Final Draft

PRE-FEASIBILITY ASSESSMENT

Small Diameter Underutilized (SDU) Wood Feedstock for a 10 MW Co-Generation Facility at the Milltown Dam Site

Milltown, Montana

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Submitted to

US Forest Service– State & Private Forestry
Montana Community Development Corporation
Bonner Development Group

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EXECUTIVE SUMMARY

The Bonner Development Group (BDG), represented by Bruce Hall, is seeking a replacement for the tax base that will be lost when Milltown Dam is removed[1], and economic development opportunities for the Milltown/Bonner area. BDG envisions developing a co-generation (co-gen) power generation facility as an anchor to an industrial park that would be located in the vicinity of the existing Milltown Dam. One perception driving the co-gen concept is that the infrastructure left behind after the dam is removed could be leveraged to develop a new power generation facility at reduced cost.

The U.S. Forest Service (USGS) anticipates that forthcoming changes in federal forest management and energy policies could lead to the intensive thinning of thousands of acres of forests in western Montana. In order for this to be economically and logistically feasible, however, USFS must find local outlets for the small diameter and underutilized (SDU)[2] materials that will be generated by these thinning operations.

The Montana Community Development Corporation's (MCDC) mission is to offer financing and business development services that create income opportunities for all community members in Montana. As part of this mission, MCDC helps entrepreneurs develop new commercial uses for a growing supply of SDU timber.

Based on these drivers and a perceived opportunity to cooperate on local economic development, USFS, MCDC, and BDG agreed to co-sponsor this pre-feasibility assessment to explore the potential of using SDU wood from local forests as the feedstock for a 10 MW co-gen plant concept at the Milltown Dam site.

A pre-feasibility assessment is an early stage and limited analysis of the probable risks and returns of an investment. Focused on gathering preliminary information, it helps decision makers determine if there is a basis for investing additional capital and time in the proposed project. Another report prepared in conjunction with this study entitled ***SDU as Biomass Feedstock: Opportunities***

[1] For more information on the Milltown Reservoir Sediments project, see EPA's website at http://www.epa.gov/region8/superfund/sites/mt/milltown.html)

[2] SDU material refers to the timber that is left in the forest because it is not economical to remove, or local capacity to process it does not exist. SDU material includes the dense understory present throughout forests as a result of many years of successful fire suppression. SDU material can come from harvest residuals, thinning operations, and various non-commercial forest treatments.

and Challenges for Montana outlines other opportunities that may exist for utilizing SDU material for developing projects in biomass.

Co-generation systems, also called combined heat and power (CHP) systems, generate electricity and thermal energy in a single, integrated system. 90% of all co-generation systems are located at or near industrial facilities to supply on-site needs. Co-generation is currently disadvantaged, particularly in small applications. Access to power markets is restricted, utilities are imposing high back-up rates and offering low buyback rates, and industrial facilities with installation potential and interest are delaying purchase decisions.

Most analysts agree that co-gen optimized to meet in-plant needs can be a competitive energy option but that a variety of institutional and market hurdles are currently limiting co-gen growth. These hurdles include the following [i]:

- The site-by-site environmental permitting system is complex, costly, time consuming, and uncertain.
- Current regulations do not recognize the overall energy efficiency of co-gen or credit the emissions avoided from displaced grid electricity generation.
- Many utilities currently charge discriminatory backup rates and require prohibitive interconnection arrangements. Increasingly, utilities are charging (or are proposing to charge) prohibitive "exit fees" as part of utility restructuring to customers who build CHP facilities.
- Depreciation schedules for CHP investments vary depending on system ownership and may not reflect the true economic lives of the equipment.
- The market is unaware of technology developments that have expanded the potential for CHP.

For the SDU wood-fired10 MW Milltown co-generation concept, this pre-feasibility assessment posed a number of key questions to gather critical early-stage information in four fundamental areas[ii]:

- Steam and Electrical Market Conditions
- Feedstock Assessment
- Permitting Issues
- Financial Projections

STEAM AND ELECTRICAL MARKET CONDITIONS

Key Questions:

- *Are there potential steam customers on-site or willing to co-locate?*
- *Does the project likely have the potential to secure a power purchase agreement with a utility to profitably sell electricity on the wholesale market?*

Key Findings:

- The majority of co-generation investments are driven by opportunities to economically create process steam in conjunction with electricity within the context of a manufacturing process. Since Stimson Lumber does not require additional steam and there are currently no prospects currently to co-locate at the Milltown site, ***the co-generation concept is immediately challenged***.

- There are examples of large scale facilities that are primarily power producers and have co-located steam hosts such as greenhouses, but ***co-locating steam hosts is not the typical configuration***. District heating could be a possibility for the heat/steam, but the feasibility of such strategy is beyond the scope of this study.

- The electrical market analysis indicates that with green tags and federal tax credit for renewable energy production, the highest likely price for the sale of electricity from the facility would be approximately $.077 per kWh. Typical generation costs in large-scale direct-fired biomass plants[iii] are $.09 per kWh. This illustrates that ***in the best case scenario, in current market conditions, there would be a loss of $.013 per kWh produced***. Further, it is often the case that small (less than 50 MW) plants have higher than $.09 per kWh generating costs (as much as $.15) since they can't achieve the economies of scale of the larger plants.[iv]

FEEDSTOCK ASSESSMENT

Key Question:

- *Is there a long-term supply of wood biomass fuel that is economically and environmentally viable?*

Key Findings:

- Our analyses indicated that ***sufficient woody biomass is physically available*** from local forests to meet the 84,000 BDT/year feedstock requirement of a 10 MW facility.

- To meet this requirement, however, woody biomass would have to be generated by ***maximizing thinning yields*** *and/or* ***conducting thinning operations on forests owned by multiple entities***.

- Using the rule of thumb that 2 to 3 times the required feedstock should be available to meet financing requirements, then ***sufficient feedstock would only be available if thinning yields were maximized <u>and</u> thinning was conducted on forests owned by multiple entities***.

- ***Unknowns regarding forest conditions and potential yields increases the level of uncertainty associated with feedstock availability***. Data available from the USFS Forest Inventory Analysis (FIA) Data Retrieval System describing potentially harvestable forests are not spatially specific and are only accurate on a larger scale than is needed for evaluating feedstock potential for a relatively small area. Data describing privately owned forests, which account for approximately 50% of the potentially harvestable forest lands within the 60-mile radius of Milltown Dam, are limited and inconsistent. It is also impossible to know how much and which forest lands will burn and how much private land will be thinned or harvested. It is as yet unknown what type and level of thinning or logging operations might be prescribed for different forests in the area.

- ***Potential political opposition to logging, trucking, and storage of woody biomass increases the level of uncertainty associated with feedstock availability***.

PERMITTING ISSUES

<u>Key Questions</u>:

- *Is it probable that a biomass power plant can be permitted at the Milltown Dam site?*
- *Is it probably that the plant's environmental impacts can be mitigated to the satisfaction of the regulatory agencies, citizens, communities, and other stakeholders?*

<u>Key Finding:</u>

- ***It would likely be very difficult for the proposed facility to mitigate real and perceived environmental impacts*** to the satisfaction of the regulatory agencies, citizens, communities, and other stakeholders**.**

PRELIMINARY FINANCIAL PROJECTIONS

Key Question:

- *Is the proposed biomass plant economically viable with a potential Return on Investment (ROI) that will attract a qualified developer as well as equity and debt financing?*

Key Findings:

- As shown in the table below***, the long-term power contract price required to cover project costs is estimated to be between $ 0.096 and $ 0.103 per kWh***. This is consistent with national data that sets a range for biomass power costs at $0.08 to $0.12 per kWh[v] .

Projected Costs for the proposed 10 MW Co-Generation Facility at the Milltown Dam site

Cost Component	**Investment Scenario 1** $20,000,000		**Investment Scenario 2** $25,000,000	
	cost / year	**cost / kWh**	**cost / year**	**cost / kWh**
Fuel	$2,970,271	$0.0353	$2,970,271	$0.0353
Operations	$2,691,072	$0.0320	$2,691,072	$0.0320
Capital	$2,394,953	$0.0285	$2,993,691	$0.0356
Total	$8,056,296	**$0.0958**	$8,655,034	**$0.1029**

- The highest possible price that can be expected in the short and medium term in a power purchase agreement would be $0.04 per kWh. If green tags and a federal tax credit were secured, the sales price could increase to as high as $0.077. Thus ***even with price supports, the highest expected contract price is below the projected cost.***

- The insufficient ROI projections and the uncertainties in feedstock, permitting, and land use as discussed above together suggest that ***it would be difficult to attract a qualified development team for the project as presently envisioned***.

As illustrated in the key findings above, ***the results of the pre-feasibility analysis indicate that developing a wood-fired 10 MW co-gen facility at the Milltown Dam site would likely face numerous challenges that would preclude its development***, particularly with private funding sources. A significant number of specific issues would have to be resolved before the co-generation project as envisioned could be considered feasible. Resolving the following issues will be required to establish a risk profile and potential for return on investment sufficient to attract private investment in support of a full feasibility study:

- Identification of a steam host with an interest in supporting the project;
- Decrease in capital costs by acquiring all existing assets, land, water rights, buildings, and associated infrastructure at the Milltown Dam site at little to no cost;
- Increase in wholesale power purchase rates by NorthWestern Energy coupled with a perception of greater stability within the company;
- Increase in long-term stability and predictability of SDU feedstock resources on public and private lands;
- Decrease of delivered feedstock costs through public subsidies as part of a hazardous fire fuel reduction strategy;
- Achievement of a high level of stakeholder support in order to facilitate public acceptance and address myriad regulatory issues.

Despite the negatives identified with the project a presently conceived, there remains a shared interest among many organizations, both locally and nationally, in finding solutions to the SDU challenge that support local economic development.

Alternative approaches could be explored for SDU outlets and/or generating new income opportunities based on SDU biomass, or generating economic development opportunities for the Bonner/Milltown area. Two possible approaches are presented. The first is based on using SDU biomass and the second is real estate development based. These two approaches reflect the different drivers for each of the three sponsoring organizations.

SDU BIOMASS ALTERNATIVE CONCEPTS

- Government entities substantially subsidize co-gen facility construction and provided a reliable supply of SDU feedstock to the facility at little to no cost.
- Develop, and perhaps subsidize, a steam host such steam as greenhouses or hydroponics facilities, some form of district heating, or other steam-using industry.
- Provide SDU to the existing wood products industry.

- Use small mobile co-gen facilities closer to harvest sites or new high temperature incinerators to burn slash on site.
- Create an “SDU Enterprise Center” which would contain a set of businesses that use SDU as feedstock, temporary shop space equipment

for start-up businesses, and training facilities to teach others how to use the SDU processes developed.
- Develop new demonstration facilities for SDU-based technologies that are not yet commercially viable, such as biorefineries, hydrogen facility, engineered wood products, and various wood fiber or wood fiber/plastic composite materials.

REAL ESTATE BASED ALTERNATIVE CONCEPTS

- Industrial park development
- Enterprise clustering
- Work with local groups in multi-dimensional land use planning efforts
- Identify and attract a single large industry to the area
- Explore emerging concepts in brownfields redevelopment, urban revitalization, conservation- or recreation-based development, and the "Restoration Economy"
- Identify other sites for development

INTRODUCTION

The Bonner Development Group (BDG), represented by Bruce Hall, is seeking a replacement for the tax base that will be lost when Milltown Dam is removed[3], and economic development opportunities for the Milltown/Bonner area. BDG envisions developing a co-generation power generation facility as an anchor to an industrial park that would be located in the vicinity of the existing Milltown Dam. One perception driving the co-gen concept is that the infrastructure left behind after the dam is removed could be leveraged to develop a new power generation facility at reduced cost.

The U.S. Forest Service (USFS) State & Private Forestry recognizes that it will take new, innovative, and large-scale management of federal forest lands to reduce the ever-growing threat of catastrophic wildfires. The Healthy Forests Initiative, the National Fire Plan, and the joint Federal-State 10-year Comprehensive Strategy Implementation Plan all call for increasing the utilization of biomass and wood fiber to help address this issue. The Department of Energy asserts that utilization of biomass can help meet a key objective of the National Energy Policy by contributing to diversification of the Nation's energy supply. [vi]

The USFS believes that such changes in federal forest management and energy policies could lead to the intensive thinning of thousands of acres of forests in western Montana. In order for this to be economically and logistically feasible, however, USFS must find local outlets for the small diameter and underutilized (SDU)[4] materials that will be generated by these thinning operations. USFS, represented by Dean Graham, has sponsored this project to help determine if developing wood-fired co-gen plants in the region could help create outlets for SDU material.

The Montana Community Development Corporation's (MCDC) mission is to offer financing and business development services that create income opportunities for all community members in Montana. As part of this mission, MCDC hired Craig Rawlings as a Small Wood Enterprise Agent to help entrepreneurs develop new commercial uses for a growing supply of SDU timber. The project is funded by the U.S. Forest Service's National Fire Plan -

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[3] For more information on the Milltown Reservoir Sediments project, see EPA's website at http://www.epa.gov/region8/superfund/sites/mt/milltown.html)

[4] SDU material refers to the timber that is left in the forest because it is not economical to remove, or local capacity to process it does not exist. SDU material includes the dense understory present throughout forests as a result of many years of successful fire suppression. SDU material can come from harvest residuals, thinning operations, and various non-commercial forest treatments.

State and Private Forestry Programs, in partnership with the Montana Department of Commerce and the Bitterroot National Forest. The National Fire Plan provides supportive funding to encourage hazardous fuels treatments on forested lands throughout western Montana and to develop economical uses for the materials which result from those treatments.[vii] MCDC has sponsored projects to explore the potential of SDU as a biomass feedstock to provide a new outlet for SDU materials and, in turn, generate new income opportunities both locally and in the greater Western Montana region.

Based on these drivers and a perceived opportunity to cooperate on local economic development, the U.S. Forest Service (USFS), Montana Community Development Corp (MCDC), and the Bonner Development Group (BDG) agreed to co-sponsor this pre-feasibility. The purpose is to explore the potential of small diameter and underutilized (SDU) wood from local forests as the feedstock for a 10 MW co-generation (co-gen) plant concept at the Milltown Dam site.

The first section of the study, **Overview of Co-generation**, provides background information co-generation including a definition, technologies and applications, market history and status, and market trends. The second section, **Pre-Feasibility Assessment**, explores four fundamental areas: steam and electrical markets, feedstock, permitting, and financial projections. This section also introduces a number of alternative options that can be considered. The third section, **Summary of Key Findings**, concisely presents the study's findings for decision making purposes. The **Appendix** section lists the advisory group and sources of additional information on bioenergy topics.

OVERVIEW OF CO-GENERATION

DEFINITION

The following provides a brief definition of co-generation[viii]:

Co-generation, also known as ***Combined Heat and Power systems (CHP)***[5], generates electricity (and/or mechanical energy) and thermal energy in a single, integrated system. Typically, co-generation systems are electric power generating units located strategically at or near industrial facilities, such as sawmills and pulp and paper mills, to supply on-site energy needs using waste wood as fuel. The thermal energy recovered in a CHP system can be used for heating or cooling in industry or buildings. Because CHP captures the heat that would be otherwise be rejected in traditional separate generation of electric or mechanical energy, the total efficiency of these integrated systems is much greater than that from separate systems.

TECHNOLOGIES AND APPLICATIONS

The following discussion on co-generation technologies and applications is excerpted from ***EREC (Energy Efficiency and Renewable Energy Clearinghouse) Reference Briefs: Co-generation or Combined Heat and Power***[ix]**.**

A typical co-generation system consists of an engine, steam turbine, or combustion turbine that drives an electrical generator. A waste heat exchanger recovers waste heat from the engine and/or exhaust gas to produce hot water or steam. Co-generation produces a given amount of electric power and process heat with 10% to 30% less fuel than it takes to produce the electricity and process heat separately. [ix]

There are two main types of co-generation concepts: "Topping Cycle" plants, and "Bottoming Cycle" plants. A topping cycle plant generates electricity or mechanical power first. A bottoming facility burns fuel first. Facilities that generate electrical power may produce the electricity for their own use, and then sell any excess power to a utility. [ix]

[5] Co-generation and Combined Heat and Power (CHP) are synonymous and both are prevalent in the industry literature. The Milltown Dam project concept is referred to in terms of co-generation, yet CHP will appear also in this study in excerpted industry information.

There are four types of **topping cycle co-generation systems**. The first type burns fuel in a gas turbine or diesel engine to produce electrical or mechanical power. The exhaust provides process heat, or goes to a heat recovery boiler to create steam to drive a secondary steam turbine. This is a combined-cycle topping system. [ix]

The second type of system burns fuel (any type) to produce high-pressure steam that then passes through a steam turbine to produce power. The exhaust provides low-pressure process steam. This is a steam-turbine topping system. [ix]

A third type burns a fuel such as natural gas, diesel, wood, gasified coal, or landfill gas. The hot water from the engine jacket cooling system flows to a heat recovery boiler, where it is converted to process steam and hot water for space heating. [ix]

The fourth type is a gas-turbine topping system. A natural gas turbine drives a generator. The exhaust gas goes to a heat recovery boiler that makes process steam and process heat. A topping cycle Co-generation plant always uses some additional fuel, beyond what is needed for manufacturing, so there is an operating cost associated with the power production. [ix]

Bottoming cycle plants are much less common than topping cycle plants. These plants exist in heavy industries such as glass or metals manufacturing where very high temperature furnaces are used. A waste heat recovery boiler recaptures waste heat from a manufacturing heating process. This waste heat is then used to produce steam that drives a steam turbine to produce electricity. [ix]

An emerging technology that has co-generation possibilities is the fuel cell. A fuel cell is a device that converts hydrogen to electricity without combustion. Heat is also produced. Most fuel cells use natural gas (composed mainly of methane) as the source of hydrogen. The first commercial availability of fuel cell technology was the phosphoric acid fuel cell, which has been on the market for a few years. There are about 50 installed and operating in the United States. Other fuel cell technologies (molten carbonate and solid oxide) are in early stages of development. Solid oxide fuel cells (SOFCs) may be a potential source for co-generation, due to the high temperature heat generated by their operation. [ix]

Co-generation systems have been designed and built for many different applications. Large-scale systems can be built on-site at a plant, or off-site. Off-site plants need to be close enough to a steam customer (or municipal steam loop) to cover the cost of a steam pipeline. Industrial or commercial facility owners can operate the plants, or a utility or a non-utility generator (NUG) may own and operate them. 90% of all co-generation systems are used by manufacturing plants – stand alone plants are not typical. Some industries and waste incinerator operators who own their own equipment realize sizable profits with co-generation. [ix]

Another large-scale application of co-generation is for district heating. Many colleges and cities, which have extensive district heating and cooling systems, have co-generation facilities. For example, the University of Florida has a 42 Megawatt (MW) gas turbine co-generation plant, built in partnership with the Florida Power Corporation. The State University of New York at Stony Brook has a 45-megawatt facility that will be upgraded to 80 megawatts over the next year and a half. [ix]

Some large co-generation facilities were built primarily to produce power. They produce only enough steam to meet the requirements for qualified facilities under PURPA. If no steam host is nearby, one can be built. For example, there are large (80 MW) plants operating under PURPA that have large greenhouses as "steam hosts." The greenhouses operate without losing money only because their steam heat is virtually free of charge. These types of plants are candidates to become Electricity Wholesale Generators in the new regulatory environment. [ix]

Many utilities have formed subsidiaries to own and operate co-generation plants. These subsidiaries are successful due to the operation and maintenance experience that the utilities bring to them. They also usually have a long-term sales contract lined up before the plant is built. One example is a 300 MW plant that is owned and operated by a subsidiary co-owned by a utility and an oil company. The utility feeds the power directly into its grid. The oil company uses the steam to increase production from its nearby oil wells. [ix]

Co-generation systems are also available to small-scale users of electricity. Small-scale packaged or "modular" systems are being manufactured for commercial and light industrial applications. Modular co-generation systems are compact, and can be manufactured economically. These systems, ranging in size from 20 kilowatts (kW) to 650 kW produce electricity and hot water from engine waste heat. It is usually best to size the systems to meet the hot water needs of a building. Thus, the best applications are for buildings such as hospitals or restaurants that have a year-round need for hot water or steam. They can be operated continuously or only during peak load hours to reduce peak demand charges, although continuous operation usually has the quickest payback period. [ix]

Several companies also attempted to develop systems that burn natural gas and fuel oil for private residences. These home-sized co-generation packages had a capacity of up to 10 kW, and were capable of providing most of the heating and electrical needs for a home. As of April 2003, none of the companies that developed these systems are selling these units. Several fuel call manufacturers are targeting residential and small commercial applications. [ix]

MARKET HISTORY AND STATUS

The following market history and status of co-generation/CHP is excerpted from ***The Market and Technical Potential for Combined Heat and Power in the US Industrial Sector:***[x]

Decentralized combined heat and power systems located at industrial and municipal sites were the foundation of the early electric power industry in the United States. However, as generating technologies advanced, the power industry began to build larger and larger central station facilities to take advantage of increasing economies of scale. CHP became a limited practice utilized by a handful of industries -- paper, chemicals, refining and steel -- with certain characteristics -- high and relatively constant steam and electric demands, access to byproduct or waste fuels. These systems were typically sized to meet the baseload thermal demand and produced electricity as a "byproduct." A large percentage of these systems consisted of boiler/steam turbines that burned low cost/low quality fuels. [x]

The very low power to heat ratio of these systems ensured that electricity generated would not exceed plant demand and resulted in very high overall fuel utilization. By the 1970s, a mature, regulated electric utility industry controlled the electricity market in the U.S. Utilities more often than not discouraged customer CHP by imposing high back-up and standby rates and by refusing to purchase excess power from on-site generators. Along with utility resistance, a host of regulatory barriers at the state and federal level served to further discourage broader CHP development. [x]

In 1978 Congress passed the Public Utilities Regulatory Policies Act (PURPA), partly to encourage energy efficiency in response to the second oil crisis. A portion of PURPA was meant to encourage energy efficient co-generation (CHP) and small power production from renewables by requiring servicing utilities to interconnect with "qualified facilities" (QFs), to provide such facilities with reasonable standby and back-up charges, and to purchase excess electricity from these facilities at the utilities avoided cost. [x]

PURPA also exempted QFs from regulatory oversight under the Public Utilities Holding Company Act and from constraints on natural gas use imposed by the Fuel Use Act. PURPA had the expected effect on CHP. Installed CHP capacity increased from about 12,000 MW in 1980 to over 52,000 MW in 1999. But PURPA also had unforeseen results. PURPA was enacted coincidentally with the availability of larger, more efficient, lower cost combustion turbines and combined cycle systems with high power to heat ratios. The power purchase provisions of PURPA coupled with the availability of this new technology resulted in the development of a number of very large merchant plants leveraged towards high electricity production. For the first time since the inception of the industry, non-utility participation was being allowed in the power market. This triggered the development of third party CHP developers who had greater interest in electric markets than thermal markets, and ultimately started the progression towards wholesale generation and open access. [x]

In the 1980s and early 1990s CHP was a requirement for participation in the electric market and third party developers actively sought industrial facilities to serve as thermal hosts. As a result, CHP penetration in sites greater than 20 MW now approaches 45% and over half of existing CHP capacity -- 29,000 MW -- is concentrated in a relative small number of plants over 100 MW in size -- 120 facilities. [x]

The environment changed again in the mid 1990s with the advent of the wholesale market for electricity. Independent power producers could now sell directly to the market without the need for QF status and CHP development slowed. In the transition to a fully restructured market, CHP is once again disadvantaged in many ways, particularly in small applications. Access to power markets is restricted, utilities are again imposing high back-up rates and offering low buyback rates, and industrial facilities with installation potential and interest are delaying purchase decisions with an expectation of low retail prices in the future. [x]

Whether this is a temporary situation or a long term trend is unclear. Most analysts agree that CHP optimized to meet in-plant needs can be a very competitive energy option in a fully restructured market and that a variety of institutional and market hurdles are currently limiting CHP growth in the transition. [x] These hurdles include the following [xi]:

- The site-by-site environmental permitting system is complex, costly, time consuming, and uncertain.
- Current regulations do not recognize the overall energy efficiency of CHP or credit the emissions avoided from displaced grid electricity generation.
- Many utilities currently charge discriminatory backup rates and require prohibitive interconnection arrangements. Increasingly, utilities are charging (or are proposing to charge) prohibitive "exit fees" as part of utility restructuring to customers who build CHP facilities.
- Depreciation schedules for CHP investments vary depending on system ownership and may not reflect the true economic lives of the equipment.
- The market is unaware of technology developments that have expanded the potential for CHP

MARKET SEGMENTS

US DOE divides the current marketplace for industrial CHP into the following segments:[xii]

Large and Medium Industrial CHP Systems — Typically found in the "process industries," such as petroleum refining, pulp and paper, and chemicals, these systems have installed electricity capacities greater than 25 MW (often hundreds of MW) and steam generation rates measured in hundreds of thousands of pounds of steam per hour. This sector represents the vast majority of the current installed CHP capacity in the U.S., and is the segment with the greatest potential for near-term growth. A small number of facilities of this type are merchant power plants using combined cycle configurations. They are owned by an independent power producer that seeks an industrial customer for their waste steam and sells excess electricity on the wholesale market.

Small Industrial Systems — Thousands of boilers provide process steam to a broad range of U.S. manufacturing plants. These boilers offer a large potential for adding new electricity generation between 50 kW and 25 MW by either modifying boiler systems to add electricity generation (e.g. re-powering existing boilers with a combustion turbine), or replacing the existing boiler with a new CHP system. Small manufacturers represent an important growth segment over the coming decade.

Smaller Commercial and Institutional Systems — With the arrival of reliable reciprocating engines and smaller combustion turbines, CHP is becoming feasible for small commercial buildings. This area, sometimes called "self-powered" buildings, involves the installation of a system that generates part of the building's electricity requirement and provides heating and/or cooling. Packaged systems with capacities starting at around 25 kW could be installed at fast food restaurants as well as in larger commercial buildings. Though an important long-term market, this segment's total capacity is expected to be modest for the next few years as the market infrastructure for distribution and installation develops.

PRE-FEASIBILITY ASSESSMENT

A ***Pre-feasibility Assessment*** is an early stage and limited analysis of the probable risks and returns of an investment. Focused on gathering preliminary information, it helps decision makers determine if there is a basis for investing additional capital and time in the proposed project. A full feasibility study for a power plant project can potentially require a $500,000 investment toward engineering studies, permitting studies, site analysis, etc.

For the SDU wood-fired10 MW Milltown co-generation concept, this pre-feasibility analysis is designed to gather critical early-stage information in four fundamental areas[xiii]:

- ***Steam and Electrical Market Conditions***
- ***Feedstock Assessment***
- ***Permitting Issues***
- ***Financial Projections***

STEAM AND ELECTRICAL MARKET CONDITIONS

Key Questions:

- *Are there potential steam customers on-site or willing to co-locate?*
- *Does the project likely have the potential to secure a power purchase agreement with a utility to profitably sell electricity on the wholesale market?*

Preliminary Information:

Potential Steam Host

At this point the proposed facility has not identified a potential user for the steam that would be produced at the facility. Stimson Lumber has indicated that they already have overcapacity to generate steam and would be unlikely to be interested in buying steam from an outside entity.[xiv]According to one industry representative[xv], steam production becomes more important to facility feasibility than electrical production in small co-gen facilities. BDG and others may choose to develop the plant as an investment in economic development to attract industry; however, this is not the typical development scenario for development of co-gen facilities.

Milltown Dam Site Status and Current Electrical Market

The Milltown Dam and electrical generation facilities are currently owned by NorthWestern Energy. The dam is capable of generating 2.5 MW of power[xvi]. NorthWestern considered the Milltown facility to be a revenue losing operation[xvii] and has not produced power there since November 2002[xviii]. A summary of NorthWestern Energy's filed default supply portfolio [xix] indicates that the contract price for power generated at Milltown Dam is based on the lesser of operating cost or market value.

For the purposes of this pre-feasibility study we assume that a new power generation plant located at or near the existing Milltown Dam facility would obtain a power purchase agreement from NorthWestern Energy. Currently, NorthWestern Energy has contracted prices for baseload power with various entities ranging from a low of $31.15/MWh ($.03115/kWh) to a high of $40.00/MWh ($.0400/kWh)[xix]. The high of $40/MWh is with the Thompson River Co-Gen plant.

Based on this information, we will assume that maximum revenue that the proposed plant could expect in the medium term from electricity production would be $0.04/kWh.

The contracted price for electricity generated at this facility could be boosted by one or more programs that are or may be available. If the co-gen facility burned only biomass, the power generated would be considered renewable energy and the facility would be eligible to sell "green tags" which are worth $0.01 to $0.02 per kWh [xxiv]. Green Tags are the environmental attributes of a renewable energy system, including the ability to offset greenhouse gas production. Green Tags are now a separately marketable commodity and can be sold by owners of renewable energy systems including biomass energy.[xx] NorthWestern Energy already has plans to purchase green tags from the Bonneville Environmental Foundation (BEF) which currently generates renewable energy from wind facilities in Washington, Oregon, and Wyoming. The State of Montana is considering a program that would use coal tax money to buy green tags from local power facilities and sell them out of state at a net profit [xxxvi]. Additional support could come from the federal government. Congress is working on a tax relief of $0.017 per kW for renewable energy. This support would be in addition to green tags. [xxiv]

This information suggests that the contracted price combined with green tags and tax relief for renewable energy could generate electricity revenues of $0.058 up to $0.077 per kWh.

Key Findings:

- The majority of co-generation investments are driven by opportunities to economically create process steam in conjunction with electricity within the context of a manufacturing process. Since Stimson lumber does not require additional steam and there are currently no prospects currently to co-locate at the Milltown site, ***the co-generation concept is immediately challenged***.

- There are examples of large scale facilities that are primarily power producers and have co-located steam hosts such as greenhouses, but ***co-locating steam hosts is not the typical configuration***. District heating could be a possibility for the heat/steam, but the feasibility of such strategy is beyond the scope of this study.

- The electrical market analysis indicates that with green tags and federal tax credit for renewable energy production the likely highest price for the sale of electricity from the facility would likely be approximately $.077 per kWh. Typical generation costs in large-scale direct-fired biomass plants[xxi] are $.09 per kWh. This illustrates that ***in the best case scenario, in current market conditions, there would be a loss of $.013 per kWh produced***. Further, it is often the case that small (less than 50 MW) plants have higher than $.09 per kWh generating costs (as much as $.15) since they can't achieve the economies of scale of the larger plants.[xxii]

ASSESSMENT OF FEEDSTOCK

Key Question:

- *Is there a long-term supply of wood biomass fuel that is economically and environmentally viable?*

Preliminary Information:

Feedstock Requirements

Woody biomass power plants use approximately 1 BDT[6] for every megawatt hour (MWh) of electricity produced [xxiii,xxiv]. Thus the proposed 10 MW plant

[6] **Bone Dry Ton (BDT)** is a unit of measurement used by the wood products industry to measure amounts of wood, in particular for the purpose of biomass energy. Wet wood is heavier than dry wood, yet it is less valuable for biomass energy production, so facilities buying wood for biomass energy typically pay on the basis of bone dry tons .The moisture content of harvested wood can vary significantly based on a number of factors. For the purposes of this preliminary assessment, we have assumed that freshly harvested wood has a moisture content of 50%. This means that two tons of freshly harvested wood (two green tons) would be equivalent to one bone dry ton (BDT).

would need 10 BDT/hour of operation. Assuming the facility would operate 24 hour/day for 350 days/year, the 10 MW plant would need approximately 84,000 BDT per year of woody feedstock. This annual amount translates to a total of 2,940,000 BDT of woody feedstock over a 35-year time period (the assumed time between subsequent forest harvests).

One rule of thumb for private financing and developing a biomass power plant is that feedstock availability must be 2 to 3 times the amount necessary for sustained operations.[xxv] This requirement came out of negative experiences of financial institutions in the 1980's. This information suggests that 6,000,000 to 9,000,000 BDT of woody biomass must be available within a 60-mile radius of the Milltown Dam site to make the project feasible from a feedstock perspective.

Potential Sources of Feedstock

Potential sources of woody biomass that could be used as primary feedstock for the proposed facility include woody materials that are currently burned or landfilled, residues from the wood products industry, and materials removed from the forest.

Woody materials that are currently burned or landfilled, such as construction and yard wastes, are not available in the quantities required to be considered a primary feedstock[xxvi]. Most of the useable residues from the wood products industry in the region are currently being used and the supply for such material is considered to be tight [xxxi]. For example, Smurfit-Stone, the largest consumer of such residues in the region, used to receive mill residues for free, but now must chip and haul wood from the forest to provide sufficient feedstock for their Frenchtown facility [xxxiii]. Competition for woody materials currently removed from local forests is also considered to be tight [xxxi].

Based on this information, we have assumed that any new industry in the area proposing to use wood as a primary feedstock can only succeed if a new supply of wood is found.

For these reasons, this resource assessment is based on the assumption that the primary feedstock for the proposed facility would be SDU resources that could be removed from local forests under new federal forest management policies.

Physical Availability of Feedstock

The potential physical availability feedstock depends on the number of acres of forest lands potentially available for harvest and the woody biomass yields that might be expected from those forest lands.

Potentially Harvestable Forest Lands

For the purposes of this study, we have assumed that only those forest lands within a 60-mile radius of the Milltown Dam site (the assumed economic haul distance [xxxi], [xxxiii]) that have slopes less than 40%, that are categorized as non-reserved[7], and that are already roaded (are not roadless) would be available for harvest.

The number of acres of forest lands meeting the radius, slope, and non-reserved criteria were estimated based on a query of the on-line USFS Forest Inventory Analysis (FIA) database retrieval system[xxvii]. These acreages were reduced by assuming that 40% of the forests meeting the first 3 criteria were roadless [xxviii]. The number of acres meeting these harvest criteria are presented in Table 1.

Potential Forest Yields

The amount of woody biomass that might be available from a forest depends, in part, on the harvest or thinning goals.

Traditional commercial logging techniques can yield SDU material from harvest residuals and from pre-commercial thinning operations. A survey of forest managers in the Flathead Valley indicated yields of 1.5 to 7.9 BDT/acre from harvest residuals, and 3.2 to 4.6 BDT from pre-commercial thinning operations.[xxix]

Non-commercial forest treatments have the potential to generate much higher amounts of SDU. Carl Fiedler (University of Montana School of Forestry) and others have developed a forest treatment prescription that they believe would reduce fire potential and restore forest health. Based on their prescription, forests in the west with high/moderate fires hazard would yield a 14.5 to 15.0 BDT/acre. This treatment, like many logging operations, could be conducted once every 30 to 35 years in drier forests and every 30 to 40 year in more moist forests. [xxx] For the purpose of this analysis we will assume this treatment would yield 14.5 BDT/acre once every 35 years.

The second and third cuts should be less costly and more profitable because the small and problem trees would have been removed the first time. There would be less SDU material and more material that can go into traditionally higher value markets[xxxi].

[7] **Reserved Timberland** is timberland that has statutory or administrative restrictions prohibiting the harvest of trees. Examples of Reserved Timberland land include lands within the National Wilderness Preservation System, Research Natural Areas, National Parks and Monuments, and State Parks. In National Forests, reserved forest lands are referred to collectively as withdrawn forest land. For the purposes of this study, forest lands categorized as Reserved Timberland were excluded from the acreage considered to be harvestable

It should be noted that very little information is available describing the condition of privately owned forests. Thus it is not known whether or not the yield estimates used in this study would be appropriate for all local forests.

Potential Feedstock Availability

The number of potentially available forest lands were combined with per-acre forest yield values to estimate the amount of woody biomass potentially available for primary feedstock for the proposed facility. The results are presented in Table 1 below.

As stated above, the 10 MW biomass energy plant concept would consume 84,000 BDT of woody biomass every year. Over a period of 35 years (the time between subsequent harvests) the plant would consume a total of 2,940,000 BDT of woody feedstock. Based on the rule-of-thumb suggesting that feedstock availability should be 2 to 3 times the amount necessary for sustained operations, there should be 6,000,000 to 9,000,000 BDT of woody biomass available within a 60-mile radius of the Milltown Dam site to make the project feasible from a feedstock perspective.

Table 1. Potential Woody Biomass Available for Feedstock within a 60-mile radius of the Milltown Dam Site

		Total Potential Woody Biomass Available[1]		
Owner Category	**Forest Land Meeting Criteria (1,000 acres)**	**from Harvest Residuals** @ 4.7 BDT/ac **(1,000 BDT)**	**from Pre-Commercial Thinning** @ 3.9 BDT/ac **(1,000 BDT)**	**from Fire Reduction Treatment** @ 14.5 BDT/ac **(1,000 BDT)**
National Forest	188	882	732	2,721
BLM	71	333	277	1,028
Tribal Trust	108	510	423	1,573
State	109	511	424	1,576
Forest Industry[2]	308	1,447	1,200	4,463
Farmer / Rancher	149	701	582	2,163
Private Corporation	16	77	64	237
Private Individual	76	357	296	1,101
All Owners	**1,029**	**4,835**	**4,012**	**14,917**
Total Federal	259	1,215	1,009	3,750
Total State	109	511	424	1,576
Total Private	549	2,581	2,142	7,963

[1] If it is assumed that harvesting operations could occur once every 35 years, the total potential amounts of woody biomass available listed in Table 1 would need to satisfy the feedstock requirements of the proposed facility for a 35-year period.

[2] Plum Creek owns most of the acreage listed in the Forest Industry owner category, which represents 30% of the forest lands meeting the selection criteria.

Information presented in Table 1 indicates that there are a total of 1,029,000 acres of forest lands that could be harvested within a 60-mile radius of the Milltown Dam. This total acreage could yield approximately 4,835,000 BDT from harvest residuals, 4,012,000 BDT from pre-commercial thinning, or 14,917,000 BDT from Fiedler's fire reduction treatment. This information suggests that, depending on the harvesting goals, a sufficient supply of feedstock could be available from local forests if it were economically, environmentally, and politically feasible to remove it.

If harvesting for feedstock were limited to National Forest lands meeting the harvest criteria, there would be 188,000 acres available that could yield 882,000 BDT from harvest residuals, 732,000 BDT from pre-commercial thinning, or 2,721,000 BDT from fire reduction treatment. This information suggests that National Forest Lands alone could not provide sufficient feedstock for the proposed facility. A further limitation to this potential source is that the federal government does not enter long-term contracts for harvesting on National Forest lands, which is usually required for financing.

The combination of all State and Federal lands make up 367,000 acres or 36% of the total forest lands meeting the harvest criteria. If all of these lands were harvested, they could yield 1,726,000 BDT from harvest residuals, 1,433,000 BDT from pre-commercial thinning, or 5,326,000 BDT from fire reduction treatments. This information suggests that, depending on the harvest approach used, the combination of State and Federal lands meeting harvest criteria could meet the feedstock needs of the proposed facility, but cannot provide 2 to 3 times the feedstock requirement as suggested for financing and development of such a facility.

Private lands make up over 50% of the forest lands meeting the harvest criteria; however, it is unknown whether or not these lands are in a condition suitable to meet yield rates described above. If all of these lands were harvestable at the indicated yields, the combination of all private lands meeting harvest criteria could yield 2,581,000 BDT from harvest residuals, 2,142,000 BDT from pre-commercial thinning, or 7,963,000 BDT from fire reduction treatments. This information suggests that, depending on the harvesting techniques used, the combination of private lands meeting harvest criteria may have the potential to meet the feedstock requirements of the proposed facility, even without harvesting of any public lands.

Environmental and Political Issues Related to Feedstock

Obtaining sufficient feedstock for the proposed facility would require the thinning of between 6,000 and 22,000 acres (9 to 34 square miles) of timberland within a 60-mile radius of the Milltown dam site every year. Over a period of 35 years (the time between subsequent harvests) a total of 210,000 to 770,000 acres

(330 to 1,200 square miles) of local forests would need to be thinned. Regardless of perceived benefits, the potential environmental impacts of such thinning activities will attract the concern of environmental organizations, and they may choose to take political actions to restrict such activities. The political activities that may result from real and perceived environmental impacts of forest thinning represent a risk to feedstock reliability and feasibility.

Delivery of this feedstock would also increase truck traffic in the region. As described above, a 10 MW plant would need 84,000 BDT per year of woody feedstock. For the purposes of this preliminary assessment we have assumed that deliveries of woody biomass will be limited to about 200 days per year because various weather conditions limit the time when woody biomass can be harvested and hauled [xxxii]. If deliveries were made 200 days per year, then the plant would need feedstock delivered at an average rate of 420 BDT/day. Assuming each truck can hold 13 BDT (at about 50% moisture content) [xxxiii], then the facility would need delivery of 33 truckloads of woody biomass per day. If deliveries were accepted 12 hours a day, then trucks would be coming and going from the facility at a rate of around three trucks per hour or one truck every twenty minutes. Like the thinning activities, the additional truck traffic created by the facility may be opposed by local organizations which may choose to take political action to restrict such activities. The political activities that may result from real and perceived impacts of increased truck traffic represent a risk to feedstock feasibility.

In addition to shortening the delivery year, the fact that deliveries cannot be made year-round means that the facility will need storage space for up to 100 days worth of feedstock, which amounts to 24,000 BDT of woody biomass feedstock. This will increase the area needed for the proposed facility, thus increase the impact that the facility has on local land use. The level of local impact created by the storage area may also be opposed by local organizations which may choose to take political action to restrict such land use. The political activities that may result from real and perceived impacts of the storage area represent a risk to feedstock feasibility.

Key Findings:

- Our analyses indicated that ***sufficient woody biomass is physically available*** from local forests to meet the 84,000 BDT/year feedstock requirement of a 10 MW facility.

- To meet this requirement, however, woody biomass would have to be generated by ***maximizing thinning yields*** *and/or* ***conducting thinning operations on forests owned by multiple entities***.

- Using the rule of thumb that 2 to 3 times the required feedstock should be available to meet financing requirements, then ***sufficient feedstock would only be available if thinning yields were maximized and thinning was conducted on forests owned by multiple entities***.

- ***Unknowns regarding forest conditions and potential yields increases the level of uncertainty associated with feedstock availability***. Data available from the USFS Forest Inventory Analysis (FIA) Data Retrieval System describing potentially harvestable forests are not spatially specific and are only accurate on a larger scale than is needed for evaluating feedstock potential for a relatively small area. Data describing privately owned forests, which account for approximately 50% of the potentially harvestable forest lands within the 60-mile radius of Milltown Dam, are limited and inconsistent. It is also impossible to know how much and which forest lands will burn and how much private land will be thinned or harvested. It is as yet unknown what type and level of thinning or logging operations might be prescribed for different forests in the area.

- ***Potential political opposition logging, trucking, and storage of woody biomass increases the level of uncertainty associated with feedstock availability***.

PERMITTING ISSUES

Key Questions:

- *Is it probable that a biomass power plant can be permitted at the Milltown Dam site?*
- *Is it probably that the plant's environmental impacts can be mitigated to the satisfaction of the regulatory agencies, citizens, communities, and other stakeholders?*

Preliminary Information:

The feasibility of the proposed project will depend on resolution of all regulatory and permitting issues. In order to be feasible, the proposed facility must be able to mitigate environmental impacts to the satisfaction of the regulatory agencies, citizens, communities, and other stakeholders.

Investigating the full range of regulations that would need to be addressed when developing the facility is beyond the scope of this study; however, selected permitting and other environmental issues that have been raised already will be addressed in this section.

Air Quality

Wildfires in overstocked and fire-suppressed forests pour huge quantities of smoke into the air that spreads across the country and beyond. The U.S. Forest Service (USFS) reports that "dense plumes of smoke (from wildfires) can be transported over hundreds of kilometers across State and international boundaries." It also reports that "several communities in the United States have experienced particulate matter concentrations from wildfire smoke that exceeded EPA's significant harm emergency action level of 600 ug/m^3, defined as an 'imminent and substantial endangerment of public health'" (EPA 1992b). [xxxiv] Prescribed burning and burning of slash piles result in localized, but more frequent, generation of air pollution. The Forest Service reports that "On a national basis, PM10 emissions from prescribed burns in 1989 were estimated to be over 600,000 tons. Seven states (including Montana) were estimated to have annual emissions over 10,000 tons of PM10 from prescribed forest and rangeland burning (EPA 1992a; Peterson and Ward 1990)."[xxxv]

One driver in the development of the co-gen plant is finding a beneficial use for SDU to help reduce the amount of air pollution caused by wildfires, prescribed burns, and burning of slash piles. Though modern co-gen facilities can be designed to burn wood very cleanly, the proposed facility would be closely scrutinized for potential pollution discharges, particularly discharges affecting air quality.

The Bonner/Milltown area is located within the Missoula City-County airshed which is a federal non-attainment area for particulate matter and carbon monoxide. This status will make it more difficult and more expensive to establish a new wood burning facility that has the potential to discharge pollutants to the air[xxxvi]. Permitting such a facility would likely fall under the jurisdiction of the Montana DEQ (rather than the Missoula City-County Health Department) and would require an EA (Environmental Assessment) which could take years to complete. [xxxvi]

In addition to local air quality issues, Regional Haze Laws are coming into effect soon -- in 2003 in Wyoming and 2008 in Montana. It is as yet unclear what these laws will mean for Montana or for a wood-burning facility. It is likely that these laws would prohibit slash burning, which could be beneficial for feedstock availability, but hauling and burning slash at a co-gen plant may or may not be viewed as a positive trade-off. [xxxvi]

Land Use

The site under consideration for the proposed co-gen facility is currently owned by Northwestern Energy and is part of the Milltown Reservoir Sediments Site. This area is slated to undergo extensive modification as part of the EPA's remediation efforts and has been the focus of various land use planning efforts. Three such plans are the Bonner Community Action Plan, the County's Two

Rivers Restoration Plan, and the State's Draft Conceptual Restoration Plan. All 3 of these plans call for the site to be re-developed for recreational uses; however, at the time it was developed, the Bonner plan did not envision and does not reflect dam removal.

The EPA, Montana DEQ, Missoula County, and others have been meeting with local organizations, individuals, and other interested parties to develop remediation and restoration goals for the Milltown Reservoir Sediments Site. As part of this effort, the County has formed the Milltown Superfund Site Redevelopment Initiative Working Group which is made up of 23 individuals representing various elements of the community. The Working Group is to study factors pertaining to, and make recommendations to, the County and its consultant, on various aspects of redevelopment and restoration. The group will evaluate how EPA's Milltown cleanup plan can be implemented and supplemented to best benefit the public. Through a collaborative process, the group will create and recommend a redevelopment plan to Missoula County that strongly reflects local preferences and is compatible with the site remedy and restoration. The redevelopment plan may include, but need not be limited to recreational, environmental, economic, historic and infrastructure developments.[xxxvii] The feasibility of the proposed co-gen facility will depend, in part, on meeting the goals, plans, or designs developed by this group.

Water

Co-gen facilities require fresh water to operate and generate wastewater. The amounts of water and wastewater depend on the type of system installed, the amount of steam generated and the back-end equipment needed.

Though fresh water is physically available at the Milltown Dam site, it may be difficult to obtain a water right for its use. At this time the entire Clark Fork River basin above Milltown Dam is closed to new surface water use appropriations. It may be possible, however, for the existing water rights associated with the dam to be transferred to a new owner and for a new beneficial use. Local water supply wells have had to be relocated due to arsenic contamination.

One driver in behind this project is the remediation of the area behind the Milltown Dam which is holding back millions of cubic yards of contaminated sediments. One of the goals of remediation is to remove contamination and restore environmentally healthy conditions in the river and underlying aquifer. The individuals and organizations that worked so long to have the dam and sediments removed are not likely to support redevelopment that includes discharge of wastewater into the river or aquifer.

Key Finding:

- ***It would likely be very difficult for the proposed facility to mitigate real and perceived environmental impacts*** to the satisfaction of the regulatory agencies, citizens, communities, and other stakeholders**.**

PRELIMINARY FINANCIAL PROJECTIONS

Key Question:

- *Is the proposed biomass plant economically viable with a potential Return on Investment (ROI) that will attract a qualified developer as well as equity and debt financing?*

Preliminary Information:

Pre-Feasibility Financial Projections

Since the project is only conceptual at this stage and no actual technical parameters have been assigned, it must be stressed that it is impossible to make accurate investment requirements. For example, the project was originally conceived in terms of co-generation but, as indicated above, if no steam exists, then financial projections based on co-generation cannot be made. Further, if technical parameters were available, an accurate investment requirement still could not be made without extensive design, engineering, construction, pre-development costs, and working capital analyses.

The projections provided below, therefore, are mainly illustrative. The purpose is to model data provided by several industry experts and in industry literature in order to generally estimate a likely investment scenario. Since no steam host is envisioned to enable a co-generation system, the investment figures represent an electricity only plant using full-condensing turbines that recycle the steam.[xxxviii]

Included in the initial investment figure would be items such as the cost of site preparation, the cost of generation and fuel handling equipment, installation and construction costs, legal and professional fees for permitting and contracting, interest on construction loans, administrative costs during start-up period, and initial working capital needs. This estimate does not include land acquisition or lease costs, and assumes that available infrastructure at the Milltown Dam facility would be available at no cost. Conversations with industry representatives and plant design consultants suggest the investment requirement for this project would likely be in the range of \$20 to \$25 million for a 10 MW full-condensing turbine facility.[xxxix]

The fuel for the proposed facility would be SDU materials removed from forests within a 60-mile radius of the facility site. For the purposes of this pre-feasibility study, we have assumed that SDU material will be removed from the forest for the purposes of hazardous fuel reduction and will be available for free at the forest landing site. This is based on the assumption that the Healthy Forest Initiative or other similar program would pay for the harvesting and transport of SDU material to the forest landing. This means that the cost of feedstock delivered to the facility will be limited to processing at the landing and hauling from the landing to the facility. Cost estimates provided by Craig Thomas of Johnson Brothers Contracting [xxxii] suggest that the cost of grinding and loading SDU at the landing is $14.66/green ton. Haul costs would include a base per ton fee plus mileage fees which differ for dirt roads and asphalt. Assuming the 60-mile haul distance includes 10 miles on dirt roads and 50 miles on asphalt, the total haul cost would be about $3.00 per green ton. Adding grinding, loading, and hauling costs and assuming 50% moisture indicates a total fuel cost of $35.32 / BDT.

The non-fuel costs of operating and maintaining the facility include salaries and wages, payroll and property taxes, professional services, maintenance, parts and supplies, etc. This study will use a rate of $ 0.032 per kWh generated.[xl]

Capital costs are the returns that must be earned on the investment in the facility to cover financial obligations to lenders and provide an acceptable return to the equity investors. Assuming the equity investors are deemed experienced and credit-worthy by lenders, a substantial part of the funds required to launch the project can be borrowed, which lowers overall capital costs. This analysis assumes that a loan for 80% of the funds required can be negotiated by the investors/developers at a rate of 6% and a period of 20 years.

Potential investors/developers in the co-gen project will likely be aware of the status of the energy market and the political uncertainties in Montana. The risk of the facility having difficulties due to a changing regulatory environment, the potential of default on contracts with energy buyers, the possibility of difficulties with fuel supplies or suppliers, etc. will affect the return the investors must expect before committing capital. Assuming investors would be attracted to the project by showing a return of 15% could be earned, the facility would need to earn 25% per equity dollar invested in pre-tax dollars if the combined Federal and State income tax rate is 40%.

The preliminary information presented above was used to develop a set of assumptions needed in financial projection calculations. These assumptions are summarized below.

- Cost of Fuel: The 10 MW plant would operate at 96% capacity, resulting in 87,600 MWh output per year. Fuel requirements are 1 BDT of fuel to produce 1 MWh of electricity (per discussion in the ***Feedstock Assessment*** section). Therefore, production of 87,600 MWh requires roughly 84,000 tons of fuel per year. The cost of fuel is $35.32 per BDT.

- Cost of Operations: The non-fuel costs of operating and maintaining the facility include salaries and wages, payroll and property taxes, professional services, maintenance, parts and supplies, etc. This study will use a rate of $ 0.032 per kWh generated

- Cost of Capital: The facility would require an investment of $20 million to $25 million. These numbers do not include land acquisition or lease costs, and that available infrastructure at the Milltown Dam facility would be available at no cost. It was assumed that 80% of the project would be funded by a 20-year loan at a rate of 6%, and 20% would be funded through equity investment requiring a 15% after-tax return. The amortization of a 20-year, 6% loan requires annual payments of $.0872 per dollar borrowed. Investors would require a ROI of 15% (which equates to 25% pre-tax return with the assumed 40% combined Federal and Montana income tax rate).

Table 2 presents projected annual costs and costs per kWh calculated for the proposed facility based on the assumptions presented above. Results are shown for two different investment scenarios.

Table 2. Projected Costs for the proposed 10 MW Co-Generation Facility at the Milltown Dam site.

Cost Component	**Investment Scenario 1** $20,000,000		**Investment Scenario 2** $25,000,000	
	cost / year	**cost / kWh**	**cost / year**	**cost / kWh**
Fuel	$2,970,271	$0.0353	$2,970,271	$0.0353
Operations	$2,691,072	$0.0320	$2,691,072	$0.0320
Capital	$2,394,953	$0.0285	$2,993,691	$0.0356
Total	$8,056,296	**$0.0958**	$8,655,034	**$0.1029**

The information in Table 2 indicates that there are three components that contribute to the costs of the proposed facility: cost of fuel (the SDU feedstock), cost of facility operations, and cost of capital. The costs presented in the table are based on preliminary information and a set of assumptions; however, any modifications to these projections must be made within one of the three categories. For example, if feedstock were harvested, processed, and hauled to the facility for free, costs would be reduced by $2,970,271 per year or $0.0353 / kWh.

In order for the facility to be feasible, revenues derived from power sales must cover projected costs of $0.096 to $0.103 / kWh. In this case, maximum projected revenues were estimated to be $0.04 / kWh for power, and up to $0.077

/ kWh with green tags and tax relief. This information indicates that even under favorable conditions, the proposed project is not financially feasible.

Key Findings:

- ***The long-term power contract price required to cover project costs is estimated to be between $ 0.096 and $ 0.103 per kWh***. This is consistent with national data that sets a range for biomass power costs at $0.08 to $0.12 per kWh[xli] .
- The highest possible price that can be expected in the short and medium term in a power purchase agreement would be $0.04 per kWh. If green tags and a federal tax credit were secured, the sales price could increase to as high as $0.077. Thus ***even with price supports, the highest expected contract price is below the feasibility requirement.***
- The insufficient ROI projections and the uncertainties in feedstock, permitting, and land use as discussed above together suggest that ***it would be difficult to attract a qualified development team for the project as presently envisioned***.

ALTERNATIVE APPROACHES

Key Question:

- *Are there alternative approaches that would meet the objectives of economic restoration and development at the Milltown Dam site, regional fuel loading reduction, and the related public benefits*?

Preliminary Information:

The results of the pre-feasibility analysis indicate that developing a wood-fired 10 MW co-generation facility at the Milltown Dam site would likely face challenges that would preclude its development, particularly with private funding sources. For this reason, alternative approaches would need to be developed for meeting the goals of the co-sponsors.

In this section we'll present some of the ideas and concepts generated by the Advisory Group and by others during the initial meeting and subsequent discussions. Two sets of alternative approaches are presented: one which is based on using SDU Biomass and one which is Real Estate based. Though there is some overlap, the fundamental assumptions/goals are different, reflecting the different drivers for each of the three sponsoring organizations. The alternatives approaches are presented as a means of capturing the ideas of the individuals who have contributed to this study. No recommendations for pursuing one alternative over another are made and none are implied.

SDU Biomass Concepts

The USFS is very interested in finding local outlets for the small diameter and underutilized materials that would be generated by intensive thinning operations envisioned by the federal government. MCDC is interested in explore the potential of SDU as a biomass feedstock to generate new income opportunities both locally and in the greater Western Montana region.

Based on the preliminary financial projections, a co-gen plant similar to the one envisioned could become feasible if capital costs and fuel costs could be lowered and the total revenue from electricity could be raised to at least a break-even point. This could occur if one or more government entities substantially subsidized facility construction and provided a reliable supply of SDU feedstock to the facility at little to no cost. It is possible that the federal and local governments could determine that the costs of thinning and subsidizing such a facility could be less than the costs associated with fighting intensive wildfires. This concept has the potential to provide net benefits to many communities in the forested regions of western Montana.

Another approach to making the co-gen concept more feasible would be to simultaneously develop a steam host. This concept has worked in the past under different regulatory and market environment, but is not typically under current conditions. Such steam hosts might include greenhouses or hydroponics facilities, some form of district heating, or other steam-using industry. Feasibility would likely be enhanced if the steam user were a government facility or subsidized demonstration project.

Another outlet for new SDU would be the existing wood products industry. This approach has the benefit of working with a facility that is already under industrial land use, is permitted for various waste discharges, and may have access to water. As stated earlier, the market for mill residuals in the area is tight. Facilities such as Smurfit-Stone may be glad to take SDU materials for free rather than obtain them at a cost. Johnson Brothers may be interested in expanding or developing new wood pelletizing operations that would, in turn facilitate development of new wood burning operations. Smurfit-Stone and others may also be interested in developing electrical generation facilities that use SDU as fuel.

Additional outlets for SDU might include using small mobile co-gen facilities closer to harvest sites or using new high temperature incinerators that minimize air pollution to burn slash on site.

The original concept for the co-gen plant was that it would be the anchor to an industrial park, attracting businesses that could use the electricity and/or steam or that would otherwise benefit from co-locating. A modification to this concept would be to create an "SDU Enterprise Center" which would contain a set of businesses that use SDU as feedstock. Each of the operations, and the center as a whole, could function as a demonstration facility and economic incubator for SDU processes developed by the USFS Forest Products Lab and entrepreneurs. In addition to fully functioning industries, the center could provide temporary shop space and equipment for start-up businesses and training facilities to teach others how to use the SDU processes developed.

Other alternatives to co-gen might include developing new demonstration facilities for SDU-based technologies that are not yet commercially viable. Such technologies might include biorefineries that make ethanol and/or industrial chemicals, hydrogen facility, engineered wood products, and various wood fiber or wood fiber/plastic composite materials. Such upcoming technologies may also be good candidates for the SDU Enterprise Center.

<u>Wood-to-Ethanol</u>

A 1997 biomass feedstocks study conducted by MSU indicated that converting wood residues to ethanol might offer both an economic and environmental opportunity in the Montana/Idaho region.[xlii] A more recent report (1999) indicates that a wood-to-ethanol plant in the Montana/Idaho region could generate returns on investment in the range of 20% to 30%, assuming the new demand on wood residuals would not dramatically increase feedstock prices. However, this study notes that though this opportunity appears attractive, it would be difficult to find the right combination of factors favorable to wood-to-ethanol production in this region. These factors include raising significant debt capital (+$30 million), ability to adopt new technologies (hydrolysis and fermentation), creating greater market opportunities for ethanol, and an ability to control or predict woody feedstock supplies.[xliii]

<u>Hydrogen</u>

Paul Williamson, Dean of The University of Montana College of Technology, envisions a plan that would make hydrogen the state's key economic development focus.[xliv] His vision includes constructing "Montana's Futures Park @UM" which would be designed to incorporate future technologies and training that provides a highly qualified workforce for the hydrogen industry and other businesses throughout the state.[xlv] A key part of R. Paul Williamson's plan is now supported by the State as set forth in House Joint Resolution No. 26. The resolution outlines actions including educating the public about the benefits of a hydrogen economy, establishing a Montana Hydrogen Futures Project initiative, encouraging development of a Montana Hydrogen Futures Park campus at UM, and creating an educational system to prepare professionals for working with hydrogen technology. [xliv]

Using 100% SDU as a feedstock for a power plant represents a 100% renewable source of energy. Like many renewable sources of energy, however, a wood-based power plant would be considered an “intermittent” source of power. In today’s 24/7 world, intermittent power is not good enough and must be backed-up by a continuous source of power. Alternatively, the energy produced could be stored. Historically, storing energy has been difficult, but today’s hydrogen technology allows hydrogen to be paired with intermittent renewable energy sources to provide an ideal energy-carrier system. With this combination, hydrogen fuel cells can produce continuous on-demand energy to power all the high-tech equipment we have come to rely on in our everyday lives.[xlvi]

A hydrogen fuel cell is a device that uses hydrogen to create electricity. In simplified terms it works like this: Hydrogen is sent into one side of the cell and into a proton exchange membrane. The hydrogen proton travels through the membrane, while the electron enters an electrical circuit, creating a DC electrical current. On the other side of the membrane, the proton and electron are recombined and mixed with oxygen from air, forming pure water.[xlvii]

Real Estate Based Concepts

MCDC’s and BDG’s goal of local economic development provides another alternative approach based on the real estate development potential of the Milltown Dam site and surrounding lands. During the course of the study, several Advisory Group members suggested the ideas listed below. It should be noted that real estate based economic development may require initial investment in infrastructure (such as water, sewer, and roads) in order to compete with other real estate based development projects in the region. Some of these ideas may face similar challenges as those described for the proposed co-gen plant.

- Industrial park development paralleling Missoula County’s development near the airport in Missoula

- Enterprise clustering which entails the co-location of businesses to realize benefits in logistics, infrastructure proximity, feedstock exchanges, local features, etc. (i.e. SDU Enterprise Center idea mentioned above might fit this scenario as well as the Eco-Industrial Park concept).

- Work within the process and framework of the Milltown Superfund Site Redevelopment Initiative Working Group to emphasize the importance of local economic development in multi-dimensional land use planning efforts

- Identify and attract a single large industry to the area to take advantage of local features and benefits of restoration efforts (i.e. computer industry, component manufacturers, other high tech, etc.)

- Explore drivers and opportunities associated with emerging concepts in brownfields redevelopment, urban revitalization, conservation- or recreation-based development, and the "Restoration Economy" that are gaining attention in other parts of the country.

- Identify other sites within the tax-base area that may provide greater opportunity and/or fewer challenges

Key Findings:

- ***There is shared interest among many organizations in finding solutions to the SDU challenge*** that supports local economic development.

- It is in the best interest of the USFS, MCDC, and the Bonner Development Group to ***revisit the drivers for this study and continue to work together*** toward these mutual goals.

- ***Alternative approaches could be explored for SDU outlets and/or generating new income opportunities*** based on SDU biomass, or generating economic development opportunities for the Bonner/Milltown area.

- ***Two alternative approaches are outlined: one approach is based on finding outlets for SDU material, and the approach is real estate based***, reflecting the different drivers for each of the three sponsoring organizations.

SUMMARY OF KEY FINDINGS

This section summarizes the key findings of the study of a SDU-fired 10 MW co-generation concept for the Milltown Dam site.

POSITIVES

No firm positives have been identified for the co-generation concept as initially conceived. What remains positive, however, is the shared interest among many organizations, both locally and nationally, in finding solutions to the SDU challenge that support local economic development. It is in the best interest of the USFS, MCDC, and the Bonner Development Group to revisit the drivers for this study and continue to work together toward these mutual goals.

Another report prepared in conjunction with this study entitled ***SDU as Biomass Feedstock: Opportunities and Challenges for Montana*** outlines other opportunities that may exist for attracting public research funding for emerging technology demonstration projects in biomass. The report asserts that it is strategic for organizations and companies in Montana to participate in national level R&D efforts in order to position for eventual private investment in biomass businesses.

NEGATIVES AND UNCERTAINTIES

Electrical and Steam Markets

- no immediate potential for a steam host at the Milltown Dam site
- Northwestern's buy back rate for power likely \$.04 per kWh or lower which is prohibitive for the typical \$.08 to \$.12 per kWh costs associated with biomass energy production
  Northwestern's uncertain economic future adds another level of complexity and uncertainty in market projections

Feedstock

- Feedstock quantities sufficient but unreliable due to historic federal policies and high percentage of private forest within economic haul distance
- Likely political opposition to SDU harvest and on-site storage

Permitting

- Significant difficulties in gaining public acceptance and regulatory compliance

Financial Projections

- capital investment requirement likely to exceed $20 million
- a minimum of $.0958 per kWh power purchase agreement with Northwestern required for a Return on Investment that would attract a qualified developer
- green tags and federal tax credit subsidies not likely to be sufficient to enable a competitive wholesale sales price of power

REQUIREMENTS FOR PROJECT FEASIBILITY

A significant number of specific issues would have to be resolved before the co-generation project as envisioned could be considered feasible. Resolving the following issues will be required to establish a risk profile and potential for return on investment sufficient to attract private investment in a full feasibility study:

- Identify a steam host with an interest in supporting the project;
- Decrease capital costs by acquiring all existing assets, land, water rights, buildings, and associated infrastructure at the Milltown Dam site at little to no cost;
- Increase in wholesale power purchase rates by Northwestern coupled with a perception of greater stability within the company;
- Increase in long-term stability and predictability of SDU feedstock resources on public and private lands;
- Decrease of delivered feedstock costs through public subsidies as part of a hazardous fire fuel reduction strategy;
- Achieve a high level of stakeholder support in order to facilitate public acceptance and address myriad regulatory issues.

ALTERNATIVES

Since the pre-feasibility analysis indicates that developing a wood-fired 10 MW co-gen facility at the Milltown Dam site would likely face challenges that would preclude its development, two sets of alternative approaches are presented. The first is based on using SDU Biomass and the second is real estate development based. These two approaches reflect the different drivers for each of the three sponsoring organizations.

SDU Biomass Concepts

- Government entities substantially subsidized co-gen facility construction and provided a reliable supply of SDU feedstock to the facility at little to no cost.

- Develop, and perhaps subsidize, a steam host such steam as greenhouses or hydroponics facilities, some form of district heating, or other steam-using industry.

- Provide SDU to the existing wood products industry.

- Use small mobile co-gen facilities closer to harvest sites or new high temperature incinerators to burn slash on site.

- Create an “SDU Enterprise Center” which would contain a set of businesses that use SDU as feedstock, temporary shop space equipment for start-up businesses, and training facilities to teach others how to use the SDU processes developed.

- Develop new demonstration facilities for SDU-based technologies that are not yet commercially viable, such as biorefineries, hydrogen facility, engineered wood products, and various wood fiber or wood fiber/plastic composite materials.

Real Estate Based Concepts

- Industrial park development

- Enterprise clustering

- Work with local groups in multi-dimensional land use planning efforts

- Identify and attract a single large industry to the area

- Explore emerging concepts in brownfields redevelopment, urban revitalization, conservation- or recreation-based development, and the “Restoration Economy”

- Identify other sites for development

APPENDIX

PROJECT SPONSORS AND ADVISORY GROUP

The sponsors of this study include U.S. Forest Service - Regions 1 / 4 and the Forest Products Lab represented by Dean Graham, Montana Community Development Corporation represented by Rosalie Cates and Craig Rawlings, and Bonner Development Group represented by Bruce Hall.

An array of other stake-holder organizations also contributed to the study through participation in advisory group:

Jim Carlson, Missoula County Health Department
Russ Forba, US EPA
Alexandra Gorman, Women's Voices for the Earth
Diana Hammer, US EPA
Dick King, MAEDC
Jim Krusemark, Northwestern Energy
Jim Leiter, BFI and Missoula Chamber of Commerce
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Carl Fielder, University of Montana School of Forestry – thinning for fire reduction
Richard Folk, University of Idaho - Small diameter tree research group
Lloyd Forrest, TSS Consultants – Financial projections, industry trends
Howard Haines, Montana DEQ – Bioenergy Engineering Specialist
Bruce Haroldson, Beaudette Engineering - Roundwood Structural Engineering
Bob Johnson, Johnson Brothers - Logging, hauling, wood processing
Jorge Kanahuati, Enlaces Ambientales – risks analysis
Chuck Keegan, University of Montana BBER – forest harvest economics
Michael Kustudia, Clark Fork Technical Advisory Committee
Carl Lehrburger, PureVision Technology, Inc. – Biorefinery

Steve Loken, Loken Construction - Engineered wood building materials
Jim Lueders, Brewers Consultant - Zero-emission brewery in Missoula
Paul Miller, Sustainable Systems, LLC - Biodiesel production in Missoula
Kent Pope, EPI - Fluidized bed combustion technology
Chuck Seeley, Smurfit-Stone - Largest wood residuals user in region
Steve Simonson, Sanders County Economic Development
Denny Sigars, Plum Creek - Largest landowner in region
Craig Thomas, Johnson Brothers – contract forestry, chipping, hauling

Several other individuals, agencies, and organizations may also perceive potential opportunities with the proposed co-gen facility. Such groups might include MAEDC, Montana DEQ, Montana Secretary of State Bob Brown, University of Montana, DOE, EPA, NRD, DOI, Homeland Security, and others. In assessing and developing this project, it is beneficial to identify and consider the many perceived opportunities and drivers that may exist. They include the following:

- Local economic development
- State and National level economic development
- Innovative and high tech industrial development for Montana
- Renewable energy production
- Energy independence
- Decentralized energy production
- Reclamation and restoration of Milltown area
- Model for other communities across Western Montana and across the nation

SOURCES OF ADDITIONAL INFORMATION

US Forest Service – Forest Products Lab, Technology Marketing Unit
Provides access on a range of related topics including SDU and biomass to energy.
http://www.fpl.fs.fed.us/tmu/publications.htm#Small%20Diameter%20and%20Underutilized%20Material

US Department of Energy – Combined Heat and Power Program
Describes DOE's efforts to working on a number of fronts to support increased use of CHP technologies.
http://www.eere.energy.gov/der/chp/

US Department of Energy – BioPower Program
Extensive information resources in support of biomass energy development at many scales.
http://www.eere.energy.gov/biopower/basics/index.htm

Biomass Research and Development Initiative
Clearinghouse site for a 30 organization advisory group guiding public investment and R&D in biomass development.
http://www.bioproducts-bioenergy.gov/

US Department of Energy National Renewable Energy Lab
Provides background information on bioenergy and related research and development.
http://www.nrel.gov/clean_energy/biopower.html

Montana Biomass Energy Program
Provides technical assistance, information development, and information to local business, government, and industry that match innovative energy technologies to local energy needs, focusing on solutions.
http://www.deq.state.mt.us/bioenergy/

Pacific Regional Biomass Program
One of five Regional Biomass Energy Programs established and funded by the U.S. Department of Energy. The program promotes the use of biomass for energy production. Biomass consists of renewable organic materials and includes forestry and agricultural crops and residues; wood and food processing wastes; and municipal solid waste.
http://www.pacificbiomass.org/members.cfm

Biomass Energy Research Association
An association of biofuels researchers, companies, and advocates that promotes education and research on renewable biomass energy and waste-to-energy systems.
http://www.bera1.org/

GLOSSARY

The following glossary of *wood to energy* terms was compiled by the US Forest Service Forest Products Lab[xlviii]:

Ash -- The non-combustible components of fuel.
Ash fusion temperature -- The temperature that ash melts.
Biogas -- A gas produced from biomass, usually combustible.
Biomass -- Any organic matter that can be burned for energy.
Bottom ash -- Ash that collects under the grates of a combustion furnace.
Boiler horsepower (BHP) -- The equivalent of heat required to change 15.6 kg (34.5 lb) per hour of water at (100°C) 212°F to steam at (100°C) 212°F.
Carbon cycle -- The process of transporting and transforming carbon throughout

the natural life cycle of a tree-from the removal of CO_2 from the atmosphere, to the accumulation of carbon in the tree as it grows, and the release of CO_2 back into the atmosphere when the tree naturally decays or is burned.

Carbon sequestration -- Refers to the provision of long-term storage of carbon in the terrestrial biosphere, underground, or oceans so that the buildup of carbon dioxide (the principal greenhouse gas) concentration in the atmosphere reduces or slows.

Bridging -- Fuel in a storage bin, hopper, or conveying system that supports itself although the fuel below it has been removed. One of the most common problems associated with wood-handling systems.

British thermal unit (Btu) -- A standard unit of energy equal to the heat required to increase the temperature 1 lb (0.45 kg) of water 1°F (0.56°C).

Char -- Carbon-rich combustible solids that result from pyrolysis of wood in the early stages of combustion and can be converted to combustible gases under certain conditions, or burned directly on the grate.

Clinker -- A slag-like material formed in the combustion process when the temperature of combustion exceeds the ash fusion temperature of the fuel.

Chipper -- A large device that reduces logs, whole trees, slab wood, or lumber to chips of more or less uniform size. Stationary chippers are used in sawmills, while trailer-mounted whole-tree chippers are used in the woods.

Co-firing -- Utilization of bioenergy feedstocks as a supplementary energy source in high efficiency boilers

Cogenerative -- Combined heat and power (CHP).

Combined heat and power (CHP) -- The simultaneous production of heat and mechanical work or electricity from a single fuel.

Combustion air -- Air that is used for the burning of a fuel.

Combustion efficiency -- The efficiency of converting available chemical energy in the fuel to heat. It measures only the completeness of fuel combustion that occurs in the combustion chamber.

Combustor -- The primary combustion unit, usually located next to the boiler or heat exchanger

Cyclone separator -- A flue gas particulate removal device that creates a vortex to separate solid particles from the hot gas stream.

Densified biomass fuels -- Biomass materials that have been dried and compressed to increase their density (e.g., pellets).

District energy system -- A system using central energy plants to meet the heating and/or cooling needs of residential, institutional, commercial, and industrial buildings and energy uses.

Excess air -- The amount of combustion air supplied to the fire that exceeds the theoretical air requirement to give complete combustion.

Flue gas -- All gases and products of combustion exhausted through the flue or chimney.

Fly ash -- Ash transported through the combustion chamber by the exhaust gases, and generally deposited in the boiler heat exchanger.

Fuel cell -- A cell similar to a battery -- it uses an electrochemical reverse electrolysis process to directly convert the chemical energy of a fuel (gas,

propane) into electricity, heat and water
Gasifier -- A combustion device that produces biogas from solid biomass.
Hogged fuel -- Biomass generated by grinding wood and wood waste for use in a combustor.
Kilowatt -- A standard unit for expressing the rate of electrical power output (i.e. subscripts e and th stand for electrical and thermal, respectively).
Live-bottom trailer -- A self-unloading tractor-trailer with a hydraulically operated moving floor that is used to remove the biomass fuel.
Metering bin -- A bin in the fuel feed stream that allows a precise feed rate of the fuel to the fire.
Mill chips -- Wood chips produced in a sawmill.
Moisture content -- The amount of moisture contained in the fuel.
On/off fuel feed -- A fuel feed system that transports fuel to the grates on an intermittent basis in response to boiler water temperature and load variations.
Over-fire air -- Combustion air supplied above the grates and fuel bed.
Particulates -- Minute solid airborne particles that result from biomass combustion.
Pyrolysis -- A process of combustion at less than stoichiometric conditions, involving the physical and chemical decomposition of solid organic matter by the action of heat in the absence of oxygen into liquids, gases, and a carbon char residue.
Residence time -- The length of time the fuel remains in a combustion zone.
Seasonal efficiency -- Represents the ratio between the total useful energy delivered to the thermal load over the full operating season and the total potential energy within the fuel burned over the period.
Steady-state efficiency -- Ratio of output to input energy when combustion system is operating under design conditions.
Turndown ratio -- A ratio found by dividing the maximum energy output by the minimum output at which efficient, smoke-free combustion can be sustained.
Under-fire air -- Combustion air added under the grates.
Whole-tree chips -- Wood chips produced in the woods by feeding whole trees or tree stems into a mobile chipper that discharge directly into a tractor-trailer.
Wood gasification -- The process of heating wood in an oxygen-starved chamber until volatile pyrolysis gases (e.g., CO, H2, O2) are released from the wood. The gases emitted are lower- or medium-Btu-content gases that can be combusted in various ways.

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