WOODCHIP FUEL SPECIFICATIONS AND PROCUREMENT STRATEGIES FOR THE BLACK HILLS

Prepared by:
Biomass Energy Resource Center
Montpelier, Vermont

For:
South Dakota Department of Agriculture, Resource Conservation & Forestry Division
Pierre, South Dakota

May 15th, 2007

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Black Hills region of South Dakota covers approximately 1.5 million acres and is heavily forested with ponderosa pine as the dominant tree species. A large majority of the region (1.2 million acres) is managed as part of the Black Hills National Forest and timber production is the primary forest management strategy. The region has a strong forest products industry comprised of three large sawmills, several small to medium sawmills, a large particle board plant, and numerous other secondary processors. Between the vast amounts of wood left behind from the commercial harvesting of sawlogs and the large volumes of wood residues generated by sawmills, there is ample supply of woody biomass ready to fuel biomass energy in the region.

As part of a strategic initiative spear-headed by the South Dakota RC&F to develop a Black Hills biomass heating market, this report was commissioned to help decision makers pursuing biomass heating systems for their facilities select and secure the appropriate type and source of woodchip fuel.

Not all systems will require the same quality of fuel, so matching the right fuel source and quality to the right system and application is extremely important. The Biomass Energy Resource Center was hired to produce wood chip fuel specifications and procurement strategies for the Black Hills Region by the South Dakota Department of Agriculture, Resource Conservation & Forestry.

There are many sources of wood which can be processed into chips and there are equally as many ways in which the wood can be harvested, processed, loaded, transported and received, all of which can impact the overall quality of the wood chip as a fuel. Optimum performance of biomass heating systems requires properly matching the right fuel with the right type and size system and there are many factors to consider when doing so.

This report presents five different woodchip fuel specifications and the suggested material handling guidelines necessary to produce the fuel to specification. The five fuel specifications span the fuel quality spectrum from high quality fuel to low quality fuel. The five specifications include:

1. A high quality heating fuel from sawmill residues
2. A high/medium-quality heating fuel from chipped small-diameter logs
3. A medium-quality heating fuel from chipped whole trees
4. A medium-quality heating fuel from chipped de-limber material
5. A low-quality fuel from ground community wood waste and/or other miscellaneous woody materials

In addition to presenting the various fuel specifications, this report presents a list of general recommendations for woodchip fuel procurement to ensure that the supply of the facility's wood fuel is available, reliable, and sustainable for the years to come.

INTRODUCTION

The Black Hills region of South Dakota covers approximately 1.5 million acres and is heavy forested with ponderosa pine as the dominant species. A large majority of the region (1.2 million acres) is managed as part of the Black Hills National Forest and timber production is the primary forest management strategy. The region has a thriving forest products industry comprised of three large sawmills, several small to medium sawmills, a large particle board plant, and numerous other secondary processors. Sawmills in the region generate an estimated 100,000 green tons of woodchips annually and there is an estimated 208,000 green tons of un-merchantable wood left behind from commercial sawlog harvesting on Black Hills National Forest (BHNF) alone.[1] Between these two sources, there is ample supply of wood to fuel expanded biomass heat and power in the region.

As part of a strategic initiative spear-headed by the South Dakota RC&F to develop a Black Hills biomass heating market, this report was commissioned to help decision makers pursuing biomass heating systems for their facilities select and secure the appropriate type and source of woodchip fuel.

Not all biomass heating systems will require the same quality of fuel, so matching the right fuel source and quality to the right system and application is extremely important. Factors that should be closely examined and considered early in the planning process are the biomass heating system's technology and capability of handling various wood fuels, the existing regional forest products industry, the regional forest management objectives and the facility operator's willingness and enthusiasm. Each project will be different. Each heating system operator will have different expectations. Each area throughout the state will have different fuel type availability or potential. There is no one-size-fits-all wood fuel specification for biomass heating.

Biomass heating systems will function and perform better with a high quality fuel. Systems that are fueled with consistent, uniform sized woodchips experience fewer mechanical jams of the fuel feeding equipment. Systems that are fed lower moisture content wood chips typically require less fuel to produce the same amount of heat. Systems that are fed cleaner woodchips (bark, needle, dirt and debris free) produce less ash and can burn longer without maintenance and removal of ash. However, burning the highest quality chip possible may not be the primary intent of the installation of a woodchip combustion system.

On the contrary, most systems are installed for the purpose of using locally available low-grade wood and reducing heating fuel bills. Many woodchip combustion systems are designed to handle a wider range of chip quality. However, smaller woodchip combustion systems tend to be more sensitive to the quality of the woodchips than larger systems. To keep the capital costs of smaller systems down, fuel handling equipment is not over-sized to handle inconsistent and low-grade woodchip fuel. Larger systems that off-set more fossil fuel by burning greater amounts of wood often have better paybacks and can afford to be over-sized in the fuel handling equipment. So, matching the right fuel source and quality to the right system and application is extremely important.

[1] Williams, James. USDA Forest Service, Northern Hills Ranger District, Black Hills National Forest.

South Dakota Department of Agriculture, Resource Conservation & Forestry

The South Dakota Department of Agriculture is committed to promoting forest health treatments designed to restore and maintain the health of fire-prone ecosystems by increasing the use of woody biomass as an energy source. The South Dakota Department of Agriculture, Resource Conservation & Forestry Division (SD RC&F), serves to conserve, protect, improve and develop the natural resources for the citizens of South Dakota. As a state government office, SD RC&F provides private land owners with the technical assistance to conserve and manage their forests.

Biomass Energy Resource Center

The Biomass Energy Resource Center (BERC) is an independent, nonprofit organization that assists in the development of biomass energy projects, from feasibility studies to commissioning. BERC is staffed by knowledgeable professionals who have over 30 years of cumulative experience in the biomass energy field and have provided technical assistance in the development of dozens of projects throughout the country.

Scope of Work

The following report details five fuel specifications to show a range of potential wood fuel specifications for various wood sources and types. This guide also intends to help decision makers determine which fuel specification is the most appropriate for a given project, since not all projects will require the same quality of fuel.

BERC was hired to produce a woodchip fuel specifications and procurement strategy by the SD RC&F. This report is intended to help decision makers determine which fuel specification is the most appropriate for a given project. The tasks performed for this report include developing at least five general woody biomass fuel supply specifications appropriate for the Black Hills region, making recommendations on fuel handling procedures and making recommendations for securing biomass supply contracts.

Specific work products include:

- The woody biomass specifications, including information relating to species, mineral content, moisture content and optimal material handling procedures.
- Guidance on how to secure woody biomass supply contracts.
- Discussion on the pros and cons of each fuel specification and the appropriate conditions under which each specification could be used.

Methodology

These specifications were developed specifically for the Black Hills region by examining a combination of important factors—the forest resource, the infrastructure of the existing forest products industry, and the technical requirements of various woodchip heating systems. A four day site visit was conducted to view the material handling systems in place for sawmill's and the commercial harvest methods first hand. Numerous chip samples were taken and laboratory analyses' were conducted to determine their fuel properties. These laboratory analysis results were compared to similar lab analysis results of western softwood species woodchips. Foremost, these specifications were developed relying upon the years of experience BERC has in successfully matching various fuel supplies with different wood systems.

CHIP QUALITY

There are numerous factors which affect the properties of wood chips and their overall quality for use as fuel. Wood can come in all shapes and sizes—and usually does. The following are the most important parameters which govern the chip's overall quality for use as a heating fuel.

Photo 1 – High quality woodchips for use as heating fuel

Chip Size, Shape, and Uniformity

Quality chips are consistent in shape and size. Typical high quality chips vary in size from 1" x 1" x 1/8" thick to 2 ¼" x 2 ¼" x ¼" thick. Chips that are relatively square and flat are easily conveyed, augured, and feed into the system smoothly. While the majority of woodchip heating systems can handle some oversized material, long "stringers" can present a risk for jamming feed augers and shutting the system down. Long stringy wood often "bridges," meaning it can form hollow cavities in hoppers and bins as the material below is removed. Material bridging can cause some systems to shut down due to the perception that the bin is out of fuel when it is not. Similarly, while most woodchip heating systems are designed to handle some amount of wood "fines," too much fines content can present issues when moisture content is either too low or too high.

Energy Content

There are several ways in which the energy content of wood can be measured. Higher heating value (HHV) measures the energy content of perfectly dry wood (zero percent moisture content). Energy content can also be expressed as the lower heating value (LHV) or the net energy after the wood's moisture content has been vaporized during combustion.

Wood energy values vary widely—from a HHV of 8,000 to 12,200 British thermal units (Btu) per dry pound. The energy value of bark can range from 7,200 – 10,800 Btu per dry pound.[2] The species of tree which the wood came from can make a difference in a wood chip's value as a heating fuel. Softwoods typically have a higher Btu value than hardwoods on a dry weight basis. The major factors which vary between species are the moisture content and the density of the wood. Additionally, certain species have higher oil contents in their wood which can boost the Btu/lb properties. Most western softwood species have a HHV of about 9,000 Btu per dry pound and ponderosa pine has a HHV of 9,140 Btu per dry pound.[3]

Moisture Content

The recoverable energy content of wood is highly dependant on the moisture content. Trees need water to grow and are predominantly comprised of water. From when a tree is cut green to when it is eventually burned, moisture content typically decreases due to air drying. During combustion

[2] Ince, Peter J. *How to Estimate Recoverable Heat Energy in Wood or Bark Fuels*, USDA Forest Products Laboratory
[3] Ibid.

the moisture content of wood fuel evaporates and absorbs energy in the process. This moisture typically escapes out the stack as heated water vapor. This net energy content of wood is referred to as the LHV.

Additionally, if the moisture content is too high the material will be difficult to handle, risk freezing in winter, and have lower fuel value, resulting in the need to burn significantly more fuel to extract the same amount of energy as a drier fuel. If the material is too dry there can be problems from dust and higher particulate emissions.

The target moisture content is 30-35%, but most woodchip combustion systems can handle wood fuel that ranges from 15% - 50%. However, softwoods can exceed 50% moisture content when cut green, even in arid climates, like the Black Hills. Consistency in moisture content is almost as important as the fuel being within the acceptable moisture content range.

Please refer to the Moisture Content and Pricing Chart (Appendix B) for information on the effect of moisture content on the cost of heating with woodchips.

Photo 2 – "Clinkers" or fused minerals in the ash from a woodchip heating system

Mineral Content

The mineral content of the fuel is a very important factor in the overall chip quality for several reasons. Minerals bound in wood contribute to the formation of ash once the rest of the wood is combusted. Certain forms of minerals in the fuel can cause complications in some biomass heating systems during combustion. In general, the lower the mineral or ash content, the better. Ideally the ash content of chips for heating should be below 2.5%. Ash can come from two main sources – the naturally occurring minerals contained in the tree itself and the dirt and debris picked up from the soil in the process of harvesting (discussed further in section 2.5 below).

Silica and alkali mineral content of the ash is another important factor. Wood fuel that contains significant amounts of potassium or sodium, sulfur, chlorine and silica (high alkali elements) form "clinkers," or fused minerals, which melt and bind to the combustion grates and refractory, limiting the combustion efficiency by blocking air flow. As the alkali content of the ash approaches 0.4lbs per million Btu the potential for mineral fusion increases significantly. Different parts of trees contain varying levels and types of minerals. "White wood" contains the lowest amounts of ash producing minerals (under 1%) whereas the bark contains upward to 6-7%. Needles contain relatively high levels of minerals and are the primary source of silica (20%) in wood fuels contributing to the fusion of ash at standard combustion temperatures. Softwood tree needles contain exceptionally high concentrations of alkali minerals.

Total ash content greater than 8% becomes problematic for most wood chip heating systems. High quality heating fuel will have the absolute lowest possible ash content.

Absence of Dirt and Other Debris

The cleanliness of the fuel is yet another important factor which relates closely to the ash content factor discussed above. In addition to generating more ash, dirt and grit can be extremely abrasive and wear down chipping equipment and other material handling equipment used to deliver fuel to the combustion chamber. Wood fuel should be kept clean and free of other foreign materials like metal objects such as nails, chipper knives, bolts, etc.

SOURCES OF WOOD FOR HEATING FUEL CHIP PRODUCTION

There are a wide range of sources of low-grade wood which can be transformed into woodchips for heating fuel. The primary sources include sawmill and post and pole mill residues, community wood trimmings, and various forest derived material.

Mill Residues

The Black Hills region has a thriving forest products industry. Within the Black Hills there are 16 sawmills producing an estimated 247 million board feet of lumber annually.[4] There is also a wide range of sawmill sizes—from the very small (several hundred thousand board feet) to the very large (over 100 million board feet annually).

Sawmills producing dimensional lumber receive round logs and saw them into square boards. In this process there is a significant volume of outer edge material wasted.

Photo 3 - A debarked log being cut into dimensional lumber.

There are some differences in how this material in handled between larger and smaller sawmills. Larger sawmills typically debark logs prior to sawing whereas some smaller mills will saw logs with the bark still on. This is an important distinction and should be looked at when considering fuel supply sources and quality. Also, larger sawmills typically have stationary chipping equipment integrated into the mill operations and chips are produced on a continual basis rather than batch runs. Many of the larger sawmills in the Black Hills region ship their chips by trucks to Wyoming to be loaded onto rail cars and shipped by rail to Longview fiber in Washington. Additionally, several sawmills send their chips and sawdust to a nearby particle board plant. Several "mom and pop" sawmills do not own chippers to process these slabs and often burn them on-site in "teepee" burners.

Photo 4 –Chips and sawdust being blown directly into a live bottom trailer at a post and pole mill.

Sawmills can produce excellent quality fuel for biomass heating systems and strong, local markets for their by-products are very important to these mills. However, it is important to remember that making chips and serving heating fuel customers is not a sawmill's primary business. Making and selling more lumber is their goal – not making by-products.

[4] Black Hills Forest Resource Association

The major differences between post and pole (P&P) mills and sawmills are that post and pole mills typically produce a lesser amount of by-products and their by-products are quite different. Log peelings from P&P mills are long stringy material which can be problematic as a biomass heating fuel. P&P mills which have doweling mills, however, can produce a chip-like product that can be used successfully in woodchip heating systems. P&P mill dowler chips can run somewhat smaller in size than the chips made from slabs at sawmills, but can perform just as well in biomass heating systems. It is important to note that the dowler chips can also contain a higher percentage of fines which can create dust and other issues in a woodchip heating system. If the fines content exceeds the allowable percentage prescribed in the fuel specification, additional screening should be considered as a means to remove the fines.

Several sawmills in the Black Hills region combine their chips and sawdust into trailers for shipment to the particle board plant. Separating the sawdust from the chips for supplying seasonal heating systems is important because sawdust fines can present problems for these heating systems such as excessive dust in the boiler room and increased particulate emissions.

Community Wood Trimmings

Many urban, suburban and rural communities in the Black Hills generate significant volumes of woody debris (excluding construction and demolition (C&D) debris). A majority of this material is from urban forestry, arboriculture, and residential yard trimmings. Many communities recycle this material along with old wooden pallets and other unpainted and untreated wood into mulch products or use it as bulking agent for composting other organic wastes. This material, in some situations, can be used for fueling biomass heating and CHP systems, although it is generally not recommended. C&D wood waste should be completely avoided.

Photo 5 – Community wood trimmings being ground into chips using a tub style grinder.

Photo 6- Community wood waste in Rapid City

If this material were to be used as a fuel source for a biomass system it is very important that any metal be removed using magnets as the ground material is discharged off the grinder's conveyor. Screening to remove excess oversized material and to remove fines will significantly improve this material's overall quality as a fuel. Lastly, every precaution should be employed to ensure that the woody material does not contain any painted, stained, glued, or treated wood. Including materials like leaves and grass clippings can significantly reduce the fuel value of this material.

Forest Derived Material

There are three main categories of material which can be used to produce fuel chips from the forest: de-limbed logs and poles; whole trees; and slash. These products can be generated as part of commercial timber harvesting or as part of a fuel reduction thinning/ restoration project. Currently in the Black Hills commercial harvesting of sawlogs leaves large volumes of unmerchantable wood in de-limber piles. There is tremendous opportunity to utilize the unmerchantable material "as is" but there is also opportunity to extract this material as small-diameter roundwood.

LOGS

Small-diameter logs can be chipped to produce high-quality heating fuel. The resulting chips tend to be more uniform in shape and size because the material being fed into the chipper is relatively consistent in shape and diameter, and the feed rate of the material is fairly consistent as well. These logs are typically 8 inches in diameter or smaller, and in various regions of the country are commonly referred to as "pulp" logs. The cost to produce chips from small diameter logs is typically high because the trees need to be cut, de-limbed, and forwarded to a central landing for chipping.

Photo 7 – Small diameter logs from a fuel reduction treatment.

There are a few techniques that can help ensure chip quality from chipping logs. Keeping the chipper knives sharp is very important. Dull or damaged knives will produce significantly more oversized stringers which can jam fuel feed augers. Another important consideration is the method in which the trees or logs are transported to the log landing. Forwarding the logs or whole trees reduces the amount of dirt which is picked up when the logs or trees are dragged with a skidder. Less dirt embedded in the bark will help keep the chipper knives sharper longer. A chipper which has a built in flail de-barker to remove the bark before chipping can also help improve the overall chip quality.

Photo 8 – Whole trees chipped into heating fuel in Chadron, Nebraska. (Photo courtesy of Tom Coston, Biterroot RC&D)

WHOLE TREES

Trees which are harvested and skidded to a central location without de-limbing can be chipped to produce a medium grade fuel chip. While the ash content of this fuel will be significantly higher than chips made from de-limbed logs (due to the higher mineral content of increased needles and bark), the ratio of white wood to bark and needles is high enough to produce a good quality fuel.

There are several strategies which can be employed to maximize the chip quality using whole trees as a chipper feedstock. The trees should be left for a period of time (several months) to dry before chipping. Dry needles tend to fall off

easier than green needles. By giving dry trees a quick shake with the grapple arm before feeding into the chipper, some needles can be removed. If possible, a chipper which uses a chain flail de-limbing/debarking mechanism prior to chipping could be used to make a cleaner chip.

SLASH/DELIMBER PILES

The de-limbing process for sawlogs generates considerable volumes of wasted wood. Depending on the type of harvest and where the de-limbing takes place the resulting slash can be used to produce a usable fuel chip. In the Black Hills where markets for small diameter logs (like pulp) are scarce, there are high percentages of "white" wood in the de-limber piles. Despite these significant volumes of white wood in the average Black Hills de-limber piles, the ratio of white wood to bark and needles tends to be lower than with whole trees (depending on what diameter the trees were).

Photo 9 – A large de-limber pile. (Photo courtesy of Jim Williams, USDA Forest Service)

There are several handling techniques that will help produce higher quality chips from this low-quality material. If possible, allow the material to dry for several months. The drier the material, the easier it will be to remove a portion of the needles from the wood in the chipping process. Also, several chipper equipment manufacturers make model which have a fines separation and discharge feature. When the knives on the disk strikes the tree stem chips are sliced off and blown up the chute and into the trailer and any fines are dropped out and blown out the side and on to the ground. While this technique will slightly reduce the tons per hour output of the chipper and it will take longer to fill a trailer, it drastically improves the quality of the chips.

Photo 10 – Fines separator/discharge feature on a Morbark whole-tree chipper.

Another strategy that works well for improving the overall chip quality of de-limber pile chips is the operator's careful selection of stems with sufficient wood volumes from the de-limber pile. The current in-forest chipping operations that produce chips for the region's sole particle board plant report chipping approximately 75% of the de-limber pile volume.[5] By leaving the worst 25% behind the chip quality is enhanced.

[5] Personal communication, Robert Baker, Baker Timber Products.

MATERIAL HANDLING CONSIDERATIONS

Chipping versus Grinding

There are two main methods of mechanically reducing wood into a useable fuel for biomass heating and power systems – chipping and grinding. Each method has its advantages and disadvantages. Chipping generally produces a more uniform material with a far greater volume of the material being within the target particle shape and size. A typical disk style chipper uses a large disk set at roughly an 18 degree angle to the in-feed of wood. The disk has several rectangular slots in which knifes are mounted on the leading edge. As the wood is fed into the chipper, the disk spins and slices the wood across the grain of the wood. Grinding is a method that uses a drum with mounted hammers which hack the wood into smaller pieces. The grinding action typically occurs with the grain of the wood being fed to the grinder and therefore produces a significant amount of long stringy material.

The quality of the chip depends on the type of equipment used and how well maintained it is, and also what the chipper is fed. Uniform stems passed through a well maintained (sharp knives) disk chipper will produce a uniform chip. Random diameter and shaped material passed through the chipper simultaneously will produce less uniform chips.

Intermediate Storage and Loading

If wood is chipped and not immediately blown into a delivery vehicle or vessel such as a roll-off container, there is the opportunity for contamination. Chips which are stock piled on the ground can pick up excess water and when the chips are eventually loaded into containers, dirt and other debris is often mixed in. If chips need to be stored prior to loading into delivery containers, stockpiling the chips on a concrete or asphalt pad is the best option to make sure dirt is not blended into the chips when using a loader to load the chips into trucks.

Photo 11 – Outdoor chip storage at the Sturgis Sawmill.

Sizing

In some situations additional mechanical sizing (screening) of the chips may be warranted. Not all chips will require sizing. If there are large amounts of oversized and/or undersized material sizing is necessary.

There are many different mechanisms to size materials – screens are just one. Many mechanisms are built for classifying materials into acceptable and unacceptable, which allows for removing either the over-sized or under-sized material and keep the rest. Ideally the sizing equipment will allow for a single pass removal of over-sized and the removal of fines. Chip sizing can significantly improve the chip quality, but is a significant added expense. If the sizing equipment can be placed in-line with the chipping equipment, maximum efficiency can be achieved and the processing costs are kept to a minimum.

Photo 12 – Sizing equipment used for removing over-sized chips and fines at the Sturgis Sawmill.

WOOD CHIP FUEL SPECIFICATIONS

WOOD FUEL SPECIFICATION 1	
Description	A high quality heating fuel from sawmill residues
Technical Requirements	
Target Moisture Content	30%
Moisture Content (Acceptable Range)	25%-42%
Minimum Btu's/lb (wet weight)	5,500 (HHV)
Target Chip Size	2" x 2" x ¼"
Maximum Chip Size	No more than 5% shall be 4 inches or larger in any dimension
Maximum Fines Content	No more than 5% shall be smaller than 1/16". No wood flour or dust is allowed.
Total Ash Content	Maximum 3% (dry matter basis)
Alkali Mineral Content of Ash	Maximum 0.2 lbs/MMBtu
General Requirements Necessary to Meet Technical Requirements	
Wood Species	Ponderosa pine and other mixed conifers
Wood Source	By-product from processing debarked logs at sawmills or post & pole mills.
Age of Wood (from time of harvesting)	Ideal age is 3-12 months. The flow of residues from the mill must be on a "first-in first-out" basis.
Method of Processing	Fuel made from chipping off-cuts/slabs from lumber production or the uniform chips off pole dowler mill (not bark peelings from post & pole mills)
Recommended Equipment	Stationary disk type chipper - grinding is not recommended. In-line screening equipment as necessary.
Handling & Storage	Stored on concrete/black-top slab or loaded directly into delivery vehicle or container with conveyor. Stock piling chips on the ground increases mud and dirt content. Under cover storage (roofed area or tarp covering) is not essential but encouraged.
Transport	Ideally in live bottom (walking floor) trailers. Roll-off containers can be substituted if the heating plant has the overhead space requirements and overall capability of receiving fuel via dump bodies.
Quality Assurances	Random sampling and laboratory testing of 2 loads annually to ensure fuel meets specifications.
Contaminants	Chips shall be free of any foreign materials including but not limited to nails, dirt, rocks, dirt, snow, ice, paint, glue, etc.

Discussion - Fuel Chip Specification 1

This is a quality fuel that will perform very well in heating systems. Due to the consistent and uniform shape and size of the resulting chips, auger and other mechanical jams will be very infrequent. This fuel will require minimal maintenance time to free blocked feed equipment. Because of the low moisture content, low ash content and the high Btu value, this fuel will burn consistently and require fewer chips to get the same heat output. Ash production will be minor and the formation of clinkers on the grate will be minimal. The availability of this supply depends on having sufficient waste generation from mills within trucking distance of the facility. Given the number large sawmills in the Black Hills region, the supply of these high quality chips is abundant. Although this material does not help achieve the goal of creating new markets for removing biomass from fuel reduction treatments of fire prone forests, it does produce easy, convenient, and cost effective fuel.

WOOD FUEL SPECIFICATION 2	
Description	A high/medium quality heating fuel from chipped small diameter logs
Technical Requirements	
Target Moisture Content	30%
Moisture Content (Acceptable Range)	25%-45%
Minimum Btu's/lb (wet weight)	4,750 (HHV)
Target Chip Size	2" x 2" x ¼"
Maximum Chip Size	No more than 10% shall be 4 inches or larger in any dimension
Maximum Fines Content	No more than 5% shall be smaller than 1/16". No wood flour or dust is allowed.
Total Ash Content	Maximum 7% (dry matter basis)
Alkali Mineral Content of Ash	Maximum 0.25 lbs/MMBtu

General Requirements Necessary to Meet Technical Requirements	
Wood Species	Ponderosa pine and other mixed conifers
Wood Source	De-limbed small diameter logs or stem tops from forest thinning operations. Stems can be chipped at landing, sort yard or even at the sawmill or P&P mill.
Age of Wood	Logs can be aged in log piles at the landing, roadside, sort yard, or even at saw/post & post mills.
Method of Processing	Logs can be de-limbed at the stump or whole tree skidded and de-limbed at the landing.
Recommended Equipment	Grapple boom fed disk type whole-tree chipper with minimum 300 horse power and 15 inch diameter capacity.
Handling & Storage	Forwarding methods should limit accumulation of soil in logs (forwarding vs. ground skidding or skidding in winter). Chips should be directly blown into delivery vessel at the time of chipping.
Transport	Ideally in live bottom (walking floor) trailers. Roll-off containers can be substituted if the heating plant has the overhead space necessary for dump body delivery.
Quality Assurances	Random sampling and laboratory testing of 2 loads annually to ensure fuel meets specifications.
Contaminants	Chips shall be free of any foreign materials including but not limited to nails, dirt, rocks, dirt, snow, ice, paint, glue, etc.

Discussion - Fuel Chip Specification 2

This specification for chipped logs yields the highest quality fuel chip from material thinned from forests. Chipped logs can produce consistent, reliable fuel with low moisture, and ash content and high Btu value. While the cost per ton to produce this quality of chip is far greater than ground slash, the heating system will perform far better with this high quality fuel. Feeding a well-maintained chipper fairly straight and uniform stems will produce fairly consistent chips which should not typically require any further mechanical sizing. There will be slightly more bark in this fuel chip than the previous and an increased amount of resulting ash, however the ash content could be kept lower by using chipping equipment which has a chain flail debarking feature prior to the disk chipping mechanism. One other potential draw back is that woodchip systems which burn chips containing fines with bark and needles may have slightly higher particulate emissions than those burning clean sawmill chips.

It is important to point out that chipping small-diameter logs is not currently happening in the region and that this would present a new market for de-limbed top wood. There are two main sources for the small diameter logs—small diameter trees that contain no sawlog and the upper stem wood that left behind after delimbing and cutting out the sawlog. Either option will require extra work to delimb material that would otherwise be left behind.

WOOD FUEL SPECIFICATION 3	
Description	A medium quality heating fuel from chipped whole trees
Technical Requirements	
Target Moisture Content	30%
Moisture Content (Acceptable Range)	25%-45%
Minimum Btu's/lb (wet weight)	4,500 (HHV)
Target Chip Size	2" x 2" x ¼"
Maximum Chip Size	No more than 10% shall be 4 inches or larger in any dimension
Maximum Fines Content	No more than 10% shall be smaller than 1/16". Minimal wood flour or dust is allowed.
Total Ash Content	Maximum 8% (dry matter basis)
Alkali Mineral Content of Ash	Maximum 0.3 lbs/MMBtu

General Requirements Necessary to Meet Technical Requirements	
Wood Species	Ponderosa pine and other mixed conifers
Wood Source	Small diameter trees harvested and chipped whole from forest thinning/restoration operations.
Age of Wood	Material should be aged 3-12 months in whole tree piles at the landing or roadside.
Method of Processing	Felling, whole tree skidding, and chipping
Recommended Equipment	Grapple boom-fed disk type whole-tree chipper with minimum 350-400 horse power and 20 inch diameter capacity.
Handling & Storage	Forwarding methods should limit accumulation of soil in logs (forwarding vs. ground skidding or skidding in winter). Chips should be directly blown into delivery vessel at the time of chipping.
Transport	Ideally in live bottom (walking floor) trailers. Roll-off containers can be substituted if the heating plant has the overhead space necessary for dump body delivery.
Quality Assurances	Random sampling and laboratory testing of 2 loads annually to ensure fuel meets specifications.
Contaminants	Chips shall be free of any foreign materials including but not limited to nails, dirt, rocks, dirt, snow, ice, paint, glue, etc.

Discussion - Fuel Chip Specification 3

There are several major benefits to this fuel specification for chipped whole trees from a material handling and fuel cost perspective. By eliminating the need for de-limbing the stem as an extra step and utilizing the whole tree without generating extra slash, the cost per ton to produce a fuel chip from this material is significantly less than from de-limbed logs. The drawback is that the whole tree chips contain higher concentrations of needles and bark which increase the fuel's ash content. As mentioned before, the mineral content of the needles can increase the clinker formation within the combustion chamber and create maintenance issues.

WOOD FUEL SPECIFICATION 4	
Description	A medium quality heating fuel from chipped de-limber pile wood
Technical Requirements	
Target Moisture Content	30%
Moisture Content (Acceptable Range)	25%-50%
Minimum Btu's/lb (wet weight)	4,300 (HHV)
Target Chip Size	2" x 2" x ¼"
Maximum Chip Size	No more than 10% shall be 4 inches or larger in any dimension
Maximum Fines Content	No more than 10% shall be smaller than 1/16". Some dust is allowed.
Total Ash Content	Maximum 10% (dry matter basis)
Alkali Mineral Content of Ash	Maximum 0.35 lbs/MMBtu
General Requirements Necessary to Meet Technical Requirements	
Wood Species	Ponderosa pine and other mixed conifers
Wood Source	In woods chipping of slash
Age of Wood	Material should be aged for several months at the landing
Method of Processing	Felling, bunching, forwarding, de-limbing, chipping
Recommended Equipment	Grapple boom fed disk type whole-tree chipper with minimum 300 horse power and 12 inch diameter capacity.
Handling & Storage	Forwarding methods should limit accumulation of soil in logs (forwarding vs. skidding or skidding in winter). Any storage of chips should be on high ground and should limit the absorption of water.
Transport	Ideally in live bottom (walking floor) trailers. Roll-off containers can be substituted if the heating plant has the overhead space requirements and overall capability of receiving fuel via dump bodies.
Quality Assurances	Random sampling and laboratory testing of 2 loads annually to ensure fuel meets specifications.
Contaminants	Chips shall be free of any foreign materials including but not limited to nails, dirt, rocks, dirt, snow, ice, paint, glue, etc.

Discussion - Fuel Chip Specification 4

This specification for chipped de-limber pile wood attempts to produce a usable fuel for heating systems from a relatively difficult material. Due to the lack of a local pulpwood market and relatively small demand for small diameter logs for post and pole mills, the wood content of average de-limber piles in the Black Hills is exceptionally high. In many cases the quality of chips produced from the tree tops in a de-limber pile may indistinguishable from chips made from whole trees. Using techniques like selectively picking through a de-limber pile to feed the chipper tops with the greatest stem wood content, allowing the material to dry sufficiently before chipping, and using chipping equipment with the fines discharge feature will significantly improve the fuel quality of this type of chips.

Given the overall quality of the chips being produced by in-woods chipping as feedstock to the particle board plant in Rapid City, these chips should proved to be an effective fuel for seasonal heating systems.

The challenge of meeting this chip specification will be maintaining the white wood to bark and needle content. If the region's forest products industry begins utilizing material down to a very small diameter as merchantable logs, the white wood content in a de-limber pile may be very low. If that happens, the quality of chips will decrease and the chips will contain a very high mineral and alkali mineral content, resulting in major formations of clinkers in the combustion equipment.

WOOD FUEL SPECIFICATION 5	
Description	A low-quality hog fuel from ground community wood waste or other miscellaneous woody materials
Technical Requirements	
Target Moisture Content	30%
Moisture Content (Acceptable Range)	25%-50%
Minimum Btu's/lb (wet weight)	4,200 (HHV)
Target Chip Size	2" x 2" x ¼"
Maximum Chip Size	No more than 10% shall be 5 inches or larger in any dimension
Maximum Fines Content	No more than 10% shall be smaller than 1/16". Some dust is allowed.
Total Mineral Content	Maximum 10% (dry matter basis)
Alkali Mineral Content of Ash	Maximum 0.35 lbs/MMBtu

General Requirements Necessary to Meet Technical Requirements	
Wood Species	All
Wood Source	Community tree trimmings and clean waste wood
Age of Wood	Material should be accumulated for several months between periodic grinding
Method of Processing	Grinders can be feed using bucket loaders or with boom grapples. May require a bucket loader to push up material within grapple reach to feed grinder
Recommended Equipment	Tub and horizontal style grinders are the more productive equipment for processing this type of debris.
Handling & Storage	All in-coming material should be checked and double checked to ensure no painted, glued, or treated wood is accepted. Un-ground material can be stored in large stock piles outdoors. All wood should be kept from leaves, grass and other "mulchy" yard waste materials.
Transport	Ideally in live bottom (walking floor) trailers. Roll-off containers can be substituted if the heating plant has the overhead space requirements and overall capability of receiving fuel via dump bodies.
Quality Assurances	Random sampling and laboratory testing of 2 loads annually to ensure fuel meets specifications.
Contaminants	Chips shall be free of any foreign materials including but not limited to nails, dirt, rocks, dirt, snow, ice, paint, glue, etc.

Discussion - Fuel Chip Specification 5

Ground community wood trimmings make for relatively low-quality biomass heating fuel because the material's consistency is poor and comes with a greater risk of contaminants. The benefits of using this material is that it is typically a low cost fuel and that it is keeping clean wood from being disposed of in a landfill. Additional mechanical sizing of the ground wood will be required to remove oversized chips and to remove excessive fines for a woodchip heating system to successfully burn this material.

It is also extremely important that the "mulchy" materials like grass clipping and leaves be handled separately and not mixed with the woody material. Mixing these materials with the wood, results in drastically lower Btu content and dramatically higher ash content.

SELECTING A FUEL SPECIFICATION

Choosing the right fuel supply source and specification depends on several critical factors that need to be addressed early in the planning process:

What are the biomass resources in the area? Is there a healthy forest products industry nearby from which sufficient residues can be used to fuel the biomass heating system? What are the potential fuel sources from the forest?

What are the biomass system owner/operator's objectives? Why do they want to use wood to heat their facility? Do they want the best fuel for the least cost with the least amount of maintenance or are they interested in playing a cooperative role as an outlet for lower-quality fuel from thinning operations?

What are the objectives of other stake-holders/ grantors and investors? Is the primary purpose of installing a woodchip heating system to create an outlet to remove more biomass from the forest and thereby reduce forest fire hazard and increase forest health? If so, does this coincide with the system owner/operator's objectives of saving heating fuel costs and running the system on the highest quality fuel at the lowest delivered cost? If not, whose goals take priority or can a compromise in fuel quality and source be found?

GENERAL FUEL SUPPLY PROCUREMENT GUIDELINES

Securing an available, reliable and sustainable woodchip fuel supply is not yet as simple as picking up the phone, immediately getting three or more quotes, and receiving the first shipment the following day. In order to get the best quality fuel at the lowest possible price, fuel buyers must first be willing to work with fuel suppliers to encourage the growth of a fuel supply industry.

Fuel chip suppliers, whether they are sawmills, loggers, or general contractors, are seldom in business exclusively to supply chips for heating. Most often suppliers are getting into the business as an add-on side business to their core business. If supplying heating markets is troublesome and not lucrative for them they may decide to get out of that business and focus on their primary business. For this reason it is extremely important to work closely with new suppliers to work through issue that may come up over time. It is also important to consider that a business which may need to invest significant capital in specialized equipment in order to supply quality chips at a fair price will require multiple customers all requiring the same type of chip. For example, a single school may burn only 500 tons per year; for a logger to justify purchasing a large chipper a contractor will need markets for at least 15,000 tons.

It is also important, when considering wood supply sources and fuel specifications, to pool demand for similar sources and specifications with other chip consumers. Developing regional "clusters" of woodchip energy systems and other chip consumers helps aggregate demand to support a viable chip supply industry. A single school consuming 500 tons annually is not enough volume demand to make owning and operating a chipping business break-even financially. Regional demand for similar fuel should be pooled to reach the volumes necessary to support profitable chipping businesses.

The following is a list of recommendations for strategies (in no particular order) which will help improve the overall success of the project and the long-term reliability of the fuel supply.

1. Understand all the project stake-holder's objectives in a biomass system before selecting a chip fuel specification. The goal of removing excess woody biomass from fuel reduction treatments will not be met if the system burns mill chips.

2. Understand the selected heating system's capacity to handle various chip quality. Auger size, fuel feed configuration, combustion controls, auger and conveyor belt motor size and many other variables dictate a system's capacity to handle more challenging biomass fuels. A chip specification can be selected after the system is selected, but generally it is best to choose a fuel first.

3. For smaller heating systems like schools, consider structuring payment by the green ton, rather than contracting payment by the dry ton. Use the chip specifications and material handling guidelines to ensure fuel is not excessively wet. This helps avoid overly complicated billing arrangements and helps avoid possible conflicts over moisture content. The Black Hills are an arid region and stringent measures to reduce moisture content in wood fuel may not be as necessary as in other regions of the country.

4. Build long-term relationship with supplier(s). Encourage the supplier's commitment to staying in the business of supplying chips.

5. Work through issues of variance in chip specifications and supply-chain interruptions with supplier.

6. Conduct lab analysis on fuel samples at out-set of supply contract and check randomly annually.

7. Selecting low-bid when contracting fuel supply can be dangerous. Always take price into the overall consideration of the availability, reliability and sustainability of the fuel supply.

8. Chipping equipment is recommended for all but the fifth specification (ground community wood waste). Grinding of random sized and shaped material is generally more efficient; chipping of logs, whole-trees and even slash can produce a much higher quality chip.

9. Some facilities which have woodchip heating systems stock-pile chips on-site to build inventory and reduce risk of fuel supply interruptions in the winter months. By chipping in the summer and fall when the material is not frozen, the cost per delivered ton can be kept low. However, chips can not be stored reliably for longer than three or four months. Accumulating logs at the log landing, or a log yard, is a better alternative. Unlike chips, logs can be stored over longer periods of time without problems. After several months of accumulating and drying, logs can be chipped in the fall and winter months. It is generally not recommended to keep large stock piles of chips or logs at public facilities like schools.

10. Consider signing longer-term fuel supply agreements. While most agreements are one to two years, longer term agreements can be very useful to suppliers when securing the necessary capital to purchase chippers and other equipment. If necessary, termination clauses can be used to reduce the risks of signing 3-5 year contracts. For supply contracts longer than one or two years, some price escalation may be necessary. Contracted wood fuel price escalation could be based on a price index, such as the consumer price index.

11. Securing back-up supply contracts with a secondary fuel supplier is highly recommended. If the primary fuel supplier runs into difficulties delivering chips, it is much less expensive to pay $10/ton more for chips from a secondary supplier than switching back to burning expensive fossil fuels for heating.

12. Keep supply arrangements and relationships as simple as possible.

13. It is important to select the intended fuel specification as early in the project development/ construction process as possible. Knowing the intended fuel source and type prior to putting the project out to bid and selecting a system type and vendor can be very helpful.

CONCLUSION

The first fuel specification for woodchips from sawmills presents a simple, high-quality fuel option which can be readily sourced throughout the Black Hills region.

The second fuel specification for chips produced from low-quality or small-diameter logs presents an excellent option for heating fuel from wood derived directly from the Black Hill's forests. Reliably sourcing this material at a competitive price may present some challenges. The need for additional de-limbing of the low-grade wood before chipping into heating fuel may make these chips relatively expensive in comparison to the other four fuel specifications.

The third specification for fuel chips from in-forest chipping of whole-trees presents a good balance of medium quality chips from material which needs to be removed from forests to effectively reduce fire hazards. The avoided cost of de-limbing should keep the cost of these chips low.

The fourth specification for chips made from de-limber pile wood is an exciting option for fueling biomass systems but comes with some minor challenges. Successfully producing a woodchip which can be used to fuel biomass heating systems will depend heavily on the content of wood in comparison to bark and needle content of the de-limber pile and the material handling methods to minimize the needle content in the fuel chips.

The fifth specification for clean community wood trimmings (no C&D) is a viable specification for communities which may be further from large tracts of forested land but may generate sufficient volumes of clean wood waste which could be used to fuel renewable energy systems like biomass heating plants. If the material is carefully separated from other materials and is properly stored and processed, it can be a viable fuel. However, this material wood fuel has the greatest potential of any of the other fuel specifications to create problems for seasonal heating systems.

It should be kept in mind that any combination of the woodchip fuel specifications can be used for a given biomass heating system. While five specifications have been presented and can be used as is, these specifications can be modified or customized to better suit the specific needs of a biomass heating project. Also, it may be useful to use several specifications, such as requiring 25% chip specification 1 and 75% chip specification 2.

While procuring fuel supply directly from forest thinning helps remove excess biomass and reduce forest fire danger, it is the most difficult supply model to implement. The most stable fuel supply models are utilization of residuals from the forest products industry.

The best wood fuel supply model will incorporate the mills, utilize the residuals to the best extent possible and, with enough demand for fuel chips, create the need to send small-diameter logs to the mill for chipping as a supplement to the volume produced from chipping residue.

APPENDIX A – FUEL QUALITY CHART

Wood Source	Primary Activity	Resulting Material	Processing Method	Loading	Heating Fuel Quality
Sawmill	Sawing dimensional lumber from debarked logs	Slabs	Chipped and screened continually	Blown directly into Live bottom trailer	High
	Sawing logs with bark	Slabs with bark	Chipped continually	Blown directly into trailers	High to medium
	Sawing logs with bark	Slabs with bark	Chipped continually	Chips stock-piled on ground and reloaded with front end loader	Medium to low
	Sawing dimensional lumber from debarked logs	Slabs	Ground periodically by contractor	Chips stock-piled on ground and reloaded with front end loader	Low
Post & Pole Mill	Peeling logs	Log peelings	As is	Conveyed directly	Low
	Dowling debarked logs	Dowler chips	As is	Conveyed directly	Medium
Community	Storm clean up and recycling clean wood waste	Various tree trimmings and old pallets	Tub or horizontal grinder	Loaded from stock pile with front end loader	Low
Forest	Commercial Harvesting or Fuel Reduction Treatments	Small diameter logs	Flail debarked & chipped after a couple months	Blown directly into trailer	High
		Small diameter logs	Chipped & screened after a couple months	Blown directly into trailer	High
		Small diameter logs	Chipped green	Blown directly into trailer	High to medium
		Whole trees	Chipped after a couple months	Blown directly into trailer	Medium
		Whole trees	Ground	Conveyed directly into trailer	Medium to low
		Slash	Chipped	Blown directly into trailer	Medium to low
		Slash	Ground	Conveyed directly into trailer	Low
		Bundled Slash	Ground	Conveyed directly into trailer	Low

APPENDIX B - MOISTURE CONTENT AND PRICING CHART

Price per Million Btu for Woodchips at Various Moisture Content Levels

	Btu/lb	Btu/lb	$/ton	$/ton	$/ton	$/ton	$/ton	$/ton	$/ton
MC	Adjusted HHV	LHV	$ 20.00	$ 25.00	$ 30.00	$ 35.00	$ 40.00	$ 45.00	$ 50.00
5%	8,645	8,585	$ 1.16	$ 1.46	$ 1.75	$ 2.04	$ 2.33	$ 2.62	$ 2.91
10%	8,190	8,070	$ 1.24	$ 1.55	$ 1.86	$ 2.17	$ 2.48	$ 2.79	$ 3.10
15%	7,735	7,555	$ 1.32	$ 1.65	$ 1.99	$ 2.32	$ 2.65	$ 2.98	$ 3.31
20%	7,280	7,040	$ 1.42	$ 1.78	$ 2.13	$ 2.49	$ 2.84	$ 3.20	$ 3.55
25%	6,825	6,525	$ 1.53	$ 1.92	$ 2.30	$ 2.68	$ 3.07	$ 3.45	$ 3.83
30%	6,370	6,010	$ 1.66	$ 2.08	$ 2.50	$ 2.91	$ 3.33	$ 3.74	$ 4.16
35%	5,915	5,495	$ 1.82	$ 2.27	$ 2.73	$ 3.18	$ 3.64	$ 4.09	$ 4.55
40%	5,460	4,980	$ 2.01	$ 2.51	$ 3.01	$ 3.51	$ 4.02	$ 4.52	$ 5.02
45%	5,005	4,465	$ 2.24	$ 2.80	$ 3.36	$ 3.92	$ 4.48	$ 5.04	$ 5.60
50%	4,550	3,950	$ 2.53	$ 3.16	$ 3.80	$ 4.43	$ 5.06	$ 5.70	$ 6.33
55%	4,095	3,435	$ 2.91	$ 3.64	$ 4.37	$ 5.09	$ 5.82	$ 6.55	$ 7.28
60%	3,640	2,920	$ 3.42	$ 4.28	$ 5.14	$ 5.99	$ 6.85	$ 7.71	$ 8.56

Wood HHV = ***9,100*** Btu/lb

HHV = Higher Heating Value (gross energy content on bone dry basis)
LHV = Lower Heating Value (net energy content after latent heat loss due to moisture content)

 This publication made possible through a grant from the USDA Forest Service.