently in sufficient quantity to meet even the high-demand scenario.

2.3.2 Energy Content by Tree Species

Given the fact that significant quantities of low-valued species are available for the project, it is instructive to consider the relative densities and energy content of these species. The following table shows estimated energy contents for the various trees species common in Minnesota. Information on energy content as measured directly by calorimetry is not available and, as such, the energy content is estimated based on the specific gravity of the various tree species as shown in the USDA, Forest Products Laboratory Wood Handbook. Research has shown that the bulk of the variation in energy content among species can be attributed to variation in specific gravity with some additional variation in extractives content. As expected, conifers with naturally higher levels of extractive will have a slightly higher energy content than shown in the table. Therefore, the values in the tables are reasonable estimates of energy content based on a standard volume, cord in this case, without accounting for extractives content.

The values in Table 5, “Estimated Energy Content of Common Minnesota Tree Species” assume an average energy content of 8,500 BTU per pound (17 MM BTU per ovendry ton) and an average wood volume of 79 cubic feet and bark volume of 11.9 cubic feet (13% bark content on average). Based on this information, the estimated energy content can vary considerably from a high of 30.3 MMBtu per cord for oak to a low of 14.9 for northern white cedar. The average energy content of low-valued species is higher than other species such as Aspen with black ash, paper birch, sugar maple and tamarack being 23.6, 26.5, 30.3 and 25.5 MMBtu per cord, respectively. Thus, the energy content of these lower-valued species is actually higher than a higher- valued species such as Aspen. This underscores the fact, with some exceptions, there are opportunities to use a portion of the wood resource for energy without competing for wood being used by the current forest products industry. Based on this information, a value of 1.3 dry tons per cord was used in our analyses to account for higher densities of low-valued species.

Table 5
Estimated Energy Content of Common Minnesota Tree Species

Tree Species	SG	lbs/cubic ft	Dry lbs/cord[1]	Wet Wt/Cord	Est MMBtu/Cord	$/MMBtu[2]
Black Ash	0.49	30.5	2,775	5,550	23.6	$2.97
Green Ash	0.56	34.9	3,171	6,342	27.0	$2.60
Bigtooth Aspen	0.39	24.3	2,208	4,417	18.8	$3.73
Quaking Aspen	0.38	23.7	2,152	4,304	18.3	$3.83
Basswood	0.37	23.0	2,095	4,190	17.8	$3.93
Paper Birch	0.55	34.3	3,115	6,229	26.5	$2.64
Balsam Poplar	0.34	21.2	1,925	3,851	16.4	$4.28
American Elm	0.5	31.1	2,831	5,663	24.1	$2.91
Red Maple	0.54	33.6	3,058	6,116	26.0	$2.69
Sugar Maple	0.63	39.2	3,568	7,135	30.3	$2.31
Oak (Pin/Red)	0.63	39.2	3,568	7,135	30.3	$2.31
N. White Cedar	0.31	19.3	1,755	3,511	14.9	$4.69
Balsam Fir	0.35	21.8	1,982	3,964	16.8	$4.16
Jack Pine	0.43	26.8	2,435	4,870	20.7	$3.38
Red Pine	0.46	28.7	2,605	5,210	22.1	$3.16
Black Spruce	0.46	28.7	2,605	5,210	22.1	$3.16
White Spruce	0.4	24.9	2,265	4,530	19.3	$3.64
Tamarack	0.53	33.0	3,001	6,003	25.5	$2.74

Notes:
[1] assumes 79 cubic feet of solid wood/cord and 11.9 cubic feet of bark at same density
[2] based on $75.00/cord delivered price

2.3.3 Stumpage Price

Due to relatively low demand for these species, stumpage price for these species are lower in value than those in higher demand. For example, Table 6, “Saint Louis County Stumpage Price Results by Species from August 2008 Oral Auction” shows prices for major species in a recent set of auction sales in Saint Louis County, Minnesota held in August of 2008. As expected, those species that have relatively low demand are those that command the lowest price. Stumpage prices for low-demand species range from slightly less than $4.00 per cord in the case of Black Ash to slightly more than $7.00 per cord in the case of tamarack. While these prices are likely to go up with increasing competition for energy applications, the current value is considerably less than high-demand species. Assuming a harvest cost of $30.00 per cord and that the average stumpage value increases to $15.00 per cord, the cost at the landing is estimated to be $45.00 per cord. Trucking costs will be discussed further in the report to provide an estimate of the expected delivered price to Nett Lake for both roundwood and harvest residues.

Table 6
Saint Louis County Stumpage Price Results by Species from August 2008 Oral Auction

Tree Species and Form	Volume Sold (cords)	Average Sold Value ($/cord)
Ash pulpwood	885	$3.85
Aspen pulpwood	22,090	$25.98
Balm of Gilead	325	$23.80
Balsam Fir pulpwood	3,480	$17.24
Basswood pulpwood	1,402	$5.46
Birch pulpwood	6,449	$10.73
Red Maple pulpwood	2,598	$4.68
Sugar Maple pulpwood	1,324	$4.60
Red Oak pulpwood	0	$0.00
Jack Pine pulpwood	1,870	$24.47
Norway Pine pulpwood	1,725	$20.18
Black Spruce pulpwood	5,637	$26.70
White Spruce pulpwood and bolts	1,330	$22.70
Tamarack pulpwood	2,015	$7.23
White Pine pulpwood	1,073	$35.67
Total	**52,203**	

2.3.4 Trucking Costs

After discussions with trucking firms and adjustment of data to reflect higher fuel prices, we estimate that the average trucking cost per one-way mile is $3.75. To put this in context, the fuel efficiency of an average truck is assumed to be five miles per gallon. Based on a current price of $4.00 per gallon for diesel fuel, the contribution to the total one-way trucking cost is $1.60 of the $3.75, roughly forty percent. Non-fuel expenses such as salaries, benefits, truck purchase and insurance are paid with the balance after accounting for fuel.

Distance from Nett Lake is calculated in straight-line distance using the FIA databases. In reality, the transportation system is not a straight line and will be greater. Using a value of $3.75 as a starting point, we assumed that the actual distance will result in a 25% increase in per-mile trucking rates. Thus, a more realistic trucking rate used in our analysis is $4.68 per one-way mile.

The average wood hauling capacity of trucks is assumed to 25 tons. Using the average density of 1.3 dry tons per cord (2.6 green tons/cord), the total cordage that could be hauled is estimated to be 9.6 cords. Dividing the trucking cost of $4.68 per mile by the average weight of 9.6 cords results in a trucking cost of $0.488 per loaded cord-mile.

2.3.5 Estimated Delivery Price

As mentioned above, the three major components of the delivered price are stumpage, harvesting and transportation. Based on the information cited above and accounting for an increase in competition for the resource, we estimate that the longer-term average stumpage rate for low-valued roundwood will be $15.00 per cord. In our discussions with loggers and those involved in the industry, we are estimating an average harvest cost of $30.00 per cord. For purposes of this study, these values are assumed to be uniform across the state. Table 7, "Estimated Stumpage, Harvesting, Trucking and Delivered Price of Low-valued Species with Distance with Total Cost On A Per-Cord and Dry Ton Basis" shows stumpage, harvesting, trucking cost with distance and the composite delivered costs using a trucking cost of $4.88 per one-way mile.

Table 7
Estimated Stumpage, Harvesting, Trucking and Delivered Price of Low-valued Species with Distance with Total Cost On A Per-Cord and Dry Ton Basis

Distance (miles)	25	50	75	100
Stumpage	$15.00	$15.00	$15.00	$15.00
Harvesting	$30.00	$30.00	$30.00	$30.00
Trucking	$12.19	$24.38	$36.56	$48.75
Total Cost/Cord	**$57.19**	**$69.38**	**$81.56**	**$93.75**
Dry-Ton Cost	**$43.99**	**$53.37**	**$62.74**	**$72.12**

To put these costs in context, the average energy content of most wood species is 8,500 BTU per pound or 17 MMBtu per dry ton. Without discounting for conversion losses due to the presence of water in wood fuels, the 75-mile value of $62.74 would result in an energy cost of $3.69 per MMBtu. Referring to table 1 of this report, this price is lower than that of many fossil fuels. However, conversion losses of at least 25% can be expected which would result in a more realistic direct comparison price closer to $4.92 per MMBtu, still lower than most fossil fuels except coal. Although raw fuel price may be lower than that of prevailing fossil fuels, the difference between wood fuel and fossil fuels must be sufficiently great to justify new investment in capital to use solid fuels such as wood biomass.

2.4 Forest Harvest Residues

As mentioned at the beginning of this report, the two dominant sources of biomass for the project are roundwood of currently non-merchantable species as well as forest harvest residues. The total estimated roundwood harvested is used to estimate the tonnage of forest harvest residues (e.g. top and limb material) that can be expected to be associated with a given level of roundwood harvest. By definition, harvest residue results from the harvesting of trees for roundwood production and the availability of harvest residues is directly tied to roundwood harvest levels. As mentioned above, forest harvest residues consist of tops and limbs that are not generally used in the manufacture of paper or building products. There are exceptions to this such as the Georgia Pacific plant in Duluth which can use whole-tree material in the production of wet-process hardboard but, for the most part, residue material is not used to produce traditional forest products such as paper or oriented strand board.

2.4.1 Site Level Guidelines

Recently, site-level guidelines for biomass harvesting and removal of forest harvest residues have been developed through the efforts of the Minnesota Forest Resources Council. These guidelines are voluntary and include management recommendations to mitigate against impacts to site productivity, soil nutrients and wildlife effects associated with biomass removal on both forested and brushland sites. While there are numerous recommendations that are designed for a variety of situations, the overall net effect of the guidelines related to removal of forest harvest residue biomass is a reduction in the total amount removed by 20%. This assumes that one in five loads of top and limb material will be redistributed on the harvest site. Also, removal of top and limb material is not recommended on nutrient-poor sites such as ombrotrophic peatlands and shallow-to-bedrock soils. Taken together, we assumed that the recommendations would reduce the total potential amount of biomass by a factor of 25% overall. This factor is used in the subsequent analysis to reduce estimates of statewide availability of forest harvest residues.

2.4.2 Estimate of Statewide Harvest Residue Biomass

A critical question regarding assessments of available tonnages of forest harvest residues relates to determination of the percentage of the total harvested volume that is made up of residue material. Multiple approaches have been used to evaluate the appropriate percentage of harvest residues for Minnesota conditions including individual tree analysis and larger-scale studies such as the Logged Area Analysis study done by the MNDNR, Forestry Division. For purposes of this report, a detailed discussion of the methodology will not be included but will be briefly presented. The reader is referred to a document referenced by the Iron Range Resources website published by Berguson in the fall of 2007 which describes the methodology in greater detail. (This document can be found at http://www.irrrb.org/_site_components/documents/user/businessforest106.pdf.)

Table 8, "Volumes Harvested by Major Species, Residue Percentages and Estimated Residue Availability Statewide" shows the estimated timber harvest levels by species group using a combination of harvest data reported by the MNDNR, the percentage residues reported by the MNDNR Marketplace, conversions to estimate green tons from cordage and the resulting estimated amount of residues produced through harvesting of pulpwood and sawlog products.

Table 8
Volumes Harvested by Major Species, Residue Percentages and Estimated Residue Availability Statewide

Cords (1,000s) Harvested by Product Type								
Species	Pulpwood	Sawlogs	Residential*	Commercial	Total	%Residue	Cord:gr ton conversion	Residue (gr tons)
Aspen	1794.4	69.6	16.7	0.6	1881.3	25%	2.25	1,058,231
Birch	240.2	27.1	41	6.3	314.6	33%	2.30	238,781
Balm	119.2	1.2	0	0.1	120.5	25%	2.40	72,300
Ash	17.4	8.3	15.1	0.2	41	33%	2.50	33,825
Oak	0.8	73.3	45.1	1	120.2	33%	2.75	109,082
Basswood	24.7	21.6	1.3		47.6	33%	2.30	36,128
Maple	98.9	12.7	15.8	4.7	132.1	33%	2.50	108,983
Cottonwood	0.6	11.6	0		12.2	25%	2.50	7,625
Other Hardwood	3.1	13.8	8.1		25	33%	2.50	20,625
Red Pine	46.4	114.7	2.9		164	11%	2.35	42,394
White Pine	2.4	7.6	1.4		11.4	11%	2.20	2,759
Jack Pine	155.9	147.7	1.7		305.3	11%	2.30	77,241
Spruce	164.5	18.4	0		182.9	23%	2.10	88,341
Balsam	167.1	7.2	0		174.3	23%	2.35	94,209
Tamarack	39.7	1.8	0.7		42.2	11%	2.50	11,605
Cedar	0.2	6.6	0.4		7.2	23%	1.45	2,401
Other Softwood	0.1	1.1	0		1.2	23%	2.20	607
Total Hardwood	2299.3	239.2	143.1	12.9	2694.5			
Total Softwood	576.3	305.1	7.1	0	888.5			
Total All Species	2875.6	544.3	150.2	12.9	3583			2,005,137

From the above table, the total biomass produced annually is estimated to be roughly two million green tons or one million dry tons at 50% moisture content (green weight basis). The ratio of green tons of harvest residues to the overall cordwood volume is 0.56 (2,005,137 green tons divided by 3,583,000 cords harvested). Expressed on a dry weight basis, this ratio is 0.28 assuming 50% moisture content. Assuming the same species mix is harvested in the future, this ratio can be applied to the maximum sustainable harvest level of 5.5 million cords to estimate potentially available harvest residues assuming future harvest should approach the 5.5 million cord level. The estimated amount of harvest residues associated with this level of harvesting is approximately three million green tons or 1.5 million dry tons of forest harvest residues.

Another factor that is important to consider is the additional biomass that may be derived from the smaller-sized portion of trees that are encountered on current harvested sites. In order to estimate the amount of this material potentially available, we used the FIA inventory data filtering out all stands less than forty years of age (assured that we were including only those stands in the merchantable range) and calculated the total statewide live-tree volume by diameter class. For purposes of this analysis, we assumed that trees in the five-to-six inch DBH range are too small for roundwood production but would be harvested if a biomass market were available. Including all forest cover types, the average percentage of live volume that occurs in this DBH class is twelve percent. This material could potentially add to the total realized amount of forest harvest residues. Also, we conducted the same analysis exclusively on the Aspen type as we were concerned that the presence of Black Spruce, by nature a small-diameter species, would skew this analysis. The average percentage of small-diameter material (5-6 inch DBH trees) in the Aspen covertype was found to be approximately 11%, not a significant difference from the overall analysis including all species. We did not carry this information forward in the analysis in this report but mention it as a potential additional source of wood biomass if markets are developed for biomass material.

After review of all of the relevant sources of data, no one singular source can be used to definitively estimate the applicable residue percentage for forest harvest residues statewide. All sources have some limitation in one way or another depending on the specific source. In the case of individual tree data on a specific species, there may be additional biomass in non-merchantable trees and other higher-residue species such as most hardwoods other than Aspen. Stand-level data such as the Logged Area Analysis study did not have roundwood harvest data associated with these sites and as such, make it difficult to apply to roundwood harvest data statewide. Starting with an overall ratio of 0.28 dry tons residue-to-cordwood and reducing this value by 25% to account for the guidelines produces a value of 0.21 which was used in our analysis.

2.4.3 Estimate of Nett Lake Low-Valued Roundwood and Harvest Residue Biomass

Using the methodology described above, the total estimated amount of low- valued roundwood and harvest residues by distance to Nett Lake is shown in Figure 3, “Available Biomass in Low-Valued Roundwood and Harvest Residues with Distance to Nett Lake”. Also, Table 9, “Forest Harvest Residue Biomass and Low-Valued Roundwood Biomass Availability and Ratio of Available:Demand with Distance from Nett Lake” shows the biomass available in low-valued roundwood and harvest residues with the ratio of each biomass form to the assumed total demand at two levels. As shown, the total amount of available wood appears to be adequate and in most cases the demand for wood resources can be met without reaching past twenty five miles. In the most extreme case of high demand, 25-mile distance and relying strictly on forest harvest residue, the ratio of available material to demand is 1.5. For sake of clarity, this value indicates that 150% of the required material is available under this set of assumptions. All scenarios including low-valued roundwood and harvest residue with greater distance show that the wood resources are expected to be more than adequate to meet the demand of a facility at Nett Lake. The total available biomass is estimated to be 110,452 dry tons within 25 miles, 322,211 dry tons within 50 miles, 605,785 dry tons within 75 miles and 1,046,887 dry tons within 100 miles of Nett Lake. According to the Bois Forte IRMP, the total allowable cut for all reservation lands is 12,886 cords. Thus, the amount of timber within the 25-mile zone that could be expected to be cut from property under management by Bois Forte is roughly ten percent of the total expected amount. At the lowest level of assumed demand (50 tons/day or 18,250 dry tons per year), the timber volume cut from Bois Forte lands could account for as much as 18,523 dry tons; slightly more than what is required assuming the low demand level or about twenty five percent of the high demand level. This value includes 14,819 dry tons of roundwood (12,886 cords allowable cut from Bois Forte properties) as well as harvest residues associated with this roundwood harvest of 3,705 dry tons. Given this analysis, the potential exists to completely satisfy the demand for woody biomass for a facility at Nett Lake through timber under management by the Bois Forte Department of Natural Resources assuming the lower level of demand.

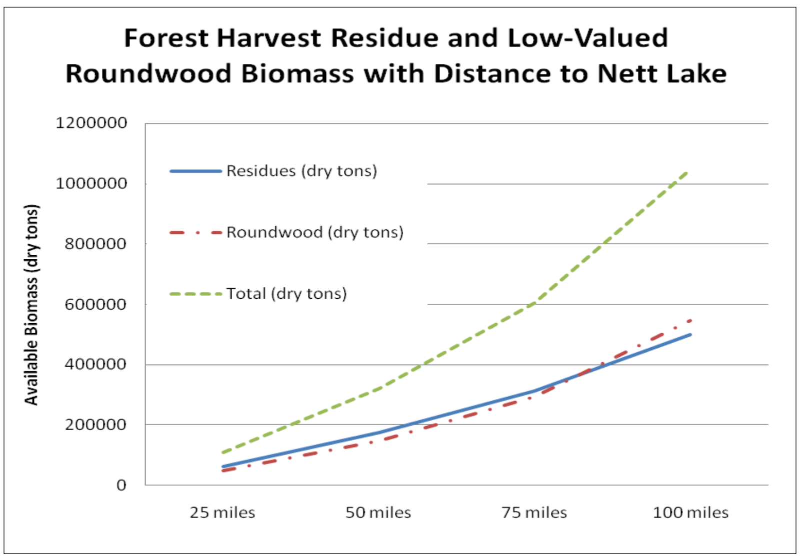

Figure 3 – Available Biomass in Low-Valued Roundwood and Harvest Residues with Distance to Nett Lake

Table 9
Forest Harvest Residue Biomass and Low-Valued Roundwood Biomass Availability and Ratio of Available:Demand with Distance from Nett Lake

Distance from Nett Lake	25 miles	50 miles	75 miles	100 miles
Residues (dry tons)	61,842	173,990	313,357	499,713
Low-Valued Roundwood (dry tons)	48,610	148,221	292,428	547,173
Total (dry tons)	110,452	322,211	605,785	1,046,887
Coverage Ratio				
Minimum Demand - 50 dtpd	6.1	17.7	33.2	57.4
Maximum Demand - 200 dtpd	1.5	4.4	8.3	14.3

2.4.4 Forest Harvest Residue Pricing

The current pricing policy for those landowners selling forest harvest residues is similar across agencies. The MNDNR assesses $0.60 per 1000 pounds of material with no distinction between dead and green biomass (Lillian Baker, personal communication). The St. Louis County Land Department procedure is to assess a charge of $1.00 per cord-equivalent (Matt Butorac, personal communication). This results in an estimated cost of less than $0.50 per green ton. These prices are relatively low and it is likely that prices will increase with increasing competition for the resource. For purposes of this analysis, we assumed that prices will increase to $5.00 per green ton or $10.00 per dry ton on all ownerships.

2.4.5 Delivered Harvest Residue Price

Similar to the calculation of delivered price of low-valued roundwood, the cost components of delivered price include stumpage, processing and transportation costs. We assume that the majority of biomass will be produced by logging operations using in-woods chippers. The following section on equipment estimates a cost for chipping of roughly $17.00 per dry ton ($8.37 per green ton). Also, the same capacity of 25 tons per load or 12.5 dry tons, is assumed which results in a per-mile trucking cost of $0.375 per ton-mile one-way haul. Combining these values, Table 10, "Cost components and total Estimated Delivered Cost of Forest Harvest Residue Material to Nett Lake, Minnesota with Distance" shows estimated delivered cost of harvest residue material by distance from Nett Lake.

Table 10
Cost components and total Estimated Delivered Cost of Forest Harvest Residue Material to Nett Lake, Minnesota with Distance

Distance from Nett Lake (miles)	25	50	75	100
Stumpage ($/dry ton)	$10.00	$10.00	$10.00	$10.00
Chipping ($/dry ton)	$17.00	$17.00	$17.00	$17.00
Trucking ($/dry ton)	$12.19	$24.38	$36.56	$48.75
Total Cost/Cord ($/dry ton)	**$39.19**	**$51.38**	**$63.56**	**$75.75**

2.4.6 Current Demand for Forest Harvest Residues

Demand for forest harvest residues exists currently by mills in Minnesota using these materials. The only forest products mill that currently uses significant quantities of forest harvest residues is Georgia Pacific at Duluth, a hardboard manufacturer. In the past, most of the forest residue material has been left on site due to lack of markets. With the construction of the biomass burning facilities in St. Paul and the Laurentian Energy Authority (LEA) project on the Iron Range, demand for energy wood has increased considerably. Also, Minnesota Power has been in the process of evaluating the feasibility of a 25 megawatt biomass-fired plant at the Syl Laskin location near Hoyt Lakes in northern Minnesota. The Minnesota Power project is partially in response to the recent passage of the 25 X 25 legislation in Minnesota which sets a goal to replace twenty five percent of the coal-fired electrical generation by the year 2025. After initial analysis, the Minnesota Power project at Hoyt Lakes has been put on hold due to high construction costs and investments in other alternative power sources such as wind. However, other power generating facilities are using wood with the existing Minnesota Power facilities using a combination of wood waste (bark and railroad ties) with a lesser component being comprised of forest harvest residues.

A recent development in this area is the announcement by Renewafuels to establish a facility near Cusson, Minnesota to produce briquettes for the taconite mining industry. This plant is expected to produce 150,000 dry tons of biomass briquettes. It is unknown at this time the specific mix of materials that will ultimately be used to produce this fuel but it is likely that the bulk of the material will be comprised of wood in some form. For purposes of this report, an assumption of 50% of the Renewafuel feedstock will be forest harvest residues. This balance could be comprised of low-valued roundwood or other plant materials. Given the fact that Cusson is only twenty miles from Nett Lake, the potential exists for local competition for biomass. Factoring the total expected demand of 150,000 dry tons for the Renewafuels project and 73,000 dry tons for the maximum-demand Bois Forte scenario would result in a total annual demand of 223,000 dry tons. Due to the fact that increasing mileage increases the area intercepted by the square of distance, adding 25 miles to the haul would increase the delivered price by approximately $10.00 per dry ton while adding about 1.5 times the amount of biomass with each 25-mile increment. The total estimated biomass from both sources is 675,000 dry tons at 75 miles. This indicates that sufficient material should be available for both projects in the area.

Table 11, "Minnesota Mills Currently Using Forest Harvest Residues and Annual Biomass Demand in Green Tons" is the estimated current and near-future demand for forest harvest residues in the state.

Table 11
Minnesota Mills Currently Using Forest Harvest Residues and Annual Biomass Demand in Green Tons

Mill	Dry tons	Comments
GP-Duluth	100,000	green tons/year - all residue – Brian Lochner
SAPPI	100,000	Personal conversation – Ross Korpela
MP Grand Rapids	30,000	100,000 total tons (25 to 30% from harvest residues)
MP Hibbard	9,000	90,000 total tons (10% from harvest residues)
LEA	140,000	
St. Paul District Energy	25,000	estimated - 1400,000 tons total - urban wood waste
Altrista	15,000	Cloquet, Minnesota former Diamond Brands
Renewafuel	75,000	Assumed ½ of needed biomass is residues
Total	494,000	

2.4.7 Harvest Residue Processing Equipment

A significant factor in determining availability of harvest residues is the logging infrastructure. While resources are important, the logging industry will ultimately affect the ability to bring the resource to market. There is a variety of equipment that can be used to process forest harvest residues including chippers, grinders and potentially, slash bundlers. There may be a need for the Bois Forte project to evaluate the equipment owned by local logging contractors, particularly tribal logging operations. In most cases, the lowest-cost option is to purchase a small chipper to be used to chip tops and limbs at the same time that roundwood is being produced. Integration of a chipper with the current roundwood production system is relatively straightforward. However, purchase of new equipment requires a steady market with a known revenue stream. Therefore, it may be necessary for active participation of Bois Forte in assisting tribal loggers with markets and financing for additional equipment. The following section evaluates the costs and capital requirements for a typical logging operation.

2.4.7.1 Equipment and Cost Calculations

The cost and practical feasibility of efficiently producing forest harvest residues is dependent on the harvesting system being used. Forestry operations in Minnesota are conducted using two dominant harvesting systems, conventional and cut-to-length, often referred to as CTL. The conventional harvesting system involves felling of trees and skidding of whole trees to a centralized landing for further processing. Trees are delimbed and bucked into 100-inch or tree-length sections and loaded onto trucks for delivery to the mill. In the case of the conventional system, trees can either be delimbed on the landing or at some other location within the logging site. However, once trees are felled, skidders are able to transport the material to the landing. This system facilitates relatively straightforward collection of tops and limbs because they can be skidded in whole-tree form to the landing. The residue material can then either be chipped on-the-fly as roundwood is being produced or residues can be piled and chipped or ground at a later date after the logging operation has been completed.

The CTL system employs a felling, delimbing and bucking system in one processing machine and produces small piles of roundwood at the site of felling of the tree. The roundwood is moved and loaded onto trucks via a forwarder. These systems don’t lend themselves to collection of top and limb material because the trees are processed on-site and not skidded to a landing in whole-tree form. According to communications with staff from the Minnesota Loggers Education Program (Dave Chura), approximately twelve percent of the logging firms use the CTL system in Minnesota. Given this fact, as markets develop for forest harvest residues, about ninety percent of the logging system currently in place is equipped to readily produce forest harvest residues.

For purposes of our analysis, we considered different harvesting and equipment scenarios used to process forest harvest residues. These are: 1) use of a smaller chipper integrated into a roundwood harvesting operation with harvest residues chipped at the same time as roundwood is being produced (in-line system), 2) the logger piles tops and limbs at a landing and the material is chipped by a chipping contractor at a later time using a larger-sized (higher throughput) chipper and, 3) harvest residues are piled near the landing and is processed using a horizontal or tub grinding system. Options 2 and 3 are similar in concept with the only difference being the equipment used to process the residue material.

2.4.7.2 In-Line Chipping Systems

We spoke with logging firms currently operating chippers to determine the type of equipment needed to process logging residues. Those operating chippers in-line (processing residues simultaneously as roundwood is being produced) have used chippers on the smaller end of the range of whole-tree chipping product lines. Our contacts indicated that the smaller family of chippers are preferred because they took less space on a log landing and were more cost-effective than a larger chipper while, at the same time, were sufficiently large to process slash and smaller whole-trees. For purposes of our analysis, we assumed that the chipper was operated by remote control (an option for all chippers quoted) and fed by the slasher operator. Therefore, we didn’t assume an additional labor cost in our calculations of variable costs. This method is currently used by chipping contractors and was the assumed system for our analysis.

Quotes on purchase price and information on operating and maintenance costs for forestry chippers were obtained from regional manufacturers including Morbark, Dynamic and Bandit. The models used in this type of application are assumed to be a Morbark Model 20/36, Bandit Model 1850 or similar models. It should be stated that the various models vary in purchase price and fuel consumption and slight variations in processing costs will result depending on the specific model chosen. The purpose of this analysis is to estimate an average expected production cost assuming a representative chipping system. Chippers in this range are priced from approximately $150,000 to $175,000 with no cab and loader. Chippers typically include the option of a conveyor bed feeding system to handle unconsolidated slash in addition to whole trees.

Utilization rate is an important issue in this analysis as it affects the quantity produced annually in operation and fixed costs are directly affected by utilization rate. In this type of use, fixed costs are distributed over a lesser amount of tonnage thereby increasing the fixed cost per ton of product. Also, the size of the logging operation will obviously affect the number of hours that the chipper is run in a given year. We assumed that the average operation is producing 15,000 cords per year. According to a survey conducted by Applied Insights North (John Powers, 2004) for the Blandin Foundation, a level of 15,000 cords per year is near the average for many producers. According to this survey (based on numbers from the Minnesota Logger Education Program), there are a total of 454 logging operations in the state with the average logging operation producing roughly 12,000 cords annually. In order to estimate a range of realistic prices, we conducted our analysis assuming, two levels of residual value (20% and 50%) at an annual production rate of 15,000 cords.

In most cost analyses obtained from manufacturers, the chipper is assumed to run anywhere from 100 to 200 days per year, eight hours per day. This is not realistic for purposes of an in-line operation. Operating hours and annual variable costs were modified to more realistically reflect the use of a chipper in an in-line application. These modifications were done to account for the reality that a chipper in this type of system is “captive” on a logging job and is not being moved from site-to-site. Therefore, the amount of forest harvest residues that could be processed in any given day depends on the output of the total logging system, not the theoretical maximum output of the chipper itself. Considering the fact that most chippers can process roughly thirty green tons per hour, the chipper has significant overcapacity relative to the logging system as a whole. For example, a typical 100-cord per day logging operation is expected to produce roughly 40 green tons of residue per day, or approximately 1.5 trucks per day. In conversations with logging contractors, slash material is allowed to accumulate and the slash is processed periodically during the day. We assumed that the chipper would be operated for 1.5 hours per day to process residues. This fact was confirmed with a larger logging contractor who indicated that a chipper used in his operation is run approximately 400 hours per year in the type of application. Given this situation, we assumed that the chipper was run 1.5 hours per day for 200 days per year for a total of 300 hours per year.

We obtained updated price quotes from manufacturers which included estimated purchasing, financing, insurance and operating costs. Costs such as purchase, interest and insurance are fixed and don’t vary with the quantity of residue material processed. In our calculations of annual fixed costs, we assumed that the chipper was financed for a five-year period at a seven percent interest rate and had a 20% residual value after the five year period. This is conservative assumption (i.e. more expensive to the mill than may be the actual case) due to the fact that the typical life of a chipper is approximately 10,000 hours.

As explained above, the utilization rate assumed by the manufacturers is too high for purposes of this analysis and the chipper will likely have considerably fewer hours per year than assumed by manufacturers; 1,500 hours in a five-year span. This is assuming a logger producing 15,000 cords per year, a slightly higher production rate than the average logger in Minnesota. However, we used the five-year, 20% residual value as the baseline estimate. In addition, we recalculated the fixed costs using a higher residual value to evaluate the effect of a 50% residual ratio.

Using the assumption of a $175,000 purchase price and a 20% residual value, the annual fixed costs were estimated to be $38,783. Assuming a 50% residual value, the annual fixed costs are reduced by $10, 500 to $28,283. This equates to a reduction in processing cost of $1.55 per green ton assuming a logging operator was processing 6,750 green tons annually. Table 12, "Summary of Cost Calculations for a Mid-sized Chipper Assuming a 20% Residual Value and 15,000 Cord/Year Logging Production Level" below shows the calculations of fixed and variable costs that are used in this analysis under the 20% residual value, 15,000 cords per year scenario. As can be seen in the following table, the total estimated output of harvest residuals using a 20% ratio of residues to roundwood is 6,750 green tons annual output for a 15,000 cord per year operation. Variable costs for knife maintenance and fuel on an hourly basis are estimated to be $59.00 per hour. The total annual variable cost for this operation is estimated to be $17,700 (300 hours X $59.00/hour). Incorporating fixed and variable costs, the chipping cost per green ton is estimated to be $8.37 per green ton or approximately $17.00 per dry ton.

Table 12
Summary of Cost Calculations for a Mid-sized Chipper Assuming a 20% Residual Value and 15,000 Cord/Year Logging Production Level

Cost Estimate for Mid-Sized In-Line Chipper	
Purchase Price	$175,000
Residual Value	0.2
Fixed Costs (annual basis)	
Depreciation	$28,000
Interest (7% for 60 months)	$6,583
Insurance	$4,200
Variable Costs/Hour	
maintenance - chipper knives	$14.00
fuel (10 gals/hr @ 4.50)	$45.00
Total Variable/hour	$59.00
Operating Assumptions	
operating hours/day	1.5
operating days/yr	200
operating hours/yr	300
Total Fixed Costs/yr	$38,783
Total Variable Costs/yr	$17,700
Total Annual Costs	$56,483
Cords logged annually	15,000
Green tons:Cords Ratio	0.2
Cord-green ton conversion (tons/cord)	2.25
Cord-equivalent of harvest residues/yr	6,750
Chipping Cost ($/green ton)	**$8.37**

2.4.7.3 Larger Chipping and Grinding System

The second system analyzed assumes that a contractor purchases a large grinder and loader to process slash from sites that have been previously logged. This assumes a contractor would pay the logger to stack slash near the landing or roadside and the grinding system would follow the logging operation. Due to seasonal considerations, we assume that the grinding and loading takes place shortly after the logging operations have ceased. Therefore, the same road system is used for both the logging and chipping or grinding operation.

Unlike the in-line chipping system, this approach is not constrained by the size of the logging operation itself. Thus, we assume that harvest residues from any logging operation that is operating a convention system would be potentially available for collection of harvest residues. The same general financial calculations were done as in case 1 above with a five year payback period and 20% residual value. We assumed that the sites are an average of 30 acres in size with 25 cords per acre of roundwood volume per acre. Therefore, the total residue biomass per site is estimated to be 338 green tons. In addition to the grinder, a loader is assumed to be needed to load slash into the machine. Also, the cost of staff needed to arrange sites for processing is assumed to be $10,000 annually. A fee is paid to the logger to stack the slash in an orderly way for processing at a cost of $2.00 per green ton. The net result of this analysis is that processing costs are estimated to be $12.43 per green ton for the grinding system. The assumptions and calculations for the grinding/loading system are shown on Table 13, “Cost and Operating Assumptions and Calculations for a Grinder/Loader Production System”.

Table 13
Cost and Operating Assumptions and Calculations for a Grinder/Loader Production System

	Grinder	Loader
Purchase Price	$284,180	$174,880
Residual Value	20%	20%
Fixed Costs (annual basis)		
Depreciation	$45,469	$27,981
Interest (7% for 60 months)	$10,689	$6,578
Insurance	$6,820	$4,197
Variable Costs/Hour		
maintenance – other than bits	$25.14	$10.93
maintenance – bits	$17.49	
fuel (20 gals/hr @ $4.50, 15 gal/hr-loader)	$90.00	$67.50
operator ($/hr) - remote from loader	$0.00	$27.33
Total Variable/hour	$132.63	$105.76
Total Fixed Costs/yr	$62,978	$38,756
Total Variable Costs/yr	$198,941	$158,633
Total Annual Costs	$261,919	$197,388

**Table 13 (Continued)
Cost and Operating Assumptions and Calculations for a Grinder/Loader Production System**

	Grinder	Loader
Operating Assumptions		
Acres/sale	30	
Cords/acre	25	
Residue %	20%	
cord-equivalents of residues per acre	5	
green lbs/cord	4,500	
green tons/cord-equivalent	2.25	
green tons of residue per sale	338	
operating hours per sale	11.25	
days/sale (includes moving)	1.5	
working days	200	
sales/year	133	
green tons processed per year per unit	45,000	
Operating Hours/year	1,500	
Other services		
Staff needed to line up sales	$10,000	
Stacking of residue (paid to loggers)	$90,000	
Processing/Loading Cost ($/green ton)	$5.82	$4.39
Staff	$0.22	
Stacking	$2.00	
Total Estimated Cost/Green Ton	**$12.43**	

A third option to use a larger chipping/loading system may be slightly less expensive (by about $1.00) per green ton but the constraints on the type of material going into a chipper are higher due to the need for relatively clean biomass. Chipping knives can be dulled by dirt in the slash, a potentially difficult problem in processing residues that have been piled after the logging job has been completed.

2.5 Forest Thinnings

An additional potential source of biomass is through thinning of stands to improve quality of the remaining stand. The most immediate source of biomass from thinning is from Red Pine stands. Thinning of Red Pine is practiced routinely as part of the management of these stands. By controlling stand density through thinning, diameter growth of remaining trees in increased, thereby increasing stand quality. An analysis of Red Pine acreage by age class surrounding Nett Lake was done to evaluate the potential for Red Pine thinning in the vicinity of Nett Lake. This analysis showed that the majority of Red Pine plantation acreage is located outside of the 25-mile zone. This is not unexpected in light of the high proportion of lowland acreage in the area surrounding Nett Lake and Red Pine is most commonly found on drier sites. However, as distance increases, more acreage in the proper age classes (greater than age 25) is available. This analysis shows that approximately 11,000 acres of plantation Red Pine between the ages of 25 and 40 is within the 50-mile zone. Assuming, an area of approximately 700 acres annually available for thinning and eight dry tons of pulpwood-sized material (about 40% of the total thinned volume), the total annual production of Red Pine pulpwood is estimated to be approximately 6,000 tons; roughly one third of the low demand assumption.

Opportunities may exist to extract smaller-sized trees from dense Aspen stands. However, research is required to evaluate the effect of thinning on subsequent stand growth in this stand type. Also, the cost of collection and the equipment required to accomplish thinning in Aspen is not developed at this time. In light of these considerations, the volume that could be extracted from these stands is not immediately available. If proven feasible, there is likely an additional six to ten dry tons per acre that could be extracted through thinning of Aspen stands at mid-rotation. However, this option is not proven and is not dealt with in detail in this report. The NRRI, along with cooperating agencies, is in the process of establishing a set of field trials evaluating thinning in mid-rotation (age 25) Aspen stands and will collect data to determine the biological effects of thinning in the ensuing years.

2.6 Fire Hazard Reduction

Generally speaking, Minnesota is not a high priority for federal efforts to reduce fire hazard. Funding allocation for fuels reduction is concentrated in drier areas of the country with high population density that threaten large populations. As a result, most of the funding dedicated to fire hazard control activity is concentrated in the western United States. However, a minor effort in fuels reduction is ongoing in the state with some fuel-reduction dollars allocated to enhance activities on federal forests. However, little additional wood volume is expected to be generated from these activities due to the fact that fire control is usually included as part of an ongoing sale. As such, this does not typically result in more timber volume being brought to market. Conversations with personnel managing federal forestlands indicates that funding for reduction of fire hazard are not likely to significantly increase wood availability in the immediate area.

2.7 Brushland Biomass

The potential exists to harvest woody biomass from brushlands, which constitute a significant portion of Northern Minnesota. These areas are dominated by small diameter Willow and Alder which occur in fragmented stands in brushland complexes. The quantity of the resource and the economic feasibility of harvest is a subject of current research underway by the NRRI and the Minnesota DNR. This research is expected to be completed within a year and more accurate estimates of costs and amounts will be made available. This resource is viewed as supplemental to low-value roundwood and residue biomass but will not substantially alter the basic conclusions of this report.

3.0 Cellulosic Biomass to Energy Technology Review

3.1 Introduction

In July 2007, members of the project team traveled to Golden, CO and met with representatives of the National Renewable Energy Lab (NREL) to review our project goals and solicit input.

In Fall 2007, Bois Forte released a general solicitation to innovative biomass to energy technology developers, and has subsequently initiated exploratory meetings with various companies. Potential options considered include:

- Solid (wood chips, pellets, briquettes)
- Liquid (ethanol, bio-oil)
- Gas (gasification for combined heat and power; and gasification with further processing to produce dimethyl ether, methanol or diesel)

3.1.1 Intellectual Property Protection

In order to gain access to information (and subsequent facility visits) Bois Forte and SEH signed confidentiality agreements with several of the technology providers. Information presented here is general in nature in an effort to not reveal specific information viewed as confidential.

3.2 Green Wood Chips

3.2.1 Description

Production of green wood chips from the available woody biomass was considered as a baseline to the study.

3.2.2 Project Team Activities

In addition to the evaluation of chipping technologies provided in chapter 2, members of the project team observed two chipping operations – a chipping demonstration of woody residues at Fond du Lac Reservation, and an on-site chipping demonstration at Nett Lake in an area of forest devastation. Additionally, representatives from Minnesota Power and from LEA held separate meetings with the project team to express interest in purchasing wood chips from the Nett Lake Sector. This activity could serve as an interim step until the biofuel demonstration project can be implemented.

3.2.3 Technology Providers

There are several providers of wood chipping equipment including: Morbark, Dynamic, Bandit, and John Deere.

3.2.4 Potential Markets for Products

The market appears to be increasing for wood chips within a 100 mile radius of Nett Lake including a new biomass to energy system Ft Francis, Ontario; a potential wood pellet plant in Mt Iron, Minnesota; a potential wood briquette plant near Orr to support Iron Range mining operations; a potential biomass to energy facility in Hoyt Lakes, Minnesota; and the existing LEA biomass to energy facility in Virginia, Minnesota.

3.2.5 Relevance to Technology Development in Minnesota

The technology for production of this fuel type is well established and several potential equipment vendors are available.

As this is an established technology, with competition already developing in the region, it is not likely to be viewed as favorably when compared to other developing technologies (such as cellulosic ethanol or Bio-oil) when competing for special financing incentives or funding programs.

3.2.6 Impact on Resources

The manufacturing process uses little to no water, produces no toxic by products, and does not create significant air emissions.

3.2.7 Economic Overview

Current production of wood chips in the Nett Lake vicinity by tribal loggers is limited due to lack of chipping and/or grinding equipment. If adequate harvesting equipment is made available to tribal loggers, it is possible that an immediate increase of biomass harvest could occur to support the outlying customer base. An additional 4 jobs is estimated per each additional 100 dtpd harvest. For purposes of our analysis we assumed an average price of $25/ green ton delivered.

3.2.8 Discussion

This category was included to provide a baseline analysis to evaluate opportunities for biomass residual harvesting without any further processing, and therefore is not given further consideration with regards to selection of an option for a biofuel demonstration project.

3.3 Wood Pellets or Briquettes

3.3.1 Description

Wood pellets and briquettes are similar in that they are both manufactured by a combination of drying, grinding, and compressing wood materials into dense, uniform shapes. Wood pellets are generally about ½ inch size, while briquettes are larger, similar to the size of hockey pucks. The dry, densified, uniform wood products have superior handling and storage characteristics when compared to raw wood chunks or chips.

3.3.2 Project Team Activities

The project team reviewed literature and interviewed several technology providers and companies producing pellets or briquettes, including active members in the Pellet Fuels Institute. Activities included a tour of an operating pellet plant in northwestern Minnesota and a tour of an operating briquette plant in Iowa.

3.3.3 Technology Providers

The Pellet Fuel Institute identifies more than twenty established pellet equipment providers include California Pellet Mill, Buhler, and Bliss. There are more than 80 pellet mills in operation in North America. Briquette plants are less common.

3.3.4 Potential Markets for Products

Wood pellets may be utilized as a fuel in residential or commercial pellet burning stoves and also may be used in industrial boilers. Pellets and the larger briquettes are increasingly being used as supplements or replacements for fossil fuels such as coal or natural gas in large heating and/or power production applications. The market appears to be growing for this fuel type as costs for propane or heating oil are on the rise, and as regulations of coal use become more stringent (due to carbon and mercury emissions).

The export market for pellets and briquettes also appears to be increasing. The European Union has set energy targets at 10% of energy production and 22% of electricity generation from renewable sources by the year 2010, requiring a major contribution from biomass imports

3.3.5 Relevance to Technology Development in Minnesota

The technology for production of this fuel type is well established and several potential equipment vendors are available.

As this is an established technology, with competition already developing in the region, it is not likely to be viewed as favorably when compared to other developing technologies (such as cellulosic ethanol or bio-oil) when competing for special financing incentives or funding programs.

3.3.6 Impact on Resources

The manufacturing process uses little to no water, produces no toxic by products, and does not create significant air emissions.

3.3.7 Economic Overview

Capital costs for 100 dtpd system would be approximately $6 million and would create approximately 10 new jobs (assuming 3 shifts). The jobs would likely be classified as low to medium skilled labor.

The current retail market value of wood pellets has recently been estimated to be an average of $250/ton nationwide and as high as $300/ton in the northeast United States. The economics for this technology appear to look positive in spite of falling petroleum oil prices. Economics are likely to improve even more when crude oil (and thus heating oil) prices return to an upward trend.

3.3.8 Discussion

In the current market, the option appears to be the most economically feasible. However implementation of a demonstration project for solid fuel wood pellets or briquettes would do little to forward development of future biofuels.

3.4 Cellulosic Ethanol

3.4.1 Description

Ethanol is a well established transportation liquid fuel supplement or replacement for gasoline. However the production of ethanol has typically been from corn or sugarcane. Production of ethanol from cellulosic biomass such as wood is receiving a great amount of attention.

While there are many possible system configurations and technology sequencing combinations available, there are two basic ways of producing ethyl-alcohol (ethanol) from cellulose:

- Cellulolysis processes which consist of hydrolysis on pretreated lignocellulosic materials followed by fermentation and distillation.
- Gasification that transforms the lignocellulosic raw material into gaseous carbon monoxide and hydrogen. These gases can be converted to ethanol by fermentation or chemical catalysis.

3.4.2 Project Team Activities

The team contacted several potential cellulosic ethanol developers and found that most of the companies were not good matches for our project due to a variety of reasons including: much larger scale sizes were needed; desired proximity to existing corn ethanol facilities; proximity to sites such as pulp and paper mills where the cellulosic waste is considered to be a “free” resource; or desire for close proximity to research and academic organziations such as large universities.

Meetings were held with several potential companies (including Pearson, EZ Ethanol and KL Energy) that are considering stand-alone woody biomass to cellulosic ethanol systems.

3.4.3 Technology Providers

There are several technology developers independently pursuing different pathways for production of cellulosic ethanol. These include Range Fuels, Verenium, Iogen, Blue Fire, Mascoma, Pearson, SunOpta, Coskata, EZ Ethanol, and KL Energy.

3.4.4 Potential Markets for Products

The market for ethanol as a transportation fuel is well developed. Mandates for ethanol biofuels have been legislated to encourage a market exists for the product.

3.4.5 Relevance to Technology Development in Minnesota

The technology for cellulosic ethanol is still very much in the research and development stage, and it is not clear which processess will be the ultimate winners. It is likely that a demonstration project for cellulosic ethanol would be a relatively short term (<5 year duration) research and development demonstration project. Long term sustainable operation of the current system model would not likely occur without iterative technology improvements (and associated additional capital).

3.4.6 Impact on Resources

The manufacturing process does require significant water inputs, may require significant air pollution controls, creates a flammable product, and currently does create a significant amount of solid waste product (due to system inefficiencies that are being improved).

3.4.7 Economic Overview

Based on candid conversations with several technology developers, production does not yet appear to be economically feasible on a sustained basis without incentives.

Dependant on the technology, capital costs for 100 dtpd system would range from ten to twenty million dollars, and would create approximately 30 new jobs (3 shifts). The jobs would likely be classified as medium to high skilled labor.

Based on the current cost of competing petroleum fuels, the economics for this technology appear to be poor at the production scale Bois Forte is interested in. Even when crude oil prices were at a record high it had not yet been demonstrated that a stand-alone wood to ethanol plant would be economically viable, even with production tax credits. However, due to the high level of attention currently being given to cellulosic ethanol, this technology would likely to be viewed very favorably when competing for special financing incentives or funding programs.

3.4.8 Discussion

The scale of the Bois Forte project does not appear to fit well with this technology at its current level of development.

3.5 Bio-oil

3.5.1 Description

Bio-oil is a renewable "carbon neutral" organic liquid fuel made from biomass via fast pyrolysis, the process of chemical decomposition of organic materials by heating in an oxygen-free environment. A major fraction of the combustible gas created is condensed into liquid bio-oil. In addition to the combustible gas and liquid bio-oil, a byproduct of the process is char, a solid material that can either be used as a stand-alone fuel, mixed back in with the bio-oil, or used as a soil amendment for agriculture. Recent interest in bio-oil production is partially driven by the perception that bio-oil production facilities may provide a market for biomass feedstocks, and therefore can stimulate rural economic development as well as provide a source of domestic energy production.

3.5.2 Project Team Activities

Per advice from researchers at NREL, the team took a close look at the bio-oil technology because the scale appeared to match well with Bois Forte's sustainable harvest. The team contacted of the technology providers listed in the next section and have had continuing ongoing discussions with four of the companies, as well as University researchers. Site visits were made to examine three bio-oil plants (two bench-scale and one commercial scale plant). Meetings with potential customers included large industrial users, power companies, and refining companies.

3.5.3 Technology Providers

There are a limited number of companies currently pursuing bio-oil technology development in North America. These include

- Dynamotive Energy Systems Corporation (Dynamotive)
- Ensyn Technologies Inc. (Ensyn)
- Frontline BioEnergy (Frontline)
- Renewable Oil International LLC (ROI)
- Advanced Biorefinery Inc. (ABRI)

In addition to the list above, there are other technology developers in Europe and elsewhere.

Dynamotive is an energy solutions provider headquartered in Vancouver, Canada, with offices in the USA and Argentina. Its carbon/ greenhouse gas neutral fast pyrolysis technology uses medium temperatures and oxygen-free conditions to turn dry waste biomass and energy crops into Bio-oil® for power and heat generation. Bio-oil® can be further converted into vehicle fuels and chemicals. Dynamotive is currently focusing on 200 dtpd size facilities. Dynamotive has been at the forefront of developing the bio-oil market via support of several demonstration projects using bio-oil to replace petroleum-based heating oil. Dynamotive is also conducting research to improve bio-oil qualities for use as a feedstock at petroleum refineries to produce transportation fuels.

Ensyn was incorporated in 1984 to commercialize its proprietary biomass to liquid technology, Rapid Thermal Processing (RTP)™. Ensyn has designed, built and commissioned seven commercial RTP™ plants in the United States and Canada; the largest, located in Renfrew, Ontario, processes 100 tons of dry residual wood per day. Projects now under way will result in plants five to 10 times the size of the Renfrew plant. Headquartered in Ottawa, Ontario, Ensyn also has operations in the United States. It was recently announced that Ensyn (teamed with UOP, NREL, and USDA) has been awarded funding by the DOE to develop methods to improve bio-oil stability, with the ultimate goal of producing transportation fuels.

Frontline is a relatively new technology development firm, founded in 2003 and located in Ames Iowa. Frontline focuses on technology and integrated systems to convert biomass residues into useful energy products through thermochemical processes (gasification and pyrolysis). With funding from a USDA Small Business Innovative Research (SBIR) grant, Frontline has been operating a laboratory bench-scale bio-oil system at its headquarters to develop high quality bio-oil via hot gas filtration. Frontline is exploring opportunities to scale up the system to a pilot scale operation. Frontline's has had recent success working with Chippewa Valley Ethanol Company (CVEC) to scale up an innovative thermal gasification system to large scale (75 ton per day with planned upgrades to 300 ton per day) in Benson, MN.

ROI, headquartered in Alabama is a company developing fast pyrolysis biorefinery technology to fractionate wood and other types of biomass into high-value products. The ROI technology has a design that can be factory fabricated in transportable modules, relatively low operating and maintenance costs, does not require boilers or process water, is cost effective at relatively small scale, is capable of processing many different biomass materials, and produces a liquid product with multiple energy and non-energy markets. It was recently announced that ROI (teamed with University of Massachusetts) has also been awarded funding by the DOE to develop methods to improve bio-oil stability, with the ultimate goal of producing transportation fuels.

ABRI is headquartered in Ottawa, Canada and is currently involved in the design and development of technology for the extraction of energy from biomass and its conversion to fuels and bio-products, the most common being the production of bio-oil from the pyrolysis of agricultural biomass. ABRI has developed processes for many types of biomass waste from forestry, agriculture, municipal and industrial sources. ABRI's systems are typically less than 10 dtpd.

3.5.4 Potential Markets for Products

Bio-oil is a replacement for bunker fuel and may be used as a fuel supply in industrial kilns, compatible gas turbines, or co-fired in power plants. Bio-oil may also potentially be further refined into higher end liquid fuels via catalytic cracking equipment typically located at petrochemical refineries. Bio-oil is also used in production of the food flavoring Liquid Smoke®

Char, a byproduct of the pyrolysis process, has potential markets as a solid fuel, coking agent, or soil supplement.

3.5.5 Relevance to Technology Development in Minnesota

The federal government has a strong interest in bio-oil and is spending significant funds on research and development to improve fuel stability issues and improve its properties to allow easier refining. Dr. Roger Ruan at the University of Minnesota is currently conducting research on microwave pyrolysis for distribute fuel production in agricultural settings.

We are not aware of any demonstration size bio-oil plants in Minnesota.

3.5.6 Impact on Resources

The manufacturing process does not require significant water inputs, does not require significant air pollution controls, creates a combustible product, and does not create a waste byproduct.

3.5.7 Economic Overview

Capital costs for a 100 dtpd system would cost approximately 20 million dollars and create approximately 23 new jobs (3 shifts). The jobs would likely be classified as medium to high skilled labor.

The economics for this technology appear to look positive if oil costs remain above $100/barrel. As this is considered to be a developing technology, it is likely to be viewed favorably when competing for special financing incentives or funding programs.

3.5.8 Discussion

This option appears to be the most viable option for a demonstration project at the scale being considered.

3.6 Gasification for Combined Heat and Power

3.6.1 Description

Gasification of woody biomass was considered to produce combined heat and power (CHP) for Nett Lake or the Fortune Bay facilities on Lake Vermillion.

3.6.2 Project Team Activities

The team met with three gasification equipment companies, and also met with the local power supply company to discuss the potential for net metering etc. Additionally, NRRI conducted thermal gasification tests on woody biomass samples from Nett Lake. The results of the tests are included in Appendix B, "NRRI Thermal Gasification Data" and may provide valuable data in the event that thermal conversion technology is utilized. There appears to be some difference in the gas composition from poplar and red pine with the poplar producing more hydrogen and carbon dioxide, but less carbon monoxide than the red pine. However, assuming 321 BTU/ft^3 for CO, 1012 BTU/ft^3 for CH_4, and 325 BTU/ft^3 for hydrogen, the BTU/ft^3 for the two gases are essentially identical – 129.5 BTU/ft^3 for poplar and 125.2 BTU/ft^3 for red pine. Therefore, it appears that both wood chips will supply gases with the same energy producing potential.

3.6.3 Technology Providers

More than 30 CHP development companies are listed on the USEPA CHP Partnership website http://www.epa.gov/chp/partnership/partners.html.

3.6.4 Potential Markets for Products

A gasification and turbine system with a feed rate of approximately 100 dtpd wood could produce approx 5 MW electricity (enough to supply approximately 5,000 homes). A year round industrial use for waste heat is critical to making economics work.

3.6.5 Relevance to Technology Development in Minnesota

Gasification of biomass for CHP is fairly well developed and several facilities are in existence around the State. The USEPA September 2007 document Biomass Combined Heat and Power Catalog of Technologies provides a comprehensive overview of gasification systems for heat and power.

3.6.6 Impact on Resources

The process does not require significant water inputs. Full scale operation is likely to require significant air pollution controls.

3.6.7 Economic Overview

Capital costs for a 100 dtpd system would be approximately $13 million and would create approximately 12 new jobs (3 shifts). The jobs would likely be classified as medium to high skilled labor. Costs do not include transmission line improvements that would likely be required to support the new power source and potential for net metering of excess power.

Costs to produce electricity from small woody biomass gasification systems typically exceed $0.10/kwhr (more than costs from the grid). Therefore uses of waste heat (such as local industry) are generally required to make the project economically feasible.

3.6.8 Discussion

This option does not appear feasible for the Nett Lake location unless a year round use for waste heat can be identified and a favorable power purchase agreement can be negotiated. This option was not feasible for the Fortune Bay location because the existing power costs were significantly less than the estimated costs to produce it from biomass.

3.7 Gasification for Production of Syn Gas with Further Processing to Methanol or Diesel

3.7.1 Description

Syngas produced via gasification of woody biomass can be further processed to create methanol, diesel, or DME.

3.7.2 Project Team Activities

The team met with Dr. John Hurley at the Energy and Environmental Research Center (EERC) in North Dakota to observe bench scale and pilot scale demonstration tests ongoing to produce methanol, diesel, or DME from woody biomass.

3.7.3 Technology Providers

The technology for woody biomass conversion to these chemicals is limited at this time and mainly being driven by research.

3.7.4 Potential Markets for Products

Existing markets are well established for methanol, diesel, or DME.

3.7.5 Relevance to Technology Development in Minnesota

EERC has plans and funding in the works to conduct a demonstration scale project at an operating wood pellet mill in Northern Minnesota. Parallel research activities may be redundant.

3.7.6 Impact on Resources

The process does not require significant water inputs. Full scale operation is likely to require significant air pollution controls.

3.7.7 Economic Overview

An economic evaluation was not conducted for this option as the process is still very much in the research development stage and sufficient information was not available to adequately consider a 100 dtpd system. It appears that an economically viable scale of production would need to be an order of magnitude larger than that being considered for Nett Lake.

3.7.8 Discussion

This option is similar to the cellulosic ethanol option as it is still very much in the research and development mode, and that the full size commercial scale will likely be an order of magnitude larger than the high end (200 dtpd) of the sustainable range that Bois Forte is considering.

3.8 Comparison of Options

Table 14, “Comparison of BioMass to Energy Options” provides a numerical ranking for each of the options based on

- Production Technology Maturity
- Product Ability to Compete on Price
- Number and Flexible Uses of Product
- Commercial Scale Magnitude
- Need for Demonstration at Bois Forte Scale
- Local Job Impacts
- Natural Resources Impacts
- Potential Social Issues
- Relative Ranking System

3.9 Technology Selection

Based on the comparison of options summarized in Table 14 it appears that bio-oil technology is the most feasible option to pursue.

It is the conclusion and recommendation of the study that bio-oil is the most feasible option to pursue for the Bois Forte project. Additional information on bio-oil technology is provided in the next chapter.

Table 14
Comparison of BioMass to Energy Options

Biomass Fuel Options	Production Technology Maturity	Product Ability to Compete on Price (based on expected production costs at BF scale)	Number and Flexible Use for the Products	Commercial Scale Magnitude compared to BF Sustainable Harvest	Opportunity for Demonstration to Prove Technology at BF Scale and Market	Local Jobs Impact at 100 dtpd Scale	Water Resource Required	Potential Social Issues	*Average Score (lowest is best)
Wood Pellets or Briquettes	1	1	4	1	5	5	1	1	2.4
BioOil and Char	3	2	1	1	1	3	2	2	**1.9**
Cellulosic Ethanol	4	5	3	4	4	1	5	4	3.8
Gasification for CHP	2	3	5	3	2	4	2	3	3.0
Syn Gas Processing to DME, Methanol or Diesel	5	5	2	5	3	2	3	5	3.8

*Rating on relative scale of 1 to 5. 1 is best score and 5 worst score based on comparison to the objectives and site specific limitations of the Bois Forte project.

4.0 Preliminary Design Considerations for Bio-oil Production Facility

This section describes design, construction and permitting criteria for a bio-oil production facility. Several of these factors would apply to the siting of any facility regardless of technology.

4.1 Bio-oil Overview

Bio-oil is a renewable "carbon neutral" organic liquid fuel made from the fast pyrolysis of low-grade woody biomass. The process includes drying and grinding of wood, followed by gasification via fast pyrolysis, the process of chemical decomposition of organic materials by heating in an oxygen-free environment. A major fraction of the combustible gas created is condensed into liquid bio-oil. In addition to the combustible gas and liquid bio-oil, the byproduct of the process is char.

Figure 4 "Bio-oil Production Process" below (excerpted from Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis. NREL/TP-510-37779. November 2006) presents a basic schematic of a bio-oil production process.

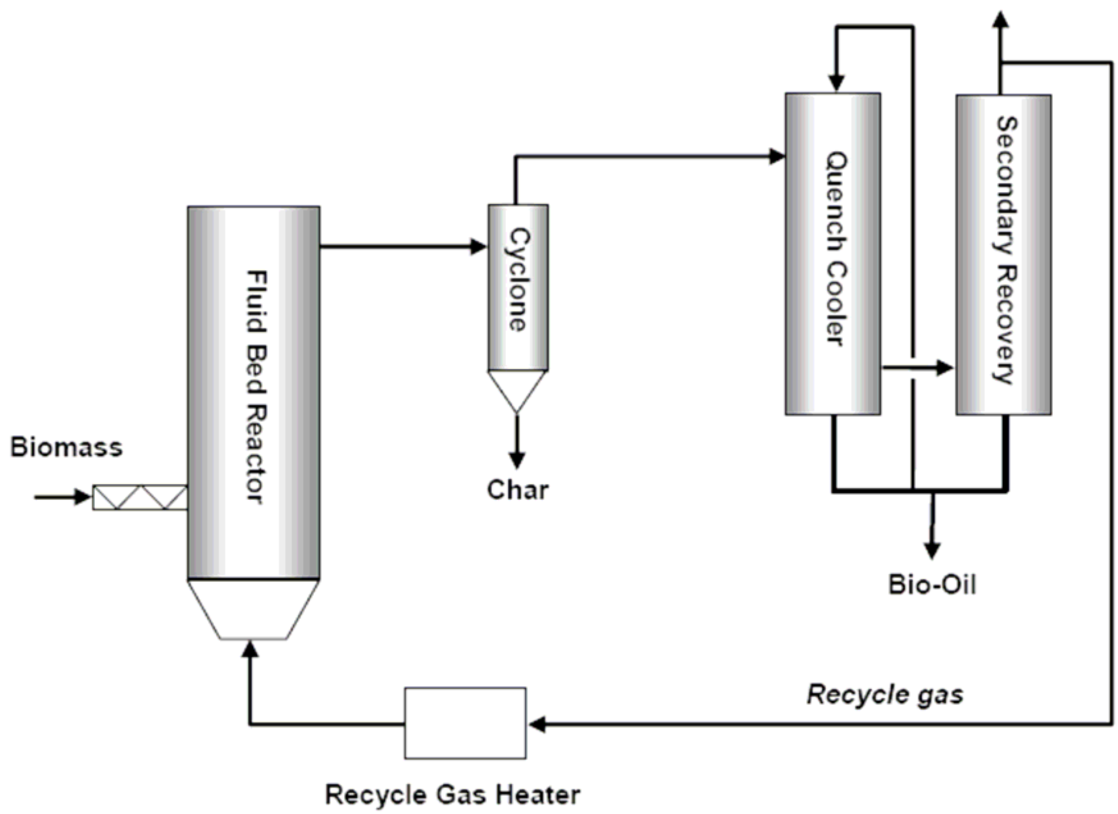

Figure 4 – Bio-oil Production Process

Bio-oil is referred to by many names including pyrolysis oil, bio-oil, bio-crude-oil, bio-fuel-oil, wood liquids, wood oil, liquid smoke, wood distillates, pyroligneous tar, pyroligneous acid, and liquid wood. For the purposes of this document, pyrolysis liquid will be termed "bio-oil".

The most important properties that adversely affect bio-oil fuel quality are incompatibility with conventional fuels, solids content, high viscosity, corrosiveness and chemical instability. Chemical and physical upgrading of bio-oil has been, and continues to be thoroughly researched. Chemical upgrading processes to produce hydrocarbon fuels that can be conventionally processed are more complex and costly than physical methods, but offer significant improvements ranging from simple stabilization to high-quality fuel products.

4.1.1 Current Interest and Research

In October 2008, the DOE announced the selection of five biofuels projects in which the DOE plans to invest up to $7 million. These awards will support research and development in the stabilization of biomass fast pyrolysis oils using non-food feedstock. Stabilization involves removing char, lowering the oxygen content, and reducing the acidity of the pyrolysis oil, derived from cellulosic biomass feedstocks. This stabilized bio-oil offers the potential of a greenhouse gas neutral, renewable, and domestically produced feedstock for a petroleum refinery. The following have been selected for the DOE awards: UOP LLC (teamed with Ensyn), Virginia Polytechnic Institute and State University, Iowa State University, RTI International (RTI), and the University of Massachusetts-Amherst (teamed with ROI).

4.2 Scale and Development

This study has evaluated three different scales for development of a bio-oil production facility:

- Pilot scale
- Demonstration scale
- Commercial scale

4.2.1 Pilot

A pilot scale demonstration plant is envisioned that would process approximately 5 to 10 dtpd of biomass. The pilot demonstration phase is recommended in order to:

- Establish local workforce operations for residual wood harvesting and preliminary processing (chipping, drying);
- Develop familiarity and support of the local community for the bio-oil technology;
- Test multiple biomass inputs (wood, brush, waste paper, etc)
- Further improve the technology for bio-oil production and quality upgrades;
- Increase market interest for improved bio-oil products;
- Build confidence in potential industrial customers for use of the bio-oil and char as fuel or other uses;
- Build a baseline for regulatory permitting approvals for both production and use of the biofuels; and
- Allow local and national economic situation to stabilize (fuel prices, market).

4.2.2 Demonstration

During operations of the pilot scale plant, plans for a demonstration scale plant would begin. The demonstration plant envisioned that would process approximately 50 to 100 dtpd of biomass and would produce 2 to 4 million gallons of bio-oil per year. Several components of the demonstration plant would be utilized for scale up to a commercial scale plant. The demonstration phase would be recommended in order to

- Build the business (staffing, marketing, financing)
- Fine tune equipment layouts and operations logistics
- Continue to establish buy-in

4.2.3 Commercial

Following successful demonstration, the plant could be scaled up for full scale commercial operations. The largest bio-oil production facility in North America is designed to process 200 dtpd biomass (although it was recently reported that Ensyn plans to build a 2000 dtpd system integrated with a biorefinery). A 200 dtpd system would produce approximately 8 million gallons of bio-oil per year. An economic analysis included in the next chapter indicates that the best return on investment is associated with the 200 dtpd size facility. The goal of the commercial phase would be to:

- Create long term sustainable jobs
- Create a positive revenue source
- Produce sustainable biofuels to reduce our nations dependence on fossil fuels and foreign oil.

4.3 Bio-oil Production Facility Components

The following components would be required for the complete system. However the pilot-scale demonstration would not likely include all of the physical components due its smaller size. This section presents an over-simplified representation of a typical bio-oil system, but illustrates the general concept.

4.3.1 Biomass Feedstock Acceptance and Storage

An area of the plant will be required to accept and store the biomass. It is assumed that the delivered loads will be green chipped wood residue or brush.

The maximum expected daily processing of woody biomass is expected to be 200 dtpd, which is roughly equivalent to 300 wet tons. Assuming the average logging truck will carry 25 tons per trip this is roughly equivalent to 12 trucks per day of biomass delivered to the plant per day on an average basis. However, due to the seasonal nature of timber harvesting, it is likely the biomass delivery frequency would be much higher during the logging season (winter) than in the off-season.

This component of the plant should include:

- Space for multiple loads (trucks)
- Visual inspection staging area
- Truck Scale (for incoming and outgoing trucks)
- Sample collection and tracking method to verify dry weight (if payment is on dry ton)

- Office and restrooms
- Reject area (for non-biomass items such as rocks)
- Seasonal storage and drying area
- Dust control system
- Fire protection

The current biomass feedstock planned for will be woody residue and brushland clearing biomass, therefore this and subsequent sections focus on the handling of these materials. It is understood that additional feedstock sources may include waste products such as paper wastes or byproducts from other biofuel production processes such as glycerin from biodiesel production, or lignin from cellulosic ethanol preparation. Testing of multiple feedstock types can occur during the pilot phase.

4.3.2 Feedstock Preparation

Raw feedstock delivered to the site would be required to meet a minimum spec size for green wood chips (2” +/-). Payment would be based on dry ton so moisture content would be confirmed prior to payment (to avoid overly wet wood being delivered). It likely that on occasion off-spec biomass would be delivered to the site (for a reduced purchase price) that would require on-site size reduction. Prior to being fed into the pyrolysis reactor, the feedstock would be further processed to meet minimum moisture content (10%) and size requirements (varies dependant on process but use 2 mm for current scenario). Laboratory analysis of the feedstock (for size and moisture content) would be required for quality control purposes.

This component of the plant should include:

- Shelter to limit interference from weather
- Space for staging input feed
- Dust control and monitoring system
- System for removal of non-desired objects (metal, rocks, etc)
- Size reduction equipment – grinder and/or hammermill (will likely require multiple machines to reduce to 2 mm)
- Dryer (fueled bio-oil, syn-gas, or reject wood)
- Sample collection and tracking method to verify input parameters
- Feed Scale (to automate loading)
- Loading equipment (dozer) and automated conveyor systems
- Automatic controls and monitoring system
- Fire protection

4.3.3 Bio-oil Production

The bio-oil production system will employ some type of pyrolysis reactor system (fluidized bed, transported bed, circulating fluid bed, ablative, rotating cone, vacuum system) that will utilize heat to convert the solid biomass into gas and char. Non-condensible gases will be utilized as fuel in the system. Condensible gases will be cooled and condensed into bio-oil. Char will also be separated out in this phase of the system via a cyclone, filter, and/or other mechanical means.

This component of the plant would include:

- Miscellaneous piping, valves, gauges and other appurtenances
- Automated conveyance and injection system
- Pyrolysis Reactor
- Char removal system and temporary storage
- Bio-oil condenser and temporary storage
- Gas recovery, cleanup, and recycle system
- Air pollution control system for exhaust gases
- Automatic controls and monitoring system
- Fire protection

4.3.4 Product Storage and Offloading

The bio-oil and char products would be temporarily stored on site to allow for quality control procedures to verify product quality. Approved products would be transported to a temporary storage area for loading into trucks for customer delivery. Reject products would be temporarily stored for reprocessing or use on site. At the commercial scale production, approximately 25,000 gallons of bio-oil and 40 tons of char would be produced daily. Transport of bio-oil and char product to clients would require approximately 10 trucks per day (assuming normal delivery Monday thru Friday).

This component of the plant would include:

- Shelter to limit interference from weather
- Space for staging and sampling product quality
- Sample collection and tracking method to verify input parameters
- Automated conveyor and loading systems to storage tanks or bins
- Storage tanks or barrels for bio-oil (and bio-oil quality rejects)
- Storage bins or barrels for char (and quality rejects)
- Automatic controls and monitoring system
- Dust control system (for char storage)
- Fire protection
- Space for multiple loads (trucks)
- Truck Scale (for incoming and outgoing trucks)

4.3.5 Administration Offices and Building

Administrative office space would be required on site for management of the plant, customer and employee meetings, safety briefings, break rooms, restrooms, storage of supplies and safety equipment, etc.

4.3.6 Laboratory

A laboratory is recommended to be located on site for the full scale commercial operation to ensure real time quality control data would be available to optimize the system process. The laboratory would be set up to assess moisture content, density, particle size, pH, specific gravity, viscosity, and other bio-oil and char chemical components.

4.4 Employee Requirements

At the commercial scale, the plant and administrative support is expected operate continuously (24 hrs/day) and employee more than 25 full time employees. Job categories will include:

- Plant Manager
- Plant Engineer
- Lab Manager/Chemist
- Shift Supervisor
- Shift Operators
- Maintenance Supervisor
- Delivery Drivers
- Administrative Assistants
- Marketing and Sales

4.5 Physical Site Requirements

Physical site requirements presented are for the demonstration/commercial scale stages of development. Site requirements for the pilot scale system would be considerably smaller and may fit with other existing facilities on Nett Lake (such as the Forestry Office building location)

4.5.1 Location

The location of the bio-oil production facility would ideally be located near the biomass source (e.g. within 25 miles) to reduce hauling costs of the raw biomass. It is assumed for this study that the facility location would be on Nett Lake near the biomass resources.

Other ideal qualities of the location would be in an area shielded from the residential area to limit community disturbance from light, noise, odors, or truck traffic. Other ideal factors include proximity to transportation infrastructure, electrical power, water supply, and wastewater discharge infrastructure.

Non-desired factors for a new site location would be areas with cultural significance, endangered species, or sensitive habitats.

4.5.2 Size

The optimal site location would have approximately 10 acres of area to allow for the various system components, and potential future expansion.

4.5.3 Transportation Infrastructure

The site location should be adjacent to roads that can handle heavy traffic and loads from the biomass delivery and product shipping. Access to railroad would provide additional flexibility.

4.5.4 Electricity

Minimum electrical power requirements would be 480V, 3 phase power.

4.5.5 Fuel

Propane or natural gas is typically required for pilot ignition of heating system. Fuel oil may be used as start-up fuel for heating system. Natural gas is not available at Nett Lake, so storage tanks will be required for propane and fuel oil.

4.5.6 Water

Water supply to the facility would be required for sanitary uses, drinking water, housekeeping operations, and for fire protection.

One potential upgrade option may involve aqueous separation of the lignin fraction using water. If that process were to be utilized, water usage requirement would be approximately 25% of the bio-oil rate produced. So at the maximum production rate of 25,000 gallons bio-oil produced, approximately 6,000 gallons per day (<5 gpm) of water would be required.

4.5.7 Wastewater

Wastewater disposal will primarily be for human sanitary uses and housekeeping. Human wastewater would be disposed in a local sewer or in an underground septic system. Wastewater generated from plant maintenance activities that may contain hazardous chemicals would be diverted to a temporary storage tank system for offsite disposal.

4.5.8 Waste Management

The bio-oil process itself does not generate significant quantities of waste. Waste containers would be required for waste generated during normal operations (administrative, housekeeping, empty containers).

4.6 Products and Properties

4.6.1 Primary Product: Bio-oil

Bio-oil, also known as pyrolysis oil, is a dark brown, free flowing organic liquid fuel with a pungent smoky odor produced from the fast pyrolysis of low-grade wood. Pyrolysis oil can be used as a substitute for fossil fuels to generate heat, power, and/or chemicals.

4.6.1.1 Grades of Bio-oil

Although the current focus is on basic bio-oil it is important to note that there are several potential upgrades to bio-oil that are currently being researched to increase its commercial value and market breadth. As summarized by David Chariamoni, et al "Power generation from fast pyrolysis liquids from biomass" (Renewable & Sustainable Energy Reviews, July 2005), six different grades of bio-oils can be classified as

- Basic pyrolysis liquids
- Solids-free pyrolysis liquids
- Pyrolysis liquids with alcohol additions
- Hot condensed pyrolysis liquids
- Pyrolysis liquid fractions
- Pyrolysis liquid/mineral oil emulsions

There are advantages and additional production costs associated with each of the "upgraded" bio-oil classifications.

4.6.1.2 Chemical and Physical Properties

Basic bio-oil is made up of the following constituents: 20-25% water, 25-30% water insoluble pyrolytic lignin, 5-12% organic acids, 5-10% non-polar hydrocarbons, 5-10% anhydrosugars and 10-25% of other oxygenated compounds. Table 15, "General Physical Properties of Bio-Oil" provides a summary the general physical properties of bio-oil. Additional information on bio-oil, including a comparison to other fuel types is included in Appendix C, "Bio-oil and Char Supplemental Data".

Table 15
General Physical Properties of Bio-Oil

Moisture Content	~20-40wt%
Ph	~2-3
Specific Gravity	~1.2
Dynamic Viscosity	50 cp @ 40ºC
Kinematic Viscosity	20-1000@25ºC & 15-500@40ºC
Flash Point	50-70ºC
Pour Point	-23ºC

4.6.1.3 Stability

The viscosity of bio-oil increases with time and elevated temperatures. For example, viscosity of a hardwood bio-oil doubled after storage at room temperature for a time period of one year. At 60 degrees Celsius, the time for the viscosity to double took one week, and at 80 degrees Celsius, it only took one day. Bio-oil is also corrosive, meaning it cannot be stored in containers made of certain materials such as carbon steel and aluminum. Bio-oil also has high oxygen content, containing up to 30% oxygen, whereas hydrocarbon fuels contain less than 1%. Bio-oil is hydrophilic, and hydrocarbon fuel is hydrophobic, causing less miscibility of bio-oil in hydrocarbon fuels. Finally, because of the high oxygen content, bio-oil must be kept in a vacuum container to prevent the process of oxidation.

4.6.1.4 Environmental and Human Health

Not only is bio-oil a renewable fuel, it is also biodegradable in both the aquatic and soil environment. The production of bio-oil is a contained process that generates little waste. When combusted, bio-oil does not produce some of the emissions associated with fossil fuels and is also considered to be carbon neutral, because it is a derivative of organic waste. Also, because bio-oil combusts below the temperature at which sulfur oxides are produced, it produces no sulfur oxide emissions. Finally, even though water may cause stability issues in bio-oil, from an environmental standpoint, the water content in bio-oil is beneficial in that it has been found to lower thermal NOx.

An MSDS for bio-oil is included in Appendix C.

4.6.1.5 Storage and Handling

Bio-oil is a transportable liquid similar in properties to petroleum-based fuels. Its viscosity is between that of #2 and #6 fuel oil. The exact nature of the chemical composition and the toxicity of bio-oil will determine the applicable classes and subsidiary classes which are applicable for transport. For transport, Bio-oil may be categorized as Class 3 – Flammable Liquids, Class 6 – Toxic Substances or Class 8 – Corrosive.

Due to the properties of bio-oil, it must be stored in an air-free environment in corrosion-resistant materials. Material selection is critical for all components contacting bio-oil. High-density polyethylenes as well as stainless steel are acceptable materials for the storage and handling of bio-oil. Copper and its alloys can also be used for pumping bio-oil with minimal abrasive particles at low velocities and moderate temperatures. (Farag, Technical, Environmental and Economic Feasibility of Bio-oil in New Hampshire’s North Country).

4.6.2 Other Products: Char

Pyrolysis char has a higher heating value than many grades of coal and because it is carbon neutral, can also be classified as a "green" fuel.

Char is highly resistant to decomposition and thus may have a residence time in soil of hundreds to thousands of years. While some biomass pyrolysis does occur naturally in wildfires, pyrolysis under controlled conditions can yield a significant amount of energy and also optimize the properties of the char that is produced. Some of the other desirable properties in char include high ion-exchange capacities and substantial microporosity, which allow it to retain nutrients and water and thereby make it a useful additive to increase the fertility of soil.

4.6.2.1 Chemical and Physical Properties

According to information provided by Dynamotive, char contains approximately 2% moisture, 11% ash, 22% volatile matter, and 64% fixed carbon. Additional data on char is included in Appendix C.

Char is a very lightweight granular black powder with a low bulk density, having similar physical properties to coke. Physical properties of char vary depending on feedstock and inputs used during pyrolysis.

4.6.2.2 Stability

According to information provided by Dynamotive, freshly produced char may have thermal stability issues that can be controlled by further processing the fine char into compressed pellets.

4.6.2.3 Environmental and Human Health

An MSDS for char is included in Appendix C. There do not appear to be any significant concerns with char, however the MSDS indicates limited toxicity information is available.

4.6.2.4 Storage and Handling

Systems for storage and handling of fresh char will include engineering controls to address stability and dust control.

4.6.3 Other Products: Heat

Dependant on the system, it is possible that enough waste heat system may be available to be recovered and used to provide heat for other adjacent uses (such as a greenhouse). This possibility will be further explored during the design of the demonstration phase.

4.7 Carbon Life Cycle Analysis

Production and use of bio-oil and char products from forestry biomass to replace fossil fuels is considered to be carbon neutral. The source of forestry biomass used is grown naturally with limited human intervention. The amount of carbon dioxide reduction will vary dependant on which fossil fuel is ultimately being replaced and in which type of system (combustion, gasification, etc). Appendix D, "Carbon Dioxide Emissions Data" provides a summary of emissions associated with different fuel types.

4.8 Permitting and Regulatory Considerations

The Bois Forte Band of the Minnesota Chippewa Tribe is a federally-recognized Indian Tribe organized under the Indian Reorganization Act of 1934 and operating under the Revised Constitution and Bylaws of the Minnesota Chippewa Tribe. As such, Bois Forte is responsible for regulation of activities which occur on its Reservation lands in cooperation with the requirements of the United States federal government. This section outlines various permitting and regulatory considerations when progressing with various components of the project.

4.8.1 Biomass Harvesting

4.8.1.1 Harvest Guidelines

The Minnesota Forest Resources Council (MFRC) recently released the Biomass Harvesting Guidelines for Forestlands, Brushlands and Open Lands (MFRC, December 2007) to be included with the Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers, and Resource Managers (MFRC, 2005). Harvesting should be conducted in general accordance with these guidelines both on and off Reservation forest lands.

Harvesting of woody biomass on Bois Forte lands is regulated by the Bois Forte Department of Natural Resources (DNR) Forestry Program, in cooperation with the federal Bureau of Indian Affairs (BIA). The IRMP provides a good summary of the Program's emphasis on sustainable forestry management, timber sales, and fire prevention.

Regulation of harvesting of biomass from areas outside of the Reservation is managed by the MNDNR Division of Forestry and local owner agencies, such as the St Louis County Land Department which manages timber sales on approximately 900,000 acres.

4.8.1.2 Quarantine on Transport of Wood

Quarantines may be in effect to reduce the spread of disease or insects (such as the Gypsy Moth or Emerald Ash Borer). These are administered by the United States Department of Agriculture (USDA) and locally by the Minnesota Department of Agriculture.

For example, in an effort to reduce the spread of the Emerald Ash Borer, as of August 1, 2007, firewood sold or distributed across State of Minnesota boundaries or more than 100 miles from its origin must include delivery ticket information regarding the harvest locations of the wood by county and state. Firewood that originates in a quarantined area is required to have a stamp, sticker, or permit with the federal shield on the package label or invoice. This certifies that the wood has gone through a process which should reduce the risk of it carrying a regulated pest as it moves out of a quarantined area. Moving firewood out of quarantine areas without proper certification is punishable by fines.

4.8.2 Land Use and Construction Code

4.8.2.1 Land Use

The IRMP indicates that a comprehensive land use plan is being developed that will address zoning. The demonstration (and expansion to commercial size) facility would need to be located in area compatible for industrial use. The Bois Forte Department of Natural Resources is responsible for making the determination as to the appropriateness of the proposed land use. To ensure that building facilities are located within proper setbacks, uses will be in accordance with the land use plan, and that stormwater and erosion controls will be in place during construction, an EAW process would be administered by the Bois Forte DNR.

4.8.2.2 Traffic

A Traffic Plan may be required by the Bois Forte to establish traffic route patterns and operating restrictions for the truck traffic.

Seasonal limits restricting weight loads to prevent road damage during Spring thaw would likely limit the weight allowed for bio-oil tanker trucks. Lighter loads would be required to move the product off site during the seasonal restrictions. Restrictions would be coordinated by the Bois Forte DPW on the Reservation, and off the reservation by other local authorities with highways under their jurisdiction.

4.8.2.3 Building and Construction Codes

Construction of new facilities would be required to be designed and constructed in accordance with the following codes:

- International Building Code
- International Fire Code
- National Electrical Code
- International Plumbing Code
- International Mechanical Code
- International Fuel Gas Code
- International Energy Conservation Code
- American Petroleum Institute Design Code

4.8.2.4 Alcohol Storage

There is a potential for alcohol storage on site if alcohol fuel blending occurs for bio-oil upgrading, or if needed for use as a cleaning agent,. The Federal Bureau of Alcohol, Tobacco, and Firearms (ATF) has specific regulations related to quantity and storage of alcohol.

4.8.3 Environmental Permits

The Bois Forte DNR is responsible for coordination of environmental permits in cooperation with the Federal regulatory agencies. The tribe is exempt from State and local laws, provided the activity occurs within the Reservation.

4.8.3.1 National Environmental Policy Act (NEPA)

The bio-oil project will require federal permits and may also use federal funds, therefore a NEPA assessment will likely be required. The Bois Forte DNR has received training and has extensive experience with NEPA compliance and the environmental assessment (EA) process. The NEPA process will require consideration of the applicability of Executive Orders, Indian Treaties, and environmental laws such as the:

- Clean Air Act (CAA)
- Clean Water Act (CWA)
- Emergency Planning and Community Right-to-Know Act (EPCRA)
- Endangered Species Act
- Fish and Wildlife Conservation Act
- National Historic Preservation Act
- National Pollution Discharge Elimination System (NPDES)
- New Source Performance Standards (NSPS)

- Noise Control Act
- Occupational Safety and Health Act (OSHA)
- Pollution Prevention Act
- Prevention of Significant Deterioration Permit
- Resource Conservation and Recovery Act (RCRA)
- Safe Drinking Water Act (SDWA)

4.8.3.2 Air Emissions

Construction and Operating Air Permits would be required for the bio-oil production facility. A portion of the gas and/or bio-oil would be utilized as fuel to create heat for the pyrolyis process and also biomass drying operations. Bois Forte DNR would coordinate the permit process with the USEPA.

4.8.3.3 Water Supply

Water supply to the facility would be required for sanitary uses, drinking water, housekeeping operations, for fire protection, and possibly for aqueous separation to upgrade bio-oil. A permit may be need to install a new groundwater well and pump system.

4.8.3.4 Stormwater

Operators of construction sites larger than 1 acre are required to obtain authorization to discharge stormwater under a NPDES stormwater permit (likely the USEPA Construction General Permit).

A Stormwater Pollution Prevention Plan (SWPP) may be required for construction and/or long term operations.

4.8.3.5 Wastewater

Wastewater disposal will primarily be for human sanitary uses and housekeeping. Wastewater would be disposed in a local sewer or in an underground septic system. A discharge permit would be required from the Bois Forte DNR.

4.8.3.6 Solid and Hazardous Wastes

The bio-oil production process does not create hazardous wastes, however small quantities of solvents may be required for plant maintenance. Spent solvents and/or other industrial wastes may require temporary storage on site.

Management of solid and hazardous wastes will be in accordance with the Bois Forte DNR policies and RCRA.

4.8.3.7 Spill Prevention, Control, and Countermeasures (SPCC) Plan

Several aboveground chemical storage tanks may be needed for product storage, off-spec storage, storage of liquid housecleaning wastes, and potential additives for upgrading. An SPCC Plan will be required.

4.8.4 Fuel Quality and Transport

4.8.4.1 Fuel Quality Standards

Standards for bio-oil quality are still in development with the American Society of Testing Materials (ASTM) International.

The technical report Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis (NREL, November 2006) indicates that "in 1996 the Pyrolysis Activity of the International Energy Agreement proposed a series of specifications for bio-oil that were modeled after ASTM specifications for hydrocarbon fuels. The proposed specifications attempted to mimic as much as possible the key properties established for petroleum fuels that have major design considerations for end use devices." A copy of the specifications (excerpted from the NREL report) is included in Appendix C.

The ASTM standards website indicates that a specification for bio-oil is under consideration that covers two grades of Pyrolysis Liquid Biofuel made from biomass. The two grades of fuel are intended for use in pressure atomizing type industrial burners. (These fuel grades are not intended for use in residential heaters, small commercial boilers, or combustion engines.) Grade C2.5 is a light biomass Pyrolysis Liquid with a suspended solids content of 2.5 mass % (maximum). Grade C25 is a medium biomass Pyrolysis Liquid having a higher heating value and viscosity than Grade C2.5 due to an increased suspended solids content of 25 mass % (maximum). ASTM review was still ongoing with the Petroleum products main-committee and the Burner sub-committee as of the Fall 2008. No further information has been received as to the status of the ASTM process.

4.8.4.2 Transportation and Handling

The report titled Transport, Storage, and Handling of Biomass Derived Fast Pyrolysis Liquids – Compliance with all International Modes of Transport (Conversion and Resource Evaluation LTD, June 2006) recommends that transportation and shipping labels indicate the contents are flammable, corrosive, and toxic to allow adequate response in the event of spills.

5.0 Business Planning

This study indicates a full-scale cellulosic bio-oil production facility appears to be technically and economically feasible if crude oil costs exceed $100/bbl. If Bois Forte decides to proceed with implementation of a demonstration project, it is appropriate to initiate planning of the overall business at this juncture.

This chapter discusses an integrated business plan for biomass procurement, storage, processing, Bio-oil production, marketing, and transport. Research and development for product improvement and market expansion is also addressed.

5.1 Economic Projections for Bio-oil Production

Appendix E, "Cost Estimate Spreadsheets" provides detailed information that serves as the basis of the cost information provided. Costs presented are based upon review of cost data provided in literature as well as recent correspondence with bio-oil technology providers. Costs details related to specific line items are deliberately vague to avoid any potential issues related to confidentiality agreements.

Costs scenarios in Appendix E consider three different rates of biomass feedstock inputs – 50 dtpd, 100 dtpd, and 200 dtpd. The 200 dtpd size appears to the most economically feasible range for long term full scale operations, and those costs are summarized below.

5.1.1 Capital Costs

Capital costs are summarized in Table 16, "Projected Capital Costs for 200 dtpd Bio-oil System" include the initial fixed costs of real estate acquisition, site preparation, facility construction, engineering, construction oversight and permitting, startup costs, and a licensing fee.

Table 16
Projected Capital Costs for 200 dtpd Bio-oil System

Cost Category	Estimated Capital Cost
Buildings, Structures, Equipment, Site Development	$ 18,300,000
Engineering Design, Permitting, Construction Management	$3,600,000
Commissioning	$700,000
Tech Licensing Fee	$3,000,000
Contingency	$3,700,000
Total Capital Cost	**$ 29,300,000**

5.1.2 Operations and Maintenance Costs

Operations and Maintenance costs will be incurred through the payment of staff labor, facility upkeep, feedstock costs, and chemical purchases. As discussed in a subsequent section, there are several variable costs associated with the annual operations costs and subsequent payback analysis. Appendix E provides several scenarios based on plant scale (50 dtpd, 100 dtpd, and 200 dtpd) and base case assumption, optimistic case assumption, and pessimistic case assumptions. For purpose of illustration, the Table 17, "Projected Annual Operations and Maintenance Costs for 200 dtpd Bio-oil System – Base Case" provides a summary of annual operations and maintenance costs using the base case. Royalty fees are not included here, but are addressed in the next section. The base case is considered to represent the most likely operation environment over a 20 year lifetime of plant operations.

Table 17
Projected Annual Operations and Maintenance Costs for 200 dtpd Bio-oil System - Base Case

Cost Category	Estimated Capital Cost
Personnel (27 Employees) w/overhead costs	$ 1,300,000
Power and Utilities	$ 700,000
Feedstock Preparation	$ 800,000
Equipment Maintenance	$ 2,000,000
Miscellaneous Chemicals and Supplies	$ 1,000,000
Administrative Costs	$500,000
Feedstocks, delivered (assuming $30/green ton)	$ 3,900,000
Total Annual O&M Costs	**$ 10,500,000**

5.1.3 Annual Revenue and Cash Flow

As discussed in a subsequent section, there are several variables associated with pricing of the bio-oil and char products that impact the annual revenues. For purpose of illustration, the table below provides a summary of the base case scenario (assuming $100/bbl crude oil environment, and value-added pricing based on carbon dioxide credits at $10/ton). The base case is considered in Table 18, "Summary of Annual Revenue 200 dtpd Bio-oil System - Base Case" to represent the most likely operating environment over a 20 year lifetime of plant operations.

Table 18
Summary of Annual Revenue 200 dtpd Bio-oil System - Base Case

Revenue Category	Quantity	Income	Debit
Bio-oil sales @ $1.23 per gallon	8,100,000 gal	$9,950,000	
Char sales @ $415/ton	12,200 tons	$5,050,000	
Total		$15,000,000	
O&M Costs			($10,500,000)
Royalty Costs (based on $3/ton of bio-oil and char sales)			(150,000)
NET CASH FLOW (assuming no finance charges)		**$4,350,000**	

5.2 Payback Timeframe Sensitivity

The payback timeframe is a function of capital costs (and financing) compared to annual net cash flow. As discussed previously, there are several variables that can impact the overall payback scenario. These include

- Scale of full-size project
- Financing of Initial Capital Costs
- Feedstock Costs
- Competitive Market Price for Biofuels
- Royalty Fees

5.2.1 Scale of Full Size Project

Obviously the larger the project size, the higher the capital costs. However economies of scale impact the overall capital cost relative to the production rate. Appendix E provides capital cost for three feed rates

- 50 dtpd
- 100 dtpd
- 200 dtpd.

5.2.2 Financing of Initial Capital Costs

Financing methods to pay for the initial costs will likely involve a combination of grants and loans. To simplify this initial evaluation, it has been assumed that loan financing would be at zero interest. Grant funding scenarios addressed in Appendix E include:

- Optimistic: 70% Grants
- Base: 50% Grants
- Pessimistic: 30% Grants

5.2.3 Feedstock Costs

As discussed in Chapter 2, biomass feedstock costs are expected to range between $25/green ton and $35/green ton dependant on market, distance, and availability. Costs estimates included in Appendix E evaluate three different feedstock cost ranges:

- Low (optimistic): $25/green ton delivered
- Medium (base): $30/green ton delivered
- High (pessimistic): $35 green ton delivered

5.2.4 Market Price for BioFuels

Pricing of the bio-fuels is partially based on competition with traditional fossil fuels.. Appendix F, “Energy Price Outlook” provides additional information on trends in fuel pricing based on the DOE Annual Energy Outlook 2009 projection. For the purposes of this analysis, we have assumed that the market for the bio-oil will be replacement of petroleum residual oil. Residual oil prices track very close to crude oil prices (shown in Table 19, “Long-Term Energy Outlook Prices ($/unit)”) so this has been used as the indicator metric.

Table 19
Long-Term Energy Outlook Prices ($/unit)

Energy Source/Activity	Year												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Imported Crude Oil Price ($/Barrel)	98.89	56.76	75.78	86.12	97.64	104.37	117.86	124.55	128.85	131.55	136.83	139.88	142.47

Energy markets are changing in response to many different factors, including the following: higher energy prices, the growing influence of developing countries on worldwide energy requirements, recently enacted legislation and regulations, changing public perceptions on issues related to emissions of air pollutants and greenhouse gases resulting in the wider use of alternate fuels and the economic viability of various energy technologies. It is important to note that projected energy costs differ between analysts. All projections are estimates, and actual production and consumption rates, as well as energy prices may trend differently than what is projected by the references used for this feasibility study.

The market price for the bio-fuels utilized in the calculations is based upon a $/MMBTU to reflect differences in energy content and density between residual oil, bio-oil and char.

Additionally, a positive price adjustment was made to account for the carbon dioxide emissions avoidance that would be associated with using biofuels. The current market for carbon credits is low, but is expected to increase significantly when/if a federal or state level carbon cap and trade program is promulgated.

Three levels of biofuel pricing were evaluated in Appendix E:

- Optimistic: based on $120/bbl crude oil and $20/ton carbon dioxide credit value
- Base: based on $100/bbl crude oil and $10/ton carbon dioxide credit value
- Pessimistic (similar to current) case: based on $70/bbl crude oil and $2/ton carbon dioxide credit value

5.2.5 Royalty Charges

Discussions with several of the bio-oil technology developers indicate that royalty charges up to five dollars would be assessed per ton of bio-oil or char produced and sold. Three levels of royalty charges were evaluated:

- Optimistic: $0/ton
- Base: $3/ton
- Pessimistic: $5/ton

5.2.6 Pessimistic, Base and Optimistic Case Scenarios

Table 20, “Payback Timeframe Scenarios” summarizes the various payback timeframes with relation to the optimistic, base (expected), and pessimistic case scenarios.

Table 20
Payback Timeframe Scenarios

Scale	50 dtpd	100 dtpd	200 dtpd
Optimistic Case	4 years	2 years	1 yr
Base (expected)	None	8 years	3 years
Pessimistic Case	None	None	None

5.3 Pilot Scale Demonstration

As the current environment is most similar to the “Pessimistic Case” presented above, it is deemed prudent to proceed cautiously with a smaller scale pilot demonstration project on the order of a 10 dtpd scale. Operation of the pilot demonstration plant would be expected to continue for approximately five years to develop improvements in production and biofuel quality, and in anticipation of a better market scenario (e.g. higher crude oil prices and carbon dioxide credit market).

The pilot scale demonstration would employ 8 people. Table 21, “Summary of Costs for a 10 dtpd Bio-oil System” presents a summary of the capital and operating costs for the pilot scale project. Cost details are included in Appendix E.

Table 21
Summary of Costs for a 10 dtpd Bio-oil System

Bio Oil Plant size (wood feed rate, dry tons per day)				**PILOT SCALE 5 to 10 dtpd (intermittent operation due to R&D)**
Bio-oil Plant Employees	**Base Pay**	**(w/ 30% overhead)**		Payroll w/OH
24 hr/day, 7 days/week, 42 hr workweeks = 4 shifts = 8760 hrs				
Plant Manager	$ 90,000	$ 117,000	0.5	$ 58,500
Plant Engineer R&D	$ 70,000	$ 91,000	1.0	$ 91,000
Lab Manager / Chemist	$ 50,000	$ 65,000	0.5	$ 32,500
Shift / Maintenance Supervisor	$ 50,000	$ 65,000	0.5	$ 32,500
Maintenance Tech	$ 30,000	$ 39,000	0.5	$ 19,500
Shift Operators (4 shifts)	$ 30,000	$ 39,000	4.0	$ 156,000
Admin Assistant	$ 20,000	$ 26,000	0.5	$ 13,000
Bio Oil delivery	$ 30,000	$ 39,000	0.5	$ 19,500
Subtotal Plant Employees			*8.0*	
Plant Annual Payroll w/OH				***$ 422,500***

ANNUAL OPERATING COSTS					
Dry Wood feed rate, dry tons per day)				**10**	dtpd
Green tons per day @	**50**	% water content		20	gtpd
Green tons per year@				6,600	gtpy
Daily Bio-oil Production, tons @	**61.7**	% oil to dry wood		6	tpd
Annual Bio-oil Production @	**330**	24 hr-days/yr		2,034	tpy
Daily Bio-oil production volume @	**10**	lb/gallon		1,233	gal
Annual Bio-Oil Production, gallons				406,890	gal/yr
Annual Bio-Oil Production, barrels	42	gal/bbl		9,688	bbl/yr
Daily Char Production, tons @	**18.5**	% char to dry wood		2	tpd
Annual Char Production tons				611	tpy
Truckloads biooil per day (approx)	8,000	gal loads		0.15	
Truckloads char per day (approx)	10	ton loads		0.19	
Total trucks per day (approx)				0.34	
Total trucks per week (approx)				2	
24 hr/day, 7 days/week, 42 hr workweeks = 4 shifts					
Feedstock Grinding	**$ 5.00**	per green ton	$	33,000	
Production Electricity kWh/hr				100	kwhr
Electricity Costs	**$0.07**	per kWhr	$	55,440	
Nitrogen			$	5,000	
Misc Chemicals			$	10,000	
Propane (for occasional startup)		Gal		1,000	
Propane Costs	**$ 3.00**	$/Gal	$	3,000	
Bio-oil internal usage for drying	**tons**	(10% of production)		203	tpy

Table 21 (Continued)
Summary of Costs for a 10 dtpd Bio-oil System

Bio Oil Plant size (wood feed rate, dry tons per day)				**PILOT SCALE 5 to 10 dtpd (intermittent operation due to R&D)**		
Bio-oil BTU value		**7,051**	BTU/lb		2,869	Mbtu/yr
Bio-oil cost (10% subtracted from total production already included)				$	-	
Plant Labor (linked ss)				$	422,500	
Equip Maintenance				$	100,000	
Misc Water & Sewer & Elec (non-production)				$	2,000	
Misc Supplies & Service				$	2,000	
Misc Admin Costs (Insurance, Admin Filings, Env Reporting, etc)				$	50,000	
Subtotal Production Costs				**$**	**682,940**	
Subtotal Feedstock Costs, green tons chipped, delivered annually						
med cost feedstock	$	30.00	per green ton	$	198,000	
Total Annual Operating Costs (Feedstock + Production)				**$**	**880,940**	
Revenue						
Bio-oil Sales	$	0.83	$/gal bio-oil	$	337,086	
Char Sales	$	280.04	$/ton char	$	170,963	
Subtotal Revenue				**$**	**508,050**	
Net Annual Operating Costs				**$**	**372,890**	

CAPITAL COSTS	quantity	units		unit cost		subtotal
Real Estate Acquisition	0	acres		-	$	-
Site Development (grading, stormwater, pavement, fencing)	0.5	acres		50,000	$	25,000
Utility Connections (power, water, etc)	1	ls		20,000	$	20,000
Grinding Equipment	1	ls		150,000	$	150,000
Drying Equipment	1	ls		150,000	$	150,000
Fast Pyrolysis System	1	ls		1,500,000	$	1,500,000
Storage Tank System, 5 days storage	1	ls		50,000	$	50,000
Truck Loading / Unloading	0	ls		-	$	-
Fire Suppression System	1	ls		100,000	$	100,000
Mobile Equipment (front end loaders, etc)	1	ls		200,000	$	200,000
Storage Blgs	10,000	sf		35	$	350,000
Offices	0	sf		-	$	-
Subtotal					***$***	***2,545,000***
Contingency	30%	subtotal	$	2,545,000	$	763,500
Engineering & Permitting	40%	subtotal	$	2,545,000	$	1,018,000
Construction Mgt	15%	subtotal	$	2,545,000	$	381,750
Commissioning - 6 mos	75%	annual labor	$	422,500	$	316,875
Tech Licensing Fee	0	ls	$	-	$	-
Total Capital					**$**	**5,025,125**
Plus Net Operating Costs During Demonstration Period	5	yrs	$	372,890	$	1,864,452
Total Capital plus 5 years Net Operating Costs					**$**	**6,889,577**

5.4 Business Plan

This section describes:

- Statement of Purpose
- The Business
- Financing Methods
- Financial Documents

5.4.1 Statement of Purpose

The purpose of the business is to harvest local cellulosic biomass and produce a renewable energy product, while creating local sustainable employment for members of Bois Forte.

5.4.2 The Business

5.4.2.1 Legal Structure

At least 51% of the ownership will be by an entity of Bois Forte. The entity (The Business) may be the Bois Forte community itself, the Bois Forte Development Corporation, a new corporation altogether, or even possibly a new Tribal Utility Authority. Determination will be based upon whatever structure works best to elicit the best funding options, minimize risk, and maintain control.

An ownership model will evolve as negotiations proceed with potential strategic business partners. Strategic business partners may include a combination of:

- Loggers and other biomass harvesting companies;
- Mature or startup bio-oil technology providers;
- Bio-oil plant construction companies;
- Research and Development Institutes;
- Bulk fuel cooperatives and transport companies; and/or
- Large industrial customers for the bio-oil and char.

5.4.2.2 Description of The Business

The purpose of this business is to provide a renewable energy product produced from multiple biomass sources. The Business will accomplish this via phased development of linked departments to address:

- biomass harvesting,
- biomass procurement,
- bio-oil production facility construction
- biomass conversion into bio-oil and char,
- customer development,
- transport to customers.

5.4.2.3 Services

5.4.2.3.1 *Biomass Harvesting*

Cost effective harvesting of the biomass resources requires specialized equipment and training that could be challenging for small business logging operators. A subsidiary could purchase specialized equipment and provide to tribal loggers via long term lease, or other rental program. This service could be started before the proposed bio-oil facility is fully operational, as other local biomass- to-energy facilities (LEA, Renewafuel, Birchems) are also procuring biomass.

5.4.2.3.2 *Biomass Procurement*

Contracting for future procurement of biomass for the bio-oil facility should begin as soon as possible to ensure an adequate supply will be available for system startup and sustainable operations. In the event that the facility construction is delayed, a market for procured biomass will likely be present at other local biomass-to-energy facilities.

5.4.2.3.3 *Bio-oil Facility Construction*

Construction of the initial demonstration facility and later expansions will likely be contracted to specialty contractors with oversight by the business.

5.4.2.3.4 *Biomass Conversion Into Bio-oils and Char*

Operation of the facility will include biomass acceptance, transport to storage, loading, and drying areas, operations and maintenance of equipment, laboratory QA/QC testing, and product storage and handling.

5.4.2.3.5 *Customer Development*

Marketing will be required to secure additional uses and local customers seeking renewable fuels and/or associated “green tag” carbon credits. Research and development may be employed to evaluate refinement of products.

5.4.2.3.6 *Transport to Customers*

The business will coordinate delivery of products to large industry and/or smaller commercial businesses.

5.4.2.4 Location

The business will be located at a site on the Nett Lake Reservation.

5.4.2.5 Management

The business will be managed locally by Bois Forte personnel, with input from outside business partners as negotiated.

5.4.2.6 Personnel

At the commercial scale, the plant and administrative support is expected operate continuously (24 hrs/day) and employee more than 25 full time employees. Job categories will include: Plant Manager, Plant Engineer, Lab Manager/Chemist, Shift Supervisors, Shift Operators, Maintenance Supervisor, Delivery Drivers, Administrative Assistants, and Marketing and Sales personnel.

5.4.2.7 Training

The Business will coordinate specialized training of employees and /or supporting business partners (such as tribal loggers). Training may include:

- Harvesting - Special Equipment and Sustainable Practices
- Procurement
- Production and Maintenance
- Quality Control
- Transport
- Business Administration
- Health and Safety
- Emergency Response

5.4.2.8 Permits

It is anticipated that the Business will hold the permits.

5.4.2.9 Legal Aspects

Since The Business will be majority owned and operated by Bois Forte on Reservation lands, state laws and requirements do not apply.

In order to attract outside business partners, Bois Forte will negotiate legal agreements in place that attracts and protects interests of external business partners and investors, including dispute resolution clauses.

5.4.2.10 Taxes

Tax accounting will be managed by The Business, and independently verified by external auditors.

5.4.2.11 Insurance

Insurance policies will be held by The Business to cover the various liabilities associated with employees, fire, transportation, product uses, and environmental releases.

5.4.3 Market Evaluation

Target Market – The focus market for the bio-oil product will be taconite kilns associated with the local steel production industry on the Iron Range. Full scale production of bio-oil would be enough fuel to serve only one kiln. There are more than several kilns operating or planned to be operating on the range. Interest on the part of the steel industry is related to use of carbon neutral fuels and to avoid mercury emissions, especially in the zero discharge area of the Lake Superior basin.

The next likely market that would be interested in the basic bio-oil product would be power plants that are facing mandates to increase biomass usage in coal burning plants. Bio-oil co-firing with coal plants requires relatively minor adjustments. Market drivers are biomass mandates and avoidance of mercury emissions especially in the zero discharge area of the Lake Superior basin.

Current potential markets for char include: industrial kilns, co-firing at power plants, use as a soil supplement, and for industrial coking operations.

Growth Potential – With additional production or quality improvements, markets for bio-oil may include: additional kilns, power plants with biomass co-firing, as a potential feedstock at large integrated bio-refinery or petrochemical refinery for production of next generation transportation fuels and chemicals, as an input for asphalt production.

Current Providers – Currently no other bio-oil production facilities are known to exist within a 100 mile radius. We have no knowledge of plan to build similar facilities in Minnesota; however it appears that planning for Dynamotive facilities may be in the works for Iowa, Maine, and Louisiana. Ensyn has two facilities operating in Wisconsin.

Competition – Competition includes other forms of biomass fuel (chips, briquettes, pellets), dependant on the end use. However, none of the other biomass fuels offer as much as versatility for expanded markets.

Methods of Distribution- Bio-oil and Char may be distributed via tanker trucks or rail.

Advertising/Marketing – Not required for current targeted industrial users. If future improvements to bio-oil open up market for commercial size boilers, advertising may be warranted.

Pricing – To be competitive with fossil fuels being replaced, with upcharge for “green tag” value to user.

5.5 Potential Business Partners

A brief discussion of potential business partners follows regarding:

- Mature or startup bio-oil technology providers;
- Research and Development Institutes;
- Refineries; and/or
- Large industrial customers for the bio-oil

5.5.1 Bio-oil Technology Providers

Selection of business partners will require significant evaluation of the pros and cons of working with established businesses versus startup companies. This is especially important when working with technology providers.

Advantages of teaming with established technology firms may include:

- Understand the business and market
- Established reputation and product brand
- Production Experience
- Support marketing and operations
- Bench Strength – deeper personnel resources

And the disadvantages of teaming with established technology firms may include:

- Less likely to give you their full attention due to diverse client base
- Licensing fees and Royalties may be expected
- May have stronger desire to control the business
- Less leverage can be applied

On the other hand, the advantages of teaming with startup technology firms may include:

- Better service due to need to establish reputation
- More enthusiasm
- Lower costs due to limited overhead
- Better opportunity to reap rewards for developing the business
- Can better negotiate contracts for future licensing fees and royalties.

Disadvantages of teaming with startup technology firms may include:

- Potentially dependent on limited staff
- Potentially less operational business experience

The team has had preliminary conversations with the following bio-oil technology providers (previously described in Chapter 3):

- Dynamotive
- Frontline
- ROI
- ABRI

5.5.2 Research and Development Institutes

Several universities and national laboratories are conducting research on improvement of bio-oil process and properties. Teaming with one or more of these institutions would provide access to research, potentially improve success of receiving federal funding and, add value in developing improvements to the system prior to going full scale.

5.5.3 Refineries

Large scale petrochemical refineries have existing equipment and infrastructure that can be used to upgrade bio-oil to transportation grade biofuels. Teaming with a petrochemical refinery company could lower overall costs and accelerate project schedule. Additionally refineries have established marketing and sales distribution networks that might aid in development of a robust customer base.

5.5.4 Large Industrial Customers for the Bio-oil

The initial target customers for the bio-oil will be large industrial facilities such as kiln facilities or power plants. Teaming with these customers at the outset to establish fuel specifications and long term purchase agreements will be key to the overall project success.

5.6 Potential Barriers

Potential barriers to successful implementation of the project may include:

- Community acceptance
- Lack of developed markets
- Lack of funding to overcome initial cost of market entry
- Lack of interest from funding agencies

5.7 Communication Plan

Successful implementation will require a structured communication plan to develop strategic relationships with project stakeholders (loggers, land managers, community members, permitting agencies, funding agencies, customers) and address potential concerns of negative consequences that may be related to resource management, sustainability, environmental impacts, operating hours, traffic concerns, tribal investment, external investors, etc. Communications may utilize existing avenues such as public meetings, news articles, informational websites, and radio broadcasts.

5.8 Funding Sources

Due to the high cost of market entry and low potential for return on investment in short term, it is likely that funding will need to be heavily based on grants from the governmental funding sources. There is currently much discussion of a broad scale federal economic stimulus plan that will favor renewable energy initiatives and the project team will be diligent in identifying potentially applicable programs.

Table 22, "Potential Funding Sources" identifies a wide variety of federal, state and local opportunities for funding. Some programs target private installations, some target public installations, and some are public-private partnerships. The structure of the funding mechanism depends on the business structure of the proposed facility. The following tables outline the various funding sources. Descriptions of the funding sources are presented in Appendix G, "Funding Information."

Table 22
Potential Funding Sources

Federal		
USDA - Rural Development 2008 Farm Bill		
Program	**Type**	**Target Entity**
Business and Industry Guarantee Program	Loan	Private
Rural Economic Development Loan and Grant Program (REDLG)	Both	Public/Private
Value Added Producer Grant Program	Grant	Private
Rural Energy for America Program (REAP)	Grant	Private
REAP Guaranteed Loan Program	Loan	Private
Rural Business Investment Program	Grant	Public/Private
Biorefinery Assistance Program	Loan	Private
Bioenergy Program for Advanced Biofuels	Grant	Private
Biomass Research and Development Initiative	Grant	Private
Rural Energy Self Sufficiency Initiative	Grant	Public
Biomass Crop Assistance Program (BCAP)	Grant	Private
US Department of Commerce Economic Development Administration (EDA)		
Program	**Type**	**Target Entity**
Public Works Grants	Grant	Public
Economic Adjustment Assistance	Grant	Public
Other Federal		
Program	**Type**	**Target Entity**
Clean Renewable Energy Bond Program	Loan	Private
US Department of Environmental Protection (USEPA) State & Tribal Assistance Grant program (STAG)	Grant	Public
USEPA Surveys, Studies, Investigations and Special Purpose Grants	Grant	Public
US Department of Housing & Urban Development (HUD) Congressional Grants, EDI Special Projects (Economic Development Initiative)	Grant	Public

Table 22 (Continued)
Potential Funding Sources

State of Minnesota		
Minnesota Department of Employment and Economic Development (DEED)		
Program	**Type**	**Target Entity**
Minnesota Investment Fund Biomass Heating Program	Both	Public
Minnesota Investment Fund	Both	Public/Private
Public Facility Authority (PFA) Credit Enhancement Program	Loan	Public
PFA Clean Water Revolving Loan	Loan	Public
Small Business Development Loan Program	Loan	Public/Private
State of Minnesota, Other		
Program	**Type**	**Target Entity**
Capital Budget Request (biannual)	Grant	Public

Local and Other Funding Sources		
LOCAL Funding and Financing Options		
Program	**Type**	**Target Entity**
Revenue Bonds	Loan	Public
Tax Increment Financing (TIF)	Loan	Private
Minnesota Governmental Agency Finance Group (MGAFG)	Loan	Public
OTHER SOURCES		
Program	**Type**	**Target Entity**
Xcel Energy Renewable Development Fund (RDF)	Grant	Private
Cargill Renewable Energy Grant	Grant	Private/Research

6.0 Conclusions and Recommendations

The results of the study conclude that:

- Adequate woody biomass is available for a sustainable 50 to 200 dtpd process.
- Production of bio-oil is technically feasible but the process can be improved to lower costs and improve bio-oil quality.
- A local market exists for bio-oil use provided petroleum crude oil costs exceed $100/bbl.
- A 50 to 200 dtpd commercial scaled bio-oil production facility would result in significant jobs and economic benefit for the Nett Lake Community.
- A smaller scale 5 to 10 dtpd pilot demonstration facility is recommended to allow system improvements, increase familiarity, and prepare for a future market with higher crude oil prices and mandated carbon reduction programs.

Next steps recommended include:

- Legislative Update (February 2009)
- Communication with Stakeholders (ongoing)
- Solidify Partners and Funding for Pilot Scale(2009 -2010)
- Pilot Scale Demonstration 10 dtpd (2010 – 2014)
- Demonstration Scale Commercial Plant 50 dtpd (2015)
- Full Scale Commercial Scale 200 dtpd (2016)

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MJB/ls

Appendix A

Relevant Correspondence

STATE OF MINNESOTA
GRANT CONTRACT

This grant contract is between the State of Minnesota, acting through its Department of Agriculture ("State") and the Bois Forte Band of Chippewa ("Grantee").

Recitals

1. Under Minn. Stat. 15.061 and Minnesota Session Laws 2007, Chapter 45, Subd. 4, the State is empowered to enter into this grant.
2. The State is in need of a feasibility study of the economic and technical viability of developing a multistream renewable energy biofuels demonstration facility on the Bois Forte Reservation.
3. The Grantee represents that it is duly qualified and agrees to perform all services described in this grant contract to the satisfaction of the State.

Grant Contract

1 Term of Grant Contract

1.1 ***Effective date*:** July 23, 2007 or the date the State obtains all required signatures under Minnesota Statutes Section 16C.05, subdivision 2, whichever is later.

The Grantee must not begin work under this grant contract until this contract is fully executed and the Grantee has been notified by the State's Authorized Representative to begin the work.

1.2 ***Expiration date*:** February 28, 2009 or until all obligations have been satisfactorily fulfilled, whichever occurs first.

1.3 ***Survival of Terms.*** The following clauses survive the expiration or cancellation of this grant contract: 8. Liability; 9. State Audits; 10. Government Data Practices and Intellectual Property; 13. Publicity and Endorsement; 14. Governing Law, Jurisdiction, and Venue; and 16 Data Disclosure.

2 Grantee's Duties

The Grantee, who is not a state employee, will:

Conduct a detailed feasibility study of the economic and technical viability of developing a multistream renewable energy biofuels demonstration facility on Boise Forte Reservation land in St. Louis and Koochiching counties to utilize existing forest resources, woody biomass, and cellulosic material to produce biofuels or bioenergy. Grantee must actively participate in the Agricultural utilization Research Institute's Renewable Energy Roundtable. Grantee must also report to the house and senate Agricultural Finance committees no later than February 1, 2009.

Bois Forte Development Corporation

1430 Bois Forte Road, Tower, MN 55790
Phone: 218-753-6400 Fax: 218-753-6404

Chairman
Kevin Leecy

Secretary-Treasurer
David C. Morrison, Sr.

Council Members
Ray Villebrun, Sr.
Mark Drift
Ray Toutloff

CEO
Andrew Datko

October 12, 2007

TO: Renewable Biofuel Technology Companies

The Bois Forte Band of Chippewa is currently in the process of identifying and evaluating potential technology providers for development of a multi-source cellulosic biomass-to-energy demonstration project in Northern Minnesota. Funding support for this feasibility study phase of this project is being provided by the State of Minnesota.

This project has the support of the Governor of the State of Minnesota, and many members of our Congressional delegation, including Representative Jim Oberstar and Senator Amy Klobuchar. We are evaluating potential technologies for their suitability and applicability to our project, and invite you to contact us if you are interested in the possibility of participating.

The demonstration project envisioned will process 100 tons per day of biomass to create a renewable fuel. Sources of biomass may include logging residuals, sawmill waste, debris from forest/brushland clearing and roadway maintenance, and cattail weed harvesting from Nett Lake.

A broad range of renewable energy technologies are currently being considered in our feasibility study including pelletization, pyrolysis, gasification, enzymatic fermentation to ethanol, and/or subsequent catalytic reformation to other chemicals including butanol, or dimethyl ether.

Potential local customers for the various renewable energy products have been identified and include domestic electricity net metering, fuel needs on the Bois Forte Reservation, regional power companies, iron ore mines, steel companies, and petrochemical industries in the Duluth/Superior area.

We will be meeting with potential technology providers/partners in November and December 2007 to determine interest and compatibility for this project. The feasibility study phase is intended to be complete by May 2008, with implementation of the physical demonstration project in 2009 or 2010.

Direct responses and questions regarding this solicitation should be directed to:
Andy Datko, 218.753.6400, ext 7712; adatko@fortunebay.com and
Mark Broses, Senior Engineer, 715.720.6236 mbroses@sehinc.com

Thank you for your interest.

Sincerely,

Andrew Datko
Chief Executive Officer

Appendix B

NRRI Thermal Gasification Data

Comparison of Gas Compositions Produced by the Gasification of Poplar and Red Pine Wood Chips

The Coleraine Minerals Research Laboratory (CMRL) of the Natural Resources Research Institute of the University of Minnesota Duluth has a BioMax 25 downflow gasifier produced by Community Power Corporation (CPC). The system control variables were optimized by using poplar wood chips as the biomass feed. CMRL was asked to characterize the gas produced from red pine wood chips compared to the gas produced from the standard poplar wood chips.

Both the poplar and red pine wood chips had been stored outside and were covered with snow. One of the feed bins had about 200 pounds of dry poplar wood chips and the other bin was empty. About 500 pounds of wet poplar wood chips were added to the dry chips and about 500 pounds of wet red pine wood chips were added to the other bin. Both bins were air dried for about 10 days.

The gasifier was started using poplar wood chips. After the temperatures appeared to have stabilized the gas composition was recorded. The results are shown in Table B1 and plotted on Figure B1. The average gas composition for the last 56 minutes of operation was 0.33 % oxygen, 12.92 % carbon monoxide, 15.59 % carbon dioxide, 2.52 % methane, and 19.25 % hydrogen. The next day the gasifier was started on poplar, but due to a slug of very wet chips the gasifier was shut down. The gasifier was restarted on red pine. Again after the gasifier temperatures had stabilized the gas composition was recorded as shown in Table B2 and plotted on Figure 2. The average gas composition for the last 55 minutes of operation was 0.03 % oxygen, 18.53 % carbon monoxide, 11.2 % carbon dioxide, 1.87 % methane and 14.39 % hydrogen. The comparison of the two gases is given below as the average compositions:

Feed stock	% O_2	% CO	% CO_2	% CH_4	% H_2
Poplar	0.33	12.92	15.59	2.52	19.25
Red Pine	0.03	18.53	11.20	1.87	14.39

There appears to be some difference in the gas composition from poplar and red pine with the poplar producing more hydrogen and carbon dioxide, but less carbon monoxide than the red pine. However, assuming 321 BTU/ft^3 for CO, 1012 BTU/ft^3 for CH_4, and 325 BTU/ft^3 for hydrogen, the BTU/ft^3 for the two gases are essentially identical – 129.5 BTU/ft^3 for poplar and 125.2 BTU/ft^3 for red pine. Therefore, it appears that both wood chips will supply gases with the same energy producing potential.

Table B1 – Gas Composition when Running with Poplar

		Percent			
minutes*	O2	CO	CO2	CH4	H2
43	1.5	16.7	11.9	4.16	16.3
61	1.1	15.8	13.0	2.46	17.2
70	1.2	14.3	14.2	2.54	18.5
73	0.6	14.8	14.8	3.14	19.7
80	0.5	14.7	14.8	3.15	19.1
87	0.3	14.1	15.1	2.37	18.7
95	0.5	12.1	16.1	2.59	19.4
100	0.5	12.7	16.1	3.19	19.7
105	0.2	14.1	15.1	1.76	19.4
110	0.2	12.4	16.1	2.27	19.7
115	0.2	13.8	15.1	1.32	19.2
120	0.2	11.3	16.1	2.55	19.7
125	0.2	11.7	16.1	2.50	18.8
129	0.2	10.4	16.1	2.83	18.3
AVG**	0.33	12.92	15.59	2.52	19.25
Std Dev	0.1618	1.4736	0.5941	0.5861	0.4783

* Time after gasifier temperatures appeared stable

** from 73 to 129 minutes

Table B2 – Gas Composition when Running with Red Pine

minutes*	O2	CO	CO2	CH4	H2
		Percent			
90	0	16.9	14.6	10.50	15.2
95	0	15.2	13.9	6.65	14.0
100	0	16.0	13.0	3.86	14.3
105	0	16.2	13.1	3.17	13.6
110	0	17.2	12.0	2.24	14.5
115	0	17.6	11.9	2.31	15.0
120	0	17.9	11.7	1.88	15.1
125	0	18.2	12.1	3.10	16.1
130	0	17.7	12.1	2.61	15.0
135	0.1	18.9	11.2	2.13	14.8
137	0	19.8	10.5	1.64	14.6
139	0	19.4	10.6	1.79	14.8
141	0	19.0	10.8	1.74	14.6
143	0	18.7	10.9	1.52	13.9
145	0.1	18.2	11.0	1.21	13.1
147	0.1	19.1	10.7	1.37	13.9
149	0.1	19.7	10.5	1.52	14.1
150	0.1	19.2	10.1	1.26	13.7
155	0	18.8	10.7	1.38	14.0
160	0.1	18.8	10.8	1.27	14.0
165	0	19.1	10.9	1.48	14.2
AVG**	0.03	18.53	11.20	1.87	14.39
Std Dev	0.0485	0.9310	0.7746	0.6078	0.6978

* Time after gasifier temperatures appeared stable

** from 105 to 165 minutes

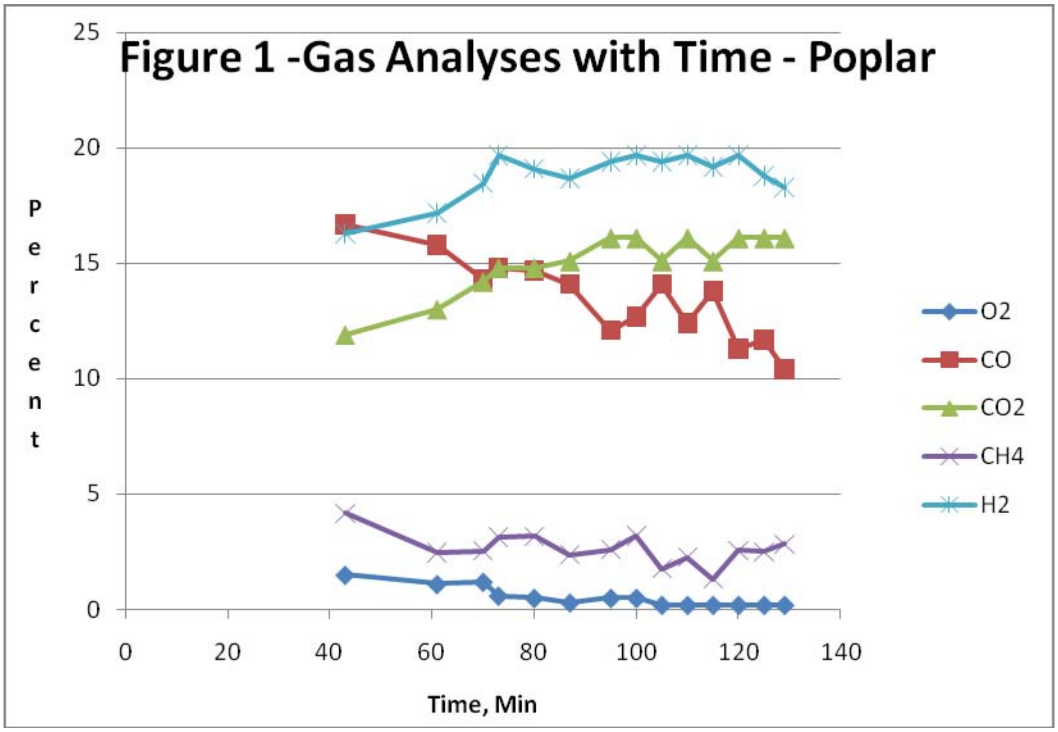
Figure 1 -Gas Analyses with Time - Poplar
Percent
Time, Min
O2
CO
CO2
CH4
H2
0
5
10
15
20
25
0
20
40
60
80
100
120
140

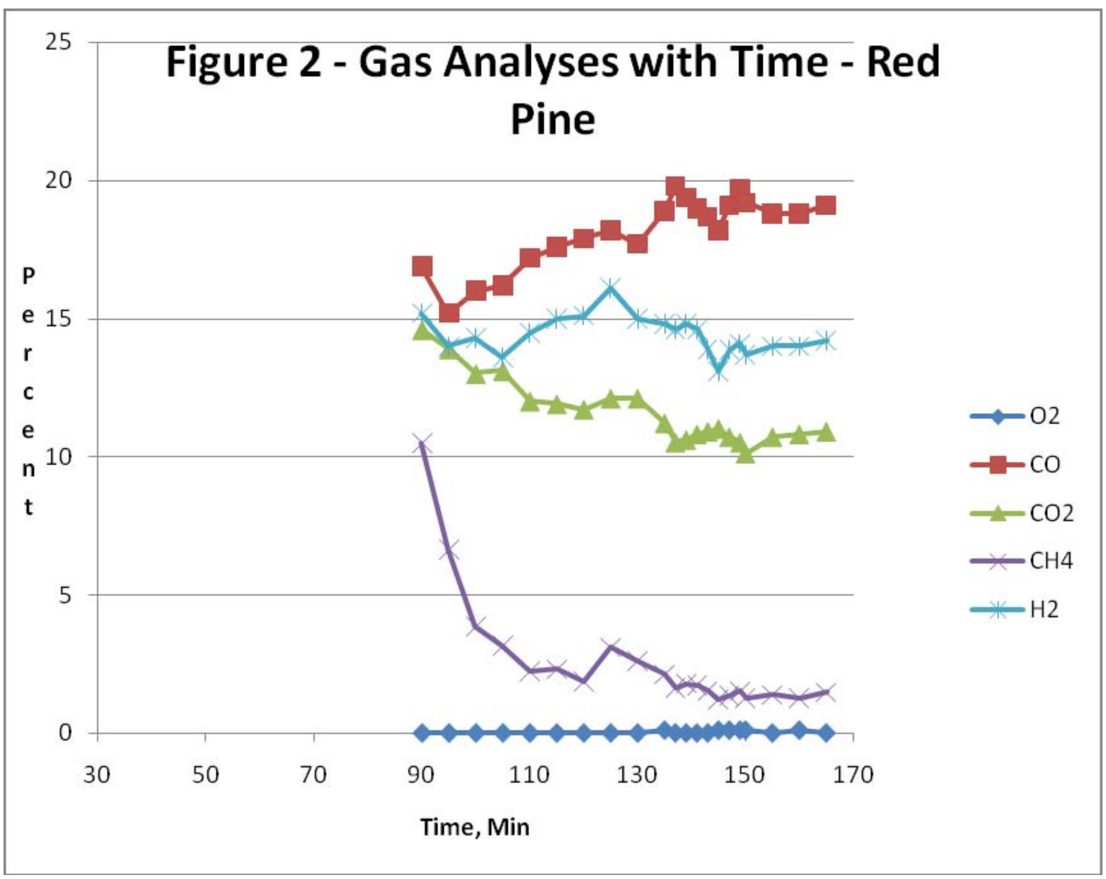
Figure 2 - Gas Analyses with Time - Red Pine
Percent
Time, Min
O2
CO
CO2
CH4
H2
0
5
10
15
20
25
30
50
70
90
110
130
150
170

Appendix C

Bio-oil and Char Supplemental Information

APPENDIX – Supplemental Information on Bio-oil and Char

Excerpted pages 25 – 26 from

Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis

Technical Report
NREL/TP-510-37779
November 2006

M. Ringer, V. Putsche, and J. Scahill

Prepared under Task No. BB06.7510

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Operated for the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

4.4 Bio-Oil Standards and Specifications

The petroleum and automobile industries have a long history of working together in a symbiotic relationship to develop the fuels and engines that work in concert to provide reliable, efficient, and clean service. As with many engineering designs there are compromises that must be made because of conflicting performance objectives. For example internal combustion engines can be designed to be more efficient than they currently are by increasing the compression ratio of the engine. This in turn requires the petroleum industry to produce fuels with higher octane levels. Chemical engineers learned that a relatively easy and inexpensive way to do this is by adding tetra-ethyl lead. Environmental engineers however recognized the pervasive increases of lead in the environment, along with the long-term health costs tied to its continued use. After restricting this method of octane enhancement, the petroleum industry was forced to develop other ways to increase octane levels in motor fuels. The alternate approaches are not as effective as tetra-ethyl lead so the internal combustion engine designer also had to compromise on the upper limits of compression ratio. Cost of course also plays a major role in these design considerations. This is a good example of the importance of developing good technical relationships between the fuel producer and the end user of that fuel.

The situation with the auto / petroleum industry can also be applied to the emerging bio-oil industry. The examples noted above with pioneering efforts to utilize bio-oil in various prime movers, and even relatively simple combustion burners, demonstrates the need for standardization of bio-oil properties. If there was a uniform set of standard specifications for bio-oil, designers of the various end use devices could select the appropriate materials and make the necessary design changes to achieve much better performance than what has already been demonstrated. Commercial acceptance of biomass pyrolysis technology will demand that these specifications be established. Unfortunately there has been little progress in this area over the years.

To a large extent the petroleum industry has laid the foundation for what a set of standards and specifications should be based on. Because there are also quality variations in petroleum hydrocarbons, the industry has established separate specifications for a number of different grades of hydrocarbon fuels. The higher grades of course command a premium price and a similar situation would be expected with bio-oil grades. The specifications for petroleum fuels are established by an independent organization such as ASTM in the United States and similar organizations in other countries. These organizations also get involved in developing/establishing the methods and protocols used for quantifying the specification property. The specifications are usually based on the end use requirements of the consumer for the given fuel and typically are concerned with such things as the ability to properly atomize, flash points or ignition temperatures, energy content (LHV), and qualities that have environmental impacts such as sulfur content.

In 1996 the Pyrolysis Activity of the International Energy Agreement under Task XIII proposed a series of specifications for bio-oil [51] that were modeled after the ASTM specifications for hydrocarbon fuels. The proposed specifications attempted to mimic as much as possible the key properties established for petroleum fuels that have major design considerations for end use devices. This was intentionally done to require the least effort on the part of the manufacturer of end use equipment to accommodate bio-oil fuels. The proposed specifications from this document are listed in Table 3.

Table 3. Proposed Specifications for Various Grades of Bio-oil [51]

Property	Light Bio-oil (~ASTM #2)	Light-Medium Bio-oil (~ASTM #4)	Medium Bio-oil (~PORL 100)	Heavy Bio-oil (~CAN #6)
Viscosity, cSt	1.9-3.4 FO 1.9-4.1 D 1.9-4.1 GT @40° C	5.5-24 @40° C	17-100 @50° C	100-638 @50° C
Ash, wt%	0.05 FO D 0.01 GT	0.05 FO 0.01 D	0.10 FO	0.10 FO
Pour point, °C min	Report	Report	Report	Report
Conradson carbon, wt%	Report	Report	Report	Report
Max. 0.1 µm filtered ethanol insol. solids, wt%	0.01 FO	0.05	0.10	0.25
Accelerated aging rate @90° C, cSt/hr	Report	Report	Report	Report
Water, wt% of wet oil, max	32	32	32	32
LHV, MJ/L min, wet oil	18	18	18	Report
C, wt% dry H, wt5 dry O, wt% dry S , wt% dry N, wt5 dry K+ Na, ppm	Report - - Max Max. Report 0.5 GT	Report - - Max. Max. Report	Report - - .2 Max. .3 Max Report	Report - - .4 max. .4 max Report
Phase stability @ 20° C after 8 hr @ 90° C	Single phase	Single phase	Single phase	Single phase
Flash point, ° C minimum	52	55	60	60
Density, kg/m^3	Report	Report	Report	Report

MSDS for bio-oil and char excerpted from Dynamotive website.

Dynamotive

The Evolution of Energy ®

About Us Biofuels & Products Technology News Room Investors Subsidiaries Contact Languages

BioOil

- Home
- BioOil®
- BioOil Plus®
- CQuest™ BioChar
- Future Applications

General BioOil Information

Content

- What is BioOil?
- Applications
- Applications Demonstration
- Environmental Choice Program
- Combustion Testing
- BioOil Handling
- Technical Requirements for BioOil Handling

What is BioOil?

BioOil is an alternative fuel made using Dynamotive's pyrolysis process of biomass. It is a dark brown, free flowing liquid fuel with a smoky odour reminiscent of the plant from which it was derived. BioOil is formed in a process called pyrolysis wherein plant material (biomass), such as sawdust or bagasse from sugar cane, is exposed to 400-500 degrees Celsius in an oxygen free environment.

BioOil contains up to 25% water. The water component in BioOil is not a separate phase and is important because it lowers the viscosity of the fuel. BioOil is not a hydrocarbon-water mix like Orimulsion. Another feature of BioOil is its propensity to change slowly over time. This is not to be considered an instability because it can take months.

BioOil is a fossil fuel substitute. It pumps well, ignites, and burns readily when atomized.

BioOil has EcoLogo certification, having met stringent environmental criteria for industrial fuels as measured by Environment Canada's Environmental Choice Program. The EcoLogo signifies that the manufacturing process of the product has been audited by a credible third party, and supported by empirical data on combustion tests conducted by both the company and authorized third parties.

http://www.dynamotive.com/en/biooil/index.html

BioOil properties and how they compare with conventional fuels

Table 1: Comparison of fuel properties – wood based pyrolysis fuel

Parameter	Unit	Analytical methods	BioOil Plus	BioOil	Heating oil #2	Heavy fuel oil
High Heating Value	MJ/kg	DIN51900	18-20	16-19	45.5	42.5
High Heating Value	MJ/L	DIN51900	23-25	19-23	39.4	41.7
Flash Point	oC	ASTM D93	50-60	48-55	38	60
Pour Point	oC	ASTM D97	-11	-15	-6	-
Density (15oC)	Kg/liter	ASTM D4052	1.22-1.3	1.2	0.865	0.986
Acidity	pH	pH meter	2-3	2-3	-	-
Solids (char)	wt %	Insolubles in Ethanol	20-23	0.01-0.2	-	-
Moisture	wt%	Karl Fisher	20-25	20-25	-	< 0.5
Ash	wt %	ASTM D482	<1	<0.02	Trace	0.08
Kinematic Viscosity	cSt	ASTM D445	-	-	-	-
20°C	-	-	1500-3700	70	3-6	2000-9000
40°C	-	-	300-500	19	1.8-3.5	500-1000
60°C	-	-	140-250	8	1.4-2.5	100-200
80°C	-	-	70-90	4	1.1-1.8	40-70

Table 2: Ultimate Analysis of different fuels (% by wt)

	BioOil	BioOil Plus	Char	Heating oil #2	Heavy fuel oil
Ash	< 0.02	<1	< 8	< 0.01	0.02-0.08
Carbon	42-47	45-51	75-78	86.4	85.7
Hydrogen	6-8	5-6	3-4	12.7	10.5
Nitrogen	< 0.1	< 0.3	< 0.3	0.006	0.18
Sulfur	< 0.02	< 0.06	-	0.2-0.7	< 2.8
Oxygen (by difference)	46-51	43-49	7-14	0.04	0.38

MATERIAL SAFETY DATA SHEET

Section I Hazardous Ingredients

Ingredients	CAS Registry Number	Concentration (%-weight/weight)
Acetic acid	64-19-7	from 1 to 5 %
Acetone	67-64-1	from 1 to 5 %
Formaldehyde	50-00-0	from 1 to 5 %
Formic acid	64-18-6	from 1 to 5 %
Glyoxal	107-22-2	from 1 to 5 %

Section II Preparation Information

Prepared by: DynaMotive Energy Systems Corporation, 230 - 1700 West 75th Avenue, Vancouver, B.C. V6P 6G2, phone 604-267-6000.
Date: July 18, 2006

Section III Product Information

Manufacturer:	Emergency Phone Numbers:
DynaMotive Energy Systems Corporation 230 - 1700 West 75th Avenue Vancouver, B.C. V6P 6G2	DynaMotive (604) 267-6000 CANUTEC (24 hours) (613) 996-6666

Product Name:	BioOil
Synonyms:	Pyrolysis oil, biomass pyrolysis oil
UN number:	UN1993
TDG Shipping Name:	Flammable Liquid N.O.S. (lignin solution)
TDG Classification:	Class 3, Packing Group III
Use:	Applications as a liquid fuel or raw material for industrial processes

Section IV Physical Data

Physical State:	liquid
Appearance:	dark brown liquid
Odour:	smoky odour
Odour Threshold:	not applicable
Vapour Pressure:	~5 kPa at 38 °C
Vapour Density:	not available
Evaporation Rate:	not available
Boiling Point:	not available
Freezing Point:	not available
pH:	~2.2
Specific gravity:	~1.2 / ASTM D4052
Pour point:	-21 °C to -33 °C / ASTM D97
Coefficient of Water/Oil Distribution:	not available

Section V Fire or Explosion Hazard

Conditions of flammability:	WHMIS Class B, Division 3. Combustible liquid. Flammable at extremely high temperatures. BioOil consists of about 25% water. When BioOil is distilled to 250 °C, the collected distillate is about 35% of original weight.
Extinguishing media:	water, foam, carbon dioxide, dry chemical. Fire fighters should wear self-contained breathing apparatus.
Flash point/method:	48 - 55 °C / ASTM D93

Issued: 2006-07-18

Page 1 of 3

UEL: not available
LEL: not available
Auto-ignition temperature: ~500°C
Hazardous Combustion Products: COx
Explosion Data - sensitivity to mechanical impact: no
- sensitivity to static discharge: no

Section VI Reactivity Data

Conditions of Instability:	normally stable
Incompatibilities:	oxidizers
Conditions of Reactivity:	high temperatures may generate highly flammable volatile organics.

Hazardous Decomposition Products: carbon monoxide, acetone, formaldehyde and other volatile organics.

Section VII Toxicological Properties

Route of Entry:

- Skin contact: may irritate
- Skin absorption: no information available
- Eye contact: Eyes are sensitive to BioOil with probable corneal damage resulting from exposure. Refer to section IX for first aid measures.
- Inhalation: irritating and can be harmful to respiratory tract
- Ingestion: irritating and can be harmful to gastro-intestinal tract

LC_{50}:	not available
LD_{50}:	> 2000 mg/kg body weight (oral, rat)
Exposure limits:	not established
Effects of Acute Exposure:	Coughing or mild breathing difficulties may result.
Effects of Chronic Exposure:	no information available
Irritancy:	no experimental information available
Sensitizing capability:	no information available
Carcinogenicity:	no information available
Reproductive toxicity:	no information available
Teratogenicity:	no information available

Mutagenicity: Mutagenic tests:

1. Ames test (*Salmonella typhimurium*): positive
2. Bone marrow micronucleus test by oral route gavage in mice: negative
3. Micronucleus test in L5178 TK mouse lymphoma cells: light mutagenic activity

Toxicologically Synergistic Products: no information available

Section VIII Preventive Measures

Engineering Controls: Engineering control measures to reduce hazardous exposures are preferred. Methods include mechanical ventilation (dilution and local exhaust), control of personnel exposure, control of process conditions and process modification. Administrative controls and personal protective equipment may also be required.

Personal protective equipment:

- Gloves: neoprene, latex or equivalent
- Respiratory protection: fume hood or NIOSH/MSHA approved organic vapour respirator as appropriate
- Eye protection: chemical safety goggles
- Clothing: plastic apron, sleeves and boots as appropriate

Storage Requirements:	Store in suitable labeled acid-proof steel or plastics such as PETE, PP, HDPE containers. Keep containers tightly closed when not in use and when empty. Protect from damage. Store in a cool, dry, well ventilated area, out of direct sunlight. Store away from oxidants.

Handling Procedures and Equipment: Follow routine safe handling procedures.

Leak or Spill Cleanup:	Before dealing with spills take necessary protective measures, inform others to keep at a safe distance and shut off all possible sources of ignition. Mix with absorbent such as floor dry, transfer carefully to container and arrange removal by disposal company. Wash site of spill thoroughly with water.
Disposal:	Follow all federal, provincial and local regulations for disposal. Use only licensed disposal and waste hauling companies. Disposal of small amounts of spilled material may be handled as described under "Leak or Spill Cleanup". Large spills must be dealt with separately and must be handled by qualified disposal companies.
Special Shipping Information:	Follow all TDG regulations and see classification in Section III.

Section IX First Aid Measures

Skin: flush the contact area with lukewarm running water for at least 15 minutes. Remove contaminated clothing, taking care not to spread the chemical. If contamination is extensive, remove the clothing under running water. Discard or decontaminate clothing before use. Unless contact has been slight, seek medical attention. Seek medical attention if irritation persists.

Eye: flush the contaminated eye(s) for at least 15 minutes with lukewarm running water, holding the eyelids open. Take care not to rinse contaminated water into the non-affected eye. Always seek medical attention for accidents involving the eyes.

Inhalation: Take proper precautions to ensure your own safety before attempting rescue. Remove source of contamination or move victim to fresh air. If breathing has stopped, trained personnel should begin artificial respiration, or if the heart has stopped, cardiopulmonary resuscitation (CPR) immediately. Seek medical attention.

Ingestion: Never give anything by mouth if victim is rapidly losing consciousness, or is unconscious or convulsing. Rinse mouth thoroughly with water. Do not induce vomiting. Have victim drink 200 to 400 mL of water to dilute. If breathing has stopped, trained personnel should begin artificial respiration, or if the heart has stopped, cardiopulmonary resuscitation (CPR) immediately.

BioChar Handling

Storage and transport temperature

BioChar is a flammable solid and TDG class 4.2 dangerous goods. BioChar contains 16-23 % by weight of organic volatile compounds. BioChar is produced within seconds in the fast pyrolysis reactor and is rapidly removed from the carrier process gas stream by cyclones. Following this the BioChar is cooled to about 40°C.

However, BioChar is not thermally stable and freshly produced pyrolytic BioChar can auto ignite spontaneously into a smouldering fire when exposed to air and/or oxygen. This self-heating is related to two processes, water adsorption of the dried BioChar and chemisorption of oxygen. Both processes are exothermic reactions. When exposed to the atmosphere, fresh dry BioChar will rapidly adsorb water vapour and oxygen, heat up and ignite if not cooled. This "heat of wetting" raises the temperature of the BioChar leading to an increase in the carbon oxidation. This creates a potential hazard wherever BioChar is stored or transported if proper precautions are not taken.

To stabilise stored BioChar:

1. BioChar can be fully wetted
2. BioChar can be deactivated in a complex process in a gas stream in which temperature and oxygen content are carefully controlled
3. BioChar deactivates over time

Shipment of BioChar

At the moment, Dynamotive is exploring different alternatives based on standard industry practices of hazardous goods transport to ensure shipping and storage safety regarding BioChar's auto ignition properties.

MATERIAL SAFETY DATA SHEET

HAZARDOUS INGREDIENTS:

Ingredients	CAS Registry Number	Concentration (%-weight/weight)
Carbon	7440-44-0	from 60 to 75 %

PREPARATION INFORMATION:

Prepared by:

Corporate Headquarters

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PRODUCT IDENTIFICATION:

Manufacturer:	Emergency Phone Numbers:
Dynamotive Energy Systems Corporation Angus Corporate Centre 1700 West 75th Avenue Suite 230 Vancouver BC V6P 6G2	**Dynamotive** (604) 267-6000 **CANUTEC** (24 hours) (613) 996-6666

Product name:	CQuest™ Fast Pyrolysis BioChar ("BioChar")
Chemical family:	Carbon
Chemical name:	Carbon
Formula:	C
Synonyms:	Wood Charcoal
UN number:	UN1361
TDG Shipping Name:	Carbon, vegetable origin
TDG Classification:	Class 4.2, Packing group II

PHYSICAL DATA:

Physical State:	Granular or fine powder
Color:	Black
Odour:	Charred odour
Volatile Content (% wt.):	18 - 30
Ash Content (% wt.):	1 - 25
Carbon Content (% wt.):	60 - 75
pH:	Not available
Solubility in Water:	Insoluble
Bulk Density:	250 - 350 kg/M3
Vapor Pressure:	Not available
Vapor Density:	Not available

FIRE AND EXPLOSION HAZARD:

WHMIS Classification:	Class B, Division 4, Flammable solids
Unusual Fire / Explosion Hazards:	BioChar dust 0.055 kg/M3 is the minimum explosion concentration. Freshly produced pyrolytic Char may be subject to auto ignition and spontaneous heating, when exposed to air and/or oxygen.
Flash Point:	Not applicable.
Auto-ignition Temperature:	200 °C for fresh BioChar; 400 °C for aged BioChar.
Extinguishing Media:	Water spray or foam.
Note:	Do not use large solid sprays of water or foam as this can stir up dust clouds and cause flash fires.
Hazardous Combustion Product:	Carbon monoxide.

REACTIVITY DATA:

Stability:	Stable under ordinary conditions of use and storage.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Oxidizers
Instability Conditions:	Excessive temperatures
Hazardous Decomposition Products:	Carbon Monoxide and Carbon Dioxide

TOXICOLOGICAL PROPERTIES:

Route(s) of Entry:	Eye Contact; Skin Contact; Inhalation; Ingestion
Effects of Acute Exposure:	Coughing or mild breathing difficulties may result.
Inhalation:	May irritate mucous membranes and the respiratory tract.
Skin Contact:	May cause irritation.
Eye Contact:	May cause irritation.
Ingestion:	Not established.
Effects of Chronic Exposure:	Not established.
LC50:	Not available
LD50:	440 mg/kg (intravenous mouse)
Exposure limits:	Not established
Irritancy:	No information available
Sensitizing capability:	No information available
Carcinogenicity:	No information available
Reproductive toxicity:	No information available
Teratogenicity:	No information available
Mutagenicity:	No information available

PREVENTIVE MEASURES:

Personal Protective Equipment:	
Eye Protection:	Safety glasses or goggles.
Skin Protection:	Latex or PVC gloves and apron or coveralls.
Respiratory Protection:	If dusting is a problem, a NIOSH/MSHA approved dust respirator must be worn.
Engineering Controls:	Use local ventilation if dusting is a problem. Eye wash stations must be available.
Storage Requirements:	Store at ambient temperature. Store away from oxidants in closed and properly labeled sacks or containers
Handling Procedures:	Avoid breathing dust. Avoid getting in eyes or on skin. Wash thoroughly after handling. Store in a cool, dry place

	away from direct sunlight, sources of ignition, and incompatible materials. Reseal containers immediately after use. Store away from food and beverages.
Spill or Leak Procedures:	Use recommended protective clothing and equipment. Clean spills in a manner that does not disperse dust into the air. Spill area can be washed with water. Collect wash water for approved disposal. Keep from entering water or ground water.
Disposal:	Waste disposal should be in accordance with existing federal, state/provincial and local environmental regulations.

FIRST AID MEASURES:

Skin:	In case of contact, wash skin with soap and water. Wash clothing before reuse. Seek medical attention if irritation occurs.
Eyes:	In case of contact, immediately flush eyes with lukewarm running water for at least 15 minutes, holding the eyelids open. Seek medical attention.
Inhalation:	If inhaled, remove victim to fresh air. If breathing has stopped, trained personnel should begin artificial respiration. If breathing is difficult, give oxygen. Seek medical attention.
Ingestion:	If swallowed, seek medical attention immediately.

↑ Top

Patents and Intellectual Property

Protection of corporate intellectual property is a critical element of Dynamotive's strategy. The objective of Dynamotive's patent strategy is to protect and maximize the long-term benefits that can be derived from its technology leadership position. The Company aggressively protects the intellectual property it develops and intends to assert its patents rights when any infringement is identified.

The Company has active inventions protected by 18 patents issued and 20 patents pending on its pyrolysis technology. The Company also owns patents on non-pyrolysis related technologies

↑ Top

All information presented herein is true and correct to the knowledge of Dynamotive Energy Systems Corp. upon date of publication.

Appendix D

Carbon Dioxide Emissions Data

Energy Information Administration
Official Energy Statistics from the U.S. Government

search Glossary

Voluntary Reporting of Greenhouse Gases Program (Fuel and Energy Source Codes and Emission Coefficients)

Voluntary Reporting of Greenhouse Gases Program
Fuel and Energy Source Codes and Emission Coefficients

Fuel	Code	Emission Coefficients: Pounds CO_2 per Unit Volume or Mass		Emission Coefficients: Pounds CO_2 per Million Btu
Petroleum Products				
Aviation Gasoline	AV	18.355	per gallon	152.717
		770.916	per barrel	
Distillate Fuel (No. 1, No. 2, No. 4 Fuel Oil and Diesel)	DF	22.384	per gallon	161.386
		940.109	per barrel	
Jet Fuel	JF	21.095	per gallon	156.258
		885.98	per barrel	
Kerosene	KS	21.537	per gallon	159.535
		904.565	per barrel	
Liquified Petroleum Gases (LPG)	LG	12.805	per gallon	139.039
		537.804	per barrel	
Motor Gasoline	MG	19.564	per gallon	156.425
		822.944	per barrel	
Petroleum Coke	PC	32.397	per gallon	225.130
		1356.461	per barrel	
		6768.667	per short ton	
Residual Fuel (No. 5 and No. 6 Fuel Oil)	RF	26.033	per gallon	173.906
		1,093.384	per barrel	
Natural Gas and Other Gaseous Fuels				
Methane	ME	116.376	per 1000 ft3	115.258
Landfill Gas	LF	[1]	per 1000 ft3	115.258
Flare Gas	FG	133.759	per 1000 ft3	120.721

Natural Gas (Pipeline)	NG	120.593	per 1000 ft3	117.080
Propane	PR	12.669	per gallon	139.178
		532.085	per barrel	
Electricity	EL	Varies depending on fuel used to generate electricity		
Electricity Generated from Landfill Gas	LE	Varies depending on heat rate of the power generating facility		
Coal	CL			
Anthracite	AC	5685.00	per short ton	227.400
Bituminous	BC	4931.30	per short ton	205.300
Subbituminous	SB	3715.90	per short ton	212.700
Lignite	LC	2791.60	per short ton	215.400
Renewable Sources				
Biomass	BM	Varies depending on the composition of the biomass		
Geothermal Energy	GE	0		0
Wind	WN	0		0
Photovoltaic and Solar Thermal	PV	0		0
Hydropower	HY	0		0
Tires/Tire-Derived Fuel	TF	6160	per short ton	189.538
Wood and Wood Waste [2]	WW	3812	per short ton	195.0
Municipal Solid Waste [2]	MS	1999	per short ton	199.854
Nuclear	NU	0		0
Other	ZZ	0		0

1 For a landfill gas coefficient per thousand standard cubic foot, multiply the methane factor by the share of the landfill gas that is methane.

2 These biofuels contain "biogenic" carbon. Under international greenhouse gas accounting methods developed by the Intergovernmental Panel on Climate Change, biogenic carbon is part of the natural carbon balance and it will not add to atmospheric concentrations of carbon dioxide.[3] Reporters may wish to use an emission factor of zero for wood, wood waste, and other biomass fuels in which the carbon is entirely biogenic. Municipal solid waste, however, normally contains inorganic materials principally plastics that contain carbon that is not biogenic. The proportion of plastics in municipal solid waste varies considerably depending on climate, season, socio-economic factors, and waste management practices. As a result, EIA does not estimate a non-biogenic carbon dioxide emission factor for municipal solid waste. The U.S. Environmental Protection Agency estimates that, in 1997, municipal solid waste in the United States contained 15.93 percent plastics and the carbon dioxide emission factor for these materials was 5,771 lbs per ton.[4] Using this information, a proxy for a national average non-biogenic emission factor of 919 lbs carbon dioxide per short ton of municipal solid waste can be derived. This represents 91.9 lbs carbon dioxide per million Btu, assuming the average energy content of municipal solid waste is 5,000 Btu/lb.

3 Intergovernmental Panel on Climate Change. *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3, Pg. 6.28, (Paris France 1997).

4 U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998*, EPA 236-R-00-001, Washington, DC, April 2000.

Appendix E

Cost Estimate Spreadsheets

Bio Oil Plant size (wood feed rate, dry tons per day)					**PILOT SCALE 5 to 10 dtpd (intermittent operation due to R&D)**		
Bio-oil Plant Employees	**Base Pay**		**(w/ 30% overhead)**			Payroll w/OH	
24 hr/day, 7 days/week, 42 hr workweeks = 4 shifts = 8760 hrs							
Plant Manager	$	90,000	$	117,000	0.5	$	58,500
Plant Engineer R&D	$	70,000	$	91,000	1.0	$	91,000
Lab Manager / Chemist	$	50,000	$	65,000	0.5	$	32,500
Shift / Maintenance Supervisor	$	50,000	$	65,000	0.5	$	32,500
Maintenance Tech	$	30,000	$	39,000	0.5	$	19,500
Shift Operators (4 shifts)	$	30,000	$	39,000	4.0	$	156,000
Admin Assistant	$	20,000	$	26,000	0.5	$	13,000
Bio Oil delivery	$	30,000	$	39,000	0.5	$	19,500
Subtotal Plant Employees					*8.0*		
Plant Annual Payroll w/OH						***$***	***422,500***

ANNUAL OPERATING COSTS						
Dry Wood feed rate, dry tons per day)					**10**	dtpd
Green tons per day @		**50**	% water content		20	gtpd
Green tons per year@					6,600	gtpy
Daily Bio-oil Production, tons @		**61.7**	% oil to dry wood		6	tpd
Annual Bio-oil Production @		**330**	24 hr-days/yr		2,034	tpy
Daily Bio-oil production volume @		**10**	lb/gallon		1,233	gal
Annual Bio-Oil Production, gallons					406,890	gal/yr
Annual Bio-Oil Production, barrels		42	gal/bbl		9,688	bbl/yr
Daily Char Production, tons @		**18.5**	% char to dry wood		2	tpd
Annual Char Production tons					611	tpy
Truckloads biooil per day (approx)		8,000	gal loads		0.15	
Truckloads char per day (approx)		10	ton loads		0.19	
Total trucks per day (approx)					0.34	
Total trucks per week (approx)					2	
24 hr/day, 7 days/week, 42 hr workweeks = 4 shifts						
Feedstock Grinding	**$**	**5.00**	per green ton	$	33,000	
Production Electricity kWh/hr					100	kwhr
Electricity Costs		**$0.07**	per kWhr	$	55,440	
Nitrogen				$	5,000	
Misc Chemicals				$	10,000	
Propane (for occasional startup)			Gal		1,000	
Propane Costs	**$**	**3.00**	$/Gal	$	3,000	
Bio-oil internal usage for drying	**tons**		(10% of production)		203	tpy

Bio Oil Plant size (wood feed rate, dry tons per day)				**PILOT SCALE 5 to 10 dtpd (intermittent operation due to R&D)**		
Bio-oil BTU value		**7,051**	BTU/lb		2,869	Mbtu/yr
Bio-oil cost (10% subtracted from total production already included)				$	-	
Plant Labor (linked ss)				$	422,500	
Equip Maintenance				$	100,000	
Misc Water & Sewer & Elec (non-production)				$	2,000	
Misc Supplies & Service				$	2,000	
Misc Admin Costs (Insurance, Admin Filings, Env Reporting, etc)				$	50,000	
Subtotal Production Costs				**$**	**682,940**	
Subtotal Feedstock Costs, green tons chipped, delivered annually						
med cost feedstock	$	30.00	per green ton	$	198,000	
Total Annual Operating Costs (Feedstock + Production)				**$**	**880,940**	
Revenue						
Bio-oil Sales	$	0.83	$/gal bio-oil	$	337,086	
Char Sales	$	280.04	$/ton char	$	170,963	
Subtotal Revenue				**$**	**508,050**	
Net Annual Operating Costs				**$**	**372,890**	

CAPITAL COSTS	quantity	units		unit cost		subtotal
Real Estate Acquisition	0	acres		-	$	-
Site Development (grading, stormwater, pavement, fencing)	0.5	acres		50,000	$	25,000
Utility Connections (power, water, etc)	1	ls		20,000	$	20,000
Grinding Equipment	1	ls		150,000	$	150,000
Drying Equipment	1	ls		150,000	$	150,000
Fast Pyrolysis System	1	ls		1,500,000	$	1,500,000
Storage Tank System, 5 days storage	1	ls		50,000	$	50,000
Truck Loading / Unloading	0	ls		-	$	-
Fire Suppression System	1	ls		100,000	$	100,000
Mobile Equipment (front end loaders, etc)	1	ls		200,000	$	200,000
Storage Blgs	10,000	sf		35	$	350,000
Offices	0	sf		-	$	-
Subtotal					***$***	***2,545,000***
Contingency	30%	subtotal	$	2,545,000	$	763,500
Engineering & Permitting	40%	subtotal	$	2,545,000	$	1,018,000
Construction Mgt	15%	subtotal	$	2,545,000	$	381,750
Commissioning - 6 mos	75%	annual labor	$	422,500	$	316,875
Tech Licensing Fee	0	ls	$	-	$	-
Total Capital					**$**	**5,025,125**
Plus Net Operating Costs During Demonstration Period	5	yrs	$	372,890	$	1,864,452
Total Capital plus 5 years Net Operating Costs					**$**	**6,889,577**

Jobs at Full-Scale

Bio-oil Plant Employees	Base Pay	(w/ 30% overhead)	50	Payroll w/OH	100	Payroll w/OH	200	Payroll w/OH
Bio Oil Plant size (wood feed rate, dry tons per day)			**50**		**100**		**200**	
Truckloads per day			2		3		7	
24 hr/day, 7 days/week, 42 hr workweeks = 4 shifts = 8760 hrs								
Plant Manager	$ 90,000	$ 117,000	0.5	$ 58,500	1.0	$ 117,000	1.0	$ 117,000
Plant Engineer	$ 70,000	$ 91,000	0.5	$ 45,500	1.0	$ 91,000	1.0	$ 91,000
Lab Manager / Chemist	$ 50,000	$ 65,000	0.5	$ 32,500	0.5	$ 32,500	1.0	$ 65,000
Shift / Maintenance Supervisor	$ 50,000	$ 65,000	3.5	$ 227,500	3.5	$ 227,500	4.0	$ 260,000
Maintenance Tech	$ 30,000	$ 39,000	1.0	$ 39,000	2.0	$ 78,000	3.0	$ 117,000
Shift Operators (4 shifts)	$ 30,000	$ 39,000	8.0	$ 312,000	8.0	$ 312,000	12.0	$ 468,000
Admin Assistant	$ 20,000	$ 26,000	1.0	$ 26,000	1.0	$ 26,000	1.0	$ 26,000
Bio Oil delivery (2 loads/driver day)	$ 30,000	$ 39,000	1.0	$ 39,000	2.0	$ 78,000	4.0	$ 156,000
Subtotal Plant Employees			*16.0*		*19.0*		*27.0*	
Plant Annual Payroll w/OH				*$ 780,000*		*$ 962,000*		*$ 1,300,000*
Equivalent logger jobs to support (4 jobs/100 dptd)			*2*		*4*		*8*	
Total Jobs (loggers & plant employees)			***18***		***23***		***35***	

Item	Parameter	Unit	50 dtpd		100 dtpd		200 dtpd	
Bio Oil Plant size (wood feed rate, dry tons per day)			**50**	dtpd	**100**	dtpd	**200**	dtpd
Green tons per day @	**50**	% water content	100	gtpd	200	gtpd	400	gtpd
Green tons per year@			32,850	gtpy	65,700	gtpy	131,400	gtpy
Daily Bio-oil Production, tons @	**61.7**	% oil to dry wood	31	tpd	62	tpd	123	tpd
Annual Bio-oil Production @	**329**	days	10,126	tpy	20,252	tpy	40,504	tpy
Daily Bio-oil production volume @	**10**	lb/gallon	6,165	gal	12,330	gal	24,660	gal
Annual Bio-Oil Production, gallons			2,025,203	gal/yr	4,050,405	gal/yr	8,100,810	gal/yr
Annual Bio-Oil Production, barrels	42	gal/bbl	48,219	bbl/yr	96,438	bbl/yr	192,876	bbl/yr
Daily Char Production, tons @	**18.5**	% char to dry wood	9	tpd	19	tpd	37	tpd
Annual Char Production tons			3,039	tpy	6,077	tpy	12,155	tpy
Truckloads biooil per day (approx)	8,000	gal loads	1		2		3	
Truckloads char per day (approx)	10	ton loads	1		2		4	
Total trucks per day (approx)			2		3		7	
24 hr/day, 7 days/week, 42 hr workweeks = 4 shifts								
Feedstock Grinding	**$ 5.00**	per green ton	$ 164,250		$ 328,500		$ 657,000	
Production Electricity kWh/hr (per NH study)			550	kwhr	962	kwhr	1788	kwhr
Electricity Costs	**$0.07**	per kWhr	$ 303,534		$ 530,909		$ 986,761	
Nitrogen			$ 80,000		$ 160,000		$ 320,000	
Misc Chemicals			$ 120,000		$ 240,000		$ 480,000	
Propane (for occassional startup)		Gal	5,000		10,000		15,000	
Propane Costs	**$ 3.00**	$/Gal	$ 15,000		$ 30,000		$ 45,000	
Bio-oil internal usage for drying	**tons**	(10% of production)	1,013	tpy	2,025	tpy	4,050	tpy
Bio-oil BTU value	**7,051**	BTU/lb	14,280	Mbtu/yr	28,559	Mbtu/yr	57,119	Mbtu/yr
Bio-oil cost (10% subtracted from total production already included)								
Plant Labor (linked ss)			$ 780,000		$ 962,000		$ 1,300,000	
Equip Maintenance			$ 1,000,000		$ 1,500,000		$ 2,000,000	
Misc Water & Sewer & Elec (non-production)			$ 20,000		$ 30,000		$ 60,000	
Misc Supplies & Service			$ 75,000		$ 125,000		$ 175,000	
Misc Admin Costs (Insurance, Admin Filings, Env Reporting, etc)			$ 250,000		$ 350,000		$ 500,000	
Subtotal Production Costs			**$ 2,807,784**		**$ 4,256,409**		**$ 6,523,761**	

Bio Oil Plant size (wood feed rate, dry tons per day)				**50** dtpd	**100** dtpd	**200** dtpd
Subtotal Feedstock Costs, green tons chipped, delivered annually						
low cost feedstock	$	25.00	per green ton	$ 821,250	$ 1,642,500	$ 3,285,000
med cost feedstock	**$**	**30.00**	**per green ton**	**$ 985,500**	**$ 1,971,000**	**$ 3,942,000**
high cost feedstock	$	35.00	per green ton	$ 1,149,750	$ 2,299,500	$ 4,599,000
Total Annual Operating Costs (Feedstock + Production)						
low cost feedstock				$ 3,629,034	$ 5,898,909	$ 9,808,761
med cost feedstock				**$ 3,793,284**	**$ 6,227,409**	**$ 10,465,761**
high cost feedstock				$ 3,957,534	$ 6,555,909	$ 11,122,761
Production Cost per gallon BioOil (not including capital costs, or offset from char sales)						
low cost feedstock				$ 1.79	$ 1.46	$ 1.21
med cost feedstock				**$ 1.87**	**$ 1.54**	**$ 1.29**
high cost feedstock				$ 1.95	$ 1.62	$ 1.37
Production Cost per gallon BioOil (not including capital) Heating Oil Equivalent (on BTU basis)						
low cost feedstock				$ 3.38	$ 2.75	$ 2.28
med cost feedstock				**$ 3.53**	**$ 2.90**	**$ 2.44**
high cost feedstock				$ 3.69	$ 3.05	$ 2.59

Bio Oil Plant size (wood feed rate, dry tons per day)	**50** dtpd				**100** dtpd				**200** dtpd			
	quantity	units	unit cost	subtotal	quantity	units	unit cost	subtotal	quantity	units	Unit cost	subtotal
Real Estate Acquisition	5	acres	3,000	$15,000	8	acres	3,000	$24,000	10	acres	3,000	$30,000
Site Development (grading, stormwater, pavement, fencing)	5	acres	50,000	$250,000	8	acres	50,000	$400,000	10	acres	50,000	$500,000
Utility Connections (power, water, etc)	1	ls	100,000	$100,000	1	ls	100,000	$100,000	1	ls	100,000	$100,000
Grinding Equipment	1	ls	300,000	$300,000	1	ls	400,000	$400,000	1	ls	500,000	$500,000
Drying Equipment	1	ls	400,000	$400,000	1	ls	500,000	$500,000	1	ls	700,000	$700,000
Fast Pyrolysis System	1	ls	3,000,000	$3,000,000	1	ls	6,000,000	$6,000,000	1	ls	10,000,000	$10,000,000
Storage Tank System, 5 days storage	30825	gal	10	$308,250	61650	gal	9	$554,850	123300	gal	8	$986,400
Truck Loading / Unloading	1	ls	300,000	$300,000	1	ls	300,000	$300,000	1	ls	300,000	$300,000
Fire Suppression System	1	ls	100,000	$100,000	1	ls	100,000	$100,000	1	ls	100,000	$100,000
Mobile Equipment (front end loaders, etc)	1	ls	1,000,000	$1,000,000	1	ls	1,000,000	$1,000,000	1	ls	2,000,000	$2,000,000
Storage Blgs	40,000	sf	35	$1,400,000	40,000	sf	35	$1,400,000	80,000	sf	35	$2,800,000
Offices	2000	sf	150	$300,000	2000	sf	150	$300,000	2000	sf	150	$300,000
Subtotal				***$7,473,250***				***$11,078,850***				***$18,316,400***
Contingency	30%	subtotal	$7,473,250	$2,241,975	25%	subtotal	$11,078,850	$2,769,713	20%	subtotal	$18,316,400	$3,663,280
Engineering & Permitting	20%	subtotal	$7,473,250	$1,494,650	15%	subtotal	$11,078,850	$1,661,828	10%	subtotal	$18,316,400	$1,831,640
Construction Mgt	20%	subtotal	$7,473,250	$1,494,650	15%	subtotal	$11,078,850	$1,661,828	10%	subtotal	$18,316,400	$1,831,640
Commissioning - 6 mos	75%	annual labor	$780,000	$585,000	65%	annual labor	$962,000	$625,300	50%	annual labor	$1,300,000	$650,000
Tech Licensing Fee	1	ls	%1,000,000	$1,000,000	1	ls	$2,000,000	$2,000,000	1	ls	$3,000,000	$3,000,000
Total				**$14,289,525**				**$19,797,518**				**$29,292,960**

Bio-oil Price Justification with Crude Oil at **70.00** $/bbl

Compare BTU value and pricing of bio-oil to low-sulphur residual oil

compare $ / btu to oil / ng etc

	Btu value		$/MMbtu			
btu value of residual oil	145,000	btu/gal				
btu value of bio oil	71,000	btu/gal		7100 btu/lb		
Ratio (bio/ resid oil)	0.49					
Price of resid oil	**70.00**	$/bbl	(follows closely with crude oil)			
Price of resid oil	1.67	$/gal	11.5		70	$/bbl
Calc'd price of bio-oil	0.82	$/gal	11.5			

Char Price Justification

Price per BTU value of bio-oil

Btu value of char	12,000	Btu/lb
	24	MMBtu/ton
$/MMbtu of bio-oil	11.5	$/MMbtu
Equiv price of char	**275.86**	**$/ton**
	0.14	$/lb

Potential Impacts of Carbon Credit Trading

Calculate Carbon Dioxide replacement value if using Bio-oil in place of fossil fuels.

Residual Oil CO_2 emissions	174	lbs CO2/MMBtu		
Residual Oil CO_2 emissions	0.087	tons CO2/MMBtu		
			Improved Price with CO2 offset value	
If CO2 offset credit	2	$/TON CO2		
then price value $/MMBtu	0.174	$/MMBtu	**PESSIMISTIC BASE CASE**	
Bio-oil price bump	$ 0.01	$/gal bio-oil	**$ 0.83**	**$/gal bio-oil**
Char price bump	$ 4.18	$/ton char	**$ 280.04**	**$/ton char**
If CO2 offset credit	10	$/TON CO2		
then price value $/MMBtu	0.87	$/MMBtu		
Bio-oil price bump	$ 0.06	$/gal bio-oil	$ 0.88	$/gal bio-oil
Char price bump	$ 20.88	$/ton char	$ 296.74	$/ton char
If CO2 offset credit	20	$/TON CO2		
then price value $/MMBtu	1.74	$/MMBtu		
Bio-oil price bump	$ 0.12	$/gal bio-oil	$ 0.94	$/gal bio-oil
Char price bump	$ 41.76	$/ton char	$ 317.62	$/ton char
If CO2 offset credit	30	$/TON CO2		
then price value $/MMBtu	2.61	$/MMBtu		
Bio-oil price bump	$ 0.19	$/gal bio-oil	$ 1.00	$/gal bio-oil
Char price bump	$ 62.64	$/ton char	$ 338.50	$/ton char

Bio-oil Price Justification with Crude Oil at **100.00** $/bbl

Compare BTU value and pricing of bio-oil to low-sulphur residual oil

compare $ / btu to oil / ng etc

	Btu value		$/Mmbtu				
btu value of residual oil	145,000	btu/gal					
btu value of pyro oil	71,000	btu/gal		7100	btu/lb		
Ratio (bio/ resid oil)	0.49						
Price of resid oil	**100.00**	$/bbl	(follows closely with crude oil)				
Price of resid oil	2.38	$/gal	16.4			100	$/bbl
Calc'd price of bio-oil	1.17	$/gal	16.4				

Char Price Justification

Price per BTU value of bio-oil

Btu value of char	12,000	Btu/lb
	24	MMBtu/ton
$/Mmbtu of bio-oil	16.4	$/Mmbtu
Equiv price of char	**394.09**	**$/ton**
	0.20	$/lb

Potential Impacts of Carbon Credit Trading

Calculate Carbon Dioxide replacement value if using Bio-oil in place of fossil fuels.

Residual Oil CO2 emissions		174	lbs CO2/MMBtu			
Residual Oil CO2 emissions		0.087	tons CO2/MMBtu			
				Improved Price with CO2 offset value		
If CO2 offset credit		2	$/TON CO2			
then price value $/MMBtu		0.174	$/MMBtu			
Bio-oil price bump	$	0.01	$/gal bio-oil	$	1.18	$/gal bio-oil
Char price bump	$	4.18	$/ton char	$	398.26	$/ton char
If CO2 offset credit		10	$/TON CO2	**BASE CASE**		
then price value $/MMBtu		0.87	$/MMBtu			
Bio-oil price bump	$	0.06	$/gal bio-oil	**$**	**1.23**	**$/gal bio-oil**
Char price bump	$	20.88	$/ton char	**$**	**414.97**	**$/ton char**
If CO2 offset credit		20	$/TON CO2			
then price value $/MMBtu		1.74	$/MMBtu			
Bio-oil price bump	$	0.12	$/gal bio-oil	$	1.29	$/gal bio-oil
Char price bump	$	41.76	$/ton char	$	435.85	$/ton char
If CO2 offset credit		30	$/TON CO2			
then price value $/MMBtu		2.61	$/MMBtu			
Bio-oil price bump	$	0.19	$/gal bio-oil	$	1.35	$/gal bio-oil
Char price bump	$	62.64	$/ton char	$	456.73	$/ton char

Bio-oil Price Justification with Crude Oil at **120.00** $/bbl

Compare BTU value and pricing of bio-oil to low-sulphur residual oil

compare $ / btu to oil / ng etc

	Btu value		$/MMbtu		
btu value of residual oil	145,000	btu/gal			
btu value of pyro oil	71,000	btu/gal		7100 btu/lb	
Ratio (bio/ resid oil)	0.49				
Price of resid oil	**120.00**	$/bbl	(follows closely with crude oil)		
Price of resid oil	2.86	$/gal	19.7		120 $/bbl
Calc'd price of bio-oil	1.40	$/gal	19.7		

Char Price Justification

Price per BTU value of bio-oil

Btu value of char	12,000	Btu/lb
	24	MMBtu/ton
$/MMbtu of bio-oil	19.7	$/MMbtu
Equiv price of char	**472.91**	**$/ton**
	0.24	$/lb

Potential Impacts of Carbon Credit Trading

Calculate Carbon Dioxide replacement value if using Bio-oil in place of fossil fuels.

Residual Oil CO2 emissions		174	lbs CO2/MMBtu	
Residual Oil CO2 emissions		0.087	tons CO2/MMBtu	
				Improved Price with CO2 offset value
If CO2 offset credit		2	$/TON CO2	
then price value $/MMBtu		0.174	$/MMBtu	
Bio-oil price bump	$	0.01	$/gal bio-oil	$ 1.41 $/gal bio-oil
Char price bump	$	4.18	$/ton char	$ 477.08 $/ton char
If CO2 offset credit		10	$/TON CO2	
then price value $/MMBtu		0.87	$/MMBtu	
Bio-oil price bump	$	0.06	$/gal bio-oil	$ 1.46 $/gal bio-oil
Char price bump	$	20.88	$/ton char	$ 493.79 $/ton char
If CO2 offset credit		15	$/TON CO2	
then price value $/MMBtu		1.305	$/MMBtu	
Bio-oil price bump	$	0.09	$/gal bio-oil	$ 1.49 $/gal bio-oil
Char price bump	$	31.32	$/ton char	$ 504.23 $/ton char
If CO2 offset credit		20	$/TON CO2	**OPTIMISTIC PRICE CASE**
then price value $/MMBtu		1.74	$/MMBtu	
Bio-oil price bump	$	0.12	$/gal bio-oil	**$ 1.52 $/gal bio-oil**
Char price bump	$	41.76	$/ton char	**$ 514.67 $/ton char**

Return On Investment Evaluation Optimistic Case

Bio Oil Plant size (wood feed rate, dry tons per day):			**50** dtpd	**100** dtpd	**200** dtpd
Capital Cost			$ 14,289,525	$ 19,797,518	$ 29,292,960
Grant Funding	70%				
Investment (zero interest loan,)	30%		**$ 4,286,858**	**$ 5,939,255**	**$ 8,787,888**
Annual Costs					
Production Costs			$ 2,807,784	$ 4,256,409	$ 6,523,761
Feedstock Costs @	**$ 25.00**	per green ton	**$ 821,250**	**$ 1,642,500**	**$ 3,285,000**
Tons Bio-oil and Char produced annually			13164.6375 tpy	26329.275 tpy	52658.55 tpy
Royalty Fee	**$0**	ton	$ -	$ -	$ -
SubTotal Annual Costs			***$ 3,629,034***	***$ 5,898,909***	***$ 9,808,761***
Annual Revenues					
Gallons Bio-Oil produced annually			2,025,203 gal/yr	4,050,405 gal/yr	8,100,810 gal/yr
Bio-oil revenue generated @	**$ 1.52**	per gallon	$ 3,083,482	$ 6,166,963	$ 12,333,927
Tons of Char produced annually			3,039 tpy	6,077 tpy	12,155 tpy
Char revenue generated @	**$ 514.67**	per ton	$ 1,563,878	$ 3,127,756	$ 6,255,513
SubTotal Annual Revenues			***$ 4,647,360***	***$ 9,294,720***	***$ 18,589,440***
Annual Net gain (or loss)			**$ 1,018,326**	**$ 3,395,811**	**$ 8,780,678**
Simple Return on Investment (without finance charges)			4.2 yrs	1.7 yrs	1.0 yrs

Optimistic Case			
Based on:	Variables		
Grant Funding		70%	
Biomass Feedstock Pricing	$	25.00	per green ton
Royalty Fee	$	-	ton
Bio-oil and Char tied to Crude Oil at		120.00	$/bbl
Carbon Credit Value:		20	$/TON CO2

Return On Investment Evaluation Base Case

Bio Oil Plant size (wood feed rate, dry tons per day):			**50** dtpd	**100** dtpd	**200** dtpd
Capital Cost			$ 14,289,525	$ 19,797,518	$ 29,292,960
Grant Funding	50%				
Investment (zero interest loan,)	50%		**$ 7,144,763**	**$ 9,898,759**	**$ 14,646,480**
Annual Costs					
Production Costs			$ 2,807,784	$ 4,256,409	$ 6,523,761
Feedstock Costs @	**$ 30**	per green ton	$ 985,500	$ 1,971,000	$ 3,942,000
Tons Bio-oil and Char produced annually			13,165 tpy	26,329 tpy	52,659 tpy
Royalty Fee	**$3**	ton	$ 39,494	$ 78,988	$ 157,976
SubTotal Annual Costs			***$ 3,832,778***	***$ 6,306,396***	***$ 10,623,737***
Annual Revenues					
Gallons Bio-Oil produced annually			2,025,203 gal/yr	4,050,405 gal/yr	8,100,810 gal/yr
Bio-oil revenue generated @	**$ 1.23**	per gallon	$ 2,486,170	$ 4,972,341	$ 9,944,681
Tons of Char produced annually			3,039 tpy	6,077 tpy	12,155 tpy
Char revenue generated @	**$ 414.97**	per ton	$ 1,260,934	$ 2,521,868	$ 5,043,737
SubTotal Annual Revenues			***$ 3,747,104***	***$ 7,494,209***	***$ 14,988,418***
Annual Net gain (or loss)			**$ (85,673)**	**$ 1,187,813**	**$ 4,364,681**
Simple Return on Investment (without finance charges)			No Return	8.3 yrs	3.4 yrs

Base Case		
Based on:	Variables	
Grant Funding	50%	
Biomass Feedstock Pricing	$ 30.00	per green ton
Royalty Fee	$ 3.00	ton
Bio-oil and Char tied to Crude Oil at	100.00	$/bbl
Carbon Credit Value:	10	$/TON CO2

Return On Investment Evaluation Pessimistic Case

Bio Oil Plant size (wood feed rate, dry tons per day):				**50** dtpd	**100** dtpd	**200** dtpd
Capital Cost				$ 14,289,525	$ 19,797,518	$ 29,292,960
Grant Funding		30%				
Investment (zero interest loan,)		70%		**$ 10,002,668**	**$ 13,858,262**	**$ 20,505,072**
Annual Costs						
Production Costs				$ 2,807,784	$ 4,256,409	$ 6,523,761
Feedstock Costs @	**$**	**35.00**	per green ton	$ 1,149,750	$ 2,299,500	$ 4,599,000
Tons Bio-oil and Char produced annually				13164.6375 tpy	26329.275 tpy	52658.55 tpy
Royalty Fee	**$**	**5.00**	ton	$ 65,823	$ 131,646	$ 263,293
SubTotal Annual Costs				***$ 4,023,357***	***$ 6,687,555***	***$ 11,386,054***
Annual Revenues						
Gallons Bio-Oil produced annually				2,025,203 gal/yr	4,050,405 gal/yr	8,100,810 gal/yr
Bio-oil revenue generated @	**$**	**0.83**	per gallon	$ 1,677,771	$ 3,355,542	$ 6,711,083
Tons of Char produced annually				3,039 tpy	6,077 tpy	12,155 tpy
Char revenue generated @	**$**	**280.04**	per ton	$ 850,931	$ 1,701,861	$ 3,403,723
SubTotal Annual Revenues				***$ 2,528,701***	***$ 5,057,403***	***$ 10,114,806***
Annual Net gain (or loss)				**$ (1,494,656)**	**$ (1,630,152)**	**$ (1,271,248)**
Simple Return on Investment (without finance charges)				No Return	No Return	No Return

Pessimistic Case			
Based on:	Variables		
Grant Funding		30%	
Biomass Feedstock Pricing	$	35.00	per green ton
Royalty Fee	$	5.00	ton
Bio-oil and Char tied to Crude Oil at		70.00	$/bbl
Carbon Credit Value:		2	$/TON CO2

Appendix F

Energy Price Outlook

Appendix – Energy Price Projections

Short Term Energy Prices

On December 17, 2008, the U.S. Department of Energy (DOE) released an early summary of the *Annual Energy Outlook 2009* (AEO2009), a case study that presents projections and analyses of the United States energy supply, demand, and prices through the year 2030. The projections are based on results from the Energy Information Administration's National Energy Modeling System. The Table "Short-Term Energy Outlook Price Summary", summarizes the average annual cost per unit of crude oil, natural gas, coal and electricity for 2006 and 2007 as well as the projected average energy cost per unit for 2008 and 2009.

Short-Term Energy Outlook Price Summary

Energy Source	Year			
	2006	2007	2008	2009
Imported Crude Oil ($/barrel)[a]	**59.10**	**63.83**	**98.89**	**56.76**
Natural Gas Wellhead Price ($/mmBtu)[b]	**6.31**	**6.22**	**7.97**	**5.82**
Coal Minemouth Price ($/mmBtu)[c]	**1.21**	**1.27**	**1.43**	**1.53**
Electricity–All Sectors (cents/kilowatthour)	**8.86**	**9.11**	**9.86**	**10.05**

a Weighted average price delivered to U.S. refineries

b Represents lower 48 onshore and offshore supplies

c Includes reported prices for both open market and captive mines

Long Term Energy Prices

Long-term projections in energy supply and demand are affected by many factors that make predictions difficult. Examples include the following: energy prices, domestic and worldwide economic growth, advances in technologies, and future public policy decisions both at a national and international level. For the purposes of projecting the long-term domestic energy trends, (i.e. energy production, consumption and prices), the information included in this report is taken from the AEO2009 summary. The data from the following long-term projections is summarized below.

Long-Term Energy Outlook Production and Consumption (Quadrillion Btu)

Energy Source/Activity	Year												
Production*	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crude Oil & Lease Condensate	**10.75**	**11.68**	**12.18**	**12.14**	**12.32**	**12.36**	**12.37**	**12.40**	**12.54**	**12.86**	**13.26**	**13.51**	**14.02**
Natural Gas Plant Liquids	**2.46**	**2.45**	**2.52**	**2.54**	**2.58**	**2.55**	**2.51**	**2.50**	**2.50**	**2.52**	**2.55**	**2.55**	**2.52**
Dry Natural Gas	**21.08**	**21.45**	**20.87**	**21.08**	**21.35**	**21.15**	**20.91**	**20.83**	**20.97**	**21.12**	**21.36**	**21.51**	**22.02**
Coal [a]	**24.06**	**24.01**	**24.21**	**24.30**	**24.49**	**24.54**	**24.54**	**24.56**	**24.46**	**24.40**	**24.37**	**24.43**	**24.41**
Biomass [b]	**3.85**	**3.81**	**4.20**	**4.45**	**4.54**	**4.71**	**4.99**	**5.16**	**5.47**	**5.68**	**5.98**	**6.11**	**6.49**
Consumption *													
Liquid Fuels [c]	**38.84**	**38.18**	**38.10**	**38.79**	**39.09**	**39.28**	**39.15**	**38.97**	**38.97**	**39.00**	**39.03**	**39.04**	**38.97**
Natural Gas	**24.10**	**23.78**	**23.09**	**23.15**	**23.48**	**23.40**	**23.27**	**23.34**	**23.54**	**23.70**	**23.88**	**23.90**	**24.03**
Coal	**22.60**	**22.44**	**22.91**	**23.19**	**23.39**	**23.45**	**23.48**	**23.59**	**23.66**	**23.78**	**23.88**	**23.98**	**23.98**
Biomass [d]	**3.00**	**2.81**	**2.98**	**3.12**	**3.17**	**3.26**	**3.46**	**3.57**	**3.80**	**3.96**	**4.18**	**4.31**	**4.55**

*The difference between production and consumption equals net imports or exports.

a Includes waste coal.

b Includes grid-connected electricity from wood and wood waste, biomass such as corn used for liquid fuels production, and non-electric energy from wood.

c Includes petroleum-derived fuels and non-petroleum-derived fuels, such as ethanol and biodiesel. Petroleum coke, which is a solid, is included. Also included are natural gas plant liquids, crude oil consumed as a fuel, and hydrogen.

d Includes grid-connected electricity from wood and wood waste, non-electric energy from wood, and biofuels heat and coproducts used in the production of liquid fuels, but excludes the energy content of the liquid fuels.

Long-Term Energy Outlook Prices, Nationwide ($/unit)

Energy Source/Activity	Year												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Imported Crude Oil Price ($/Barrel)	**98.89**	**56.76**	**75.78**	**86.12**	**97.64**	**104.37**	**117.86**	**124.55**	**128.85**	**131.55**	**136.83**	**139.88**	**142.47**
Gas Wellhead Price ($/MMBtu)	**7.97**	**5.82**	**6.07**	**6.13**	**6.41**	**6.55**	**6.81**	**7.04**	**7.34**	**7.65**	**8.06**	**8.44**	**8.48**
Coal Minemouth Price ($/MMBtu)	**1.43**	**1.53**	**1.51**	**1.53**	**1.57**	**1.60**	**1.65**	**1.66**	**1.68**	**1.71**	**1.74**	**1.77**	**1.80**
Electricity (Cents/kilowatthour)	**9.86**	**10.05**	**9.44**	**9.63**	**9.75**	**9.96**	**10.20**	**10.47**	**10.75**	**11.06**	**11.42**	**11.81**	**12.14**

A. Long-Term Price Outlook, West-North Central Region

Projected energy prices (in 2007 dollars per MMBtu) are summarized in the table below**.**

Excerpted from AEO 2009 Table 14. Energy Prices by Sector and Source - West North Central

Average Price to All Users (2007 dollars per MMBtu, unless otherwise noted)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020	2030
Liquefied Petroleum Gases	19	21	16	20	21	23	24	26	26	27	29
E85 4/	26	34	33	23	25	26	27	26	24	28	28
Motor Gasoline 5/	22	26	19	22	24	25	26	27	28	29	32
Jet Fuel	16	22	15	15	17	19	19	21	21	22	25
Distillate Fuel Oil	20	26	18	18	20	21	22	24	25	25	28
Residual Fuel Oil	10	13	7	17	19	20	21	22	23	23	26
Natural Gas	9	11	9	9	9	9	9	9	9	9	11
Other Coal	1.24	1.40	1.32	1.31	1.33	1.36	1.37	1.40	1.44	1.47	1.62
Coal to Liquids	0.00	0.00	0.00	0.00	0.00	1.09	1.10	1.11	1.12	1.20	1.36
Electricity	20	22	22	22	22	21	22	22	22	22	23

The West-North Central Region is defined by the U.S. Census Bureau as containing the states of Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota and North Dakota.

B. Limitations

Energy markets are changing in response to many different factors, including the following: higher energy prices, the growing influence of developing countries on worldwide energy requirements, recently enacted legislation and regulations, changing public perceptions on issues related to emissions of air pollutants and greenhouse gases resulting in the wider use of alternate fuels and the economic viability of various energy technologies. It is important to note that projected energy costs differ between analysts. All projections are estimates, and actual production and consumption rates, as well as energy prices may trend differently than what is projected by the references used for this feasibility study.

Energy Information Administration
Official Energy Statistics from the U.S. Government

search

Glossary

Home > Forecasts & Analysis > Annual Energy Outlook 2009 Early Release

Annual Energy Outlook 2009 Early Release

Report #:DOE/EIA-0383(2009)
Release Date: December 2008
Next Release Date: November 2009
(full report available early 2009)

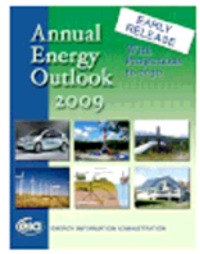
The Annual Energy Outlook presents a midterm projection and analysis of US energy supply, demand, and prices through 2030. The projections are based on results from the *Energy Information Administration's* National Energy Modeling System. The *AEO2009* Early Release includes the reference case. The full publication, to be released in early 2009, will include complete documentation and additional cases examining energy markets.

- Annual Energy Outlook 2009 Early Release Overview
- AEO2009 Early Release Summary Presentation
- AEO2009 Press Release

Projection Tables

- Summary Reference Case Tables
- Year-by-Year Reference Case Tables
- Regional and other detailed tables

Download the Presentation



AEO2009 Early Release Summary Presentation [874 kb]

Related Materials

Presentation Data
AEO2008
Past AEO Editions
Projection Contacts

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Appendix G

Funding Information

Appendix – Potential Funding Sources for Biofuel Production Facilities

A. FEDERAL OPTIONS

A.1 USDA – Rural Development.

The 2008 Farm Bill – Food Conservation and Energy Act provides a multitude of possible opportunities for financing assistance for both public and private entities.

<u>Business and Industry (B&I) Guarantee Program</u>
The B&I Guaranteed Loan Program is used to improve, develop, or finance business, industry, and employment and improve the economic and environmental climate in rural communities.
http://www.rurdev.usda.gov/rbs/busp/b&I_gar.htm

<u>Rural Economic Development Loan and Grant Program (REDLG)</u>
The REDLG program provides funding to rural projects through local utility organizations. The local utility, typically a Cooperative, is provided with zero interest loans which are then passed through to local businesses for projects that will create and retain employment in rural areas. http://www.rurdev.usda.gov/id/redlg.htm

<u>Value Added Producer Grant Program</u>
Grants for planning activities and for working capital for marketing value-added agricultural products and for farm-based renewable energy projects. Eligible applicants are independent producers, farmer and rancher cooperatives, agricultural producer groups, and majority-controlled producer-based business ventures.

<u>Rural Energy for America Program (REAP)</u>
(formerly Rural Energy/Energy Efficiency Program, Section 9006)
The REAP grant program provides grants for energy audits and renewable energy development assistance. It also provides funds to agricultural producers and rural small businesses to purchase and install renewable energy systems and make energy efficiency improvements.

<u>Rural Energy for America Program Guaranteed Loan Program (REAP)</u>
The REAP Guaranteed Loan Program encourages the commercial financing of renewable energy (bioenergy, geothermal, hydrogen, solar, and wind) and energy efficiency projects. Under the program, loan guarantees are up to 85 percent of the loan amount

<u>Rural Business Investment Program (RBIP)</u>
The Rural Business Investment Program (RBIP) is a joint initiative between the U. S. Department of Agriculture (USDA) and the Small Business Administration (SBA). It provides venture capital's funding to VC's via the SBA and USDA

<u>Biorefinery Assistance Program</u>
The program assists in the development of new and emerging technologies for the development of advanced biofuels that increase energy independence, promote resource conservation, public health, and the environment, diversify markets for agricultural and forestry products and agriculture waste material; and create jobs and enhance the economic development of the rural economy.
http://www.rurdev.usda.gov/rbs/busp/baplg9003.htm

<u>Bioenergy Program for Advanced Biofuels</u>
Title IX of the 2008 Farmbill (Section 9005) Provides for payments to eligible producers to support and ensure an expanding production of advanced biofuels.. Limited amount of money to large (>150 MGPY) producers http://www.ers.usda.gov/FarmBill/2008/titles/titleixenergy.htm

Biomass Research and Development Initiative http://www.brdisolutions.com/default.aspx
Provides financial assistance to promote research, development, and demonstration, (RD & D) related to the production of biofuels and bioproducts within three technical areas.

1. FEEDSTOCK DEVELOPMENT, RD&D for feedstock development, logistics (harvest, handling, transport, preprocessing, & storage) relevant to production of raw materials for conversion to biofuels and biobased products.
2. BIOFUELS AND BIOBASED PRODUCTS DEVELOPMENT a. RD&D of cost effective technologies for cellulosic biomass in production of biofuel & biobased products, b. Diversification of technology relevant to production of bioproducts (chemicals, animal feed, co generated power) to increase feasibility of fuel production in a biorefinery.
3. BIOFUELS DEVELOPMENT ANALYSIS, a. Strategic Guidance, b. Energy &Environmental Impact, c. Assessment of Federal Lands.

Rural Energy Self Sufficiency Initiative
Provides grant assistance for enabling eligible rural communities to substantially increase the energy self-sufficiency of the eligible rural communities. The program provides financial assistance to communities, in the form of a grant limited to 50% of the cost of the proposed activities, with the purpose of enabling rural communities to substantially increase their energy self-sufficiency. The grant may be used to conduct energy assessments of the community, formulate and analyze ideas for reducing energy use from conventional sources and for developing and installing an integrated renewable energy system.

Biomass Crop Assistance Program (BCAP)
Provides support to the establishment and production of crops for conversion to bio-energy in project areas and to assist with collection, harvest, storage, and transportation of eligible material for use in a biomass conversion facility.
The BCAP is being implemented by the Farm Service Agency.

A.2 US Department of Commerce, Economic Development Administration (EDA).

The federal EDA provides project financing and funding to specific eligible counties within the State, typically based upon income and unemployment rate, to both public and private entities.

Public Works Grants
Grant program to assist distress communities by attracting new industry, encouraging business expansions, diversify local economies, and generate long-term private sector jobs.

Economic Adjustment Assistance
Grant program to assist states and local areas design/implement strategies for facilitating adjustment to changes in their economic situation that are causing or threaten to cause serious structural damage to the underlying economic base.

A.3 Other Federal

Clean Renewable Energy Bond Program
Congress has approved an additional $800 million in authorization for the Clean Renewable Energy Bond (CREB) program. The funding amount represents the total value of bonds that can be issued under this program, not the value of the tax credits themselves. CREBs are a “tax credit bond,” that offers cooperatives the equivalent of an interest-free loan for financing qualified clean energy projects for a limited term.

Federal Direct Appropriations (Earmark)
US Department of Environmental Protection (EPA) State & Tribal Assistance Grant program (STAG). STAG grants, non-competitive, may be authorized by Congress in the annual appropriation of the EPA budget. STAG has funded a wide range of different types of projects that provide assistance to various entities. Congress can authorize a specific level of funding to a designated grantee to undertake a particular activity or project. It should be noted that a recipient of STAG funding may be required to provide a financial match of up to 45% of project costs.

Federal Direct Appropriations (Earmark)
US Department of Environmental Protection (EPA) Surveys, Studies, Investigations and Special Purpose Grants (an EPA discretionary grant program). Discretionary, non competitive, grants may be authorized by Congress in the annual appropriation of the EPA budget. The EPA's Surveys, Studies, Investigations and Special Purpose Grants have funded a variety of different types of projects that provide assistance to various entities. Congress can authorize a specific level of funding to a designated grantee to undertake a particular activity or project.

Federal Direct Appropriations (Earmark)
US Department of Housing & Urban Development (HUD) Congressional Grants, EDI Special Projects (Economic Development Initiative). Special non-competitive HUD Congressional grants may be authorized each year in the annual appropriation and accompanying conference report or congressional record. Congress can authorize a specific level of funding to a designated grantee to undertake a particular activity or project. Only entities designated by Congress can apply for the funds. It should be noted that the HUD EDI has not received an appropriation for several budget cycles.

B. STATE OF MINNESOTA

B.1 Minnesota Department of Employment & Economic Development (DEED)

Minnesota Investment Fund Biomass Heating Program
This program provides grants and loans to local units of government for the installation of biomass heating projects in publicly owned facilities.

Minnesota Investment Fund
The Minnesota Investment Fund provides grants to help add new workers and retain high-quality jobs with a focus is on industrial, manufacturing, and technology-related industries to increase the local and state tax base. The grants are awarded to local units of government who provide loans to assist expanding businesses.

Public Facility Authority (PFA) Credit Enhancement Program
The program reduces borrowing costs on general obligation bonds issued for certain purposes by providing a limited state guarantee of the bond payments, thereby allowing issuers to receive higher bond ratings.

Public Facility Authority (PFA) Clean Water Revolving Loan
Provides low interest financing to finance wastewater facilities that meet effluent standards mandated under the Clean Water Act.

Small Business Development Loan Program
The Small Business Development Loan Program provides loans to create jobs and assist with business expansions. Small business loans are made by the Minnesota Agricultural and Economic Development Board (MAEDB) through the issuance of industrial development bonds backed by a state-funded reserve of 25 percent.

B.2 State of Minnesota, Other

State Bonding Bill
Capital Budget Request: On a bi-annual basis, (next cycle 2010), the Department of Finance advises local units of Government when they can make specific requests for state appropriation for capital improvements. Theses types of grants must be publicly owned and serve a public purpose (reference MN Statute 16A.86).

C. LOCAL Funding & Financing Options

Revenue Bonds
There are two common types of Municipal Bonds used to finance utility improvements,
both are revenue bonds. The city uses revenues from the sewer or water enterprise fund to pay off and retire the debt. Revenue Bond, to issue a revenue bond, a source of revenue needs to be specified for repayment. General Obligation Revenue Bond, a general obligation bond is similar to a Revenue Bond in that there is an identified source of incoming enterprise revenue to pay off the debt, backed by the taxing power of the city if the revenue is insufficient to repay the debt.

Tax Increment Financing (TIF)
Economic Development TIF is established to discourage commerce, industry or manufacturing from leaving moving to another state or city, and increase employment in the city , and preserve and enhance it's tax base. Must pass the **"**But For**"** test. "But for TIF, would the development or redevelopment happen?" Must be for an identified public purpose and must pass other statutorily required rules, other mandated tests and be financially prudent for the local unit of government.

Minnesota Governmental Agency Finance Group (MGAFG)
MGAFG provides loan financing assistance to communities for capital improvement projects. The program is tax-exempt pooled financing which can lower issuance costs. No minimum or maximum loan amount is required. The loan terms are from 1 to 26 years. Interest rates are determined by current market conditions.

D. OTHER SOURCES

Xcel Energy
Renewable Development Fund
The Xcel Energy Renewable Development Fund (RDF) promotes start up, expansion and attraction of renewable energy projects and companies in the Xcel Energy service area.

Cargill
Direct awards of grants for research and development of renewable energy technologies and companies. Active in private sector and research institutions.

Appendix H

Photos

Photo 1 Welcome


Photo 2 Nett Lake

Photo 3 Nett Lake Reservation Map

Photo 4 Residual Biomass

Photo 5 Old residual biomass in forest

Photo 6 Residual Biomass

Photo 7 Roundwood

Photo 8 Sawdust piles at former sawmill site

Photo 9 Waste wood at former sawmill site

Photo 10 Residual Biomass

Photo 11 Biomass Chipping Demonstration at Fond du Lac Reservation

Photo 12 Biomass Chipping Demonstration at Fond du Lac Reservation

Photo 13 Biomass Grinding Demonstration at Nett Lake

Photo 14 Biomass Grinding Demonstration at Nett Lake

Photo 15 Woody Biomass being conveyed to LEA power plant

Photo 16 Pellet Plant in Marcell MN

Photo 17 Wood Pellets

Photo 18 Wood Pellet Bags

Photo 19 Wood Briquettes

Photo 20 Western Biomass Cellulosic Ethanol Plant in Upton WY
(from KL Process Engineering website)

Photo 21 Bio-oil samples

Photo 22 Bio Char in powder form and in pellet form

Photo 23 Laboratory Bench Scale Bio-oil Production (Courtesy of Frontline)

Photo 24 Dynamotive 10 tpd demonstration plant (from Dynamotive website)

Photo 25 Dynamotive 200 tpd commercial bio-oil plant (from Dynamotive website)

Photo 26 100 tpd Biomas Gasifier under construction (courtesy of Frontline)

Photo 27 100 tpd biomass gasifier building (courtesy of Frontline)