FINAL REPORT

BIOMASS BOILER MARKET ASSESSMENT

October 5, 2006

Submitted to
Montana DNRC

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

The Fuels for Schools (FFS) program is the second phase of a 3-phase U.S. Forest Service (USFS) initiative to facilitate the removal of hazardous fuels from our forests and promote the use of wood biomass as a renewable natural resource as an energy source for heating systems in public and private buildings. The FFS program in Montana now includes four operational biomass boiler heating system projects and 11 more in the design/construction phase. Pre-feasibility assessments have been completed for more than 200 buildings in 60 communities in the region. The work presented in this report is a follow-up to a study completed in December 2004 called **Assessment: Potential for Expanding the Fuels for Schools Concept to other Institutions and Industries,** which assessed the potential opportunities and challenges presented by converting or replacing existing boilers in the state of Montana with SDU wood-fueled boilers.

1.2 Improving Financial Attractiveness

Experience gained from the existing and on-going Fuels for Schools projects indicates that opportunities for improving financial attractiveness of a new boiler system can be found in the following five categories:

- biomass boiler system equipment, including fuel storage and conveyance
- boiler building
- mechanical/electrical within the boiler building
- mechanical integration
- fees, permits, and other non-capital costs

Reductions in the cost of biomass boiler system equipment can be found in three areas: (1) The capacity and type of wood storage should be coordinated with the projected volume and rate of wood fuel to be used by the facility. (2) Reducing the cost of the wood handling system can result in significant project cost savings. The cost of automated wood handling systems for wood chips is typically higher than those for wood pellets. (3) Projects with limited vendors (such as small steam pellet boilers) or high wood fuel costs (such as wood pellet projects located far from existing wood pellet production facilities) might be avoided.

Boiler building costs can be reduced by reducing the building size required by reducing space requirements, using less expensive building materials and designs, and re-using space in existing facilities. Biomass boiler installations in new facilities will also have lower reduced building costs.

Non-capital costs for a biomass boiler project include design fees, printing, travel, permits and related costs. The bid timing, duration and contractual relationships between wood boiler system vendors and general contractors also impact total project costs. CTA's experience with biomass projects suggests the following:

- The ideal bid climate is between Mid-January and Mid-March. Biomass projects should plan for at least a three week bid duration.
- Bidding requirements are viewed by vendors as too cumbersome and should be simplified.
- The use of design/build, construction manager at risk or performance contracting project delivery methods would increase the level of contractor input in the design of wood heating projects and reduce the time lost to value engineering processes after a bid opening, and reduce potential change orders.
- Bidding using a single contract should avoid any potential schedule or scope conflicts between the general contractor and wood boiler system vendor.
- Minimize time for project closeout.

1.3 Factors Impacting Project Viability

For the purposes of this study, project viability for replacing existing boilers with biomass boilers is defined by simple payback, the number of years it would take for annual fuel cost savings (from using less expensive wood biomass rather than fossil fuel) to pay for the cost of the new biomass boiler system. Since almost 90% of the existing boilers in the state use natural gas, **the analyses reported are based on natural gas** as the existing fuel unless otherwise noted. (As will be illustrated later, with the exception of coal, all other fossil fuels used in boilers in Montana are more expensive on a per-BTU basis than natural gas, thus the economics of conversion would be better than for natural gas.)

Numerous facility-specific factors affect the potential economic and technical viability of a given biomass boiler conversion project; however, our analyses indicate that there are three main factors that are best indicators of potential project viability:

- Existing boilers need to be a minimum of 1 to 1.5 mmBTU/hour output for conversion to biomass to be considered viable.
- Existing annual fuel use needs to be a minimum of 1,000 to 3,000 mmBTU/year of fuel for conversion projects to be viable.
- Existing annual fuel cost needs to be a minimum of $20,000 for conversion project to be viable.
  - As noted above, with the exception of coal, all other fossil fuels used in boilers in Montana are more expensive on a per-BTU basis than natural gas.

1.4 Refining Identification of Potential Customer Base

Based on the assumptions used in this study, the best opportunities for conversion are likely to be in universities, hospitals, and other institutions with larger boiler systems that would have paybacks of less than 10 years. The analyses conducted for this study indicate that there are 91 boilers with paybacks less than 10 years, and 47 boilers with paybacks of less than 7 years.

1.5 New Installations

Experience indicates that biomass boiler installations in new construction projects may have greater potential market than boiler conversions. When designing a new building, it is possible to match the biomass system size to the projected heating load. Installations in new facilities also eliminate integration costs associated with conversions. Analyses conducted for this study indicate the potential for boiler installations in new buildings to be a total of **84 to 280 boilers per year**.

1.6 Feedback from Potential Customers

High initial cost, uncertainly in the reliability of fuel supply, air emissions, space, and increased O&M were recurring concerns among existing and potential biomass consumers. Most potential customers indicated the need for more information - and more specific information. Interviews indicate that facility managers would like to see a payback of less than 10 years without grant funding, but also get grant funding to help minimize initial costs.

1.7 Feedback from Manufacturers

The wood heating vendors interviewed all expressed interest in the future of the wood heating system industry in Montana and throughout the west. The majority of wood heating systems have been installed in industrial applications, often related to the wood products industry. Several vendors emphasized the need to maintain a quality wood fuel source in order to minimize potential problems with non-industrial users of wood heating systems. The use of metal building systems and packaged boiler buildings were noted as potential cost savings for future projects.

2.0 INTRODUCTION

2.1 Background

2.1.1 Fuels for Schools Program

The U.S. Forest Service (USFS) is interested in facilitating the removal of hazardous fuels from our forests by assisting in the development of viable commercial uses of removed woody materials. The Fuels for Schools program is the expansion phase, the second phase of a 3-phase USFS initiative to promote and encourage the use of wood biomass as a renewable, natural resource to provide a clean, readily available energy source suitable for use in heating systems in public and private buildings.

The Fuels for Schools program was developed in response to the aftermath of the Bitterroot Valley Fires of 2000. It is a partnership between six state foresters and the Northern and Intermountain Regional Foresters. It includes four operational projects in Montana located in Darby, Philipsburg, Thompson Falls and Victor, Montana, Ely, Nevada, Council, Idaho and 11 more in the design/construction process. Pre-feasibility assessments for more than 200 buildings in 60 communities in the region have been developed at this point in time. The next phase of the initiative is the expansion of this concept to other schools, institutions, and industries.

2.1.2 Previous Work

The work presented in this report is a follow-up to a study completed in December 2004 called **Assessment: Potential for Expanding the Fuels for Schools Concept to other Institutions and Industries** (available at www.fuelsforschools.org). The purpose of this study was to assess the potential opportunities and challenges presented by converting or replacing existing boilers in the state of Montana with SDU wood-fueled boilers. The report describes and identifies the potential candidates for boiler conversion in the state of Montana based on selected criteria, and highlights potential strategies to focus efforts for concept expansion and commercialization. The findings of this study indicated the need to pursue four activities to further efforts towards commercialization of the Fuels for Schools concept:

- Engage key stakeholders
- Assess wood resource viability
- Explore additional partnerships, drivers, and opportunities
- Disseminate information

2.2 Purpose

The purpose of this study is to assist FFS in its efforts towards commercialization by sharing experience and providing information on methods for improving the financial attractiveness of wood biomass boiler projects, factors that impact project viability, refining the potential biomass boilers customer base, projections for installing biomass boilers in new installations, and feedback from potential consumers and manufacturers.

2.3 Focus/ disclaimer

The focus of this study is on the conversion of existing fossil fuel-burning boiler systems to wood biomass boiler heating systems, with a lesser focus on biomass boilers installed in new facilities. This study also focuses on larger automated biomass boiler systems, not on small hand-fed boilers or furnaces. The information in this report reflects the experience and professional judgment of CTA Architects Engineers and its project partners with additional input from the USFS, the Montana DNRC, and its partners.

Much of the information presented in this report is based on assumed representative characteristics and conditions of a "typical" facility that uses a boiler. **Every facility is unique and may or may not be represented by the information presented**. This information is not intended to be used to make investment decisions, but rather to paint a picture of the potential biomass boiler market conditions in Montana. In addition, the markets related to energy, construction, and biomass boilers are currently highly dynamic and conditions represented in this report are likely to change.

It is also important to note that the biomass boiler market, especially for smaller systems, is still emerging in the United States and the characteristics and conclusions presented in this section are likely to change within the next several years.

3.0 IMPROVING FINANCIAL ATTRACTIVENESS

It is clear that one major barrier to installing biomass heating systems, whether conversions or new installations, is total project cost. Wood heating systems cost substantially more than conventional fuel systems. The annual savings is substantial given current fossil fuel prices; however, some facility owners are reluctant to make the large investment given the uncertainty of energy prices that have been experienced in the past. Some degree of subsidy may be required to broaden the market beyond the large scale projects with fast paybacks (< 5 years), "early adopters" or entities motivated by more than the project cost.

Related to the cost differential between biomass boiler heating systems and conventional boiler systems, are the hidden costs of conventional systems. In terms of first costs, a conventional boiler system may appear to be the most cost effective choice. When the long term costs and impacts of burning fossil fuels are considered, however, the wood biomass boiler systems are often more competitive. In this section we will identify the financial parameters a facility manager must consider when making the decision to install a biomass boiler.

It is important to note that the biomass boiler market, especially for smaller systems, is still emerging in the United States and the characteristics and conclusions presented in this section are likely to change within the next several years.

3.1 Biomass Boiler System Costs

To date, CTA has evaluated more than 200 buildings throughout the northwestern United States and designed 13 biomass boiler projects, six of which are now operational. Selected characteristics of these projects, including total project cost, are presented in Table 1.

As can be seen from Table 1, total costs for these projects do not correlate directly with boiler size. The least expensive biomass projects completed to date cost $455,000 (not including additional equipment and site improvements made by the school district) for a wood chip system in Thompson Falls, Montana. The least expensive wood pellet system is projected to cost $269,000 in Burns, Oregon. The general breakdown of costs for these two projects is presented in Tables 2 and 3.

Table 1. Characteristics of completed biomass boiler projects

Facility Name	Location	Boiler Size (mmBTU/hour output)	Project Type	Wood Fuel Type	Total Project Cost
Harney District Hospital	Burns, OR	0.75 mmBTU	Major renovation. New pellet system tied to a new heat pump system	Pellets	$269,000
Troy School District	Troy, MT	0.65mmBTU	New pellet system in existing steam boiler room	Pellets	$298,755
Townsend School District	Townsend, MT	2.2 mmBTU-	Pellet system using existing hot water boilers	Pellets	$425,000
Thompson Falls School District	Thompson Falls, MT	1.6 mmBTU	Stand-alone boiler building tied to existing steam system	Chips	$455,000
Glacier High School	Kalispell, MT	7 mmBTU	New facility with integrated wood chip and natural gas hot water system	Chips	$480,000
Victor School District	Victor, MT	2.6 mmBTU	Stand-alone boiler building tied to existing steam system	Chips	$615,000
Philipsburg School District	Philipsburg, MT	3.87mmBTU	Stand-alone boiler building tied to existing hot water system	Chips	$684,000
Darby School District	Darby, MT	3 mmBTU	Stand-alone boiler building tied to existing steam & hot water system	Chips	$970,000
City of Craig	Craig, AK	4 mmBTU	Stand-alone boiler building tied to existing hot water systems	Chips	$1,400,000
UM Western	Dillon, MT	14 mmBTU	Addition to existing steam system	Chips	$1,400,000
Council School District	Council, ID	1.875 mmBTU	Stand-alone boiler building tied to new heat pump system	Chips	Incorporated into Performance Contract
Kellogg School District	Kellogg, ID	2 mmBTU	Stand-alone boiler building tied to existing hot water system	Chips	Incorporated into Performance Contract
White Pine School District	Ely, NV	3 mmBTU	Stand-alone boiler building tied to existing steam system	Chips	Incorporated into Performance Contract

Table 2. Cost breakdown for a wood chip boiler system installed in a new free-standing building

System Component	Cost	% of Total
Wood Boiler System Equipment	$136,000	30%
Building	$170,000	38%
Mechanical/Electrical	$100,000	22%
Mechanical Integration	$15,000	3%
Fees, Permits, Printing, Etc.	$34,000	7%
Total	**$455,000**	**100%**

Table 3. Cost breakdown for a wood pellet boiler system with external pellet silo

System Component	Cost	% of Total
Wood Boiler System Equipment	$130,000	48%
Building (silo)	$9000	3%
Mechanical/Electrical	$55,000	21%
Mechanical Integration	$55,000	21%
Fees, Permits, Printing, Etc.	$20,000	7%
Total	**$269,000**	**100%**

The wood chip boiler system for the **Thompson Falls School District** is a semi-automated surge-bin system. One half of the boiler building contains the surge bin and wood fired boiler. The other half of the building is dedicated to wood chip storage. Chips are delivered to the facility in live bottom trailers or in small dump trucks. The chips are unloaded on to a concrete slab-on-grade with adjacent concrete and concrete block walls. The chips are transferred to the surge bin using a small front end loader. The surge bin capacity is approximately 6 tons. The chips are automatically conveyed to the combustion chamber/gasifier via contained augers. The gasifier and steam boiler are in a close-coupled configuration. The system includes a cyclone and automatic ash removal system.

The wood pellet boiler system for the **Harney District Hospital** will be located within a new boiler room for the hospital. A wood fuel silo will be located adjacent to the boiler room. Pellets will be delivered to the silo using a grain auger or pneumatic delivery system. Pellets are transferred to the metering bin in the boiler room via a flexible auger. The pellet boiler is a direct-fired configuration, with the pellet burner located below the boiler. Minimal mechanical integration is needed within the boiler room.

3.2 Opportunities for Reducing Total Project Costs

The total cost for a biomass boiler installation can be broken into five basic components:

- biomass boiler system equipment, including fuel storage and conveyance
- boiler building
- mechanical/electrical within the boiler building
- mechanical integration
- fees, permits, and other non-capital costs

The experience gained from these demonstration projects has indicated opportunities for reducing project costs in each of the cost components. Opportunities for reducing total project costs within each cost component are described below.

3.2.1 Reducing Cost of Biomass Boiler System Equipment

A typical wood biomass boiler system includes wood fuel storage, a boiler building, wood fuel handling systems, a combustion chamber, boiler, ash removal, cyclone, stack and electronic controls. The variables in this list of system components include the use of silos of various sizes for wood fuel storage, chip storage areas of various sizes, boiler buildings of various sizes, automated versus manual ash removal and cyclones for particulate removal. Biomass boiler conversions designed by CTA are typically sized to meet 50% of the peak design load, which occurs very infrequently. Systems sized to meet 50% of the peak load should be capable of meeting about 90% of the actual annual load. The existing natural gas boiler is kept in place to meet the remainder of the peak load and as back-up.

Experience gained from the 13 demonstration projects indicates that the greatest opportunities for reducing the cost of the biomass boiler system equipment can be found in three areas:

(1) Wood fuel storage type: The capacity and type of wood fuel storage should be coordinated with the projected volume and rate of wood fuel to be used by the facility. For example; facilities using more than 2,000 tons of chips are likely to use below ground bunkers rather than slab on grade chip storage buildings.
(2) Wood handling system: The wood handling system can have a significant impact on total project cost. The cost of automated wood handling systems for wood chips is typically higher than those for wood pellets.
(3) Wood fuel type: Costs for the boiler system can be reduced by selecting the optimal wood fuel type for the facility conditions

3.2.1.1 Wood fuel storage type

Wood biomass storage can be achieved using five basic approaches:

- Delivery van/roll-off container
- Surge bin
- Small below ground bunker
- Slab on grade
- Large below ground bunker
- Silos

Wood chips can be stored in the **delivery vans** and remain on site until the next load is needed. The Grand Isle School District in Vermont uses this technique, and purchased two trailers in order to always have one trailer on site while the other trailer was filled. The controls for the live-bottom trailer are exposed to the weather, and need to be maintained on a frequent basis. **Roll-off containers** (such as a construction waste dumpster or trash compactor) can be transported directly from a logging operation landing site in the forest to the wood burning facility. The container would be linked to an auger or conveyor adjacent to the boiler room. No applications of this technology are known to be in use at this time.

For projects with boilers less than 1 mmBTU/hr output capacity, wood can be stored within a boiler building and transferred with a small front-end loader to a **surge bin** capable of storing 3-7 days of wood fuel. As demonstrated by the Thompson Falls School District project, this system is less expensive than a comparable fully automated system for the Victor School District, but results in increased operations and maintenance (O&M) costs associated with loading wood chips into the bin. Based upon the feedback received from the Thompson Falls School District, the building for the surge bin system would be larger than the fully automated prototype developed for the Victor and Philipsburg School Districts. Increasing the building footprint for the surge bin system would add $20,000-$25,000 to the cost of future surge bin projects.

For projects with boilers between 1-3 mmBTU/hr output capacity, a 10-15 ton wood storage bin (1 to 2 weeks storage) constructed from **cast in place concrete four feet below grade** with fully automated wood handling systems would be the most economical balance between capital costs and long range operations and maintenance costs.

Alternatively, chips can be delivered to a **slab on grade** facility and augured or conveyed to the wood boiler system. The projects in Victor, Philipsburg and Kalispell use this approach. Experience suggests that the slab on grade delivery method is the most economical approach to wood chip storage for boilers with an output capacity between 3-8 mmBTU. The capacity can be increased based upon how the wood fuel is delivered to the facility. For example; a slow moving delivery vehicle exiting the building results in piling more material at the rear of the building. Using truck-based conveyors allows the height of the wood fuel pile to reach 12 feet.

For larger systems (larger than 8 mmBTU/hour output) with greater daily demands for fuel, chips can be dropped into a **below ground bunker**. The completed project in Darby and the project under construction at the University of Montana in Dillon use this approach.

Based on the explanations above, CTA suggests the following potential opportunities for reducing cost of wood chip storage for systems less than 3 mmBTU/hour output:

- Install a multi-day storage bin, which offsets capital dollars with operations & maintenance dollars.
- Install a smaller (10 to 15 ton) wood storage bin and maintain fully automated features of a larger (25 to 30 ton) wood boiler system. Based upon recent cost estimates developed for the Deer Lodge School District, the projected cost of a smaller capacity wood storage bunker associated with a fully automated wood handling system are comparable to the larger capacity wood storage surge bin systems.

Wood Pellet Silos may be round or square. The size of the silo is dependant upon the heating demand of the facility as well as the capacity of delivery trucks. For example, if a facility uses only 100 tons per year (20 tons during the coldest month) and delivery vehicles can carry 25 tons, a 30 ton silo might be selected to provide an additional surplus of fuel before the next delivery (about 1 week of additional capacity during the coldest month). If a facility uses 200 tons per year (40 tons during the coldest month) and delivery vehicles can carry 25 tons, a 60 ton silo might be selected to provide more than two truck loads of pellets and additional surplus of fuel before the next delivery (about 2 weeks of additional capacity during the coldest month). An alternative is to make use of larger capacity silos in a community to receive bulk shipments of pellets (by truck or rail car) and to transfer smaller quantities of pellets to the facility. The additional cost of handling the pellets several times would need to be considered. Those costs may be offset by a lower price associated with purchasing pellets in bulk and by providing smaller pellet storage silos on the site of the wood fired heating systems.

Silos can be designed to accommodate both wood pellets and wood chips in industrial settings with some success. The BTU content of wood chips is significantly lower than that of pellets, resulting in a lower BTU capacity of the silo when storing chips. In addition, wood chips have higher moisture contents and are more irregular in size than wood pellets, resulting in additional handling problems of the wood chip fuel in a silo.

Based on the explanations above, CTA suggests the following potential opportunities for reducing cost of wood pellet silos:

- Install a pellet boiler with a silo and wood handling system that can also handle wood chips
- Consider the use of silos to store both wood pellets and wood chips. Additional conveying equipment may be required; however, fuel flexibility for the end user may provide additional security.

Vendors have also suggested that storage silos equipped with augers to handle both pellets and wood chips represent a good opportunity for reduced project costs and provide the end user with greater flexibility for wood fuel contracts. Consideration should be given to potential freezing and clogging of chips in silos, and the increased cost of larger auger systems designed to handle both chips and pellets.

3.2.1.2 Wood handling system: automated vs. semi-automated

As noted above, fully automated wood chip systems require greater capital costs for the initial investment, but require less labor to operate, primarily associated with transferring wood from the chip storage area to the combustion chamber.

If the input from the Thompson Falls School District were to be incorporated into future surge bin systems, the chip storage bay would be 4 feet wider, adding $20,000-$25,000 to the building component of the total project cost of $455,000.

If the wood boiler system for the Thompson Falls School District had been fully automated, the equipment costs would have been approximately $240,000 rather than $130,000, for a total project cost of $560,000. The completed project in Thompson Falls represents a savings of $110,000 over an automated system, or 20% reduction in total project costs.

It appears that surge bin systems provide significant cost savings over fully automated wood chip systems.

3.2.1.3 Wood fuel type: chips vs. pellets

Costs for the wood boiler system can be reduced by selecting the optimal system for the facility conditions. The most basic choice is the type of wood fuel burned: wood chips or wood pellets.

Pellet systems are typically smaller than wood chips systems. Standard pellets boilers are currently available in sizes less than 1,000,000 BTU/hour output; sizes greater than 800,000 BTU/hour are likely to be more expensive than an equivalent wood chip boiler. Pellet boilers also work best with hot water systems; there are limited number manufacturers of small scale steam systems. The smaller size of the pellet boiler allows use of a smaller boiler building or space within an existing boiler building, which reduced the cost of the boiler building (see below).

Many manufacturers of wood chip boiler systems produce systems between 1-20,000,000 BTU/hour output. Individual vendors focus on systems between 1-5,000,000; 5-15,000,000 and greater than 15,000,000 BTU/hour output. Industrial applications of wood fired boilers can exceed 100,000,000 BTU/hour output.

Boilers in the 800,000 to 1,000,000 BTU/hour range are considered to be large for a standard pellet system and small for a standard wood chip system, thus boiler costs in this range are relatively high.

As pointed out above, it is important to note that the biomass boiler market, especially for smaller systems, is still emerging in the United States and these characteristics are likely to change within the next several years.

3.2.1.4 Additional ideas for reducing boiler system costs

DNRC, USFS, CTA, vendors, and contractors are beginning to build a knowledge base for installing conversion and new boiler system projects; but experience is still limited. Discussions among the project team, DNRC, USFS, project operators and owners, and manufacturers have generated additional ideas that could further reduce the cost of the biomass boiler system. *These ideas have not been fully developed or tested*, but the ideas are presented in this section for future exploration and consideration.

Alternative delivery vehicles

Wood chips and pellets have been delivered to completed facilities in live-bottom trailers. The chips or pellets drop from the rear of the trailer onto a slab on grade, a below-grade bunker or in the case of wood pellets, into a receiving bin attached to a grain auger. Delivery vehicles equipped with a **pneumatic fuel conveyor** appear to have the potential to avoid the cost, maintenance and liability associated with on-site grain augers. A pneumatic blower could be added to a live bottom trailer or dump body, providing an opportunity for existing wood pellet haulers to provide greater flexibility in fuel storage for end users.

Depending upon the conveying limits of pneumatic conveyors, access problems associated with some projects might be eliminated. The use of pneumatic delivery might reduce the total project cost by eliminating the need for an on-site grain auger.

CTA has discussed delivering wood pellets with **grain haulers** located in Great Falls. Using grain haulers, the projected hauling costs for delivering pellets would be similar to the hauling rates for live bottom trailers but eliminate the need for an on-site auger. A typical 20-25 ton grain truck has a vertical reach of 30 feet. Discussions were based on using existing grain haulers. It should be noted that grain trucks tend to require frequent maintenance and are often beyond their useful life when sold as used vehicles. New grain trucks may cost more than $80,000. In either case, purchasing a grain hauling vehicle to serve a single facility may not improve the project economics.

Pneumatic fuel conveyors could increase the storage capacity of wood chips storage bins (below or at grade). For example the capacity of the on-grade storage bin for the new Glacier High School in Kalispell would increase from 55 tons to 110 tons by increasing the average depth of the chip pile from 6 to 12 feet. A fully automated wood chip system with a very small storage bin 16 feet square located 8 feet below grade would have only a 25 ton capacity. Using pneumatic conveyors, that capacity might be increased to 37 tons by increasing the depth of the chip pile from 8 to 12 feet.

Standardized boiler sizes

Most wood fired boiler system vendors customize each system to the specific application and produce a relatively small quantity of wood fired systems each year. Throughout the development of the Fuels For Schools program it has been suggested that standardizing boiler sizes would allow wood fired boiler systems to be purchased either in bulk by several facility owners, or “off the shelf” by local mechanical contractors bidding on projects. The bulk purchase of wood fired boiler systems appears to be limited by the variations in project types pursued and project financing requirements of each facility owner. Providing “off the shelf” systems would require greater standardization in wood fired boiler systems than currently exists. The actual cost savings associated with off the shelf wood boiler systems is likely to be minimal at this point in time. It is unlikely that major manufacturers of boilers would team with wood fired boiler system vendors on standardizing systems until the capacity of the wood boiler system equipment vendors increases. It is unlikely that the wood boiler system equipment vendors would be able to increase their production capacity without support from a major manufacturer.

Linked boilers

Another approach would be to link a series of small wood fired boilers together to more closely match the demand for heat. This is commonly done with fuel oil, propane and natural gas boilers. It appears that the most appropriate application for linked boilers would be in wood pellet systems. This approach is being used in the Townsend School District project, and allows a single auger to be used from the silo to both boilers.

3.2.2 Reducing Cost of Building

Reducing the costs of the building can be accomplished by reducing the building size required by reducing space requirements, using less expensive building materials and designs, and re-using space in existing facilities. Biomass boiler installations in new facilities will also have lower reduced building costs. These potential cost reduction opportunities are described below.

3.2.2.1 Building size

The size of a chip storage/boiler building is has typically been designed to accommodate delivery from a live-bottom chip van. The boiler room is typically located adjacent to the chip storage area to facilitate the transfer of chip to the boiler. The resulting footprint is approximately 32 feet wide by 48 feet long, and costs approximately $150,000. Buildings with this footprint have been able to accommodate wood fired boiler systems between 1 and 7 mmBTU. The building footprint may be reduced to 18 feet by 48 feet for wood boiler systems of less than 2 mmBTU. The projected cost for the smaller building is $90,000. Based upon the recently completed project in Thompson Falls, semi-automated systems would require a larger foot print (36 feet x 48 feet), at a cost of approximately $175,000.

(See the appendix for total project cost comparisons.)

3.2.2.2 Building materials and designs

Like any building, the choice of building materials and building design impact the cost of the building and the total project cost. The experience CTA has gained to date indicates that there are potential opportunities for reducing project costs via choices in trusses, roofing, and siding construction. Suggestions in these three areas are presented below. See the appendix for total project cost comparisons.

Trusses. The projects in Darby and Victor used laminated timbers and decking for the roof structure. Subsequent projects in Philipsburg and Thompson Falls have used wood trusses. Wood trusses appear to provide substantial savings, and are produced throughout the Western United States in communities of all sizes. Based on these experiences, CTA suggests using wood trusses instead of laminated beams and laminated decking.

Roof. The projects in Darby, Victor and Philipsburg used low-sloped roofs. Subsequent projects in Thompson Falls, Montana, Ely, Nevada and Council, Idaho have used 4:12 roof systems. Although 4:12 sloped roofs appear to provide substantial savings, 4:12 roofs may not be appropriate at all facilities. Based on these experiences, CTA suggests using 4:12 sloped roof instead of low-sloped membrane roof.

Exterior materials. The projects in Darby, Victor, Philipsburg and Thompson Falls, Montana and Council, Idaho have used concrete block construction. The University of Montana-Western project in Dillon, Montana is constructed using metal studs with brick veneer. The project in Ely, Nevada uses a metal building system with metal siding. Wood or metal studs represent a cost savings compared to concrete or brick; however, exterior metal panels may not be appropriate or allowed for all facilities. Some facilities, for example, have specific aesthetic requirements for new buildings that prevent the use of less expensive exterior materials. In addition, providing durable finishes within the boiler room and wood storage bin may be difficult to achieve with wood or metal framed walls. Based on these experiences, CTA suggests considering use of wood or metal studs with metal siding *when circumstances allow* rather than concrete block or brick.

3.2.2.3 Existing facilities

As described above, boiler buildings represent a significant component of total project cost. Total project costs can be reduced by using existing facilities wherever possible. Using existing boiler rooms for new wood fired boiler systems can represent significant savings over free-standing boiler plants/wood storage facilities. For example, if the University of Montana-

Western had built a free standing boiler plant to accommodate the wood-fired boiler system, the building foot print would have expanded by 1,200 square feet, or $120,000-$150,000. The mechanical integration between two separate boiler plants may have added an additional $150,000-$200,000 in cost to the project.

One advantage of pellet systems is that they may be small enough to fit within the existing boiler room. Boiler rooms designed for older boilers may be sufficiently large to fit a new wood biomass system with little remodeling. For example, the wood boiler systems for the Troy and Townsend School Districts were able to accommodate wood pellet boilers within the footprint and height of space available. A new boiler room would have been approximately 20 feet square or an additional $40,000.

See the appendix for total project cost comparisons.

3.2.2.4 New installations

In new installations, total project cost for biomass boilers systems can be reduced by appropriate consideration of space allocated to the boiler room. We suggest programming adequate space (footprint and height) for a wood boiler system in new facilities, even if a fossil fuel system is selected for initial installation. A boiler room sized for a biomass system is typically twice the typical size of a fossil fuel system (1500 SF versus 750 SF). Note that a minor increase in the size of the boiler room on a proposed facility benefits from being a relatively small component of a large project (for example, 1,500 SF in a 230,000 SF building).

- Program adequate space for a wood boiler system in new facilities. Include adequate height requirements for wood boiler system (18 to 20 feet).
- Typically requires a boiler room approximately twice the usual size of a fossil fuel boiler room (1,500 SF versus 750 SF).

The design team for the new Glacier High School in Kalispell was able to integrate wood boiler technology early in the design process, and to modify the building design and boiler room configuration to accommodate both wood fired and natural gas boiler systems. The minor increase in the size of the boiler room represented a relatively small component of a large project (1,500 SF in a 230,000 SF building).

See the appendix for total project cost comparisons.

3.2.2.5 Additional ideas for reducing building costs

Discussions among the project team, DNRC, USFS, project operators and owners, and manufacturers have generated additional ideas that appear to be potential opportunities for reducing the cost of the biomass boiler building. These ideas have not been fully developed or tested, but the ideas are presented in this section for future exploration and consideration.

Standardized boiler buildings. CTA has standardized the building design used for projects in Victor, Philipsburg, and Council. Each successive project realized savings (accounting for the impact of inflation). For example, the fees for the wood fired boiler system for Darby were approximately $135,000. The fees for the projects of similar size in Victor and Philipsburg were approximately $50,000 each. Fees for a similar project in Deer Lodge are projected to be $39,000. See the appendix for total project cost comparisons.

Pneumatic delivery vehicles. As described above, using pneumatic delivery vehicles have the potential to reduce biomass boiler system costs by increasing the storage capacity of wood chips storage bins (below or at grade). For this reason, pneumatic delivery may also reduce project costs by reducing building footprint (by allowing taller storage piles). This concept has been explored for the Deer Lodge, Stevensville (MT) and Dayton (WA) School Districts.

3.2.3 Reducing Cost of Mechanical/Electrical Integration

Replacing an existing fossil fuel boiler system with a biomass boiler system requires some level of mechanical integration to connect the new system to the components of the electrical, mechanical, and distribution systems that remain in place. As described above, total project costs are less for facilities that require less mechanical integration. Installing biomass boilers in proposed (new) facilities eliminates integration costs.

Opportunities for cost reductions associated with minimizing integration costs are listed below. See the appendix for total project cost comparisons, which include the cost of mechanical integration.

Closer proximity to existing boiler room. Integration costs are less when the distance between the boiler and the space(s) to be heated is shorter; shorter distance (20 to 25 feet) is less expensive than longer distance (greater than 100 feet). The savings is the result of fewer linear feet of buried pipe which can cost between $150-$200/LF. A project requiring only 20 lineal feet of pipe would cost $16,000 less than a project requiring 100 lineal feet of buried pipe.

Existing equipment. Total project costs can be reduced by modifying existing equipment rather than purchasing new equipment. For example, modifying existing boilers to burn wood pellets or wood chips could reduce project costs by $50,000 or more. The State of Montana requires a mechanical engineer with experience in combustion systems to design the modifications to existing boilers.

Paybacks. Although extensive integration costs typically indicate lower project viability, projects requiring extensive integration in order to increase total heating capacity will have less negative impact than projects in which extensive integration is required for replacement with no additional capacity. For example, if a project requires an additional $100,000 of integration, but results in 2,000 additional dka of natural gas being displaced, the overall cash flow for the project would be improved.

3.2.4 Reducing Non-Capital Costs

Non-capital costs for a biomass boiler project include design fees, printing, travel, permits and related costs. CTA has found that in addition to fees, the bid timing, duration and contractual relationships between wood boiler system vendors and general contractors impact total project costs. CTA's experience with biomass projects has generated the following list of potential opportunities for reducing non-capital project costs.

3.2.4.1 Bid timing

CTA has tracked the relationship between construction costs and bid timing and have identified a consistent 8-10% increase in construction cost based upon projects bid between June and August versus projects bid between January and March. The primary benefit of bidding projects between January and March is the ability for a contractor to avoid hidden costs associated with working in winter conditions. CTA's experience with biomass projects has generated the following list of potential opportunities for improving bid timing to help reduce non-capital project costs.

- The ideal bid climate is between Mid-January and Mid-March. Only four projects have been bid during that time frame (The General Contract for the Darby School District, Townsend School District, University of Montana-Western and the Wood boiler system contract for Thompson Falls). Most of the boiler conversion projects installed in Montana have been bid in February, April, May, June and October. In order to be able to bid more projects in the January-to-March time frame, construction documents will need to be prepared during the summer and fall of the previous year. Facility owners may need to proceed with developing projects without grant resources being committed to the project.

- If the Fuels for School program continues to be funded from congressional allocations in October, those funds are typically not available to the State of Montana DNRC until December or January. If the grant applications are received in February and funds are distributed in April, most projects would proceed with design during the summer months, construction documents during the fall, and receive bids from general contractors and wood boiler system vendors in the early winter. This allows a project to be constructed during the spring and summer months. In general this budget cycle works well with the design and construction cycle for each project.

- Construction documents may be prepared without knowing which wood boiler system contractor will be selected. Any modifications to a prototypical building would be made during the shop drawing review process. The project for the Philipsburg School District used this approach.

- All aspects of the construction industry have been experiencing rapid and volatile inflation during the past 30 months. This trend is projected to continue for at least the next 18 months and will continue to impact the total project costs associated with all construction projects.

- Wood boiler system vendors are often completing past projects during the fall and early winter months, with limited time for reviewing bid documents for upcoming projects. Many wood boiler system vendors are negotiating directly with facility owners and contractors and are not interested in pursuing publicly bid projects. Performance contractors in the state of Montana have the ability to select wood boiler system vendors based upon the quality and performance of the system, rather than through a public bid process. The use of the performance contracting process may provide a means of expanding the use of wood boiler systems in publicly funded projects.

- Wood boiler system vendors are experiencing 16-20 week lead times for the boilers they purchase from manufacturers around the country. Releasing drawings for bid in January allows projects to be awarded in February, and for the 16-20 week delivery period to be coordinated with the optimal construction of the project between June and August.

3.2.4.2 Bid duration

Biomass projects installed in Montana have been bid between 15 and 25 days. Greater bid durations can allow contractors more time to review the project documents and ask for clarifications in advance of the bid date. Although no specific cost savings can be attributed to longer or shorter bid durations, contractors and vendors are likely to add additional costs to their bids when little time is provided to answer potential questions they may have. Future projects should plan for at least a three week bid duration.

3.2.4.3 Bid documents

Wood boiler system vendors have often stated that the bidding requirements are too cumbersome for what are stated to be simple projects. These vendors have often requested exceptions to bid bonds and insurance requirements. Federal Acquisition Regulations and State of Montana bid requirements require that basic public bid requirements be met. Although no specific cost savings can be attributed to simplifying public bid requirements, additional costs may occur if only a limited pool of wood boiler system vendors are willing to bid on publicly funded projects. As noted above, the performance contracting process can be used to overcome the concerns of wood boiler system vendors.

3.2.4.4 Value engineering processes

The typical design/bid/build process does not allow for meaningful contractor input on projects in advance of bidding. Projects bid with various additive alternates allow the facility owner to consider the financial impact and benefits of various wood boiler system and building components. It is important to limit the number of alternates to 2 to 3 to keep the bidding process as simple as possible. The cost savings attributed to value engineering will vary from project to project. The use of design/build, construction manager at risk or performance contracting project delivery methods would increase the level of contractor input in the design of wood heating projects. These alternative project delivery methods may not result in lower project costs but can be used to reduce the time lost to value engineering processes after a bid opening, and reduce potential change orders.

3.2.4.5 Multiple contract issues

Three of the completed projects in Montana were bid using multiple contracts (one for the wood boiler system and one for the general contractor). Two projects were bid using a Construction Manager at Risk and single contract. The Troy School District, Townsend School District & the University of Montana-Western projects were bid using a single contract, establishing the wood boiler system vendor and mechanical and/or general contractor during the bid process.

Bidding using a single contract is unlikely to reduce project costs, but should avoid any potential schedule or scope conflicts between the general contractor and wood boiler system vendor. At this point in time only a limited number of general contractors in the state of Montana are familiar with the systems and services wood boiler system vendors provide.

3.2.4.6 Performance contracting

An alternative approach to construction contracting would be to use a performance contractor such as Chevron, Johnson Controls, McKinstry, or Siemens to design and construct the wood boiler system. This process has been used for the projects in Ely, Nevada as well as Council and Kellogg, Idaho. The end user selects a performance contractor who partners with a design team, wood boiler system vendor and related contractors to deliver the completed project. This process allows the performance contractor to negotiate directly with the most qualified wood boiler system vendors for the project. Facility owners typically pay for a portion of the total project cost through future energy savings, making the combination of wood boiler systems and performance contracting a viable approach to funding the additional costs associated with most wood boiler systems. The primary drawback associated with performance contracting is that the contractor's fees and profits are not always readily identifiable in the contract, and the payback period is often lengthened to meet the consumers risk tolerance resulting in higher financing costs for the project when compared to conventional loans or bonds.

3.2.4.7 Payment issues

The facilities constructed under the first phase of the Fuels For Schools program involved multiple tiers of grants from the USDA Forest Service to a local RC&D, and then to the school district. This resulted in delays of payment to general contractors or wood boiler vendors of 45 days or more. The additional cost associated with delays in payment cannot be quantified; however, delays may have impacted general contractors and wood boiler system vendor's willingness to bid on future projects.

The current phase of the Fuels For Schools program utilizes a simplified grant process directly from the Montana DNRC to the school district. The payment process works smoothly when the school district spends their own funds first, seeks reimbursement from the DNRC, and uses the grant funds to make the remaining payments.

3.2.4.8 Project closeout issues

As a project approaches substantial completion, the contractor submits a list of items to be completed prior to receiving final payment. The architect or engineer reviews the list, adds additional items, and authorizes the appropriate payment in accordance with the work completed to date. This project closeout period is typically two to four weeks in duration.

Delays in Project Closeout have been experienced on several completed projects. Facility owners have confused the completion of the general contractor's scope of work with the wood boiler system contractor's scope. The general contractors to date have been from nearby communities and have been responsive to completing unfinished aspects of the project in a timely manner. The wood boiler vendors are not in the Montana region, and often coordinate travel with related projects prior to completing their scope of work. Delays in completing unfinished aspects of the wood boiler systems have resulted in delays in final acceptance of the wood boiler system. Wood boiler systems also require additional training prior to proper operation, which can result in delays in final acceptance of the wood boiler system.

The additional cost associated with delays in payment cannot be quantified; however, delays may impact general contractors and wood boiler system vendor's willingness to bid on future projects.

3.2.4.9 Project familiarity

Increasing familiarity and experience with biomass projects should lead to reduced non-project costs. Experienced design teams can become more cost effective in delivering the design services needed to implement projects. For example, A&E fees have varied from $25,000 for the Troy School District to $135,000 for Darby. The scope of work for most projects is similar regardless of project size. For example the fees for the Troy School District (650,000 BTU) and Glacier High School (7,000,000 BTU) were approximately $25,000. The low fee associated with the Glacier High School can be attributed to integrating the wood boiler system into a very large project during the design process. If a wood boiler system of the same size had been added to the school after completion of the building the fees would have been approximately $75,000.

See Appendix for total project cost summaries.

Other potential opportunities for cost reductions from project familiarity include:

- Regulators and stakeholders become familiar with biomass projects could reduce permitting fees. The only Fuels For Schools project requiring an air quality permit in the state of Montana is the University of Montana-Western project in Dillon. Had the project been slightly smaller in output capacity, an air quality permit would not have been required. The total cost of the air quality permit and associated engineering fees was greater than $10,000.
- Templates have been developed for the project manuals associated with the bid documents. This has reduced design fees by approximately $1500 per project.

3.3 Recommendations

This section presents a summary of the recommendations that our experience suggests represent the greatest opportunities for improving financial attractiveness.

Where applicable, implement the following:

- Model the projected heating loads for a facility in order to arrive at an appropriate size for the wood boiler.
- Coordinate the capacity and type of wood storage with the projected volume and rate of wood fuel to be used by the facility.
- Reduce the size of wood storage bins and maintain automated wood handling systems or use semi-automated wood handling systems.
- Avoid projects with limited number of wood boiler system vendors (such as small steam pellet boilers).

- Avoid projects with high wood fuel costs (such as wood pellet projects located far from existing wood pellet production facilities).
- Encourage wood chip and wood pellet haulers to work with grain haulers and/or purchase pneumatic equipment for delivery to facilities using wood fired boiler systems.
- Assist wood boiler system vendors and national boiler manufacturers to standardize wood boiler system designs to simplify mainstream adoption of technology by engineers and facility owners.
- Simplify building designs to incorporate standard 4:12 wood trusses & metal siding and/or metal building technology.
- Integrate wood boiler systems into existing boiler rooms.
- Modify existing boilers to burn wood.
- Integrate wood boiler systems into new facilities during the design process.
- Avoid projects with large mechanical integration costs.
- Coordinate project schedules with ideal bid timing of January to March and ideal construction schedules of April to October.
- Maintain bid durations of 3-4 weeks.
- Release bid documents to wood boiler system vendors and general contractors under a single contract.
- Simplify bid requirements while maintaining public bid requirements.
- Link facility owners with performance contractors.
- Simplify payment procedures.

3.4 Additional Opportunities For Improving Financial Attractiveness

Over the course of the Fuels for Schools program, numerous ideas have emerged as potential additional opportunities for improving financial attractiveness, beyond those already described in the sections above. In-depth explorations of these opportunities are beyond the scope of this assessment but are presented here as potential avenues to address in future work.

Wood Fuel Supply and Delivery

Discussions among the project team, DNRC, and USFS have generated numerous ideas related to opportunities for improving the financial attractiveness of biomass boiler systems by addressing wood fuel supply issues. Experience suggests that there are numerous opportunities for improving the handling, storage, and delivery of wood supply.

Project Financing

Issues related to project financing are beyond the scope of this market assessment; however discussions among the project team, DNRC, and USFS suggest that improving project financing processes and mechanisms could provide an opportunity to improve overall biomass boiler project viability.

Building Commissioning

When considering a new biomass energy project, a facility should also consider re-commissioning building systems and implementing appropriate energy conservation measures. Some facilities may, in fact, achieve greater savings from energy conservation measures than from conversion to biomass fuels, and may not be strong candidates for conversion to wood fired boiler systems.

As wood boiler systems are commissioned, problems with the distribution or control of the existing system may be revealed, impacting the operation of the wood boiler system and volume of wood consumed. This situation has been encountered on almost every one of the wood fired boiler systems installed under the Fuels For Schools Program. The impact of using less fossil fuel and less wood fuel should be carefully examined in the initial project analysis.

4.0 FACTORS IMPACTING PROJECT VIABILITY

The purpose of this section is to provide a framework for assessing the potential viability of biomass project based on the impact of individual factors. Each facility and organization will have its own expectations and tolerances for time required to achieve positive cash flow and system payback. Schools and other government institutions, for example, are typically budget driven and work within long planning horizons. Private sector organizations, by contrast, are typically profit driven and work within short planning horizons. In this section we describe the basis for project viability, metrics that can be used to describe viability, and how individual factors impacts project viability metrics.

4.1 Financial Driver for Biomass Conversions

For the facility owner, the main driver for converting an existing boiler to a wood biomass boiler is financial -- a biomass boiler has the potential to save money by burning a less expensive fuel. Table 4 illustrates the difference in fuel costs and fuel cost savings compared to wood chips for several fuels used in boilers in Montana. As indicated by Table 4, wood chips are less expensive per unit heating value ($/mmBTU) than any of the other fuels listed (using winter 2005 prices).

Table 4. Heating value, price, cost per mmBTU, and fuel cost savings compared to wood chips for various fuels

Fuel	Fuel Heating Value (BTU/unit)		Fuel Price ($/unit)	Fuel Cost ($/mmBTU)	Fuel Cost Savings compared to wood chips ($/mmBTU)
Electricity*	3,413	BTU/kW	$0.086 /kW	$25.00	$21.81
Fuel Oil	138,690	BTU/gal	$2.22 /gal	$16.00	$12.77
Propane	90,502	BTU/ gal	$1.36 /gal	$15.00	$11.79
Natural Gas	1,000,000	BTU/dka	$11.00 /dka	$11.00	$7.76
Wood Pellets	16,400,000	BTU/ton	$110.00 /ton	$6.70	$3.47
Coal	18,000,000	BTU/ton	$63.00 /ton	$3.50	$0.26
Wood Chips	10,800,000	BTU/ton	$35.00 /ton	$3.25	$0.00

**Electricity is not a fuel, but many boilers in Montana run on electricity rather than burning a fuel directly.*

Boiler conversion projects are viable when, over the long run, the annual fuel cost savings generated by converting to biomass are greater than the cost of the new biomass boiler system plus the additional maintenance costs associated with a biomass boiler (compared to those of a fossil fuel boiler).

As an example, an existing 10 mmBTU/hour natural gas boiler might use around $102,000/year in natural gas. A new biomass boiler would be sized to meet 90% of the annual heat load, retaining the existing natural gas boiler for meeting peak loads and as back up. Under these conditions, a new biomass boiler would use around $38,000/year in wood chips, for a first-year savings of $64,000. The simple payback on the biomass system would be about 13 years.

Converting from an existing boiler to a wood biomass boiler requires a greater initial investment and higher annual O&M costs than for an equivalent fossil fuel system. However, in a viable project, the saving in fuel costs (wood vs. fossil fuel) will pay for the initial investment and cover the additional O&M costs in a number of years. After the initial investment is paid off, the project continues to save money (avoided fuel cost) for the life of the boiler. Since inflation rates for fossil fuels are typically higher than inflation rates for wood fuel, increasing inflation rates result in greater fuel savings and thus greater project viability.

CTA assumes inflation rates of 4% for fossil fuels and 2% for wood fuel in our biomass project assessments. Although natural gas and other fossil fuels have recently seen 30% inflation/year for the past 3 years, it is possible that it will flatten out or decline back to an average of 4% to 6%.

4.2 Project Financial Viability Metrics

The potential financial viability of a given project depends not only on the relative costs and cost savings, but also on the financial objectives and expectations of the facility owner. For this reason, the impact of selected factors on potential project viability is presented using the following metrics:

- initial total project cost
- simple payback
- 30-year cumulative net cash flow
- 30-year cumulative net cash flow minus initial total project cost
- 30-year return on investment

Total initial project cost includes all of the costs required to design and build a biomass boiler system in an existing facility with an existing boiler and steam or hot water distribution system. Simple payback is the total project cost divided by the first year annual cost savings that would be achieved by converting from the existing fuel to wood biomass. Since 89% of all existing boilers use **natural gas**, the examples in the following section are based on converting to biomass from existing natural gas boilers. The 30-year cumulative net cash flow is the result of a cash flow analysis of converting to a biomass boiler that includes a loan at 4.6% over 10 years and the inflation rates described above. The 30 year return on investment is based on using initial total project cost to represent the investment cost and the 30-year cumulative net cash flow to represent the earning.

4.3 Impact of Individual Factors

Numerous facility-specific factors affect the potential economic and technical viability of a given biomass boiler conversion project. Our analyses indicate, however, that there are a few factors that appear to have the greatest impact on potential project viability:

- Existing boiler size (in mmBTU/hour output)
- Existing annual fuel use (in mmBTU/year)
- Existing annual fuel cost (in $/year)

The impacts of each of these factors on project viability are discussed below.

4.3.1 Existing Boiler Size

As indicated above, the economic viability of biomass boiler conversions are driven by annual fuel cost savings. Larger boilers consume more fuel and have higher annual fuel costs than smaller boilers. For this reason, larger boilers make better candidates for boiler conversions. Table 5 presents the impact that existing boiler size has on project viability metrics. Figures 1 to 3 illustrate the impact over selected boiler size ranges.

Note that the values in the table are based on the existing boilers that use **natural gas** as the existing fuel (89% of existing boilers in the state are fueled by natural gas). With the exception of coal, other fossil fuels used in boilers in Montana are more expensive on a per-BTU basis than natural gas (see Table 8), so the simple payback time for the same size boilers would be shorter.

Table 5. Impact of Existing Natural Gas Boiler Size on Project Viability Metrics

Existing Boiler Size (mmBTU/hr)	Biomass Boiler Size (mmBTU/hr)	initial total project cost ($)	30-year cumulative net cash flow	simple payback (years)	30-year ROI
0.25	0.08	$100,000	-$156,490	---	---
0.5	0.15	$100,000	-$67,042	595	---
1	0.30	$101,029	$110,547	36	0.3%
2	0.60	$230,629	$303,745	28	0.9%
3	0.91	$360,229	$496,944	27	1.1%
4	1.21	$428,820	$767,624	23	2.0%
5	1.51	$470,400	$1,072,608	19	2.8%
10	3.02	$675,000	$2,601,719	13	4.6%
13	3.93	$675,000	$3,675,091	10	5.8%
14	4.23	$675,000	$4,032,881	9	6.1%
15	4.54	$675,000	$4,390,672	9	6.4%
20	6.05	$759,422	$6,072,409	7	7.2%
25	7.56	$881,222	$7,706,676	7	7.5%
50	15.12	$1,490,222	$15,878,011	6	8.2%
80	24.19	$2,221,022	$25,683,614	5	8.5%

Figure 1. Impact of Natural Gas Boiler Size on Simple Payback

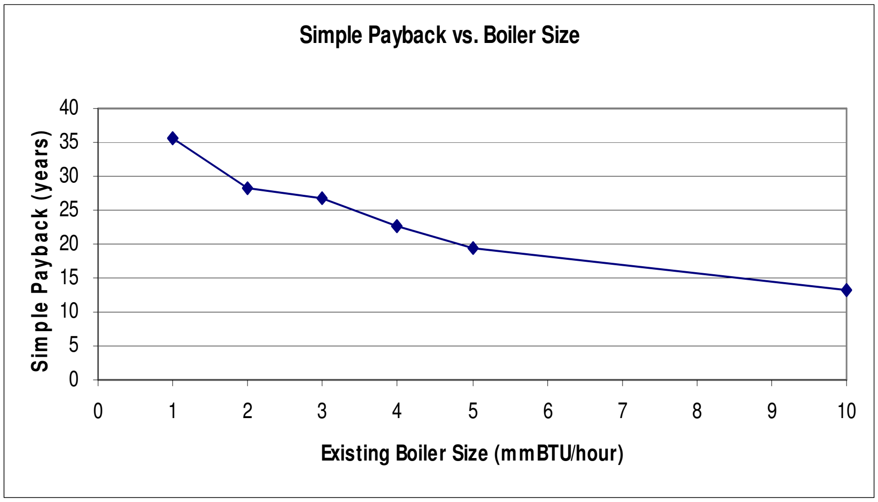


Figure 2. Impact of Natural Gas Boiler Size on 30-year Cumulative Net Cash Flow minus Initial Total Project Cost

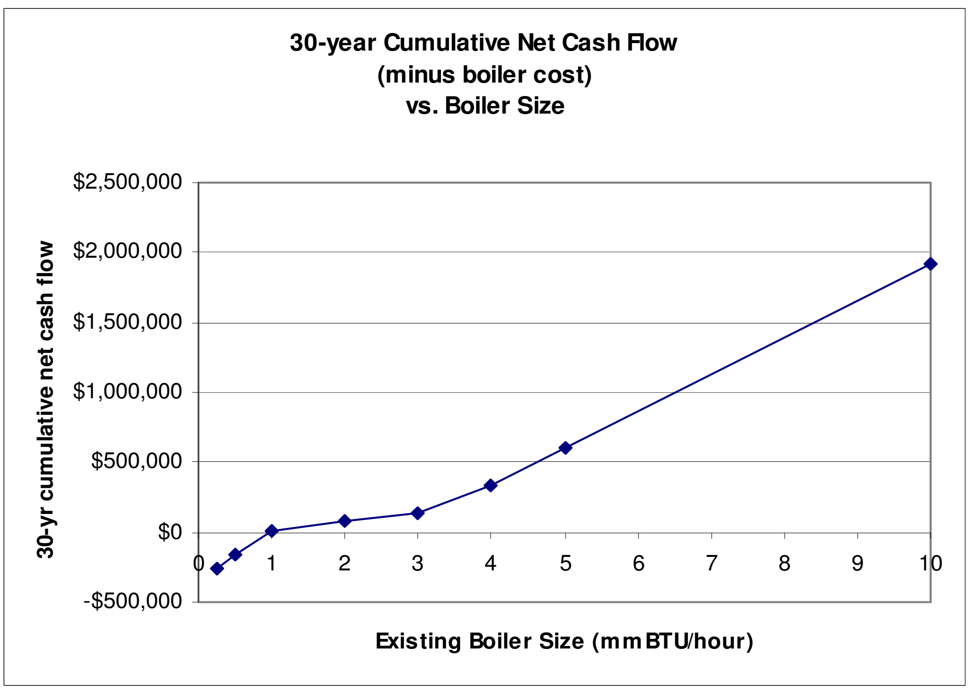
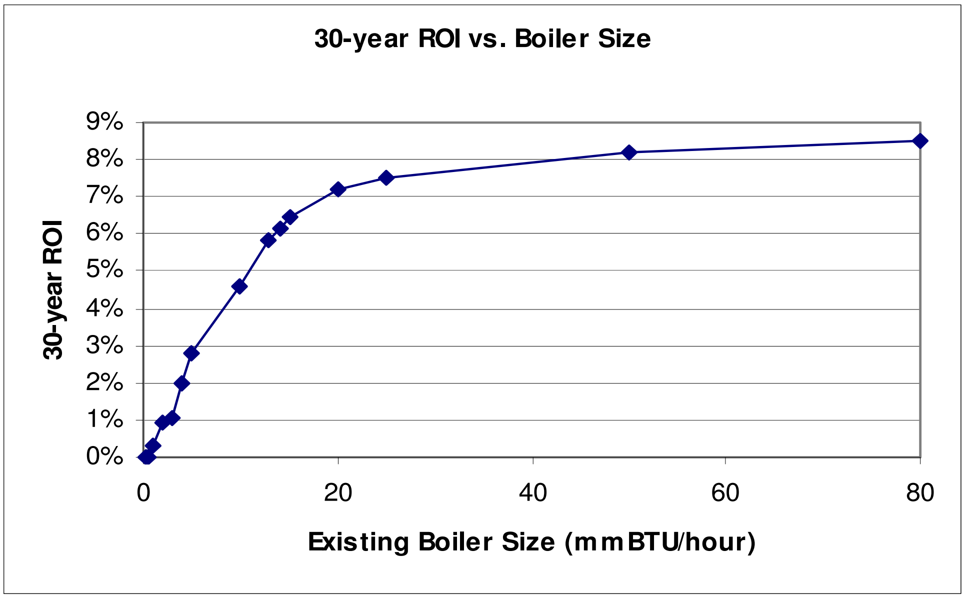


Figure 3. Impact of Natural Gas Boiler Size on 30-year Simple Return on Investment



Each facility owner will have different financial goals, expectations, and tolerances; however, it can be assumed that no project will be considered economically viable unless it pays for itself within 30 years, which is the expected life of some system components. Based on this criterion, it appears that existing boilers should be at least 1 to 1.5 mmBTU/hour output for conversion to biomass to be considered viable. (As noted earlier, this relationship is based on natural gas as the existing fuel source.)

4.3.2 Existing Annual Fuel Use

As indicated above, boilers that have higher annual fuel use generate greater annual fuel cost savings when converted to biomass. Boilers with annual fuel use sufficient to generate significant annual cost savings make better candidates for boiler conversions. Table 6 presents the impact the annual natural gas fuel use has on project viability metrics. Figures 4 to 6 illustrate the impact over selected natural gas fuel use ranges. Values are based on natural gas as the existing fuel.

Table 6. Impact of Annual Natural Gas Fuel Use on Project Viability Metrics

Annual Fuel Used (mmBTU/yr)	Biomass Boiler Size (mmBTU/hr)	initial total project cost ($)	30-year cumulative net cash flow	simple payback (years)	30-year ROI
250	0.08	$100,000	-$148,691	-95	---
500	0.16	$100,000	-$51,444	267	---
1,000	0.33	$112,329	$127,392	73	0.4%
2,000	0.66	$253,229	$337,437	48	1.0%
3,000	0.99	$394,129	$547,481	35	1.1%
4,000	1.32	$443,322	$873,993	29	2.3%
5,000	1.64	$488,527	$1,205,570	25	3.1%
10,000	3.29	$675,000	$2,913,687	14	5.0%
12,500	4.11	$675,000	$3,886,155	13	6.0%
15,000	4.93	$675,000	$4,858,624	12	6.8%
20,000	6.58	$801,903	$6,642,394	11	7.3%
25,000	8.22	$934,323	$8,419,158	11	7.6%
50,000	16.44	$1,596,423	$17,302,975	10	8.3%
75,000	24.66	$2,258,524	$26,186,793	9	8.5%

Figure 4. Impact of Annual Natural Gas Fuel Use on Simple Payback

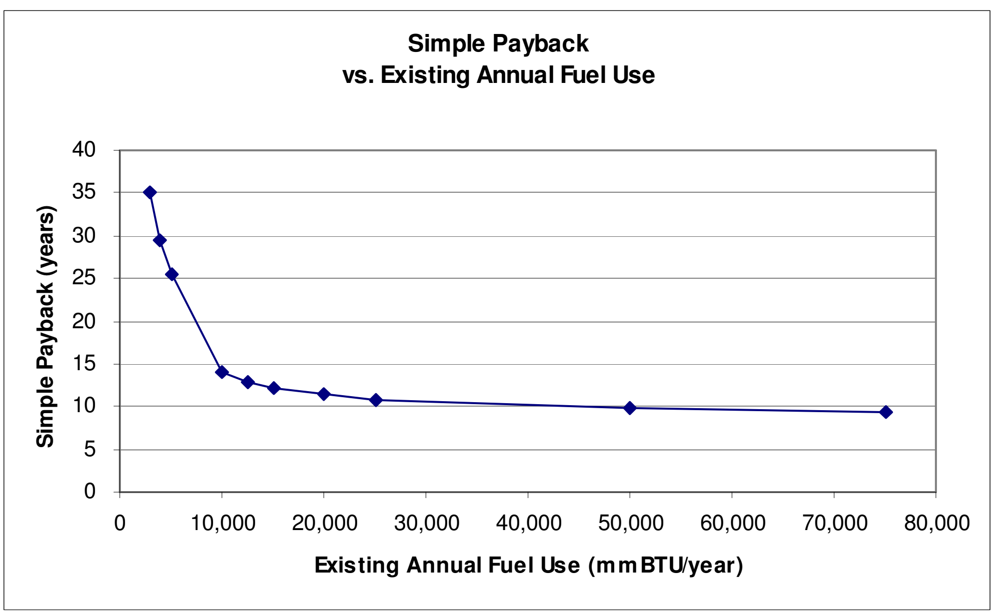


Figure 5. Impact of Annual Natural Gas Fuel Use on 30-year Cumulative Net Cash Flow minus Initial Total Project Cost

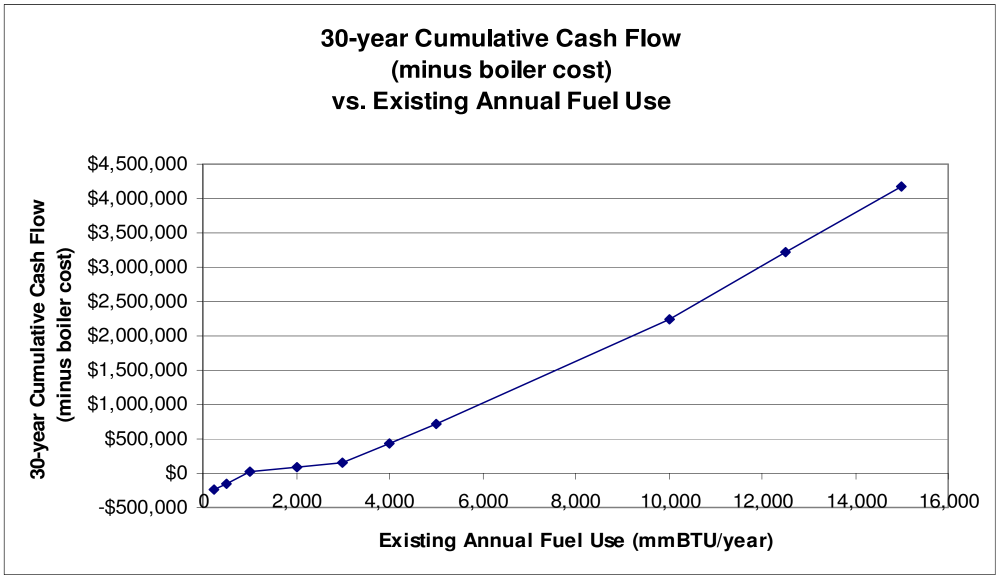
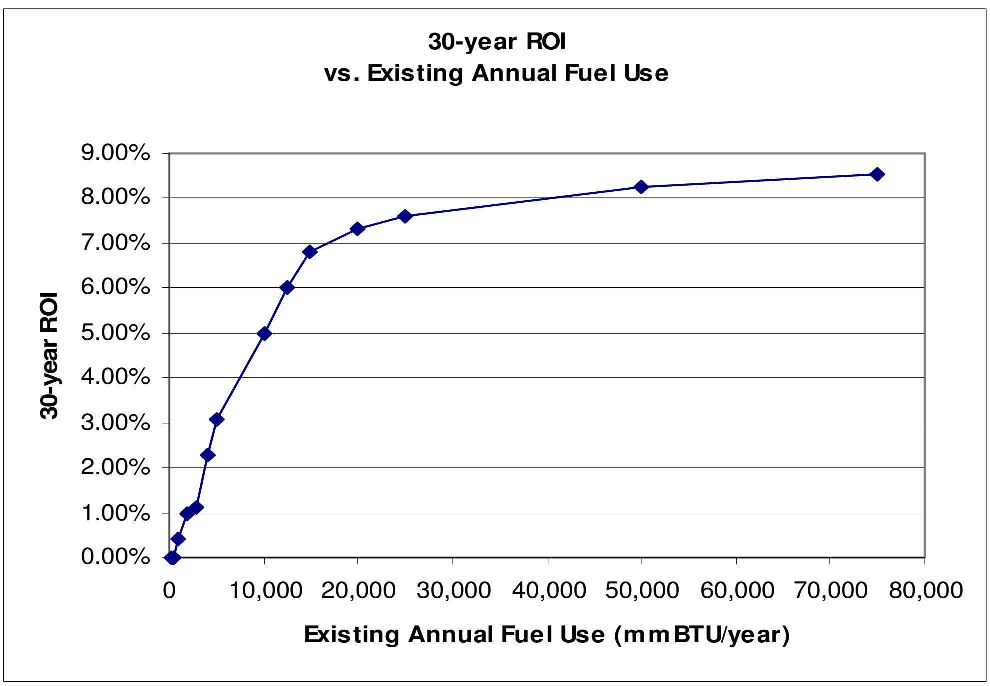


Figure 6. Impact of Annual Natural Gas Fuel Use on 30-year Simple Return on Investment



Information developed to evaluate the impact of existing fuel use on project viability suggest that projects may be viable when existing natural gas boilers use a minimum of 1,000 to 3,000 mmBTU/year of fuel.

One factor on its own can be a good indicator of potential project viability, but **it is important to remember that each project is unique and rules-of-thumb don't always apply**. For example, the new Public Works Facility in Bismarck, N.D. is projected to use less than 2,000 mmBTU/year of natural gas, but the operators of the facility plan to obtain wood fuel for free and the existing building could be used for chip storage, so the overall project is viable. Similarly, a Montana DNRC Nursery greenhouse in Missoula, MT uses less than 1,000 mmBTU/year of natural gas, but because it uses a hot air furnace system (rather than boiler), project costs are expected to be sufficiently low to maintain project viability.

It should be also be noted that CTA has encountered numerous facilities that are consuming significantly less fossil fuel than might be expected for a facility of that size based upon the rule of thumb of 30-40 BTU/SF/year. It appears that as fossil fuel prices rise, some facilities simply turn down or turn off the heat in order to control their utility budgets. (Although turning off the heat may actually consume more energy than using a night time set back of 8-10 degrees lower than the daytime setting of 68-72 degrees.) These facilities may be good candidates for Energy Conservation Measures and Performance Contracting projects either related to or instead of a wood boiler project. In the future it should be possible to quickly compare the annual BTU's consumed by a facility to the rule of thumb to determine if such a facility falls above or below the norm.

4.3.3 Existing Annual Fuel Cost

CTA's experience suggests that the factor that has the greatest impact of potential project viability is existing annual fuel cost. This single factor accounts, directly or indirectly, for boiler size, boiler use, fuel use, and fuel price. And as stated repeatedly above, it is the difference between existing annual fuel cost and biomass annual fuel cost that drives project economics. Table 7 presents the impact the annual fuel (natural gas) cost has on project viability metrics. Figures 7 to 9 illustrate the impact over selected annual fuel cost ranges. Values are based on **natural gas** as the existing fuel. As stated earlier, other sources of energy used for boilers in Montana (oil, electricity, propane) are more expensive than natural gas on a per-BTU bases, so the impact of rising energy prices would be even greater than illustrated for natural gas.

Table 7. Impact of Annual Natural Gas Fuel Cost on Project Viability Metrics

Existing Annual Fuel Cost ($/year)	Biomass Boiler Size (mmBTU/hr)	initial total project cost ($)	30-year cumulative net cash flow	simple payback (years)	30-year ROI
$5,000	0.15	$100,000	-$169,125	730	---
$10,000	0.30	$100,000	$7,687	36	0.25%
$20,000	0.60	$227,611	$71,636	28	0.92%
$40,000	1.20	$426,884	$326,536	23	1.91%
$50,000	1.49	$467,979	$586,874	20	2.75%
$75,000	2.24	$570,719	$1,237,717	15	3.92%
$100,000	2.99	$673,459	$1,888,560	13	4.55%
$150,000	4.48	$675,000	$3,653,186	9	6.39%
$200,000	5.98	$753,750	$5,242,549	7	7.16%
$250,000	7.47	$874,132	$6,737,406	7	7.48%
$300,000	8.97	$994,514	$8,232,264	6	7.71%
$400,000	11.96	$1,235,277	$11,221,979	6	8.01%
$500,000	14.94	$1,476,041	$14,211,695	6	8.20%
$1,000,000	29.89	$2,679,860	$29,160,271	5	8.60%
$1,500,000	44.83	$3,883,679	$44,108,848	5	8.74%

Figure 7. Impact of Annual Natural Gas Fuel Use on Simple Payback

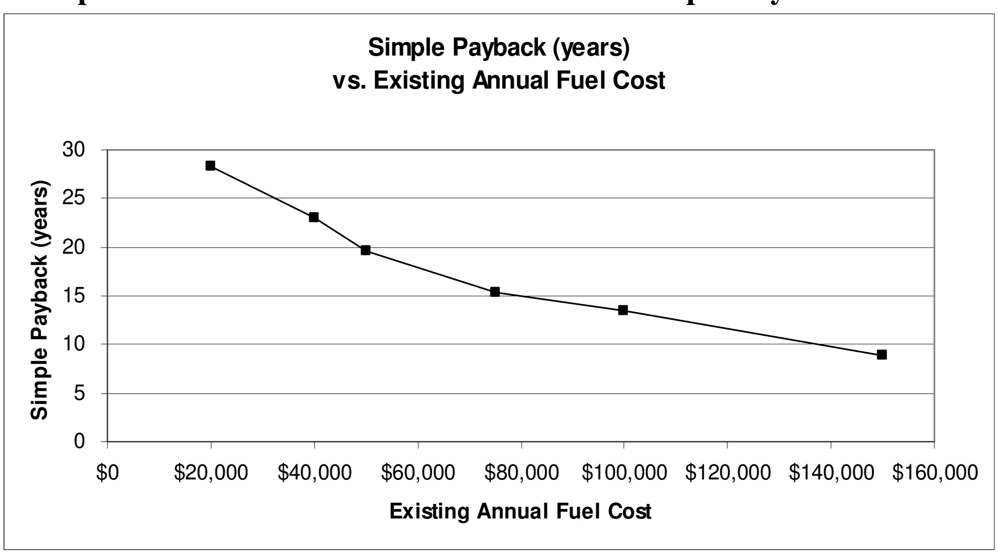


Figure 8. Impact of Annual Natural Gas Fuel Cost on 30-year Cumulative Net Cash Flow minus Initial Total Project Cost

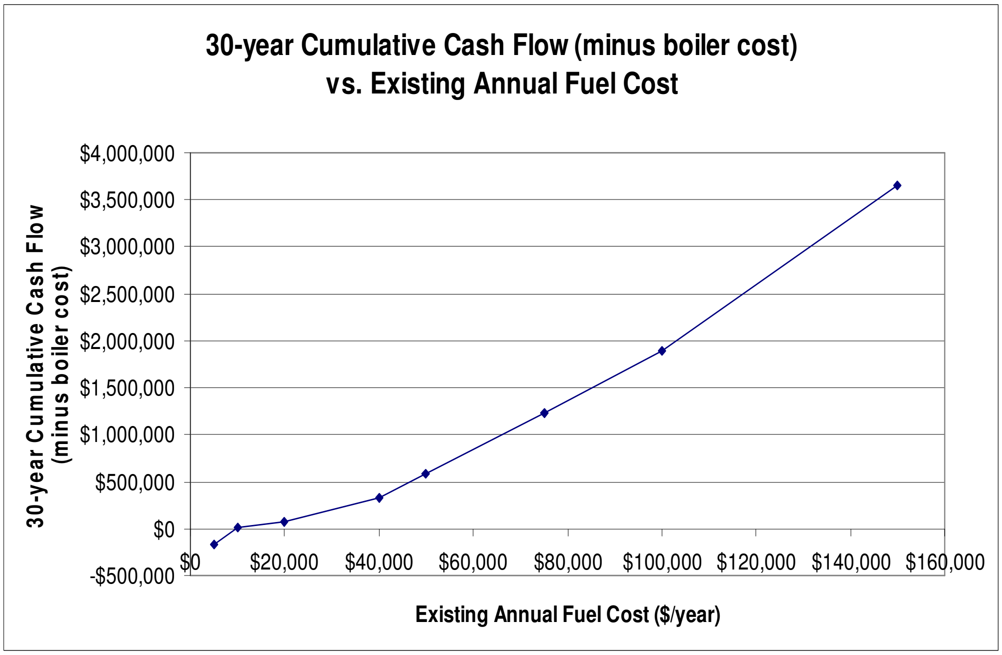
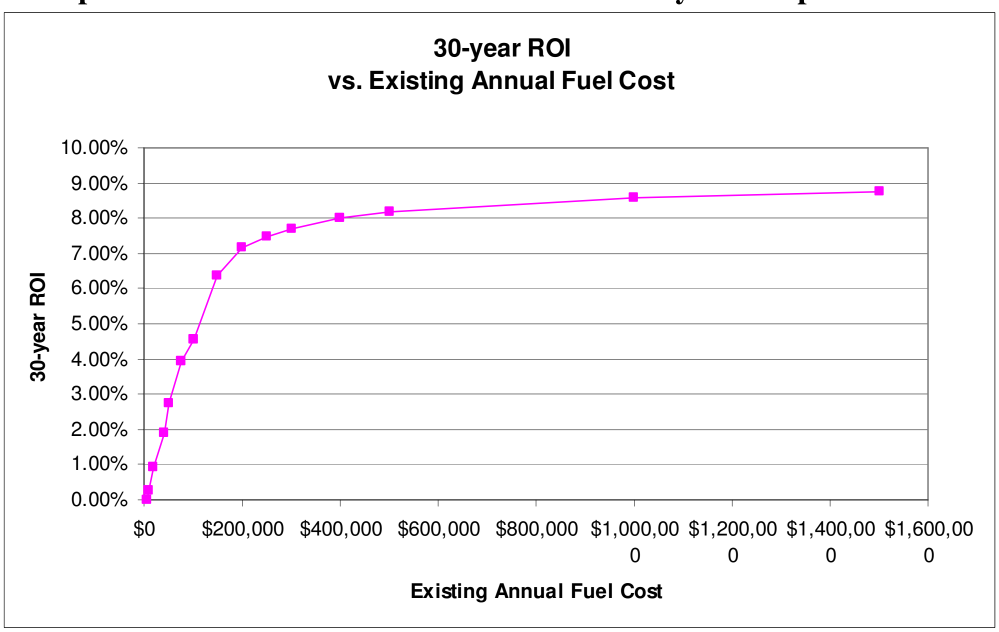


Figure 9. Impact of Annual Natural Gas Fuel Use on 30-year Simple Return on Investment



Information developed to evaluate the impact of existing natural gas cost on project viability suggest that projects may be viable when existing natural gas boilers spend a minimum of around $20,000 per year on fuel.

5.0 REFINING IDENTIFICATION OF THE POTENTIAL CUSTOMER BASE

The previous boiler study presented analyses of information provided in the State's database of boiler certificates to help identify the potential market for converting existing boilers to use wood biomass. These analyses began to define this potential market and revealed several areas where further refinements could be made. In this section, we use updated information and additional project assessment and design experience to further analyze factors that help refine identification of the potential customer base for boiler conversions. We also discuss additional considerations to help further refine the relative opportunity for conversion based on the information available in the boiler database.

5.1 Disclaimer

It is important for the reader to recognize that the information in this report reflects the experience and professional judgment of CTA Architects Engineers and its project partners. When reading information presented in this report it is important to note the following:

- Information presented is based on characteristics and conditions assumed to be representative of "typical" facilities that use a boiler.
- Every facility is unique; the results presented may or may not be representative of a specific boiler of facility.
- Market conditions related to energy, construction, and biomass boilers are currently highly dynamic, and conditions represented in this report are likely to change.
- The information in this section is not intended to be used to make investment decisions, but rather to paint a picture of the potential biomass boiler market conditions in Montana.

5.2 Updated Fuel Costs

In the previous boiler study, analyses based on then-current fuel costs indicated that there are 79 boilers in the state with payback periods of 15 years or less when boiler replacement was not required (the payback period represented the number of years required for fuel cost savings to pay for the cost of installing a new wood-burning boiler system). As fossil fuel prices increase, payback periods for boiler conversions should decrease.

Table 8 presents the fuel costs used in the previous study and the updated fuel costs used in this study. Fossil fuel prices have become highly volatile. The analyses presented in this report are based on the updated fuel costs presented in Table 8; changes in fuel prices change the results of our analyses.

Table 8. Fuel costs and number of boilers with payback periods under 15 years in the previous study and in this study

Fuel	Previous Study (2004) ($/ mmBTU)	Current Study (2005) ($/ mmBTU)	Increase
wood chips	$3.24	$3.52	9%
natural gas	$8.00	$11.00	38%
electricity	$25.00	$25.00	0%
wood pellets	$7.00	$7.00	0%
fuel oil	$10.00	$16.00	60%
coal	$3.00	$3.50	17%
propane	---	$15.00	---

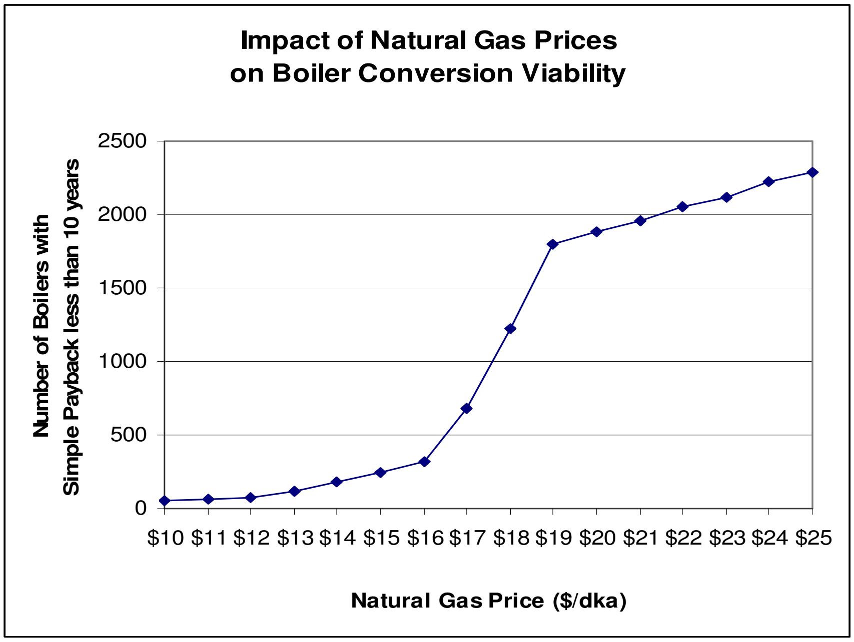
5.2.1 Impact of Natural Gas Prices

Almost 90% of existing boilers in Montana use natural gas as their only or primary fuel source. In this study it is assumed that natural gas is available for $11.00/mmBTU (as compared to $8.00/mmBTU in the previous study). Since natural gas prices appear to be increasing rapidly, it is interesting to explore the impact that increasing fuel costs might have on the viability of biomass boiler conversions. The impact of natural gas prices on the numbers of boilers with paybacks of less than 10 years is illustrated in Table 9. It is interesting to note that at 4% inflation, natural gas prices would double in less than 18 years (wood prices would likely also rise during that time, but at a rate closer to 2%).

Table 9. Impact of natural gas prices on numbers of boilers with paybacks <10 years

price of natural gas ($/mmBTU)	number of boilers with payback <10yrs	percent of boilers with payback <10yrs
$10.00	56	1.1
$11.00	**68**	**1.3**
$12.00	75	1.4
$13.00	122	2.3
$14.00	176	3.4
$15.00	242	4.6
$16.00	321	6.2
$17.00	683	13.1
$18.00	1221	23.4
$19.00	1793	34.4
$20.00	1886	36.2
$21.00	1957	37.6
$22.00	2050	39.4
$23.00	2121	40.7
$24.00	2224	42.7
$25.00	2287	43.9

Figure 10. Impact of natural gas prices on numbers of boilers with paybacks <10 years



5.2.2 Impact of Other Fuel Prices

The values presented in Table 8 illustrate that, aside from coal, natural gas is the least expensive fossil fuel on a per-BTU basis of all the commonly used boiler fuels in Montana. The impact of doubling the price of other fuels on numbers of boilers that might be viable for conversion is presented below.

There are 64 existing boilers in Montana that list **electricity** use as their fuel source (section 5.4 explains that not all of the 101 electric boilers listed in the database are viable for conversion). At the assumed current price of $25/mmBTU for electricity, **4 existing electric boilers would have a payback of less than 10 years**. At $50/mm BTU, 15 electric boilers would have a payback of less than 10 years (assuming wood prices stay the same).

There are 196 existing boilers in Montana that list **oil** use as their fuel source. At the assumed current price of $16/mmBTU for oil, **9 existing oil boilers would have a payback of less than 10 years**. At $32/mm BTU, 125 oil boilers would have a payback of less than 10 years (assuming wood prices stay the same).

There are 356 existing boilers in Montana that are believed to use **propane** use as their fuel source. At the assumed current price of $15/mmBTU for propane, **3 existing propane boilers would have a payback of less than 10 years**. At $30/mm BTU, 99 propane boilers would have a payback of less than 10 years (assuming wood prices stay the same).

There are 42 existing boilers in Montana that list "other" as their fuel source. For the purposes of the analyses conducted for this study, the "other" fuel(s) were assigned a fuel price of $11.03/mmBTU (the average of all other fuels). At this price, 7 existing boilers using some “other” fuel source would have a payback of less than 10 years (assuming wood prices stay the same).

5.3 Facility Type Data

The Montana Department of Labor and Industry’s database of boiler certificates includes several pieces of information for each active boiler certificate, including *Facility Type*. Facility type listings provided in the database include school, church, hospital, public assembly, rest home, assisted living, retirement center, day care, and not applicable.

Facility type could be an important factor in determining the potential viability of boiler conversion if it could be used as an indicator of the facility’s thermal load profile. Boilers serving facilities with a sustained demand for space heat and hot water and/or a large power or process steam demand (such as hospitals, nursing homes, prisons, and industries) have thermal profiles that are more viable for conversion to biomass boilers. Boilers in facilities that require only space heat (such as civic and commercial buildings) are less viable for conversion. Adding a hot water load to the system (such as commercial buildings, schools, and dormitories with showers and kitchens) increases conversion viability. In the previous study, all *Not Applicable* boilers were assumed to have an “average” thermal profile.

5.3.1 FUFs used in the Previous Study

In the previous study, the facility type listed in the database was represented by an assumed facility utilization factor (FUF). The FUF is equivalent to the fraction of time a boiler is running at full capacity. Facilities with heavy or more uniform boiler demands have higher FUFs. Facilities with lighter or more intermittent boiler demands have lower FUFs. Hospitals, for example, have a relatively high facility utilization factor, whereas the FUF for a building used for public assembly would be relatively low. Table 11 illustrates the effect that FUF has on the amount of fuel used in a given year for a 1,000,000 BTU/hour boiler.

FUF values were assigned based on the stated facility type; however, many other factors affect actual boiler usage. For example, facilities with redundancy or over-capacity in the boiler system would have a lower FUF than a similar facility type without redundancy or over-capacity. The FUF is a relative index and cannot be used to directly estimate fuel consumption.

Table 10. Impact of FUF on Annual Fuel Use for a 1 mmBTU/hour boiler

	Annual Fuel Use		
FUF	Fuel Oil (gals/yr)	Propane (gals/yr)	Natural Gas (dka/yr)
0.03	1,895	2,904	263
0.06	3,790	5,808	526
0.08	5,053	7,743	701
0.15	9,474	14,519	1,314

5.3.2 Treatment of Facility Type in This Study

It was originally thought (as described in the proposal for this study) that reviewing the facility name and facility owner information provided in the database would yield sufficient information to make a reasonable estimate of the thermal profile (represented by the assigned FUF value) for each *Not Applicable* boiler. However, upon reviewing the database in greater detail, it became apparent that it would be not be possible to assign FUF values with a greater level confidence than the average value; we could not be confident that the new estimate would be better – and could be worse - than using the "average" FUF value used in the first study. In addition, experience accumulated over the past year in biomass projects suggests that the thermal profile and existing boiler usage for each facility is unique, and highly unlikely to be similar to the FUF assigned to that boiler's facility type. For this reason, we have developed one FUF to represent existing boilers (FUF = 0.084) and one to represent biomass boilers (FUF = 0.25). These two factors are used in the analyses presented in this report.

To understand the impact that the facility utilization factor has on payback periods, the *Not Applicable* boilers were analyzed using a range of assigned FUF values. As can be seen in Table 12, using a higher FUF will result in a greater number of boilers with shorter payback periods.

Table 11. Number of boilers with payback periods of less than 15, 10, and 5 years for all *Not Applicable* boilers using different FUF values

Facility Utilization Factor (FUF)	payback <15 years	payback <10 years	payback <5 years
0.03	47	12	0
0.06	102	37	0
0.084	**137**	**61**	**0**
0.15	283	108	10

5.4 Identify Electric Boilers

The first boiler study indicated that there are 101 electric boilers in the state. Based on the assumptions made in the first study, all of the boilers with paybacks of 15 years or less when replacement is not required – the best candidates for conversion - list electricity as the fuel source. The experience of CTA suggests that some, and perhaps many, of the boilers listed as using electricity may not be eligible for conversion.

For the purposes of this study, we assumed that boilers listed as located in medical facilities and used to generate steam for sterilization and/or humidification and would not be eligible for conversion. Boilers fitting this scenario were identified as those with *hospital* listed as the facility type, *electricity* listed as the fuel source (even though natural gas is used for heating), and/or the facility name or location indicates use for sterilization (*surgery*, *operating room*, or *sterilizer*, for example).

There are 34 boilers with *hospital* listed as the facility type and *electricity* listed as the fuel source. Of these 34 boilers, the 20 boilers listed in Table 12 are likely used for sterilization and/or humidification and would not be eligible for conversion. These 20 boilers were eliminated from the boiler database for further analysis.

Table 12. Boilers in the database that are likely used for sterilization and/or humidification and not eligible for conversion

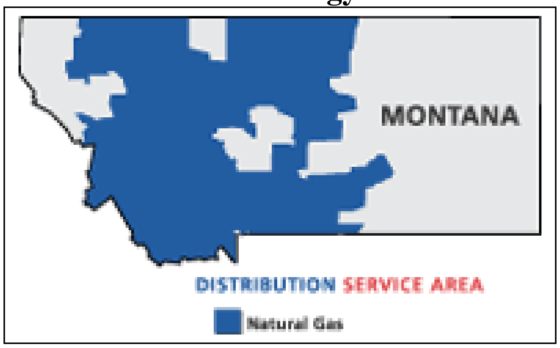
Facility Name	Location
Glendive Medical Center	Glendive
Big Horn Memorial Hospital	Hardin
Great Falls Clinic Surgery Ctr	Great Falls
Great Falls Clinic Surgery Ctr	Great Falls
Marias Medical Center	Shelby
Rocky Mt Surgical Center	Bozeman
Northern Rock's Surgi Center	Billings
St Lukes Community Hospital	Ronan
Phillips County Hospital Assn	Malta
Marcus Daly Memorial Hospital	Hamilton
Daniels Memorial Hospital	Scobey
Sheridan Memorial Hospital	Plentywood
St Lukes Community Hospital	Ronan
Marcus Daly Memorial Hospital	Hamilton
Rocky Mt Surgical Center	Bozeman
Yellowstone Surgery Center	Billings
Yellowstone Surgery Center	Billings
Yellowstone Surgery Center	Billings
Blackfeet Indian Health Service	Browning
Mountain View Nursing Home	White Sulphur Springs

5.5 Propane versus Natural Gas

The boiler database provides no information that can be used to directly estimate whether the fuel source for boilers listed as using "gas" or "gas/oil" use natural gas or propane. However, it can be assumed that any gas or gas/oil boiler located in an area that is not served by natural gas line must be using propane. It is also reasonable to assume that any gas boiler located in an area where natural gas is available would use natural gas as the primary fuel source, since propane is more expensive, although exceptions to this assumption are known to occur.

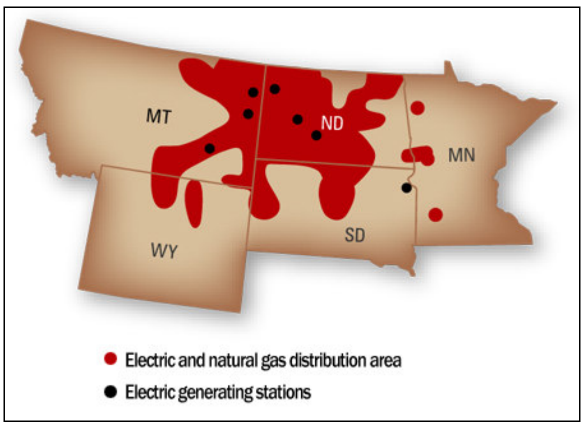
Northwestern Energy (NWE) and Montana-Dakota Utilities Co (MDU) are the two companies that provide Montana with natural gas. Maps illustrating the natural gas service areas for these two companies are provided in figures 11 and 12. Both NWE and MDU were contacted to determine which cities and towns in Montana did not have access to natural gas. Boilers in these towns that list "gas" or gas/oil as their fuel source could be assumed to be using propane. Based on this information and this assumption, 407 out of 6,102 boilers with gas listed as their fuel source can be assumed to be using propane (this number could be higher). The boiler database was modified to assume that these 407 boilers use propane. The database analyses presented in this report reflect that change.

Figure 11. Northwestern Energy's Natural Gas Service Area



http://www.northwesternenergy.com/showitem.aspx?M=1852&I=67

Figure 12. Montana-Dakota Utilities' Natural Gas Service Area



http://www.mdu.com/our_company/company_eng_distribution.htm

5.6 Facility Types with Majority of Eligible Boiler Conversions

Table A-1 (in the appendix) indicates that with the revised analysis of the database (reflecting updated fuels prices, identification of propane boilers, and elimination of inappropriate electric boilers and boilers with unusable information), there are 342 boilers with paybacks of less than 15 years. Of these 342 boilers, 91 have paybacks of less than 10 years, 47 have paybacks of less than 7 years, and no boilers have paybacks of less than 5 years.

Of the 91 boilers with paybacks of less than 10 years, 60 listed *Not Applicable* for the facility type, 15 listed *hospital*, and 15 listed *school*. A list of the schools and hospitals with paybacks less than 10 years is provided in Table 13 and 14. Institutions such as schools and hospitals may have financial structures that can tolerate longer payback periods as compared to businesses which may require payback periods of less than 5 years.

Table 13. Hospitals with Simple Paybacks less than 10 years

Existing Boiler Size (mmBTU/ hr)	Simple payback (years)	30-year cumulative net cash flow	Facility	City
12.50	9.64	$3,630,955	DEACONESS MED CTR/BOILER RM	BILLINGS
12.54	9.61	$3,645,698	NORTH VALLEY HOSPITAL-BLR RM	WHITEFISH
12.54	9.61	$3,645,698	NORTH VALLEY HOSPITAL-BLR RM	WHITEFISH
14.64	8.23	$4,421,540	BENEFIS HEALTHCARE EAST-BLR RM	GREAT FALLS
14.64	8.23	$4,421,540	BENEFIS HEALTHCARE EAST-BLRM	GREAT FALLS
20.00	6.78	$6,288,024	DEACONESS MED CTR/BOILER RM	BILLINGS
20.00	6.78	$6,288,024	DEACONESS MED CTR/BOILER RM	BILLINGS
20.00	6.78	$6,288,024	DEACONESS MED CTR/BOILER RM	BILLINGS
20.92	6.67	$6,600,335	COMMUNITY MEDICAL CENTER	MISSOULA
20.92	6.67	$6,600,335	COMMUNITY MEDICAL CENTER	MISSOULA
24.00	6.37	$7,638,560	ST PETER'S HOSPITAL - BLR RM	HELENA
24.00	6.37	$7,638,560	ST PETER'S HOSPITAL-BLR RM	HELENA
26.78	6.16	$8,577,183	BENEFIS HOSPITAL - BLRM	GREAT FALLS
63.13	8.98	$2,837,115	NEW HOSPITAL - A-BLR RM	BOZEMAN
63.13	8.98	$2,837,115	NEW HOSPITAL - A-BLR RM	BOZEMAN

Table 14. Schools with Simple Paybacks less than 10 years

Existing Boiler Size (mmBTU/ hr)	Simple payback (years)	30-year cumulative net cash flow	Facility	City
12.31	9.79	$3,559,820	BEAVERHEAD HIGH SCHOOL-GYM	DILLON
13.84	8.71	$4,124,103	CUT BANK HIGH SCHOOL-BLR RM	CUT BANK
14.50	8.31	$4,368,097	JUNIOR HIGH SCHOOL-BLR RM	KALISPELL
14.50	8.31	$4,368,097	JUNIOR HIGH SCHOOL-BLR RM	KALISPELL
17.25	7.17	$5,359,530	MONTANA TECH OF UNIV OF MT	BUTTE
18.50	6.98	$5,781,572	WESTERN MONTANA COLLEGE	DILLON
20.38	6.73	$6,415,360	MONTANA TECH-HEATING PLANT	BUTTE
24.44	6.34	$7,787,795	WESTERN MONTANA COLLEGE	DILLON
50.00	5.32	$14,926,827	MSU - CENTRAL PLANT	BOZEMAN
50.00	5.32	$14,926,827	MSU - NUTRITION CENTER	BOZEMAN
5.36	9.78	$1,855,179	CIRCLE HIGH SCHOOL	CIRCLE
5.99	9.22	$2,157,249	ROOSEVELT ELEMENTARY SCHOOL	EUREKA
7.25	8.40	$2,759,951	DUTTON HIGH SCHOOL	DUTTON
7.96	8.05	$3,100,858	RONAN SCHOOL	RONAN
7.96	8.05	$3,100,858	RONAN SCHOOL	RONAN

Note that Western Montana College in Dillon is in the process of converting to biomass. This facility was included in this table for comparative purposes.

These values suggest that of the facility types for which we have information, hospitals and schools appear to be facility type with the greatest number of boilers that appear to be most eligible for conversion.

5.7 Boiler System Type

CTA's experience to date suggests that biomass boilers that are 1 mmBTU/hour or smaller would likely best be designed to use wood pellets as their fuel source; boilers greater than 1 mmBTU/hour are better suited to using wood chips. Analyses of potential boiler conversions conducted for this study indicate that none of the boilers with a payback of less than 10 years are smaller than 1 mmBTU/hour. This suggests that pellet boilers are less likely to be appropriate for boiler conversion projects; however, they may be appropriate for new installations.

Small boilers systems are disadvantaged because they are likely to have a lower annual fuel use and insufficient annual fuel savings to cover conversion to biomass. Small biomass systems are also more expensive on a per-unit basis than large systems. For very small systems, fossil fuel system costs are very low in comparison to wood systems.

5.7.1 Total Project Cost vs. Boiler Size

The payback analyses presented in this report use a boiler cost curve that was developed by CTA based on industry information modified by local experience. This curve is presented in Figures 13 and 14.

Figure 13. Boiler system cost based on boiler size for boilers 0.1 to 80 MMBTU/hour

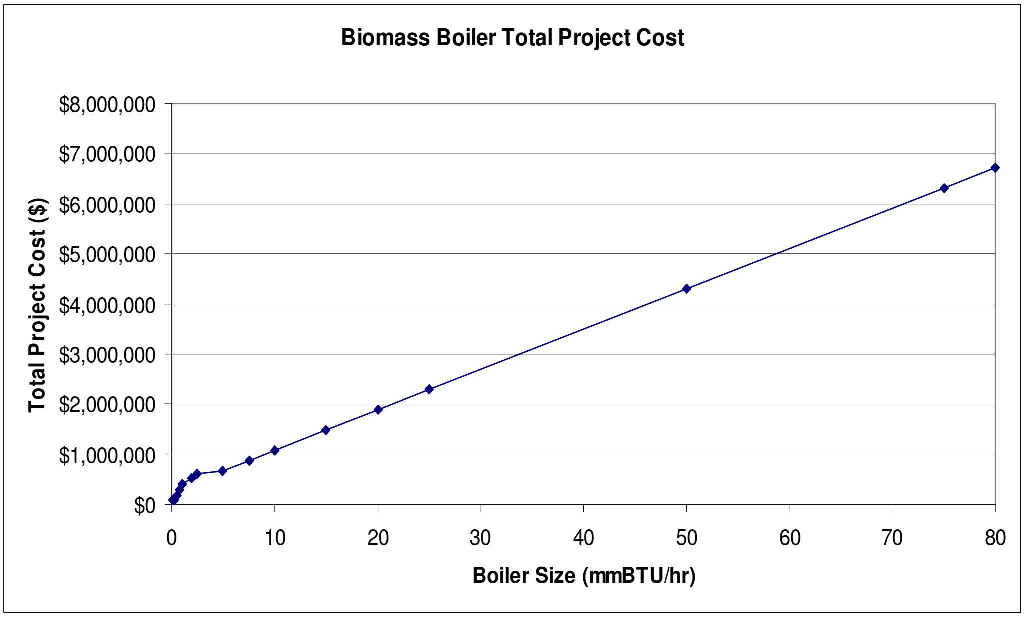
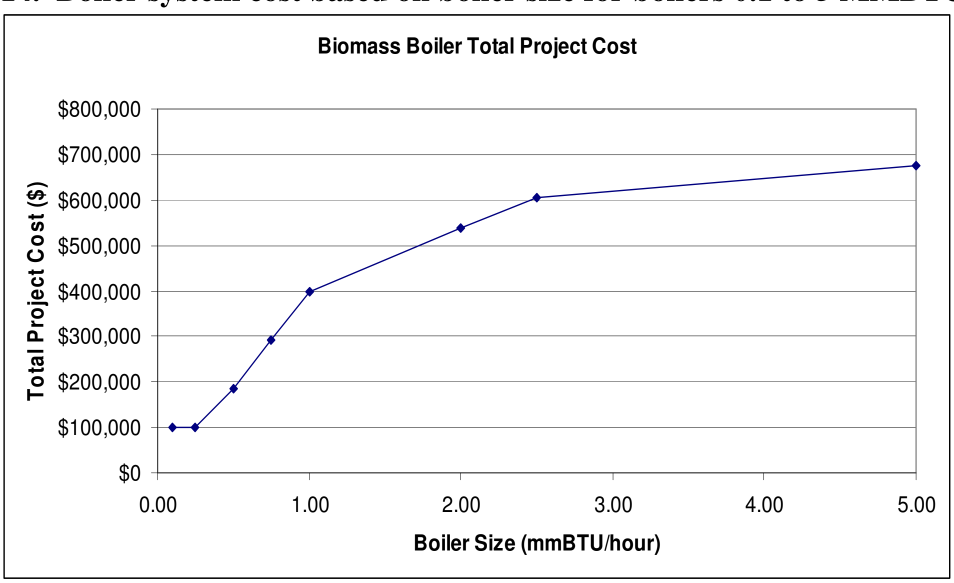


Figure 14. Boiler system cost based on boiler size for boilers 0.1 to 5 MMBTU/hour



As might be imagined, biomass boiler projects benefit from economy of scale – larger projects are less expensive on a unit basis than smaller projects. This is illustrated in Figure 15.

Figure 15. Total Project Cost per unit size

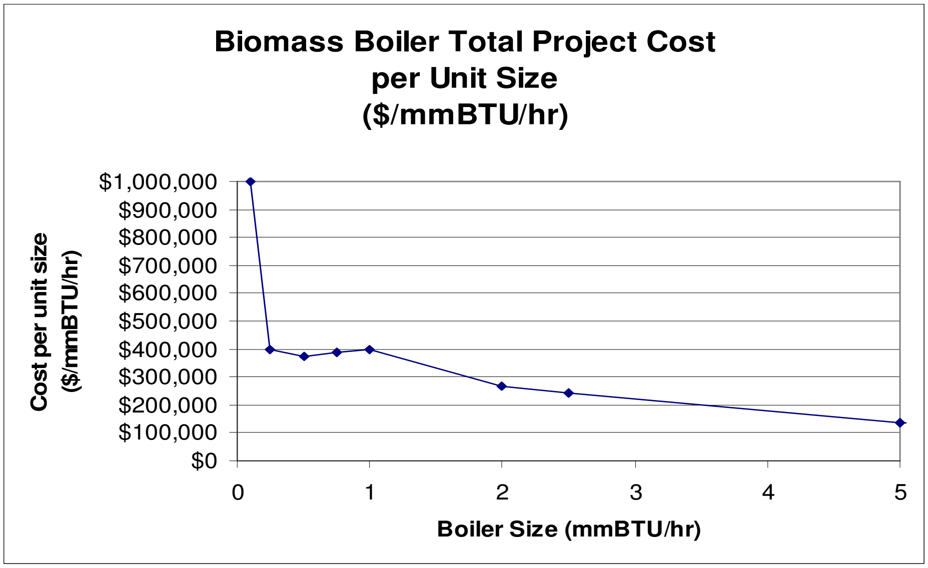


Figure 15 illustrates that boilers that are around the 1 mmBTU/hour are not optimal from an economic standpoint. Energy analysis might indicate that optimal performance would be achieved by a smaller boiler, but smaller boilers can actually be more expensive than slightly larger boilers in the 1 MMBTU/hour range. This size is at the upper end of the size range for pellet systems, and at the low end of the size range for wood chip systems. Pellet boiler technology is also geared towards very small systems (less than 500,000 BTU/hour); above 500,000 BTU pellet system manufacturers have less experience.

Smaller pellet systems face a set of additional cost barriers.

- All wood boiler vendors are very busy (pellet and chip)
- There is a lack of experience in bidding pellet projects
- The State of Montana requires ASTM certification on boilers. Many pellet boiler systems are made outside the U.S. and don't have this certification; obtaining this certification adds cost to the system.

Note that integrating a pellet system into a new facility should be effective in controlling total project cost (similar to experience with the wood chip system at Glacier High School).

5.8 Best Conversion Opportunities

The analyses of conversion opportunities presented in this report are based on project economics as represented by total project cost, simple payback, and 30-year cumulative net cash flow. Based on these analyses of the boiler database, there are a total of 342 boilers with a simple payback of less than 15 years. Of these 342 boilers, 91 have a payback of less than 10 years, 47 have a payback of less than 7 years, and no boilers have a payback of less than 5 years.

5.8.1 Boiler Characteristics

Based on simple economics, the best opportunities for conversion are those boilers with a payback of less than 10 years. Table A-1 in the Appendix presents all of the boilers in the state with simple payback of less than 10 years. The basic characteristics of the 91 boilers with a payback less than 10 years are illustrated in figures 16 to 18 below. Note that the number of boilers with paybacks of less than 10 years reflect both project economics and the total number of boilers that exist in each category.

Figure 16. Sizes of boilers with paybacks of less than 10 years

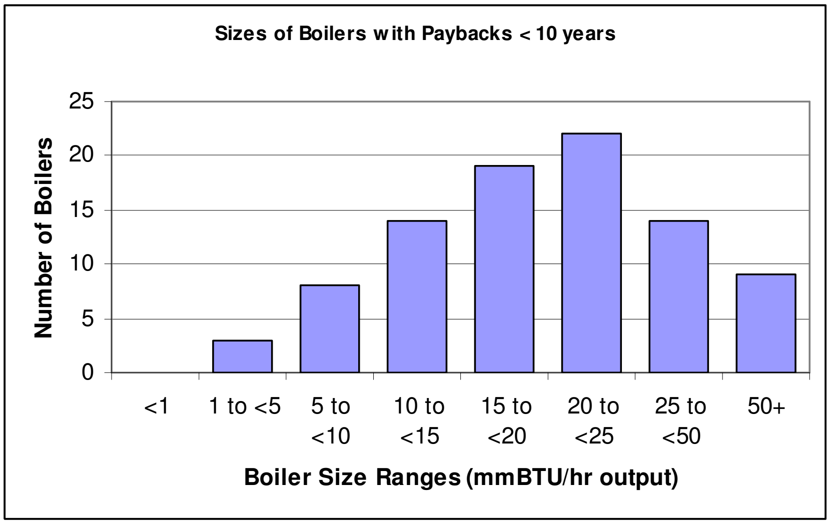


Figure 17. Existing Fuel Types of boilers with paybacks of less than 10 years

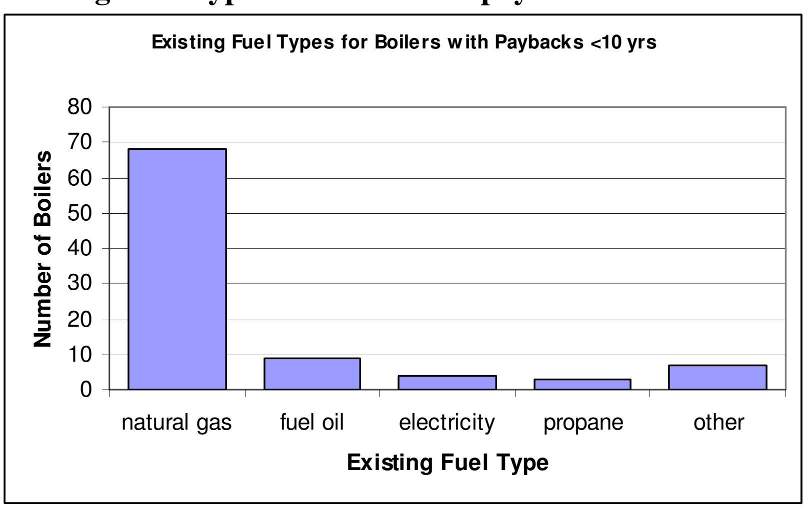
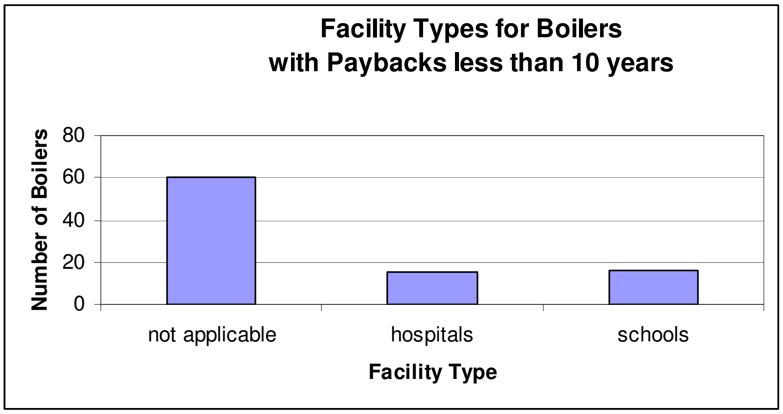


Figure 18. Facility Types of boilers with paybacks of less than 10 years



5.8.2 Other Considerations

This section is based on converting existing boilers to biomass boilers for individual facilities. Other potential market opportunities not discussed in the section include connecting boilers in several facilities via district heating, developing combined heat and power system, and using boilers for both heating and cooling.

As discussed earlier in this report, facility owners have differing financial expectations, risk tolerances, and structures. Institutions and government agencies are likely able to take a longer financial view than private sector facilities. Universities, in particular, may have additional drivers for using wood biomass (for example, using renewable energy) for facility heating.

The success of the Fuels for School program to date has greatly increased the number of smaller schools that are interested in converting their existing boilers to wood-fueled boilers. Although smaller facilities tend to have longer payback periods, facilities already familiar with biomass boiler system may represent greater conversion opportunity than facilities with shorter payback but lacking such familiarity.

It is also important to note that the analyses presented in the report are based on current conditions. Fossil fuel prices are volatile and the biomass boiler market is rapidly changing. This combination is leading to emerging opportunities in biomass systems in general and smaller system in particular. In the near future, however, the focus of the market appears to be on larger (>1 mmBTU/hour) boiler systems.

5.8.3 Summary

Based on the analyses in this report and the experience CTA has gained with wood biomass boiler systems over the last five years, it appears that the best opportunities for conversion are boilers that have a payback of less than 10 years that are located at universities, hospitals, and other institutions, and boilers with paybacks less than 7 years in private sector facilities.

The boilers installed through the Fuels For Schools program provide future facility operators with a wide range of built applications of wood boiler systems to review prior to proceeding with a wood boiler project. It is important for the participants in the Fuels For Schools program to maintain accurate records of wood consumed, fossil fuels consumed, the price of wood and fossil fuels, and resources spent on operations and maintenance. For some users, air quality monitoring results have a significant impact on their decision to invest in a wood boiler system.

6.0 NEW INSTALLATIONS

The previous sections of this report addressed biomass boilers as a replacement for existing fossil fuel boilers. Experience indicates that biomass boiler installations in new construction projects may prove to be an even greater potential market than boiler conversions.

When designing a new building, it is possible to more carefully model the future energy use and to match the biomass system size to the projected heating load. If a new facility combines the use of conventional and biomass fuels, the biomass system does not need to meet 100% of the load, which allows the biomass system to work more effectively, with the fossil fuel source operating at low load and peak load conditions. New installations reduce or eliminate the additional costs associated with integrating the wood boiler system into the facility. For example, any heating system would require pumps, valves, piping and control systems, and the cost of providing those components of the heating system for the wood boiler system are rarely different from those of a fossil fuel system.

New installations are also a good opportunity for wood pellet systems that use an array of small boilers to match the heating load. New facilities are often heated with an array of fossil fuel boilers in order to match the fluctuations in the heating load. Small wood pellet boilers are similar in size to fossil fuel boilers and can be installed in a manner that requires only one feed auger from a pellet storage silo to deliver pellets to a small metering bin for each pellet boiler.

The potential numbers and locations of new construction projects involving biomass heat will likely be determined based on: (1) the projected location and rate new construction (development), and (2) the viability of biomass boilers in new installations associated with potential development.

6.1 Examples of New Construction Installations

An example of a biomass boiler heating system installed in a new building is the new Glacier High School located in Kalispell, Montana. The School District reviewed the preliminary cash flow assumptions for the project (indicating approximately 750 tons of wood chips on an annual basis and approximately $1,400,000 in savings over a thirty year period), and determined that providing future generations with flexibility of heating fuel resources made sense. As the building design and energy model for the project was developed, it was determined that the facility would use approximately 2,000 tons of chips each year, and generate savings of more than $4,000,000 over a thirty year period. The recent rise in natural gas prices only improved the project performance. The school district had selected a Construction Manager at Risk to bid and construct the project, allowing the wood boiler system contractor to be selected well in advance of the remaining building components.

The total project costs associated with the project are similar to the semi-automated wood boiler system in Thompson Falls, although the wood boiler system in Glacier High School will be fully automated and has a heating capacity four times that of Thompson Falls. Much of the control of the total project cost came in the form of a minor expansion of the boiler room footprint (from 750 to 1,500 SF) and that the materials used to enclose the space are a small portion of a building that is approximately 230,000 SF in size. Additional control of the total project costs came in the form of low fees (a minor addition to the basic architecture and engineering fees associated with the project), CMAR bonding (the CMAR is bonding the entire $40 million dollar project, and the wood boiler system is a minor portion of that bond), building permits (the wood boiler system permit is a small portion of a large project), and that a crane already on site for erecting the steel frame can also be used for boiler installation.

One immediate benefit of the wood boiler system to the project is that during the second winter of construction when the building is fully enclosed and heat is needed to complete the installation of mechanical and electrical systems and interior finishes, the wood boiler system should be available for providing that heat at a substantially lower price than temporary natural gas or propane heating units. This should also allow for a full year of training on the system in many different loading conditions prior to occupancy.

6.2 Projections for New Installations

There are two components to estimating the potential for biomass boiler installations in new construction projects: (1) predicting new construction projects and (2) predicting which of these new construction projects might be viable for biomass boilers.

The following section presents the results of projections using two different approaches. The first uses boiler installation data from the last 10 years as a basis for predicting boiler installations for the next 10 years. The second uses a GIS tool called Business Analyst to predict population growth by geographic region and then use these data to generate estimates of the construction potential for new facilities by facility type.

6.2.1 Projections based on boilers installed in last ten years

The boiler database was analyzed to determine the characteristics of boilers installed over the past 10 years. This information can be used as one prediction of the numbers and characteristics of boilers that might be installed in the state over the next 10 years.

Analysis of the boiler database indicates that over the last 10 years (1994 through part of 2004) there were 2,825 boilers installed in Montana. The database does not indicate if these boilers were replacements or new construction installations so it is likely that some of these boilers are replacements installed in existing facilities. **Using the past as a predictor of the future, these numbers suggest that an average of about 280 boilers will be installed in Montana each year,** some of which will be replacements in existing facilities**.**

6.2.1.1 Boiler installations by year

The number of boilers installed each year for the past 10 years is presented in Table 15. The values in this table suggest that the numbers of boilers installed each year over the past year has remained fairly consistent.

Table 15. Number of boilers installed in Montana each year for the past 10 years

Year of Installation	Number of Boilers
1994	262
1995	273
1996	213
1997	293
1998	330
1999	298
2000	283
2001	292
2002	354
2003	214
2004*	13
average**	282

** represents only part of 2004*
*** does not include 2004*

6.2.1.2 Boiler installations by facility type

The numbers of boilers installed over the past 10 years by facility type is listed in Table 16. Although most of the boilers listed in the database list *Not Applicable* under the facility type, this information suggests that almost 50 boilers are installed each year in schools, and almost 20 are installed each year in hospitals, assisted living facilities, and rest homes.

Table 16. Number of boilers installed in Montana in the last 10 years by facility type

Facility Type	Number of Boilers
Not Applicable	1,783
School	491
Church	148
Public Assembly	130
Hospital	127
Assisted Living	33
Retirement Center	33
Rest Home	72
Day Care	7

In the previous study we indicated that the thermal profile (heat and hot water demands) of hospitals, assisted living facilities, and rest homes make them better candidates for biomass boiler systems. It is important to note, however, that these boilers may or may not be used for heat and hot water demands – some may be used for sterilization or very small systems that would not be viable as biomass systems. In addition, CTA has found that some boilers in hospitals and nursing homes are used only for space heat (and not domestic hot water or cooling), and would not produce the same savings as steam boilers in hospitals that produce space heat, domestic hot water and cooling using absorption chillers.

6.2.1.3 Boiler installation by size

The number of boilers installed over the past 10 years by boiler size (BTU/hr) is listed in Table 17.

Table 17. Number of boilers installed in Montana in the last 10 years by boiler size

Boiler Size (BTU/hr)	**Number of Boilers**
< 300,000	1,067
300,000 to <999,999	1,071
1,000,000 to 2,999,999	526
3,000,000 to 5,000,000	80
> 5,000,000	81

CTA's experience suggests that boilers less than 1,000,000 BTU/hr in size are better candidates for using wood pellets rather than wood chips, although systems are now being developed to manage and convey wood chips for smaller systems.

The most problematic size range appears to be between 800,000 and 1,000,000 BTU/hr. Boilers in this size range are larger than many wood pellet system manufacturer's standard sizes yet smaller than many wood chip boiler system sizes. There may be an opportunity for manufacturers to fabricate systems that meet the needs of this significant market sector.

6.2.1.4 Equivalent wood fuel value

Table 18 presents the number of boilers installed in Montana over the past 10 years categorized by the wood fuel value equivalent (mmBTU/year).

Table 18. Number of boilers installed in Montana in the last 10 years by wood fuel value required

Wood Fuel Value Required (mmBTU/year)	**Number of Boilers**
<2,000	2,538
2,000 to <5,000	200
5,000 to <10,000	46
10,000 to 20,000	29
> 20,000	12

Analysis of the database suggests that if all of the 2,825 boilers installed in Montana over the last 10 years used wood as a fuel source, they would require an estimated total of 2,883,542 mmBTU/year wood fuel value, or an average of 1,021 mmBTU/year per boiler. Assuming the fuel value of wood is 10.8 mmBTU/ton (at 40% moisture), this translates to an equivalent of 266,995 tons wood per year for all of the boilers installed over the past 10 years, or an average of 94 tons wood per year per boiler. For comparison, the smallest wood chip boiler system in the Fuels for Schools is projected to burn approximately 350 tons of material per year.

If, as indicated in Table 19, an average of 280 boilers were installed each year, that would translate to a new wood demand of 26,320 tons of wood per year, which could be generated from thinning from approximately 2,600 acres per year.

CTA's experience suggests that biomass boiler projects with fuel requirements less than 1,000 to 3,000mm BTU/year are unlikely to be viable (except under unique circumstances). Using 2,500 mmBTU/year as a guideline, only 281 (about 10%) of the 2,816 boilers installed over the past 10 years in Montana would have been viable as biomass systems. Using the past as a predictor of the future, this information suggests that about 28 boilers will be installed each year that would be viable as biomass systems. The sizes of these systems would vary, but based on the information in the paragraph above, this would translate to a new wood biomass demand of about 2,632 tons/year which could be generated from thinning an additional 260 acres/year (biomass and acreage numbers are rough estimates).

6.2.1.5 Boiler installation by fuel source

Table 19 presents the number of boilers installed in Montana over the past categorized by the fuel source used. Similar to the overall database, almost 90% of the boilers installed over the past 10 years use natural gas as their fuel source.

Table 19. Number of boilers installed in Montana in the last 10 years by fuel source

Fuel Source	Number of Boilers
natural gas	2,365
propane	241
other	134
oil	44
electric	32
wood	2
coal	7

6.2.1.6 Boiler installation by boiler use

Table 20 presents the number of boilers installed in Montana over the past 10 years categorized by boiler use. Most of these boilers (75%) were installed for space heating using water as the medium.

Table 20. Number of boilers installed in Montana in the last 10 years by boiler use

Boiler Use	Number of Boilers
Space Heating - Water	2,089
Hot Water Supply	341
Space Heating - Steam	275
Process	85
Power	19
Other	16

6.2.2 Projections based on GIS demographic and economic data

In this section, available GIS demographic and economic data were analyzed to estimate the number of new boilers that might be installed in new facilities in the next 10 years. These projections are based on assuming that most boilers are located in businesses (as defined by the Census; likely to include most schools), that historical business growth rates will continue over the next 10 years, and the percentage of businesses that contain boilers will remain the same over the next 10 years.

6.2.2.1 Method

The State's boiler database was compared with census projections and with commercial demographic and economic data derived from ESRI Business Analyst commercial data sources and other demographic and economic research reports from Montana. This analysis was completed at the county level. This analysis does not predict boiler demand in new installations, but attempts to identify broad demographic and economic trends in Montana and describe correlations between data sources and descriptive statistics to provide a better understanding of the potential demand. The complete analysis is presented in **Boiler2 GIS Demographic and Economic Report** by Geodata Services (May 2006), which is available upon request. The information presented below was derived from the information presented in the GIS report.

Data from the Census Bureau County Business patterns were used to determine the number of business in each county of Montana for the years 1998 and 2003. Annual growth rates for businesses in each county were calculated from the census data by subtracting the number of businesses in 1998 from those in 2003, and calculating a simple annual growth rate dividing the subtracted amount by the time period. (*There are many additional factors affecting the actual annual growth rate that are not accounted for in this simplistic estimate; caution should be used in interpreting these results.*) This information can be found in the Montana Demographic & Economic Report developed for this study by Geodata Services Inc (not included due to length). As might be expected, the greatest growth rates occurred in the western counties, and those counties in the Billings area.

6.2.2.2 Projection estimates

The number of business in each county in 2003 was combined with the annual growth rates to predict the number of businesses in each county in 2006 and 2016 (2016 represents a 10-year projection). Information in the State's boiler database was compared to Census Bureau data to estimate the percentage of businesses in each county that have boilers. These percentages were applied to the predicted number of businesses in each county in 2006 and 2016 to calculate the estimated number of boilers that might be installed in new businesses over the next 10 years.

Using the GIS data and projection methods described above, there will be an average of about 84 new boilers installed in new facilities in Montana each year for the next 10 years. Note that this number applies only to businesses as defined by Census Bureau County Business patterns.

The two different projection methods presented suggest two different estimates for the number of new boilers that might be installed each year in Montana – one method indicates 84 new boilers will be installed in Montana each year, and the other methods indicates 280 new boilers/year. The method indicating 84 new boilers per year was based on the number of new buildings built each year in Montana, while the method suggesting 284 new boilers/year covers both new boilers installed in new building, multiple boilers in a single building and new boilers installed in existing buildings as replacements.

6.3 Opportunities for District Heating

Both of the prediction tools listed above assume that new boiler installations will follow patterns similar to past installations – one or more boilers installed to serve single facilities. An alternative installation scenario is district heating, where steam or hot water generated by one or a set of boilers is distributed to multiple buildings.

The project team for this study believes that the potential exists for using biomass boilers for district heating in new construction projects in Montana. One potential application would be in the rapidly growing "box store" retail areas (like North Reserve Street in Missoula) that are springing up on the edge of cities around Montana. Another potential application would be in existing or expanding university, government, retirement, and health care campuses across the state. In both cases, it is believed that the greatest viability would be achieved if the concept of district heating were introduced early in the process, such as during master planning. Montana State University and the UM College of Technology are in the process of updating their campus plans – an ideal time to introduce the possibility of conversion to biomass boiler systems. A study is currently underway to evaluate the potential for district heating for the city of Philipsburg, Montana.

One example of a biomass district heating system is District Energy St. Paul in Minnesota. According to their website (http://www.districtenergy.com/AboutUs/):

> *District energy systems produce hot water, steam or chilled water at a central plant and then distribute the energy through underground pipes to buildings connected to the system. Individual buildings do not need boilers, chillers or cooling towers. Customers*

use the hot and chilled water to meet their space heating, water heating, processing and air-conditioning needs. Once used in customer buildings, the water is returned to the central plant to be reheated and re-chilled and then re-circulated through the closed-loop piping system.

District Energy St. Paul uses wood chips (biomass), natural gas, oil or clean-burning coal to fuel its district heating and cooling systems. With the April 2003 startup of an adjacent wood-waste-fired combined heat and power facility, managed by an affiliate, the company reduced its reliance on coal and oil by 80 percent. This produces significant environmental benefits and helps the community solve a local wood waste disposal problem. Our customers benefit from reduced costs, yet another fuel source, and the knowledge that they are using an environmentally sustainable source of "green energy" to heat and cool their buildings.

District energy systems offer many environmental benefits. They increase energy efficiency; reduce air pollution; decrease emissions of ozone-depleting refrigerants; combat global warming; enhance fuel flexibility; facilitate the use of renewable energy; and help manage the demand for electricity.

6.4 Opportunities for Combined Heat & Power

Wood boiler systems have been used to generate power by using waste heat to turn a turbine or using steam to operate a piston or turbine. Waste heat turbine systems are still in the developmental stages, and do not appear to be commercially available in the United States. A steam piston generator is currently being used at the Eagle Stud Mill in Hall, Montana. The piston generator is approximately 50 years old, and was removed from another facility. It appears that piston generators are no longer in production, and are typically relocated from other facilities. Steam turbines continue to be manufactured and installed throughout the country.

Electrical load profiles and steam flows are required to determine project viability; these data are not available from the boiler database. Boilers in the database listed as providing power vary in size from 120,000 to 8,000,000 BTU/hr in size, however many gaps in the data exist.

Based upon research done for the wood boiler system at the University of Montana-Western campus in Dillon, a steam turbine capable of providing approximately 150 kw would add approximately $850,000 to the project cost. The turbine would require at least a 200 psi boiler, operating at 150 psi or less. The boiler is piped in a manner that allows the steam to flow through the turbine or through a separate pressure reducing station. The change-over is typically automated to reduce the risk of the turbine tripping off-line, or building excessive steam pressure. Combined heat and power system are optimized when they operate 24 hours a day, 365 days a year, reducing power demands on campus from 6 am to midnight, and selling power back to the grid from midnight to 6 am. Initial investigations suggested that Northwest Energy may not have a need for the surplus power generated by this system during off-peak hours. Combined heat and power systems may require additional staffing, further eroding any potential savings.

The greatest limitation on co-generation appears to be steam flow. Combined heat systems with the best paybacks are designed around steam flows of 10,000-15,000 pounds/hour. Many facilities in Montana may only achieve steam flows at those levels intermittently.

The best opportunities for combined heat and power appear to be existing facilities operating high pressure boilers 24 hours a day, with steam flows greater than 10,000 pounds per hour. Currently the University of Montana in Missoula and Montana State University in Bozeman operate combined heat and power facilities using natural gas as the fuel source. Other facilities of similar size may be identified from the State of Montana DNRC and A&E division.

6.5 Opportunities for Gasification

An emerging technology is the gasification of wood, resulting in a gas used to generate heat in a furnace or boiler or to turn a turbine in order to generate power. Nexterra has developed and installed gasification systems for large industrial users such as wood mills. Community Power Corporation, Biomaxx and the Energy and Environmental Research Center at the University of North Dakota are each in the process of developing gasification systems, some of which may be commercially available in the future. The majority of the smaller gasification systems are projected to be in the 200,000 to 1,000,000 btu size range and may reduce the initial capital investment if the gas produced is used in conjunction with an existing boiler to produce heat rather than to generate power. As gasification systems become commercially available, the financial viability of small scale wood boiler systems may improve.

6.6 Opportunities for Cooling

A limited number of facilities heated with wood have also incorporated absorption chillers into the steam cycle to provide chilled water for cooling. The University of Idaho in Moscow, Idaho and Chadron State College in Chadron, Nebraska have used this technology to heat and cool college campuses with wood fired boilers.

In order to incorporate this technology into a project, a significant demand for cooling must be needed over many months of the year. For example, the annual heating load in Moscow, Idaho is roughly equal to the annual cooling load. In many communities in Montana, cooling is not integrated into facilities, or is provided using cooling towers, packaged condensing units or heat pumps.

Absorption chillers require the production of steam. Facilities using boilers that produce hot water would not be able to incorporate absorption chillers.

The use of absorption chillers should be addressed early in the design and development of a project in order to determine the potential costs, benefits and disadvantages of using such a system to provide cooling for a facility.

7.0 FEEDBACK FROM POTENTIAL CONSUMERS

Successfully moving the USDA initiative beyond the Fuels for School program and towards commercialization requires understanding how information, issues, and viability factors are perceived and considered by potential customers of biomass heating system.

To get a sense of what potential costumers think about biomass heating system, a variety of facility owners were selected for interviews. Facility owners to be interviewed were selected from the following categories:

- Existing boilers that appear to be good candidates for conversion
- Facilities that had positive initial assessments but chose not to install a biomass boiler
- Facilities that have (or had) biomass boilers that were not associated with the Fuels for Schools program

Where possible, interviewees within each of these categories were further selected to obtain viewpoints from industries, universities, and other institutions. The list of facilities that were interviewed is provided in the Appendix.

Each interviewee was provided pertinent excerpts of this report and a set of interview questions, and then later interviewed over the phone. The interviewees were asked to discuss the financial, O&M, fuel, and other factors that did or might affect their choice of boiler heating system. A summary of the information derived from these interviews is presented below.

7.1 Facilities with positive assessments but did not convert

There were four facilities interviewed that fell within this category. The facility types interviewed were schools and hospitals.

7.1.1 Financial Factors

Lack of ability to cover initial costs was cited by more than one interviewee. Most indicated that payback on initial investment would have to be less than 10 years, but even with a good payback these facilities felt that it would be difficult to come up with the necessary funding for initial costs. One facility said they had a bad experience with something they believed was performance contracting and are not willing to consider that as an option. Schools in rural areas that are losing student population are concerned about getting less money from the State in the future.

One facility felt that their positive assessment was due to overly optimistic (or pessimistic in the case of the cost of natural gas) assumptions. They did not want to spend more of their limited resources investigating a project that was likely to be less financially beneficial than presented.

One interviewee said that the value engineering (focused on reducing firsts costs, rather than focused on total cost of ownership) done on a major renovation project ended up cutting back on their heating system. They recognized that this upfront savings would cost them in the long run and wondered what such a cost cutting process would have done with a much more expensive biomass boiler heating system.

7.1.2 Operations & Maintenance Factors

Facility operators were generally concerned about the additional O&M required by biomass. Some were concerned about the additional cost and/or time for O&M, but there seemed to be a greater concern with additional real or perceived risk associated with biomass O&M – more things can go wrong. Several cited that natural gas systems are essentially maintenance free. One person cited the extra burden of having two systems (biomass plus natural gas) instead of one.

7.1.3 Fuel or Fuel Supply Factors

The reliability of a wood fuel supply was cited as the biggest concern by more than one facility. They would like to have a long-term contract for wood chips, at least 7 to 10 year guaranteed supply. One facility was concerned about environmentalists blocking the supply of wood. There were also concerns about how they would store large quantities of wood on site.

7.1.4 Other Factors

One facility had a relatively positive assessment, but felt they could not maximize the opportunity due to site logistics, including having multiple buildings on different systems. This facility needed a smaller system and wanted one that was "plug-and-play", which was not among the options considered in the assessment. (Note that this assessment appeared to be one of the earliest conducted.)

Space for the boiler building and fuel storage was another concern that was often cited. It was not clear from the interviews what was perceived as the space needs, in particular for wood fuel storage.

Air emissions were cited as a concern. One facility was concerned that there might be special issues related to air emissions due to their close proximity to a national park. This facility was also concerned about public perception – steam coming out of the stack would be perceived by the public as smoke. This person wanted to see several working examples of biomass boiler systems that had no emission problems at all, not just theoretical numbers.

One facility indicated they did not pursue funding because of timing. They were preparing for a large facility expansion and felt they missed the opportunity to get biomass under consideration. (Note that this facility did the expansion at the start of the FFS program.) It was not clear to them who would have applied for the grant, when biomass should have been considered. They wish they would have had more information on the process or sequence of events that has to occur (from the facility's end) to get biomass boilers considered for a new facility.

7.2 Existing or former wood boilers that were not part of FFS

There were four facilities interviewed that fell within this category. The facility types interviewed included a large wood products industry, a small industry (not wood products industry), a school that converted away from pellets, and a coal burning facility that was listed as wood burning.

7.2.1 Financial Factors

These facilities installed wood-burning boilers for economic reasons – it was less expensive than other systems. The school with the pellet boiler has switched to fuel oil (natural gas is not available) which is much more expensive than pellets.

7.2.2 Operations & Maintenance Factors

O&M factors were not cited by most facilities with existing boilers.

In this category there was one school that used to have a pellet boiler that cited O&M as the reason for eliminating their pellet boiler. This pellet boiler was designed, built, and installed by "local farmers and handymen" some 20 years ago and caused endless problems. Malfunctions in the safety switches and fuel loading end almost caused the school to burn down twice. The system required attention 2-3 times a day and had to be shut down once a week to clean out clinkers. If the pellets had any rocks or debris, the system would shut down. They also had to monitor the frequent deliveries of pellets which had to be ordered 1-2 months in advance. They also felt the system was very dirty. (Note that in the past, pellet manufacturing did not include systems to eliminate dust.)

7.2.3 Fuel or Fuel Supply Factors

One large existing wood biomass boiler facility was very concerned that the FFS program was taking fuel that is already in short supply for existing wood users. According to this interviewee, local facilities have had to shut down for several days this spring (2006) due to lack of supply. On the west coast, some facilities are buying low-grade studs to make chips. This interviewee felt that the USFS should put up additional timber sales in the area if it is going to subsidize new biomass boilers. They also cited increase competition for wood from mills that are able to use smaller diameter wood that was once used as fuel, new pellet mills in the area, and improvements at mills so that less wood waste is generated (wood waste that used to be available as fuel).

A facility with a small wood boiler system indicated that they have never had any trouble getting wood over the past 20 years.

The school with the pellet boiler indicated that there was only one source of pellets (Eureka) of high enough quality for their system.

7.2.4 Other Factors

One interviewee was listed in the boiler database as using wood, but they have been burning coal since 1966. They said that their utility bills are much less than other comparable hospitals in the state. Even with emission issues, they said that with their low heating costs, they had no reason to even consider converting to biomass.

One facility interviewed was a small industry that chose to strive to be energy self-sufficient more than 20 years ago. Their buildings are super-insulated, are designed to optimize passive solar gain, and are equipped with solar panels to help heat hot water. They installed a wood-burning boiler (Chief Brand) to generate hot water for radiant heat flooring. He said they get more heat with this system and that radiant heat is very nice.

The school with the pellet boiler indicated that dust from handling the pellets seeped into the school (which is old) and was a real problem.

7.3 Existing boilers that appear to be good candidates for conversion to biomass

There were eight facilities that had paybacks of less than 10 years (based on the analyses conducted for this study) that were interviewed for this study. Facility types included schools, public buildings other than schools, one non-profit, one small industry, and two hospitals.

7.3.1 Financial Factors

The size of the initial investment was daunting to some facility operators. Even when the potentially short paybacks were explained, it was hard for some to believe biomass boilers could make financial sense.   There was an expectation of 5-10 year payback for new equipment by most facilities. One hospital expected a 2-3 year payback on any investment. They look at investments in terms of $/sq ft payback, so an investment in new biomass boiler would be compared to a similar investment in other equipment, such as a new MRI machine.

One facility operator said he would need more information on savings, logistics, and layout, but if biomass boilers could save money, we have his interest. A non-profit facility didn't know how they would come up with the initial funding since they have to do fundraising for every investment they make.

One facility (an industry) recently replaced their existing boiler with an on-demand ("instant") water heating system. Their boiler was undersized and slow to respond to their demands.   They determined that the on-demand system would be a much smaller initial investment plus save energy costs down the road compared to a new boiler system.

7.3.2 Operations & Maintenance Factors

Biomass boiler systems were perceived by some to require significantly more O&M than natural gas boiler systems for things like watching fuel delivery and ash removal. Some had no idea how much additional O&M would be required for a biomass system. Others added that the number of moving parts increased O&M, made the system more vulnerable to break-down, and represented increased liability.

7.3.3 Fuel or Fuel Supply Factors

Availability and reliability of wood fuel supply, cost of fuel transportation, and on site storage of fuel were common concerns. Often, fuel supply was the main factor of concern – both availability and reliability. One facility was very excited to pursue a biomass system if they could get help with the supply end.

One facility was concerned that if they FFS program was successful and many biomass boilers were installed in the state, that the cost of wood chips would be driven up and the potential savings would be diminished.

One facility expressed concern that wood biomass was a much messier fuel than natural gas.

Another facility was very concerned about rising natural gas prices, and recognized that the paybacks would only become shorter as natural gas prices go higher.

7.3.4 Other Factors

Space to accommodate a new boiler system and future wood fuel storage was cited as a concern by several facilities. Space and logistics were of particular concern for one facility that was housed in a historical landmark building. One facility said they were located in an area of prime real estate value, so the space for a new biomass boiler would have to be compared to other things they could do with that land.

Air quality concerns were cited by several facility owners. One facility that uses natural gas with fuel oil as a back-up indicated they get complaints every time they switch to fuel oil. They were concerned that the same thing would happen if they switched to wood.

Some of the interviewees knew very little about biomass systems and wanted more general information. One wanted to see information from other similar biomass boiler systems. One (a non-profit) said they wanted to study the financial feasibility of converting to biomass, but couldn't afford to pay for a study.

One interviewee (from a hospital) had seen the presentation by Angela Farr (FFS Coordinator for Montana) and thought it was very informative. Based on this presentation and the assessment estimates shared during the interview, he felt it was foolish not to pursue biomass boilers and was in the process of filling out the FFS pre-feasibility assessment form.

The facility with the new on-demand hot water system indicated that it was very small and took up much less space than a boiler system. This facility is interested in trying out new technologies and approaches, and perceived boilers in general and biomass boilers in particular as very old technologies using an old approach.

7.4 Summary

High initial cost, uncertainty in the reliability of fuel supply, air emissions, space, and increased O&M were recurring concerns among existing and potential biomass consumers. Most interviewees indicated the need for more - and more specific - information, especially information based on existing demonstration projects. The Fuels for Schools pre-feasibility assessments have been considering a project to be "good" if the simple payback is less than 15 years with grant funding. Interviews indicate that facilities would like to see a payback of less than 10 years without grant funding, but also get grant funding to help minimize initial costs.

8.0 FEEDBACK FROM MANUFACTURERS

Projects constructed through the Fuels for School program have relied upon the expertise and input from more than a dozen manufacturers and vendors of wood heating systems. Completed projects in the region have integrated wood heating systems from Chiptec, Decton, KOB, Messersmith, Precision Energy Service and Solagen. In addition, Advanced Recycling Equipment and Talbotts have provided bids on projects in the past three years. Beyond the active vendor participants in the Fuels For Schools projects, CTA has been in contact with Biomas Combustion Systems and HS Tarm.

All of the vendors noted above were provided with a brief summary of this report and a two page survey in order to document feedback on the Fuels For Schools program and level of interest in serving the Montana market. In addition to written responses to the survey, an interview with the vendor was conducted over the phone. The vendors were asked to provide background information about their company, the wood heating systems they provide, the number of completed installations, feedback on the Montana market, project cost, bidding and constructing projects in Montana.

The information collected from this survey is discussed in general terms only. Specific responses from individual companies are not included or noted in this report.

8.1 Company Information

The vendors interviewed have been in business between 2-31 years. The variation in years reflects both the sustained interest in heating facilities with wood and the more recent market conditions that have allowed the wood heating industry to grow. Many vendors commented on how many vendors have come and gone from the industry in the past 20 years.

8.2 Manufacturer's System Information

Vendors were asked to provide information regarding the systems they design and construct.

8.2.1 Wood Fuel Types

The majorities of the vendors provide systems that burn wood chips, sawdust, wood pellets and hog fuel. Most vendors emphasized the need for good quality wood fuel and a consistent source of wood fuel. For example wood fuel with consistent size and moisture content, from a common source is more desirable than variations in chip size or moisture content. Wood fuel with low bole wood content in relation to bark, needles and debris have caused problems in the operation of wood-fired heating systems.

8.2.2 Wood Fuel Handling

The majority of the vendors provide conveying systems as needed for the project. Augers are most dominant conveying equipment. Walking floors and bucket elevators are used less frequently.

8.2.3 Combustion Methods

All but one of the vendors uses a direct fired combustion technology, resulting in a small footprint for the equipment but tall assembly of the combustion chamber and boiler.

8.2.4 Boiler System Size Range

Vendors provide systems between 300,000-60,000,000 BTU/hr. The majority of the vendors provide systems greater than 1 mmBTU and less than 20 mmBTU. Manufacturers of pellet boilers produce equipment between 50,000 and 150,000 and between 340,000-4,250,000 btu.

8.2.5 Heating Mediums

The majority of vendors of wood chip systems provide systems producing hot water, steam, and in some circumstances, hot air. In general hot air systems are used in agricultural facilities, or as a part of a fuel drying system. The majority of manufacturers of wood pellet systems provide hot water systems only.

8.2.6 Typical Emissions

All vendors emphasized the ability to comply with air quality standards for each project, which have varied from federal EPA standards, AP-42 standards for wood boilers, and state and local standards for PM-2.5 and PM-10. In some circumstances the base unit complies with emission standards, while other projects require the use of cyclones and bag houses to meet standards. (Vendors were not asked to provide emission data as part of the interview process.)

8.3 Number of Installations by Facility Type and Location

Vendors were asked to quantify the number of installations by facility type and location. The chart below summarizes that general information. Where no specific breakdown of project type was provided the quantities provided were averaged between the categories. The majority of wood heating systems have been installed in industrial applications, often related to the wood products industry. Most industrial users of wood heating systems have prior experience with wood fuel handling systems and the processes for acquiring new equipment.

The majority of the Non-US boilers have been provided by a single European manufacturer. Although the number of wood fired boilers installed by the vendors in Montana is relatively small, the overall number of wood-fired boilers installed by vendors throughout the US is significant and steadily increasing.

Table 21. Installations by Facility Type and Location

Facility Type	US	Montana	Non-US	Total
Schools	52	6	1,201	1,259
Hospitals	29	0	1,200	1,229
Civic	30	1	1,200	1,231
Commercial	38	0	1,200	1,238
Industrial	215	4	1,205	1,424
Total	364	11	6,006	6,381

8.4 Feedback on Montana Market

Six questions were asked regarding the Montana market for wood heating systems. The categories are listed below.

8.4.1 Capacity to Serve Growing Market in Montana

The combined capacity of the vendors surveyed is 75-130 systems per year. Small pellet boilers represent 55-105 of those systems while larger wood chip systems represent 20-25 of these systems. Most vendors anticipate serving the Montana market from their existing manufacturing facilities.

8.4.2 Level of Interest in Partnering with North American Boiler Manufacturers

The majority of the vendors have a long history of working with boiler manufacturers to provide wood fired heating systems. None of the vendors envisioned changing that relationship in any substantial way. CTA, DNRC and USFS had envisioned a potential benefit from a more direct partnership between boiler manufacturers and wood fired heating vendors. If future partnerships between boiler manufacturers and wood vendors lead to greater standardization in system types, the specification of wood fired boiler systems may be simplified.

8.4.3 Level of Interest in Partnering with Montana Mechanical Contractors

The majority of the wood heating system vendors are interested in working with Montana mechanical contractors to install and service projects constructed in the region. This relationship is likely to lead to expanded local expertise in the installation and service of wood fired boilers, and end user confidence in wood fired boiler systems.

8.4.4 Level of Interest in Partnering with Montana Manufacturers

None of the vendors had any interest in partnering with Montana manufacturers. The prevailing reason given is additional oversight of the staff and end product. Many emphasized the need for good quality systems to represent the capabilities of the wood heating industry. Others noted that transportation costs are high, but not a significant portion of the total project cost. Wood boiler vendors who partner with Montana manufacturers may identify a competitive advantage for future projects.

8.4.5 Market Conditions that would encourage Montana Manufacturing

Most vendors anticipated manufacturing their systems in their current or expanded facilities regardless of additional market activity in Montana.

8.4.6 Barriers and Opportunities

A dependable and consistent quality wood fuel source as noted in section 8.2.1 was most often cited as a potential barrier to the expansion of wood heating systems in Montana (or any other region). Several vendors emphasized the need to maintain a quality wood fuel source in order to minimize potential problems with non-industrial users of wood heating systems. All of the wood fired boiler systems installed through the Fuels For Schools program operate most effectively when the wood fuel supply is consistent in size, material type and moisture content.

8.5 Feedback on Project Cost

Vendors were asked a number of questions regarding potential cost savings on future projects. Those questions are summarized below.

8.5.1 Standardizing Boiler Systems to Reduce Cost

Many of the vendors felt that standardization of the boilers exists, and therefore is unlikely to result in any significant savings.

8.5.2 Bulk Purchase of Boilers to Reduce Cost

A limited number of vendors felt that bidding several wood heating projects in one package would reduce the cost of the project. Some vendors felt that the quantity of projects would not be great enough to realize any significant savings.

8.5.3 Improvements to Building Design to Reduce Cost

Considering the use of metal building technologies and packaged boiler buildings was suggested.

8.6 Feedback on Bidding

Vendors were asked a number of questions regarding the bidding process. Those questions are summarized below.

8.6.1 Preferred time of year

The preferred time of year varied significantly from vendor to vendor. Most emphasized the need for adequate time to construct and install the heating system.

8.6.2 Preferred bid duration

The preferred bid duration varied from vendor to vendor, with a preference for 4-5 weeks to bid a project. Most emphasized the need for adequate time to review the project documents.

8.6.3 Bid to owner or contractor

Most vendors preferred to bid directly to the contractor. Several vendors noted that many end users of public facilities are unfamiliar with the bidding process and are unable to understand differences between wood heating systems. Most vendors work directly with industrial facility owners and maintenance staff in designing, installing and operating wood heating systems.

8.6.4 Improvements to Bid Documents

Vendors commented on the additional paperwork associated with bidding publicly funded projects.

8.7 Feedback on Constructing Projects in Montana

Vendors were asked a number of questions regarding constructing projects in Montana. Those questions are summarized below.

8.7.1 Equipment Deposits

The majority of the vendors expect to receive a 25-35% deposit before proceeding with the design and construction of their equipment. This is the standard of the equipment industry, but not the standard of the construction industry.

8.7.2 5% Retainage

The majority of the vendors expect a 5% retainage to be withheld with each application for payment.

8.7.3 1% Gross Receipts Tax

Several of the vendors who supplied systems in Montana were not aware of the impact if the 1% Gross Receipts Tax. This tax is returned to Montana based corporations, but not to out-of-state contractors.

8.8 Summary

The wood heating vendors interviewed all expressed interest in the future of the wood heating system industry in Montana and throughout the west. The majority of wood heating systems have been installed in industrial applications, often related to the wood products industry. Several vendors emphasized the need to maintain a quality wood fuel source in order to minimize potential problems with non-industrial users of wood heating systems.
The use of metal building systems and packaged boiler buildings were noted as potential cost savings for future projects.

9.0 APPENDIX

9.1 Total Project Cost Comparisons

Darby School District Darby, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$261,000	27%
Building	$150,000	16%
Mechanical/Electrical	$100,000	10%
Mechanical Integration	$324,000	33%
Fees, Permits, Printing, Etc.	$135,000	14 %
Total	**$970,000**	**100%**

Victor School District Victor, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$240,000	39%
Building	$200,000	32%
Mechanical/Electrical	$134,000	22%
Mechanical Integration	$5,000	1%
Fees, Permits, Printing, Etc.	$36,000	6%
Total	**$615,000**	**100%**

Philipsburg School District Philipsburg, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$264,000	38%
Building	$172,000	25%
Mechanical/Electrical	$100,000	15%
Mechanical Integration	$100,000	15%
Fees, Permits, Printing, Etc.	$48,000	7%
Total	**$684,000**	**100%**

Kalispell School District Kalispell, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$313,000	65%
Building	$131,000	28%
Mechanical/Electrical	$0	0%
Mechanical Integration	$0	0%
Fees, Permits, Printing, Etc.	$36,000	7%
Total	**$480,000**	**100%**

Troy School District Troy, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$80,000	27%
Building	$10,000	3%
Mechanical/Electrical	$158,755	46%
Mechanical Integration	$28,000	9%
Fees, Permits, Printing, Etc.	$22,000	7%
Total	**$298,755**	**100%**

Townsend School District Townsend, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$90,000	21%
Building	$10,000	2%
Mechanical/Electrical	$100,000	24%
Mechanical Integration	$194,000	46%
Fees, Permits, Printing, Etc.	$31,000	7%
Total	**$425,000**	**100%**

University of Montana-Western Dillon, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$682,000	49%
Building	$338,969	24%
Mechanical/Electrical	$115,000	9%
Mechanical Integration	$110,000	8%
Fees, Permits, Printing, Etc.	$132,781	10%
Total	**$1,378,750**	**100%**

Thompson Falls School District Thompson Falls, Montana		
System Component	**Cost**	**% of Total**
Wood boiler system	$136,000	30%
Building	$170,000	38%
Mechanical/Electrical	$100,000	22%
Mechanical Integration	$15,000	3%
Fees, Permits, Printing, Etc.	$34,000	7%
Total	**$455,000**	**100%**

City of Craig Craig, Alaska		
System Component	**Cost**	**% of Total**
Wood boiler system	$319,000	23%
Building	$240,000	17%
Mechanical/Electrical	$200,000	14%
Mechanical Integration	$586,000	42%
Fees, Permits, Printing, Etc.	$55,000	4%
Total	**$1,400,000**	**100%**

Harney District Hospital Burns, Oregon		
System Component	**Cost**	**% of Total**
Wood boiler system	$130,000	48%
Building	$75,000	28%
Mechanical/Electrical	$34,000	13%
Mechanical Integration	$0	0%
Fees, Permits, Printing, Etc.	$30,000	11%
Total	**$269,000**	**100%**

9.2 List of Boilers with Simple Payback of less than 10 years

Table A-1. Boilers with a simple payback of less than 10 years

Manu Year	Existing Boiler Size (BTU/hr)	Owner	Facility	City	Total project cost	Simple payback (years)	30-year cumulative net cash flow
1997	72,000,000	SIDNEY SUGARS INCORPORATED	SIDNEY SUGARS INC -	E HOLLY ST	$2,026,142	5.02	$23,845,001
2000	72,000,000	SIDNEY SUGARS INCORPORATED	SIDNEY SUGARS INC -	E HOLLY ST	$2,026,142	5.02	$23,845,001
1987	70,203,000	STATE OF MONTANA	UNIVERSITY OF MONTANA-P HOUSE	MISSOULA	$1,982,367	5.04	$23,238,272
1960	70,203,000	STATE OF MONTANA	UNIVERSITY OF MONTANA-P HOUSE	MISSOULA	$1,982,367	5.04	$23,238,272
1986	62,853,000	ADVANCED SILICON MATERIALS	ADVANCED SILICON MATERIALS	BUTTE	$1,803,321	5.12	$20,756,661
1989	60,000,000	SIDNEY SUGARS INCORPORATED	SIDNAY SUGARS INC -	E HOLLY ST	$1,733,822	5.16	$19,793,391
1997	60,000,000	ROSEBURG OFFICE PRODUCTS	ROSEBURG FOREST PRODS-BLRM	MISSOULA	$1,733,822	5.16	$19,793,391
1988	25,112,000	MONTOLA GROWERS INC	MONTOLA GROWERS - BLR RM	CULBERTSON	$883,951	5.31	$9,465,445
1946	50,000,000	STATE OF MONTANA	MSU - CENTRAL PLANT	BOZEMAN	$1,490,222	5.32	$16,417,049
1993	50,000,000	STATE OF MONTANA	MSU - NUTRITION CENTER	BOZEMAN	$1,490,222	5.32	$16,417,049
1946	45,000,000	DILLON SCHOOL DISTRICT 10	MARY INNES SCHOOL-BLR RM	DILLON	$1,368,422	5.43	$14,728,878
1940	8,000,000	INLAND TRUCK PARTS	INLAND TRUCK PARTS	MISSOULA	$595,140	5.56	$5,568,245
2002	35,000,000	BORDEN INC	BORDEN INC-BLR RM	MISSOULA	$1,124,822	5.74	$11,352,536
1989	34,429,000	BORDEN INC	BORDEN CHEMICAL-BLR RM	MISSOULA	$1,110,913	5.76	$11,159,747
1964	19,642,000	MONTOLA GROWERS INC	MONTOLA GROWERS-BLR RM	CULBERTSON	$750,701	5.76	$7,302,428
1996	30,000,000	CHS INC	CENEX REFINERY-PLANT	LAUREL	$1,003,022	5.97	$9,664,365
2000	30,000,000	STATE OF MONTANA	UNIVERSITY OF MONTANA-P HOUSE	MISSOULA	$1,003,022	5.97	$9,664,365
1987	30,000,000	LUZENAC AMERICA INC	THREE FORKS MILL - BLR RM	THREE FORKS	$1,003,022	5.97	$9,664,365
1986	26,780,000	BENEFIS HEALTHCARE EAST	BENEFIS HOSPITAL - BLRM	GREAT FALLS	$924,583	6.16	$8,577,183
2002	26,000,000	PLUM CREEK TIMBER COMPANY	PLUM CREEK TIMBER CO-BLR PLANT	COLUMBIA FALLS	$905,582	6.22	$8,313,829
1987	27,335,000	TESSENDERLO KERLEY INC	JUPITER SULPHER-PLANT	BILLINGS	$938,103	6.22	$8,634,776
2002	27,000,000	TESSENDERLO KERLEY INC	JUPITER SULPHUR INC-BLR RM	BILLINGS	$929,942	6.24	$8,523,260
1990	25,488,000	BIG SKY BREWING COMPANY	BIG SKY BREWING	MISSOULA	$893,110	6.25	$8,140,960
2000	26,400,000	TESSENDERLO KERLEY INC	JUPITER SULPHUR-PROCESS BLDG	BILLINGS	$915,326	6.28	$8,323,528
1994	25,000,000	MINERALS TECHNOLOGIES INC	BARRETTS PLANT - BLR RM	DILLON	$881,222	6.29	$7,976,195
1965	24,442,000	STATE OF MONTANA	WESTERN MT COLLEGE-BLR RM	DILLON	$867,629	6.34	$7,787,795

2000	24,321,000	BUTTE-SILVER BOW COUNTY	BUSINESS DEVELPMENT CNTR-BLRM	BUTTE	$864,682	6.35	$7,746,941
1984	24,000,000	ST PETER'S COMM HOSPITAL	ST PETER'S HOSPITAL - BLR RM	HELENA	$856,862	6.37	$7,638,560
1986	24,000,000	ST PETER'S COMM HOSPITAL	ST PETER'S HOSPITAL-BLR RM	HELENA	$856,862	6.37	$7,638,560
1993	22,043,000	SIDNEY SUGARS INCORPORATED	SIDNEY SUGARS INC -	E HOLLY ST	$809,190	6.55	$6,977,810
1950	22,000,000	PLUM CREEK TIMBER COMPANY	PLUM CREEK TIMBER CO-BLR PLANT	COLUMBIA FALLS	$808,142	6.56	$6,963,292
1990	20,925,000	COMMUNITY MEDICAL CENTER	COMMUNITY MEDICAL CENTER	MISSOULA	$781,955	6.67	$6,600,335
1990	20,925,000	COMMUNITY MEDICAL CENTER	COMMUNITY MEDICAL CENTER	MISSOULA	$781,955	6.67	$6,600,335
1996	20,922,000	BURLINGTON NORTHERN	MAIN FLOOR BOILER ROOM	HAVRE	$781,882	6.67	$6,599,322
1950	20,922,000	BURLINGTON NORTHERN	MAIN FLOOR BOILER ROOM	HAVRE	$781,882	6.67	$6,599,322
1963	20,700,000	ALLWASTE CONTAINER	ALLWASTE CONTAINER-BLR RM	MILES CITY	$776,474	6.70	$6,524,368
1950	20,500,000	LUZENAC AMERICA INC	THREE FORKS MILL - BLR RM	THREE FORKS	$771,602	6.72	$6,456,841
1979	20,499,000	DEER LODGE COUNTY	COPPER VILLAGE MUSEUM	ANACONDA	$771,578	6.72	$6,456,503
1962	20,377,143	STATE OF MONTANA	MONTANA TECH-HEATING PLANT	BUTTE	$768,609	6.73	$6,415,360
1965	20,048,000	CONAGRA INC	TRANSBAS - BLR BLDG	BILLINGS	$760,592	6.77	$6,304,230
1990	20,000,000	VHA DEACONESS MEDICAL CTR	DEACONESS MED CTR/BOILER RM	BILLINGS	$759,422	6.78	$6,288,024
1990	20,000,000	VHA DEACONESS MEDICAL CTR	DEACONESS MED CTR/BOILER RM	BILLINGS	$759,422	6.78	$6,288,024
1990	20,000,000	VHA DEACONESS MEDICAL CTR	DEACONESS MED CTR/BOILER RM	BILLINGS	$759,422	6.78	$6,288,024
1980	20,000,000	MONTANA REFINING CO	MONTANA REFINING CO	GREAT FALLS	$759,422	6.78	$6,288,024
1973	20,000,000	MONTANA REFINING CO	MONTANA REFINING CO	GREAT FALLS	$759,422	6.78	$6,288,024
1969	20,000,000	FLATHEAD COUNTY	COURTHOUSE-BLR RM	KALISPELL	$759,422	6.78	$6,288,024
1997	18,500,000	STATE OF MONTANA	WESTERN MONTANA COLLEGE	DILLON	$722,882	6.98	$5,781,572
1981	17,250,000	STATE OF MONTANA	MONTANA TECH OF UNIV OF MT	BUTTE	$692,432	7.17	$5,359,530
1969	17,250,000	STATE OF MONTANA	MONTANA TECH OF UNIV OF MT	BUTTE	$692,432	7.17	$5,359,530
1998	16,738,000	WESTERN SUGAR	WESTERN SUGAR CO-BLR RM	BILLINGS	$679,960	7.25	$5,186,661
1999	16,738,000	LOUISIANA PACIFIC CORP	LOUISIANA PACIFIC CORP - BLRM	DEER LODGE	$679,960	7.25	$5,186,661
1960	16,738,000	NORTHWEST HEALTHCARE CORP	BLRM	KALISPELL	$679,960	7.25	$5,186,661
1963	16,738,000	NORTHWEST HEALTHCARE CORP	BLRM	KALISPELL	$679,960	7.25	$5,186,661
1969	16,738,000	NORTHWEST HEALTHCARE CORP	BLRM	KALISPELL	$679,960	7.25	$5,186,661
1969	16,738,000	RY TIMBER	RY TIMBER	LIVINGSTON	$679,960	7.25	$5,186,661
2000	16,431,000	CHS INC	CENEX-BLR HOUSE	LAUREL	$675,000	7.33	$5,079,809
2000	16,341,000	CHS INC	CENEX-BLR RM	LAUREL	$675,000	7.37	$5,046,637
1990	15,000,000	CHS INC	CENEX - BLR RM	LAUREL	$675,000	8.03	$4,552,383
1990	15,200,000	TESSENDERLO KERLEY INC	JUPITER SULPHUR INC-BLR RM	BILLINGS	$675,000	8.05	$4,553,924

1960	7,958,000	RONAN SCHOOL DISTRICT #30	RONAN SCHOOL	RONAN	$593,394	8.05	$3,694,252
1994	7,958,000	RONAN SCHOOL DISTRICT #30	RONAN SCHOOL	RONAN	$593,394	8.05	$3,694,252
1988	12,490,000	PLUM CREEK TIMBER COMPANY	PLUM CREEK TIMBER CO-BLR RM	PABLO	$675,000	8.15	$4,349,172
1992	14,645,000	BENEFIS HEALTHCARE EAST	BENEFIS HEALTHCARE EAST-BLRRM	GREAT FALLS	$675,000	8.23	$4,421,540
1980	14,645,000	BENEFIS HEALTHCARE EAST	BENEFIS HEALTHCARE EAST-BLRM	GREAT FALLS	$675,000	8.23	$4,421,540
2002	14,500,000	FLATHEAD SCHOOL DISTRICT 5	JUNIOR HIGH SCHOOL-BLR RM	KALISPELL	$675,000	8.31	$4,368,097
1966	14,500,000	FLATHEAD SCHOOL DISTRICT 5	JUNIOR HIGH SCHOOL-BLR RM	KALISPELL	$675,000	8.31	$4,368,097
1991	1,560,000	PRINCE INC	PRINCE INC-TRUCK REPAIR SHOP	FORSYTH	$173,605	8.31	$916,972
1981	7,247,000	DUTTON SCHOOL DISTRICT 28	DUTTON HIGH SCHOOL	DUTTON	$563,830	8.40	$3,323,781
1990	14,520,000	THOMPSON RIVER LUMBER	THOMPSON RIVER LMBR-BLR HOUSE	THOMPSON FALLS	$675,000	8.43	$4,306,524
1990	14,520,000	THOMPSON RIVER LUMBER	THOMPSON RIVER LMBR-BLR HOUSE	THOMPSON FALLS	$675,000	8.43	$4,306,524
1954	3,600,000	ALSCAR INVESTMENT JOINT	NORMAN DALE PROPERTIES	BILLINGS	$412,188	8.55	$2,256,938
1994	14,000,000	STATE OF MONTANA	GF SCHOOL FOR DEAF & BLIND	GREAT FALLS	$675,000	8.61	$4,183,812
1968	13,838,000	CUT BANK SCHOOL DISTRICT 15	CUT BANK HIGH SCHOOL-BLR RM	CUT BANK	$675,000	8.71	$4,124,103
1998	6,560,000	SHERIDAN COUNTY	SHERIDAN COUTHOUSE - BSMT	PLENTYWOOD	$535,265	8.81	$2,965,816
1990	13,600,000	STILLWATER MINING COMPANY	BOILER ROOM	COLUMBUS	$675,000	8.86	$4,036,383
1993	6,313,000	BOZEMAN DEACONESS	NEW HOSPITAL - A-BLR RM	BOZEMAN	$524,995	8.98	$2,837,115
1993	6,313,000	BOZEMAN DEACONESS	NEW HOSPITAL - A-BLR RM	BOZEMAN	$524,995	8.98	$2,837,115
1998	3,280,420	SHERATON HOTEL	SHERATON HOTEL - 23RD FLOOR	BILLINGS	$396,571	9.03	$2,019,390
1979	5,990,000	EUREKA SCHOOL DISTRICT 13	ROOSEVELT ELEMENTARY SCHOOL	EUREKA	$511,564	9.22	$2,668,814
1989	13,000,000	GALLATIN LAUNDRY	GALLATIN LAUNDRY - BLR RM	BOZEMAN	$675,000	9.27	$3,815,240
1973	12,553,000	SURFACE TECHNOLOGY INC	SURFACE TECHNOLOGY INC	MISSOULA	$675,000	9.60	$3,650,489
1948	12,540,000	NORTH VALLEY HOSPITAL	NORTH VALLEY HOSPITAL-BLR RM	WHITEFISH	$675,000	9.61	$3,645,698
1999	12,540,000	NORTH VALLEY HOSPITAL	NORTH VALLEY HOSPITAL-BLR RM	WHITEFISH	$675,000	9.61	$3,645,698
1993	12,500,000	VHA DEACONESS MEDICAL CTR	DEACONESS MED CTR/BOILER RM	BILLINGS	$675,000	9.64	$3,630,955
1988	12,500,000	FIRST PRESBYTERIAN CHURCH	FIRST PRESBYTERIAN CHURCH	HAVRE	$675,000	9.64	$3,630,955
1995	12,553,000	BRUCE TUTVEDT	BOILER HOUSE	KALISPELL	$675,000	9.75	$3,590,884
1998	12,350,000	MOTEL 6 OPERATING LP 0322	MOTEL 6 #322 - MECH RM	MILES CITY	$675,000	9.76	$3,575,669
1996	12,350,000	MOTEL 6 OPERATING LP 0322	MOTEL 6 #322 - MECH RM	MILES CITY	$675,000	9.76	$3,575,669
1967	5,360,000	CIRCLE SCHOOL DISTRICT 1	CIRCLE HIGH SCHOOL	CIRCLE	$485,369	9.78	$2,340,548
1968	12,307,000	BEAVERHEAD COUNTY H. S,	BEAVERHEAD HIGH SCHOOL-GYM	DILLON	$675,000	9.79	$3,559,820
1958	5,175,000	THOMPSON RIVER LUMBER	THMPSON RIVER LMBR-BLR PLANT	THOMPSON FALLS	$477,677	9.97	$2,244,153

End of Report