NEDERLAND COMMUNITY BIOFUELS PROJECT: TECHNICAL DESCRIPTION, OPERATIONAL RESULTS, AND COST BENEFITS ANALYSIS










Final report evaluating the viability of wood waste as a renewable resource for generating heat and electricity in municipal applications

Submitted to:

U.S. Environmental Protection Agency Region VIII, Office of Solid Waste

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Many entities deserve credit for their contributions to the Nederland Community Biomass Project:

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Executive Summary

The objective of the Nederland Community Biomass Project was to prove the viability of using forest waste as a renewable fuel resource for generating heat and electricity for use in a municipal facility. Nederland is a small town located about 20 miles west of Boulder in the Rocky Mountains of Colorado. The project was designed to service the Town's community center, a building with an occupied, conditioned space of 20,000 square feet. In addition to demonstrating the feasibility of wood waste for both heat and power, the project was also intended to demonstrate a unique approach to fire mitigation and to replace the community center's aging boilers. The project was initiated in the Fall of 2002 by the Colorado Governor's Office of Energy Management and Conservation (OEMC) hosting a meeting to identify a mountain community interested in a combined heat and power (CHP) project using forest thinnings. From this meeting emerged a bioenergy task force comprised of the Town of Nederland, Bioenergy Corporation and various state and federal agencies.

Although a good faith effort was put forward, power generation ultimately did not prove feasible due to steam quality issues. This result likely indicates that a hot water system would be a better fit, both economically and technically, for biomass applications.

In addition to ensuring compliance with the appropriate federal and state air quality regulations, the project conducted an air study to evaluate the emissions of the system. The study found the biomass plant to have lower emissions than wood slash disposal.

Of the various methods explored for supplying fuel to the pilot project, tub grinding (by a contractor) of the wood waste collected at a community drop off location was determined to be the most feasible method for the Town. The cost of this preferred method is estimated to be $13 per ton.

Three fuel quality factors were demonstrated to be important to plant operation:

1. chip size – four-inch wood chips are optimal for the Town of Nederland system,
2. contamination level – clean chips allow the system to function at a higher level of efficiency and minimize time and cost of cleaning out process waste, and
3. moisture/thermal content – dry wood chips optimize the boiler system performance, but wet chips can also have high thermal content if stored in a clean and dry location.

The total cost of the project was $443,000. The current operating scenario of the plant is projected to save about $8,150 per year.

Beyond saving on fuel costs, the environmental and social benefits of this pilot project include reduction of air emissions (as compared to prescribed burns), use of a rapidly renewing fuel source, improvement of forest health, reduction of losses from wildfires, economic development, and public relations value.

The pilot project took on significant technical challenges in the development of a system that is the first of its kind in Colorado. Through this project, the Town of Nederland, along with its private and public partners, was recognized for its vision for innovatively doing the right thing for the environment and saving on heating costs.

This report details the project history, plant, technical description, fuel supply issues, air emissions, operations and maintenance requirements, costs, benefits and factors to consider when replicating the pilot project in other communities.

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1 Introduction

The Nederland Community Biomass Project is an example of public and private partners combining resources, expertise, and ingenuity to design, build, and operate a successful solution to multiple community needs: heating public buildings, mitigating fires, and using resources responsibly. The project is a collaborative effort between the Town of Nederland, BioEnergy Corporation, and the following state and federal agencies:

- The Colorado Governor's Office of Energy Management and Conservation (OEMC)
- Colorado State Forest Service
- U.S. Forest Service
- U.S. Environmental Protection Agency
- Colorado State University.

The original objective of the Community Biomass Project was to prove the viability of using forest waste as a renewable fuel resource for generating heat and electricity for use in a municipal facility. This pilot project was the first of its kind known in Colorado and considered to be an evolutionary process in its nature. The pilot project proposed to burn forest waste in a firebox and to provide steam to a steam-powered microturbine to generate electricity, and waste heat, for the Town of Nederland's community center. The pilot was officially initiated in May 2003 when the Town of Nederland Board of Trustees held a public meeting and approved the project. Eighteen months later, the system is providing heat for the community center. Although the microturbine does not provide electric power as anticipated, the pilot project is highly successful in many ways. This report documents the 18-month process from project concept to completion, sharing operational results, costs, benefits, and lessons learned.

1.1 Project Overview

Nederland, Colorado is a small western town with a population of approximately 1,375. It is located in the Rocky Mountains at 8,236 feet above sea level and lies approximately 20 miles west of Boulder, Colorado. The town community center is home to six tenant organizations:

- Backdoor Theater
- Nederland Area Seniors
- Nederland Community Library
- Nederland Lions Club
- Tourism and Recreation Program
- Wild Bear Center for Nature Discovery

The building is approximately 30,000 square feet, but only 20,000 square feet are occupied and receiving heat from this project. Prior to this pilot project, two equally sized natural-gas boilers over 30 years old provided heat for the building. These boilers currently provide backup to the pilot wood-fired system. The current heating demand is approximately 20,500 therms/year. However, near-term plans to expand or replace the existing building could triple this heating demand. The pilot project is positioned to provide the heat for a new building without significant modification or funding.

The scope of the biomass project was to demonstrate on a small scale the feasibility of using wood waste for both heat and power. The Town of Nederland was in the unique position of needing to replace and rebuild a large portion of its community center as it had been damaged in a catastrophic snowstorm. The equipment and project size grew quickly when a used boiler became available at a favorable price. Among other reasons, this used boiler was pursued to help keep project costs down and avoid the lead-time required for a new purchase. At its inception, the project, including the boiler, was designed to have the flexibility to increase both the amount of heat produced and the power generated to meet any required future reconstruction plans following the storm.

The pilot project proposed to answer the following questions:

- Is it possible to use local forest wastes to generate enough heat and electricity to sufficiently heat and power the town's community center?
- Can it be done cost effectively?
- Do benefits to the public support the cost?
- How do air emissions compare with other wood disposal methods? With conventional heating systems?
- Is there enough wood waste to support the investment? How does the wood waste supply look for the future?
- What types of local infrastructure will need to be developed to support a wood burning plant?
- If it works in the Town of Nederland, will it work in other places?

1.2 History and Partners

Tables 1 through 9 below highlight the project history and roles of the various partners throughout the process.

Table 1. Project History and Partner Roles - Fall 2002

Milestone	Description	Responsible Party
Bioenergy Task Force Convened	Information Session and Tour conducted at Town of Nederland Community Center; Multi-party presentations made regarding biomass utilization and potential bioenergy applications	Colorado State Forest Service

Table 2. Project History and Partner Roles - Spring 2003

Milestone	Description	Responsible Party
Initial Meeting	With knowledge of the Task Force, a gathering of professionals from the forestry, biomass and energy industries convened a meeting at OEMC to discuss the opportunities in Colorado for a community based biomass power project. Several local governments and the US Air Force Academy were present as the potential recipients of a pilot project. At this meeting the Town of Nederland volunteered to be the site for the pilot project and OEMC and the USFS agreed to fund the project in conjunction with Delta Dynamics.	OEMC

Table 3. Project History and Partner Roles - Spring 2003

Milestone	Description	Responsible Party
Project Approved	Town of Nederland Board of Trustees held a public meeting and approved the pilot project.	Town of Nederland

Table 4. Project History and Partner Roles - Summer 2003

Milestone	Description	Responsible Party
Tour to Chadron State College	Tour for interested parties to view similar technology and the biofuel system at Chadron State College	Colorado Wood Utilization and Marketing Assistance Center (COUMAC)

Table 5. Project History and Partner Roles - Summer 2003

Milestone	Description	Responsible Party
Site Identified	Town of Nederland identified a site - a nearby construction shed that needed concrete slab improvements and road grading.	Town of Nederland
Equipment Ordered and Purchased	The boiler was special ordered and modified for this application.	Town of Nederland OEMC U.S. Forest Service
Utilities Interconnected	BioEnergy worked with Xcel Energy to set up temporary service for the pilot project and to assess larger issues of standby power and interconnection regulations.	Town of Nederland BioEnergy

Table 6. Project History and Partner Roles - Fall 2003

Milestone	Description	Responsible Party
Equipment Delivered	The boiler, microturbine, and other mechanical systems were delivered.	BioEnergy
Design and Installation Completed	Plant design and engineering was completed.	BioEnergy
Fuel Delivery System Installed	The fuel delivery system was designed and installed.	BioEnergy

Table 7. Project History and Partner Roles - Winter 2003

Milestone	Description	Responsible Party
First Wood Delivered; wood tested	Developed and implemented a system to ensure reliable supply of chips for the project; first batch delivered; tested British Thermal Unit (BTU) values of random wood chip samples.	Colorado State Forest Service Town of Nederland
Plant fully operational	All equipment in place and installed, connected, tested and fueled.	BioEnergy Town of Nederland
Pilot Run Completed	Pilot project ran for 105 days (1,561 hours) during the winter/spring of 2004.	BioEnergy Town of Nederland

Table 8. Project History and Partner Roles - Spring/Summer 2004

Milestone	Description	Responsible Party
Evaluated and Tested Emissions	Contractors for the State Health Department conducted air quality tests and assisted in evaluating environmental impacts.	ENSR International

Table 9. Project History and Partner Roles - Fall 2004

Milestone	Description	Responsible Party
Operated Full System	First heating season, heat portion of system is fully operational.	Town of Nederland
Evaluate and Document Project	Community outreach and market information will be researched and reported. Final report.	OEMC The Brendle Group
Conduct Publicity (Transferability and Deliverables)	All participating partners will promote the project on their websites and in conference presentations, and OEMC will issue press materials.	OEMC All parties

Building off of the context outlined in this Section on the project's overview, history and partners, Section 2.0 describes the technical aspects of the biomass project.

2 Technical Description

2.1 Basics of Wood Energy Systems[1]

Small- and moderate-sized communities in forested areas face danger from forest fires burning out of control. Adding to the situation, Colorado mountain communities, including the town of Nederland, have experienced growing residential settlements in densely forested areas. In the Intermountain West, the severity and frequency of forest fires has increased due to drier seasons and an overabundance of dense, overstocked stands. This overabundance of material is the result of effective fire suppression and the high costs of harvesting and using small-diameter trees. If more of this material could be economically used, the risk of disastrous fires would be greatly reduced, vigorous forest growth would be sustained, and needed employment opportunities for economically disadvantaged rural residents would be provided.

Cogeneration is the simultaneous production of heat and electricity, commonly called combined heat and power (CHP), from a fuel consisting of a single fuel or blended fuels. Traditionally, if a large volume of heat is available, a steam turbine is used to produce utility-scale electricity, although any electrical generation can be a cogeneration unit. When intending to produce steam for a turbine, two common mistakes can be made when installing a CHP system: buying a steam boiler that produces inadequate steam quality for the turbine to operate (usually less than 100 lbf/in2) or oversizing the system. Oversizing the system results in additional capital costs, not better quality steam.

Biomass facilities can use different types of combustors (including traveling grate, pile burner, suspension burner, and fluidized bed), boilers (including fire tube and water tube), exhaust-gas cleanup systems, and wood fuels (including whole tree chips, mill or plant residues, sawdust, pellets, and cordwood).

Automation and controls for fueling wood-burning heating systems are not as finely developed as for fossil-fuel-based combustion. They usually fall into one of three levels: manual loading, semi-automatic, and fully automatic. Wood-burning systems also are restricted in their ability to account for fluctuations in heat demand because of varying seasonal heating loads or other reasons.

Fuel quality also can be a limiting factor as fuels with moisture contents greater than 60 percent (wet basis) typically cannot be burned reliably. Common challenges for wood-fired systems are ensuring adequate fuel procurement and solving the complex fuel handling and storage issues. Fuel handling and storage requirements can increase system costs to 50 percent greater than fossil fuel systems. Furthermore, combustion efficiencies of 65 – 75 percent may be expected compared to 80 percent obtained from gas- or oil-fired units. The difficulty of automatic firing, slow response to peak demand, and the need to remove and dispose of ash are additional considerations when weighing the costs and benefits of a wood-fired system.

Despite these drawbacks, wood-fired systems can be cost effective where wood has a low local market value and fuel prices are high. Or, as discussed above, the wood source can solve a more serious problem, namely forest fire mitigation through management.

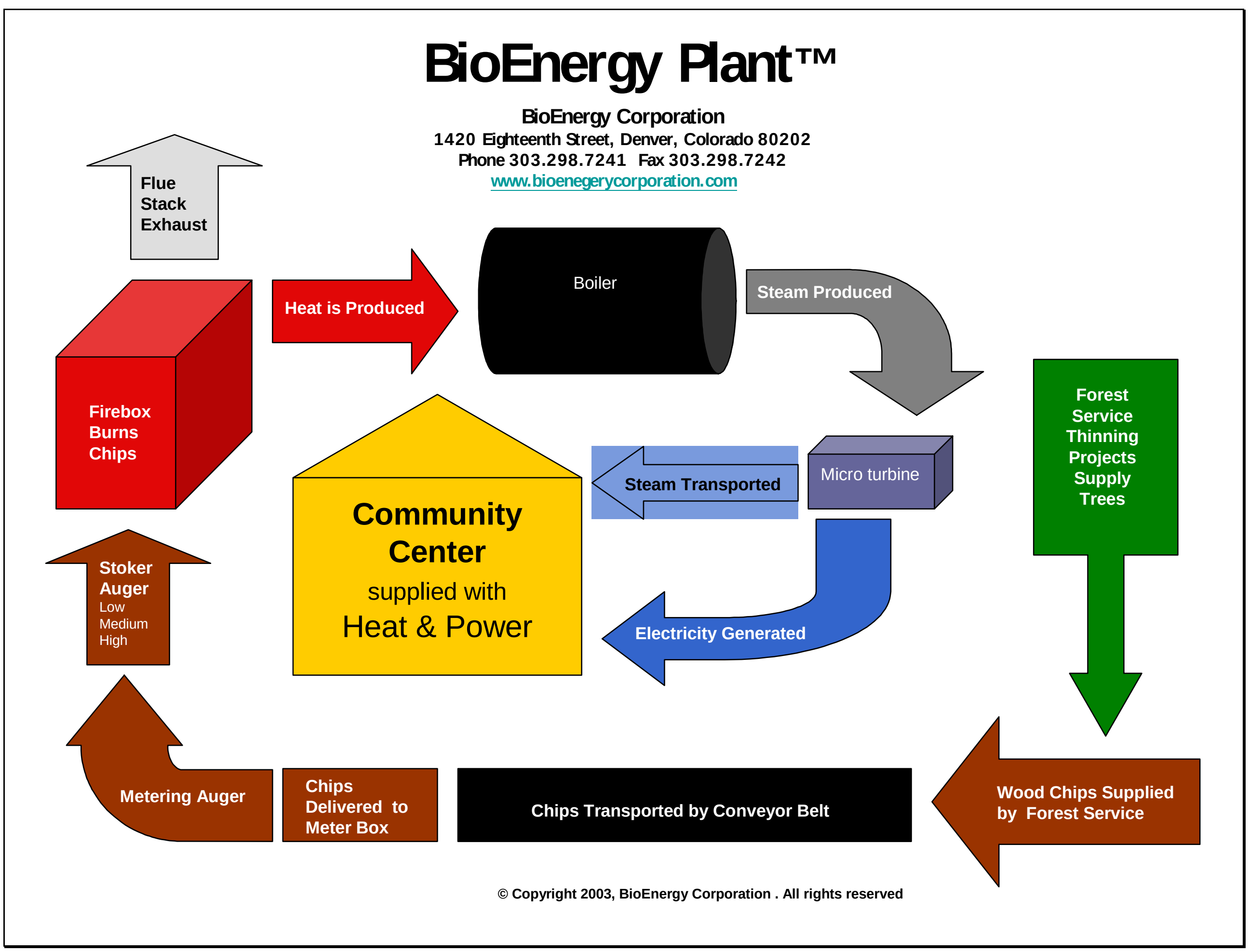
[1] Section 2.1 is excerpted from "Basic Wood Energy Information", John Zerbe and Richard Bergman, USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. www.fpl.fs.fed.us/tmu/small-scale_wood_energy.htm

2.2 Equipment Descriptions

The following diagram illustrates the fuel delivery system and steam plant as designed for providing heat to the community center. The microturbine shown did not ultimately prove feasible for the project: the system, as it exists to date, is providing space heating but not electricity to the community center. The operation of the microturbine is further discussed at the conclusion of this section.

The BioEnergy system combusts wood chips that are stored in an enclosed shed with a heated floor that dries the material. The chips then enter the negatively pressured firebox for primary combustion. Secondary air is added to the process to increase combustion temperatures to nearly 2,000 degrees Fahrenheit. The air is drawn through a Clever-Brooks 120-horsepower boiler that has been re-tubed for this project. Steam is generated in the boiler and delivered to the current community center boiler header via insulated piping. Stack gas is drawn through the combustion chamber and the boiler is vented to the atmosphere through a 12-inch by 12-inch vertical stack. The system also is equipped with a condenser (plate and frame heat exchanger) and cooling tower to distribute waste heat. In addition, the system is closed-loop to conserve water. Excess steam beyond what is needed to heat the community center is condensed and used for boiler makeup.

Figure 1.1 Biomass Equipment Diagram



The specifications of the individual components in the system are described as follows:

Fuel Supply	Steam Plant
Storage Bin Auger: Gearmotor: Nord Clincher SK5282AXB-100 Nord Motor: Type SK100 L/4 3ph, 3HP Bearing: Pillow Block VPS365 3 ½ " **Travel of Hopper Auger:** Nord Minicase Gear Reducer SK2563NB-71 Motor: Type SK71 S/4 3ph, .34HP Switches: Telemechanique XCK-L106 **Belt Conveyor:** Serial # 8916C-4880-0402 Reducer: Nord SK 1282 AZB Motor: Dayton 3N087, 1HP,3.4A Controls: GE Fanuc IC300OCS100 **Metering Auger:** Dayton ½ HP motor 1725rpm 5.5A Reducer: Nord SK3382AFB Switch: Omron ZE-Q-2S **Stoker Auger:** Dayton Motor 3N087H, 1HP, 3.4A Reducer: Nord SK3382AFB	**Combustion Air Blowers:** Dayton 4C108 HP Direct Dayton 1C791 direct **Firebox:** Messersmith Firebox @3.5MMBtu output **Boiler:** Cleaver Brooks LFME-8-12 Boiler 100 BHP @120 psi (Manufactured 1955, estimated) **Cooling Tower (Condenser):** BAC FXT 58-A Air Coil **Induced Draft Fan:** Dayton Model 3C107 Danfoss 2800 AC Drive **Heat Exchanger:** Alfa Laval TS6-MFG 150psi/300'F **Microturbine:** Delta Dynamics

The following photographs taken during construction and operation of the fuel delivery system and steam plant further illustrate the system components and provide a pictorial history of the project:

Figure 2.1 Site Work

The Town of Nederland selected a former construction shed located approximately 70 yards uphill from the community center for the project site. The site needed concrete slab improvements and road grading.

Figure 2.2 Fuel Storage Building

A separate building was constructed adjacent to the construction shed for fuel storage. The chip storage building can store approximately 150 cubic yards of chips, approximately 9 days fuel supply to meet peak heating demand. See Section 3.1 for further discussion of fuel delivery issues.

Figure 2.3 Storage Bin Auger

The storage bin auger transports the wood from the storage bin to the travel-of-hopper auger.

Figure 2.4 Travel-of-Hopper Auger

In this photo, a conveyor transports wood from the storage bin to the hopper that feeds the firebox.

Figure 2.5 Firebox and Boiler

The photo at left shows the firebox and steam boiler. The photo at right shows the wood combustion process inside the firebox.

Figure 2.6 Feedwater Tank

This photo shows the system's feedwater tank and its related controls.

Figure 2.7 Completed Construction - Exterior

This photo shows the site after construction was completed. The building at left was the original storage shed that was converted to the biomass steam plant. The steeper-pitched building at right houses the fuel storage bay and fuel delivery equipment. It was constructed as part of this project. The cooling tower for rejecting excess heat from the system can be seen at left. Site preparation included road grading to provide access to the fuel storage bay by truck. This photo was taken from just outside the community center located just yards downhill from the plant.

As previously mentioned, the system was initially intended to also provide steam to a microturbine to generate electricity. The cogeneration element of the pilot project made it the first of its kind known in Colorado and presented a particular technical challenge. Despite a good faith effort, power generation did not prove to be feasible for the Town of Nederland biomass system. Ultimately, the boiler was unable to produce steam of adequate quality (lbf/in2) to operate the turbine. The system's size was a key factor. The system was oversized to accommodate a possible future expansion of the community center (and thus an increase in the heating load). In the end, the oversized boiler compromised the steam quality. It is possible that the microturbine operation could still prove viable in the future with an increase in the system's heating load (due to the building's expansion).

2.3 Emissions Issues

Compliance with Air Quality Regulations

At the start of a project similar in nature to the Town of Nederland biomass plant, local and state agencies should be contacted to determine the necessary regulatory steps for the design and implementation phase of a project. As a part of the grant awarded by EPA an air emissions study was conducted to determine the applicability of the Town of Nederland Biomass Project with federal and state air quality regulations. Of the 5 federal and 19 state regulations investigated, the Biomass Plant is only subject to the state regulations detailed in **Table 10**:

Table 10. State Regulations Applicable to Project

Regulation Number and Title	Reason for Regulation
Regulation 1 – Particulates, Smokes, Carbon Monoxide and Sulfur Oxides	Applies to all new and existing sources. The following subcategories apply: - Opacity Standards - Particulate Matter Standards
Regulation 2 – Odor Emissions	Applies to any potential source of air contaminants.
Regulation 3 – Stationary Source Permitting and Air Pollutant Emission Notice Requirements	Applies to all sources of air pollutants. Source category emissions exceed the *de minims* thresholds for exemption from submitting an APEN and permit application.

An Air Pollution Emission Notice (APEN) was filed by the Town of Nederland with the CDPHE, as required. This annual notice states that the Plant will operate within the requirements of the CDPHE and is renewable annually. The APEN does not require any testing on the part of the plant operator. CDPHE performed opacity tests on the system and found the output to be within the normal range.

Beyond compliance, the air emissions study conducted in the summer of 2004 evaluated two additional questions:

1. How do the pilot project air emissions compare to prescribed burning?

2. How do emissions compare to other conventional heating systems?

Initial stack emissions tests on the system were conducted to analyze performance and to characterize emissions. Beyond answering the three questions above, this testing was also instrumental in trouble-shooting the system's performance. Specifically, testing identified a need for improving the feed delivery system to decrease the risk of over-feeding the process and increasing carbon monoxide (CO) and total organic carbon (TOC) emissions. This finding led to feed delivery system upgrades for more consistent fuel delivery.

The results of the study are summarized below. Ultimately, the study indicated that the biomass plant is a preferred alternative for wood slash disposal because it reduces pollutant discharge to the environment and produces building heat.

Comparison of Biomass Plant Emissions with Prescribed Burning

The combustion of wood products and all other fossil fuels have the potential to emit oxides of nitrogen (NOx), CO, sulfur dioxide (SO2), total suspended particulate matter (TSP), particulate matter with an aerodynamic diameter less than 10 microns (PM10), total organic carbon (TOC), and hazardous air pollutants (HAPs). **Table 11** compares air emissions from the Town of Nederland Biomass Plant with emissions from other wood disposal methods in units of pounds of pollutant per pound of wood combusted. The data are based on actual system testing during fall 2003 as well as on U.S. Environmental Protection Agency emission factors for other wood combustion processes. The total emissions from the Town of Nederland Biomass Plant are lower than other fuel management practices. PM10 and TOC were not sampled during the stack test and emission factors are unavailable for some other combustion types. HAP emissions from the Biomass Plant were calculated and are well below reporting requirements.

Table 11. Comparison of Emissions From Various Fuel Management Techniques.

Pollutant	Wildfire	Slash Debris	Line Fire	USEPA-42 Emission Factor	Town of Nederland Biomass Plant
(lbs pollutant/ton wood)					
NOx	4.0	8.96	8.96	5.1	1.42
CO	140.0	82.9	448.0	6.24	5.93
TSP	17.0	13.44	112.0	5.82	3.92
PM10	--	8.96	89.6	5.20	--
TOC	24.0	4.03	--	0.18	--

Comparison of Biomass Plant Emissions with Conventional Heating

Table 12 compares emission factors for similar sized boilers (as the Town of Nederland Biomass Plant) combusting different fuels. Although emissions from the Town of Nederland Biomass Plant are higher than natural gas emissions, they are better than conventional wood heating systems.

Table 12. Comparison of Biomass Plant Emissions with Conventional Heating

Pollutant	Coal	Distillate Fuel Oil	No. 6 Fuel Oil	Natural Gas	Town of Nederland Biomass Plant
(lbs pollutant/MMBtu)					
NOx	0.25	0.14	0.37	0.10	0.30
CO	10.58	0.04	0.03	0.08	0.53
SO2	2.98	0.51	2.65	0.001	0.025
TSP	0.58	0.01	0.07	0.01	0.35
PM10	0.24	--	--	--	0.35
TOC	0.38	0.002	0.01	0.01	0.039

Optional Device for Emissions Control

BioEnergy offered the Town of Nederland the option to install a cyclone separator to remove particulates from combustion exhaust. The cyclone separator was not required to meet air quality regulations, but would decrease the opacity of the exhaust air. In short, a cyclone separator would benefit the system in a way very similar to a car that has been operating without a muffler and has one added. At the time of this report, the town has decided not to install this $7,000 add-on.

Other Process Wastes

Aside from air emissions, the process produces solid waste from wood combustion – a combination of fly ash and clinker. Clinker is molten rock material formed in the combustion process. The solid waste is collected from the firebox and placed outside the building in a storage area. The waste is loaded into a pick-up truck with a bobcat and hauled to the landfill approximately three times per heating season. (As an alternative to landfilling, the fly ash may be eligible for other uses, such as road base, fill dirt, and mine waste neutralization.) This waste creates extra work for the maintenance crew because it must be removed on a daily basis and the fire box must be cooled before it can be opened to remove the debris. A cleaner fuel supply would, however, decrease the clinker problem significantly. The Town is considering a filter or chip shaking system to clean the chips before they enter the fuel storage area in an attempt to eliminate the problems they encounter with a dirty fuel supply.

An automated ash removal system would decrease the daily fire box cleaning required by the maintenance crew. However, an automated ash removal system is not typically used for biomass systems similar to the size of the Town of Nederland's plant and was found to be cost prohibitive for the Town. The automated system is basically a trough under the fire box with an auger that can be activated as needed to remove accumulated process waste. The waste is temporarily stored in a metal-lined container to cool before disposal. Ultimately, the town elected not to include this estimated $12,000 add-on in the initial plant design.

3 Operational Results

3.1 Fuel Requirements

As discussed in Section 2.1 Basics of Wood Energy Systems, the principle challenge in all wood-fired boiler systems is managing the complexities of fuel storage and delivery. This project was not an exception. This section first generally discusses all the options explored for procuring, collecting, moving material, and implementing the process. The section then presents a summary of results from the options explored. Finally, the section discusses fuel quality issues.

At the time of the Town of Nederland biomass pilot project, the primary methods used in the area for slash reduction during thinning activities were: (1) "lop and scatter", (2) pile burning or (3) the use of broadcast prescribed burning. The "lop and scatter" method involves cutting the branches and tops of the removed trees and scattering on the forest floor at an acceptable depth. Additionally, whole tree chipping, a relatively new practice in this area, was also being used. This method involves chipping small-diameter trees in the woods and blowing the chips directly back into the forest.

Production/Supply/Delivery Requirements: Options and Results

On an average winter day, the plant burns approximately 3 tons of wood chips (fuel). Assuming the plant runs 8 months per year, the plant will run an average of 240 days/year and will burn approximately 720 tons of fuel/year. It was recommended to the Town of Nederland to keep at least 1 month (84 to 93 tons) of chips supply on hand at all times with an additional supply of chips on hand at the slash drop-off site for emergency purposes.

The project used numerous methods to procure chips. Depending on the method, chip costs ranged from free (or very minimal) up to $62.50/ton. (Note: A price of $15/ton is considered typical; the one-time cost of $62.50 noted in the following table is considered exceptionally high - about four times greater than expected.). Most of these methods utilized the Town of Nederland Biomass Collection site. This is a community and wood waste slash drop-off site that allows local landowners and contractors a place to drop off waste wood with no tipping fees. Often these chips originate from community landowner fire mitigation projects on their properties. Once the slash is at the site, the slash must then be chipped into a dump truck and delivered to the biomass plant. Chips also can be stored for a time at the slash drop-off site and delivered to the facility when necessary. The slash site has enough storage space to provide fuel for a complete heating season. Weather did not appear to impact the quality of the chips because water and snow moisture from outdoor storage only penetrate the chip pile a couple of inches.

The Town of Nederland explored the option of using a town employee to chip this material as the material was received, thus creating employment in the local area. The town would have to pay an employee to operate this chipper, and he/she could produce an average of 1.5 tons of chips per 8-hour day. If this employee worked everyday for 1 year to supply chips to the facility, he/she would only produce 547.5 tons each year. The town also utilized a tub grinder in order to chip large amounts of the slash at one time.

Chips also can be procured through local contractors that have access to chippers and a truck delivery method. Often these chips originate from local thinning operations (e.g., Wineger Ridge, Sugarloaf, Gilpin County, etc.). These chips must be paid for in order to make the chipping operation economically feasible for the local contractors. Another delivery mechanism is to pay a composting or waste hauling company, (e.g., A-1 Organics, Oxford Recycling, Western Disposal) to deliver chips from other projects in the area. As these composting or waste hauling companies do charge for their services, the economic feasibility of this particular delivery mechanism is questionable. The chip products that result from this particular mechanism are also questionable.

Table 13 summarizes the differences between the options explored for chip production/supply/delivery. (Note that each method is explained further following the table.)

Table 13. Fuel Supply Options

Source	Labor Rate	Hours	Cost of purchase or process	Yield (yard3)	Tons	Cost/ton delivered to slash pile	Cost/ therm	Cost/therm hauling to plant	Total Cost/ therm
A Nederland Slash Drop-off Site	$10	245	$2,450	1000	200	$12.25	0.097	0.068	0.165
B Oxford Recycling			$250	40	8	$31.25	0.247	0.068	0.315
C Gilpin County			$225	40	8	$28.13	0.223	0.068	0.291
D Estes Park wildfire mitigation work			$500	40	8	$62.50	0.494	0.068	0.562
Sources A-D totals & blended costs			$3,425	1120	224	$15.29	0.121	0.068	0.189
E Tub grinding of community slash pile through Oxford Recycling		8*	$3,950						
	50**	32	$1,600						
	85***	32	$2,720						
	e cost		$8,270	3200	640	$12.92	0.102	0.068	0.170

Explanatory Notes for Table 13

Source A: Town of Nederland Biomass Collection Facility (slash drop-off site)

- Slash brought by landowners and contractors
- No tipping fee collected though discussion has occurred to have small fee to go toward site clean-up, chipper repair/maintenance, etc.
- Town of Nederland crew chips into dump truck and delivers to storage facility or community center parking lot
- Have used Boulder County Work Release Crew and students have been used to drag slash to the chipper operator. Moving the chips to the chipper operator increases production significantly (i.e., two loads per hour as opposed to two to four loads per day.
- The summary for Source A does not include the capital cost of the chipper. The yield estimate is an estimate per Ron Trzepacz.

Explanatory Notes for Table 13 (continued)

Source B: Provided by Oxford Recycling

Source C: Gilpin County

- Town of Nederland hauls slash from Gilpin County using Gilpin County roll-offs and truck.
- This has been a "best we can do right now" method. While this method might save Gilpin County from future tub grinding costs, it is NOT an efficient means of hauling biomass due to the volume hauled per turn-around.

Source D: From Estes Park wildfire mitigation work

- Colorado State Forest Service (CSFS) and Town of Nederland shared cost to haul 4 semi-trailer loads to Town of Nederland Collection Facility
- CSFS: $500/Nederland: $350

Source E: Community slash piles were sent to Oxford Recycling for tub grinding

- * Oxford billed hours of tub grinder use = 8 hours.
- ** Town of Nederland employee burdened labor.
- *** Town of Nederland hourly equipment cost.
- The line items indicated on the "e cost" row are the total for Source E.

Other miscellaneous sources not detailed in the above table:

- From 2003 tub grinding operation, CSFS paid $1700 to A-1 Organics to tub grind one pile in Gilpin County and one pile from Stewardship Contract area on Magnolia Road.
- From Colorado Department of Transportation (CDOT) road work between Nederland and Rollinsville, Town of Nederland hauled chips produced by CDOT crews
- From Eldora Ski Area
- From City of Boulder (Betasso Water Treatment Facility) wildfire mitigation project, CSFS paid $350 to W. Disposal for roll-off delivery and dump at Town of Nederland Collection Facility

The overall conclusion presented by the preceding table is that on-site chipping with the Town-owned chipper was the least expensive method, but requires an extended execution time due to the limited throughput of the chipper. As a result, BioEnergy recommended the tub grinding method (source E in the preceding table, completed by Oxford Recycling). The overall cost of tub grinding was comparable to chipping (approximately $0.17/therm equivalent) and a very favorable comparison to natural gas ($0.68/therm).

The Town has currently selected to use tub grinding, approximately two times per year, as their method of choice. In addition to the previously-detailed, favorable economic analysis of tub grinding, the impact of staff from the various methods also contributed to this decision (chipping is hard, loud, and dirty work).

It appears that the primary procurement methods will include the following:

1. Community supported slash/biomass collection and chipping

2. The use of roll-offs to collect chips being produced on private land during wildfire mitigation/defensible space projects and from public lands during thinning/chipping operations
3. Tub grinding large slash piles on public lands instead of winter-time burning

Fuel Quality Requirements

Three factors affect fuel quality:

1. chip size,
2. contamination levels, and
3. moisture content.

The operation of the Town of Nederland's biomass system is optimal when four-inch wood chips are used. However, chips up to 7 inches are common in the system due to the irregular uniformity produced by the tub grinder. The wood chipper typically produces chips that are more uniform. Clean chips free of dirt and particles yield the best results for the system; both the methods of tub grinding and wood chipping can produce clean fuel, if applied correctly. Clean chips allow the system to function at a higher level of efficiency, and they minimize the time spent cleaning out the burner. It was recommended that chips not be stored, at any stage of transportation to the heat plant, where there were high amounts of rocks and dirt. This tactic ideally avoids contact with the ground until they reach the heat plant's storage facility.

Moisture content and BTU values for the wood chips burned at the biomass facility are very important numbers in determining overall boiler system performance. By comparing the moisture content of wood chips to the overall BTU values of those chips, actual recoverable heat produced by the system can be evaluated. Energy contained within these biomass chips is actually used to vaporize the water contained in the chips. In essence, the firebox has to burn more chips in order to obtain a certain level of boiler system performance.

As part of the project, BioEnergy collected random samples of chips from the biomass storage area at different times throughout February and March of 2004. These chips were produced from local thinning operations and fire mitigation efforts. The biomass chips came from the Nederland area, and the samples are believed to have consisted of a mix of ponderosa pine, lodgepole pine, and Douglas-fir. Next, a certain amount of the samples were dried in an oven in order to determine moisture content. Once completely dried, the chips were weighed and placed into separate bags. The samples were saved and then both wet and dry samples were tested in a bomb calorimeter to determine BTU values. Significant differences were measured in the BTU values obtained from wet and dry chips. These findings are shown in the following **Tables 14 and 15**. Green specimens contain an average of 6324 BTU/lb and the dry specimens contain 8,529 BTU/lb. In essence, this shows that the system is losing approximately 2,200 BTU/lb of wood chips in order to vaporize the water.

Formula for determining moisture content:

Moisture Content in % =
[(Green Weight – Oven Dry Weight) / Oven Dry Weight] x 100

Table 14. Green Specimens

Sample	Date	Moisture Content (%)	Heat (BTU/lb)
1a	2/20/04	38.5	6690.166
1b	2/20/04	44.26	5941.155
2	2/27/04	27.03	6181.299
3	3/8/04	48.11	6249.388
4	3/16/04	34.76	6559.596
5	4/1/04	13.47	*8239.694

Table 15. Dry Specimens

Sample	Date	Moisture Content (%)	Heat (BTU/lb)
1a	2/20/04	1.05	8548.435
1b	2/20/04	1.22	8934.785
2	2/27/04	0.89	7862.822
3	3/8/04	2.27	8417.292
4	3/16/04	2.55	8596.745
5	4/1/04	1.05	8816.103

Average for green specimens: 6324.321 BTU/lb*

**(This average excludes Sample 5. The specimen was dry enough to be considered a dry specimen. This sample is included to show that even "wet" chips, if clean and dry, can contain high levels of BTU content.)*

Average for dry specimens: 8529.364 BTU/lb

From the results of this study, the consideration of the fuel moisture content to be used in a biomass system is important. These factors should be included in the design of any plant.

3.2 Run-time Data

Table 16 presents operating hours, chip consumption and heat produced for the plant operation during the winter and spring of 2004. Please note the following for the data presented in **Table 16**:

- The total wood quantity (tons/week) is based on Town staff estimates (versus directly measured quantities), and
- the heat produced (in therms) is a calculation based on the estimated wood quantity (this is not a value determined from actual system measurements).

Table 16. Plant Operating Hours, Chip Consumption and Heat Produced

Calender Week	Plant Operating Hours	Biomass Plant Consumption (tons/week)	Heat Produced (therms)
02/01/04	84	6.68	562
02/08/04	120	9.54	802
02/15/04	72	5.72	481
02/22/04	152	12.08	1,016
02/29/04	168	13.36	1,123
03/07/04	168	13.36	1,123
03/14/04	168	13.36	1,123
03/21/04	0	0.00	0
03/28/04	48	3.82	321
04/04/04	96	7.63	642
04/11/04	168	13.36	1,123
04/18/04	96	7.63	642
04/25/04	120	9.54	802
05/02/04	77	6.12	515
05/09/04	24	1.91	160
Total	**1,561**	**124.10**	**10,438**

3.3 Operation and Maintenance Issues

Routine, preventative maintenance activities include:

- moving wood/transferring chips,
- operating the chipper,
- removing and disposing of waste,
- testing fuel quality, and
- making repairs.

One key maintenance activity for the biomass system is the removal and disposal of waste. As previously mentioned, the system operation produces process waste that is a combination of fly ash and clinker (sand, gravel, rocks, etc.). This waste is cleaned daily from the firebox and accumulated, outside the heating facility, until it is moved to the landfill.

4 Costs and Benefits

4.1 Economic Costs and Benefits

The Town of Nederland Community Biomass Project cost a total of $443,246 to design and install. The cost is itemized in **Table 17** below. The budget includes $83,757 in additional project costs that were approved by the Town and were unforseen at the inception of the project.

Table 17. Cost Summary

Item	Budgeted Cost	Actual Cost	Difference
Boiler	$207,000	$200,136	-$6,864
Steam Delivery System	$32,700	$31,019	-$1,681
Chip Delivery System	$131,500	$165,858	$34,358
Boiler Upgrade	$0	$650	$650
Site Improvements	$0	$16,843	$16,843
Utilities	$0	$5,792	$5,792
Insulation	$0	$4,934	$4,934
Air study and final report	$20,000	$18,014	-$1,986
Total	$391,200	$443,246	$52,046

Table 18 highlights the amount paid by each of the participants in the collaborative project. Because the project is a pilot test, the Town of Nederland obtained state and federal dollars to help offset the financial risks of the project. These contributions accounted for 24 percent of the total project budget.

Table 18. Participant Contributions

Organization	Payments	% of Total
Town of Nederland	$345,232	77%
OEMC	$40,000	9%
U.S. Forest Service	$40,000	9%
EPA	$25,223	6%
Total	$450,455	

The column of **Table 19** labeled "Pilot Project Scenario" shows the annual cost savings for the steam plant based on its operation during the pilot project. Note that this information specifically reflects the costs incurred during the pilot phase. Any costs, including operational and maintenance costs, going forward beyond a pilot phase would need to be considered on an actual operating basis. The column of **Table 19** labeled "Potential Expanded Capacity" project annual costs savings for operations at three times the current level based on the potential expansion of the Community Center. The new building is anticipated to be up to three times the size of the Community Center that currently is being heated. The biomass system is sufficiently sized to accommodate this increased operation. The savings of **Table 19** are underestimated because they do not account for indirect savings, such as reduced fire mitigation costs or reduced insurance premiums from avoided forest fires that could potentially damage town assets. However, the savings do assume a significant reduction in plant maintenance costs, down to 2 hours per day from the current start-up situation of 8 hours of maintenance per day.

Table 19. Annual Cost Savings

		Pilot Project Scenario	Potential Expanded Capacity
System Load Information	*Heating Demand (therms/yr)*	20,506	61,518
	Wood use (tons/yr)	241	723
Biomass System Costs	*Wood Cost ($/yr)*[1]	$3,440	$10,320
	O&M Cost ($/yr)[2]	$5,310	$15,930
Natural Gas Costs	*Projected Cost ($/yr)*	$16,897	$50,691
Net Annual Savings (Natural Gas - Biomass System Costs)		$8,147	$24,441

[1] Includes processing costs.
[2] Includes labor costs. (The cost of disposing slash if not burned assumed to negate the cost of ash disposal.)

By way of comparison, **Table 20** summarizes other wood energy boilers from a 1993 study of seven systems in the northeast United States. The table shows that the Town of Nederland Biomass System is not the least expensive by comparison, but is within the order of magnitude of other such systems. It is difficult to compare first costs and cost to build per MMBtu as the scope of the retrofit to wood from the existing conventional heating system varies from project to project. Furthermore, it is worth noting that the cost of wood for the Town of Nederland could potentially be lowered in the future. The $15 per ton shown below reflects a blended cost from four actual strategies employed during the pilot heating season: (1) town-owned Vemeer chipper ($12 per ton), (2) purchase from Oxford Recycling ($31 per ton), (3) purchase from Gilpin County ($28 per ton), and (4) purchase from Estes Park ($62 per ton). Conceivably, the town could charge a nominal fee for chips to offset costs for operating the Vemeer chipper (or tub-grinder services) for a net $0 per ton. This would increase the fuel savings per year to $34,766. It should also be noted that this analysis does not account for the rising costs of natural gas. Furthermore, due to a strong existing biomass infrastructure in the New England states, these facility heating projects are easier to bring on line.

Table 20. Summary of Wood Boilers from Northeast United States Study

Facility	First Cost ($)	Rated Capacity (MMBTU)	Cost to Build/ MMBtu ($/MMBTU)	Annual Consumption (Tons)	Cost/Ton ($/Ton)	Fuel Savings ($/yr)	Simple Payback (yrs)
Nederland Community Center (at full capacity)	$475k	3.5	$136k	723	$15	$24,441	14 yrs
Mountain View School	$385k	10.8	$36k	1,278	$23	$8,536	45 yrs
Camp Gabriels Correctional Center	$750k	12.5	$60k	2,583	$23	NA	NA
Green Acres Housing	$105k	2.2	$48k	450	$25	$33,470	3 yrs
Calais Elementary School	$162k	0.52	$312k	140	$25	$19,375	8 yrs
Leland & Grey High School	$465k	NA	NA	180	$29	$50,000	9 yrs
University of Maine	$118k	2.1	$56k	653	$22.40	$4,466	26 yrs
St. Joseph's Abbey	$174k	0.84	$207k	358	$17.50	NA	NA

4.2 Environmental and Social Benefits

Although the economic analysis above is not overwhelmingly positive in terms of costs and savings to the Town, the environmental and social benefits of the project add significantly to its value. From the outset, the Town recognized this as a pilot project with many technical details still to be worked out. However, the primary driver of forest health warranted the technical risks for the project. Considering the following benefits, the project is a net gain for the Town of Nederland and its project partners:

- Reduced air emissions compared to prescribed burns, particularly smog-producing carbon monoxide (CO) and nitrous oxides (NOx).
- Reduced impact on global warming. Compared to fossil fuels, wood combustion does not produce a net carbon dioxide output (a leading greenhouse gas) since the CO_2 generated during combustion equals the CO_2 consumed during the lifecycle of the tree.
- Use of a rapidly renewing fuel source versus a dwindling supply of fossil fuel
- Healthier forests and reduced losses from wildfires:
    - Reduced insurance liability.
    - Reduced fire fighting costs.
    - Reduced losses to property.
    - Reduced wildlife losses.
- Economic development. The town is able to redirect costs from fuel purchases to labor wages for maintaining the fuel supply. Labor wages stay in the local economy – natural gas purchases do not.
- Buffer against rising natural gas prices.
- Public relations and image building. The Town of Nederland is recognized for its vision for innovatively doing the right thing for the environment while saving on heating costs.
- Replicability. The Town of Nederland is leading the way for other mountain communities, and communities located near to the mountains, by helping to develop an emerging concept into a more mature and commercially viable system.

5 Replicability

From the project outset, the federal and state partnering organizations were very interested in the possibility of transferring the Town of Nederland project results to other communities. Based on the Town of Nederland's experience, including the professional experience of the project partners and national resources on wood energy[2], the following parameters are offered to help others evaluate the applicability of a biomass system for their communities. If a community meets these rough parameters, it would need to develop a more specific feasibility analysis with the help of biomass professionals.

Fuel Supply

Is there an adequate supply of local wood? First and foremost, prospective projects must have a steady and long-term viable supply of fuel and the moisture content of the fuel should be considered for the plant design. Annual fuel supply for the eight examples described earlier range from 140 tons/year for an elementary school to 2,583 tons/year for a correctional facility. In the seven northeast examples, wood chips were purchased from outside sources. In the case of the Town of Nederland, wood chips were supplied by local forest thinning operations, including slash from local residents thinning their personal properties to protect their homes from wildfire. Other communities considering biomass systems would need to evaluate the availability of wood from either their own operations or from external sources. Generally, wood fuels are competitive in cases where wood has low economic value (e.g., thinning material from overstocked stands or undesirable undergrowth in forests), transportation costs for residue wood are favorable, and long-term supplies are available. A prospective adopter of a wood-heating system would need to ensure long-term contracts for wood fuel supply. Rising costs for current fuel sources also should be taken into account and it has to be noted that natural gas prices significantly escalated in 2004, as did oil prices which rose to their highest level ever on international markets. The take-home message for the Town of Nederland Biofuels Project is that overall wood/biomass supply over the next 10 to 20 years should be adequate. The challenge will continue to be the production, supply and delivery infrastructure needed to get the material to the facility in an economically sound manner.

How will the wood be transported from its source to the firebox? Common challenges for all wood-fired systems are ensuring adequate fuel procurement and solving the complex fuel handling, storage and quality issues. In the case of the Town of Nederland, an entirely new storage facility was needed. In addition, a physical space for collecting and staging wood prior to storage was needed. Transportation costs may limit the benefits of burning wood fuel as, for example, hauling wood biomass from outside a 30-mile radius is usually not economical. Ideally, the wood collection site and biomass plant should be located at the same site to avoid further transportation costs and fuel handling steps. Furthermore, fuel contamination and the system designs required to address them should be a key consideration in the design of the biomass system.

Heating Demand

What space(s) will be heated by the biomass system? What is the heating demand? As long as fuel supply is not a limiting factor, savings will be greatest from larger systems. Therefore, it is best to design the system for the greatest wood use needed and then size the boiler and

[2] "Wood Biomass for Energy", Forest Products Laboratory, www.fpl.fs.fed.us.

system components accordingly. The rated capacities of the eight examples ranged in size from 0.5 MMBTU to over 12 MMBTU and the Town of Nederland system was fairly typical at 3.5 MMBTU. For replicability purposes, hot water systems may prove to be a better fit for biomass applications, both economically and technically. As noted in Section 2.1, wood-fired systems are slower to respond to shifts in heating demand caused by seasonal or other fluctuations. This fact must be taken into account when examining the applicability of wood to specific situations.

Physical Space

The Town of Nederland project team had to identify significant space for the project. The team converted a used storage shed into the steam plant and built a new fuel storage and handling facility adjacent to the plant. In addition, the Town had to dedicate off-site space for collecting slash from local residents and staging the fuel supply for delivery to the storage building. These factors should all be taken into account for new projects. The complex issues of fuel delivery and storage increase the overall footprint of a wood-fired project relative to its conventional counterparts.

Adequate Budget:

The necessity of a larger-sized boiler and the need for a wood-handling plant involve 1.5 to 4 times the investment cost of oil-fired package boilers. Furthermore, a combustion efficiency of 65 to 75 percent may be expected when burning wood, compared with 80 percent obtained from gas-or oil-fired units. High capital costs, low plant efficiency, and increased maintenance levels may offset the benefits of reduced fuel costs. Installation costs vary highly because of different types and capacities of equipment.

In addition, costs vary depending on whether the equipment is new or used. An additional alternative would be to convert equipment already in place, but using an alternate type of fuel (e.g., a natural gas boiler could be converted to burns wood). Today, complete wood fuel burner/boiler packages are estimated to cost $50 to $75 per pound of steam generation per hour, or $50,000 to $75,000 per million Btu/hour of heat input. Fuel costs for this type of system are estimated to be $0 – 30 per ton, with an average cost of $15/ton. The current fuel cost for the Town of Nederland project is estimated to be just under $13/ton (employing the tub grinding method).

Available Staff

During pilot testing of the Town of Nederland system, staff members were spending approximately 40 hours per week maintaining and operating the system. Maintenance time was increased due to fuel quality issues that caused the auger to break repeatedly because of rocks and debris in the fuel supply. Once the system has been fine-tuned, it is estimated that it will require only 2 hours per day to maintain; this is consistent with the case studies from the northeast U.S. An operator needs to be on call in case of problems. Maintenance, such as cleaning boiler tubes and keeping up storage, metering, and control components, would not be excessive for wood versus fossil fuel, but operating the complex fuel delivery system will increase operating and maintenance hours. Additional maintenance requirements are highlighted in Section 3.3. Staff should track their hours for their various activities (routine maintenance, repair, site upkeep, etc.) and management should plan and allow for hours to integrate the biomass system with the site.

An Inventory of Anticipated Benefits

Ultimately, the feasibility of a biomass system depends on whether the anticipated benefits are sufficient considering the technical and cost drawbacks previously discussed. Example questions to consider in evaluating the potential benefits include the following:

- Will the system offset current wood disposal costs?
- Does the system provide an outlet for slash/forest residue utilization? Will this utilization foster biomass production and delivery infrastructure, provide for small business opportunities and help stimulate local economies?
- Will it offset rising fuel costs?
- Does it help solve other problems, such as reducing wildfire hazard and risk, improving forest health and providing an outlet for slash and biomass that would otherwise be burned in the forest during the high- pollution winter time?
- Are there air quality concerns in the area?
- Is there an existing system in place that can be converted?
- Is there access to used equipment?
- Is there a local market for wood ash, perhaps as a soil amendment or as an additive to concrete or road base materials?

Positive Community Perception

The results of the Town of Nederland project showed that positive community perception is an important part of a project's overall success. As part of a master's thesis by a Colorado State University student, community members were surveyed about their knowledge, support and various perceptions of issues related to the biomass project.

From the preliminary results of this survey, the following issues were found to be important to the community:

- Use of forest biomass to heat the Town's Community Center,
- Use of Town land for forest biomass storage, and
- Creation of defensible space perimeter around landowner property.

Similarly, the following issues were found to be not as important to community members:

- Annual net savings,
- Dynamics of the project team, and
- Pollution and other health concerns of the biomass system.

Again, the results of this survey were preliminary in nature; the study is anticipated to be complete in April of 2005[3].

Drawing from the information of these replication parameters and the project lessons learned, the project partners will seek to share information on the project with a broad audience. The project itself serves as a valuable tool for promoting project replication. A number of tours have already occurred to showcase this pilot effort, including:

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[3] For more information on this study, please contact Mike Eckhoff, Department of Forest, Rangeland & Watershed Stewardship, NRRL 101, Colorado State University, Fort Collins, CO, 80523-1472, (970)491-3194.

1. Tour for the Society of American Foresters (April 17, 2004)
2. National Biomass Conference
3. Colorado Biomass Conference (July 30, 2004)
4. Interested Parties Tour, including County Commissioners, facility managers, School District personnel, and Municipal Facility Managers (June 18, 2004)
5. Gilpin County (to consider if it would fit the County's need for future government buildings)

For the future project information sharing, this report itself will serve as a central document detailing the project experience and providing a basis for other communities to make their own decisions about the project potential and applicability. From this report, the project partners will develop shorter outreach materials and disseminate through various mediums, including the OEMC website. The target audience for the outreach will include local and statewide audiences, western state regional groups, and professional energy technical/trade organizations. The project partners have also agreed to develop presentations for their respective niche areas for venues such as the Department of Energy Industry of the Future Conference, the Colorado Wind and Distributed Energy Conference and the Colorado Renewable Energy Society Conference. The Town also plans to host an educational open house for the project, targeting a wide audience from the general public to local- and state officials to the media.