Wood Waste Alternatives in Lincoln and Lancaster County

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1. Introduction

Waste wood is generated in nearly every sector of society and represents a significant portion of the solid waste stream. The increasing emphasis on recovering and utilizing wood waste is important because the material represents a significant portion of the solid waste stream and is often not addressed by recycling programs instituted at the local level. In addition, a variety of wood residue is generated that never enters the municipal solid waste stream, but must be handled, reused, recycled, or disposed of in some way.

A variety of solid waste management, energy production, and environmental objectives can be achieved through the recovery and processing of wood waste. Nationally, increasing waste disposal costs, decreasing landfill capacity and growing markets for recycled wood indicate new opportunities for reusing and recycling wood waste materials.

Wood waste includes all parts of the tree not used by the forest products industry in the manufacturing process. Wood waste is a part of the biomass : it is an organic product and thus a renewable source (NWMSU, 1994). Wood waste can be defined as being either: "clean," untreated, treated or containing physically separable items. Some wood waste consists of only "clean" or untreated materials. Other wood waste contains material that is treated or chemically changed in some way. In addition, some wood waste contains non-wood materials that can be physically separated from the wood such as pallets with staples, lumber with nails and wood containing pieces of metal.

The purpose of this study is to provide up-to-date information on opportunities for processing and using wood waste in value added products or as a fuel source. The primary emphasis of this report is based on energy recovery as well as technological, environmental and regulatory issues affecting the processing and use of wood waste for fuel.

The study is organized in the following sections.

1. Wood Waste Generation and Recovery
   U.S vs. Lincoln and Lancaster County
2. Markets for Scrap Wood
3. Assessing Technology to Process Wood Waste
4. Environmental and Regulatory Issues for Utilization of Wood Chips for Energy Recovery
5. Cost/Benefit Analysis
6. Alternative in Lincoln and Lancaster County
7. Financing

2. Wood Waste Generation and Recovery

<u>The amount of wood waste generated in U.S.</u>

The amount of wood waste generated in the U.S. has increased steadily since 1960. In 1994, 14.6 million tons of wood wastes were generated. This amount represented 7% of the Municipal Solid Waste (MSW) generated in the U.S. Table 1 summarizes the amount of wood waste generated and recovered in the U.S. since 1960. Prior to 1990 wood waste recovered was negligible. This means less than 0.005 % or 50,000 tons per year were recovered. In 1994, however, wood recovery had increased to about 10%.

Table 1: Generation and Recovery of Wood in the U.S. (million tons)

	weight generated	weight recovered	recovery as a percent of Generation
1960	3	Neg.	Neg.
total MSW	87.8	5.9	6.7%
1965	3.5	Neg.	Neg.
total MSW	103.4	6.8	6.6%
1970	4	Neg.	Neg.
total MSW	121.9	8.6	7.1%
1975	4.4	Neg.	Neg.
total MSW	128.1	9.9	7.7%
1980	6.7	Neg.	Neg.
total MSW	151.4	14.5	9.6%
1985	8.2	Neg.	Neg.
total MSW	164.4	16.4	10%
1990	12.3	0.4	3.2%
total MSW	195.7	33.4	17.1%
1993	13.7	1.3	9.6%
total MSW	206.9	45	21.7%
1994	14.6	1.4	9.8%
total MSW	209.1	49.3	23.6%

Source: EPA Characterization of Municipal Solid Waste in U.S.

This trend is expected to continue through the 1990's. Trends in wood waste generated has grown steadily from 3 million tons in 1960 to 15 million tons in 1994. The EPA projects that the amount of wood generated will increase to be 20.3 million tons in near 2000.

Lincoln and Lancaster County

There are favorable opportunities other than disposal for private entrepreneurs and industries that generate wood waste by processing it into a variety of products. It is cheaper for hiring a contractor to grind wood waste into landscape mulch ($13-$15/ton) than to dispose of it in the landfill($16/ton). Despite these opportunities, wood waste is still landfilled, chipped (which decreases its value), or is burned outdoor piles in Nebraska, all of which results in the loss of available economic resource.

The city estimates that 19,000 tons of wood wastes were landfilled in Lincoln-Lancaster

County in 1996. A survey of local pallet companies indicated that about 5,466 tons of wood were recycled into rebuilt pallets in 1996. This amount increases the total amount of wood waste generated to 24,466 tons annually. Roughly 22% of the total wood waste were recycled and saved 15,000 cubic yards of landfill space. The economic value for the landfill space saved is $150,000 per year. It is estimated that through more aggressive separation of wooden pallets as well as wood waste from commercial and residential construction would divert up to 5,000 more tons of wood waste. This would increase the recycling rate to 43%.

3. Markets for Scrap Wood

There are a number of alternatives for the disposal of wood wastes. Waste wood processors must be aware of the specifications of the potential market in terms of quantities and characteristics so they can provide products to meet the demand. Revenue-generating markets will not only benefit processors by avoiding the cost of landfilling waste wood but also by generating income for the program from the sale of the end product. Markets vary regionally, depending on the local economy, growth rate, type and costs of competing materials.

The purpose of this section is to provide an overview of opportunities for processing wood waste in Lincoln and Lancaster County.

Fuel

Waste wood can not only be burned as fuel to generate thermal or electrical energy, but wood waste can also be used to produce charcoal or ethanol. Wood waste can be processed and used as fuel in residential, institutional, municipal, commercial, industrial, and utility boilers or furnaces. Ethanol fuel can be produced from waste wood by converting the cellulose in the wood into alcohol.

There is a large market potential to use wood waste as a fuel in industrial and utility boilers. This potential is due to a variety of factors, including:

-- Wood waste is an indigenous, abundant, renewable energy source.

-- The use of wood as fuel has several air emission benefits compared to fossil fuels.

-- Wood waste may be co-fired with coal in utility and industrial boilers, which may reduce acid gas emissions (A Sourcebook on Wood Waste Recovery & Recycling in the Southeast, 1994).

Landscape mulch

Landscape mulch is used as a ground cover material to control weeds, prevent moisture loss in the soil, and for aesthetic purposes. Mulch is placed around the base of shrubs, bushes, trees and in flower beds.

The market potential for mulch is extremely large, since mulch is in large demand by homeowners, landscaping firms, and others involved in landscaping, such as golf courses. A benefit to mulch made from wood waste is that it tends to last longer than bark mulches.

The city of Lincoln currently generates over 9,010 tons of woodchip mulch through the Department of Parks and Recreation and the Department of Public Works and Utilities. This amount represented 37,500 cubic yards of wood chip mulch that was distributed at no cost to local residents in 1996.

Wood pallet construction and recycling

Wood pallets can be made from small particles of wood waste that are dried, compressed, and extruded into pallets. This type of business is very labor intensive and requires a lot of hard work to be successful. The traditional approach to recycling wooden pallets is to collect old pallets, dismantle them and make new pallets.

There are three pallet companies in Lincoln and Lancaster County that use this recycling approach. The largest pallet consumer uses 5,000 tons of wood per year, Stewart Pallet Recycling Company, while the smallest uses only 10 tons. These operations either shred their waste into landscape mulch or disposed of it in the landfill.

.**Compressed wood/chipboard**

Hardboard and fiberboard are wood composites produced by separating wood fibers from lignin, and hot pressing the mixture of fibers and resin into sheets. Particleboard is a composite produced by mixing small wood particles or fibers with either phenolic or urea formaldehyde resin and hot pressing the material into particleboard sheets.

There may be new markets for wood waste in hardboard fiberboard and particleboard manufacturing in the future. Most hardboard and fiberboard manufacturing facilities utilize wood waste generated on site or by an adjacent industry. Most particleboard manufacturing facilities utilize wood waste such as planer shavings as furnish. The overall demand for particleboard and therefore for wood furnish to manufacture into the material may increase in the future as a result of increased competition for and decreased availability of dimension lumber.

Pulp and Paper

The pulp and paper industry uses wood to produce pulp and ultimately paper and paper products. Pulp may be produced from either softwoods or hardwoods. The wood is traditionally supplied as roundwood or chips from harvested wood or mill residue.

The pulp and paper industry requires a large amount of wood fiber, and industry is expected to grow in the future. The industry is also expected to use increasing amount of recycled fiber (i.e. recycled paper and paper products).

Energy Recovery

Wood waste for recovery energy in industrial/commercial applications is used throughout the country. Industries that generate a significant amount of wood wastes have found it profitable to avoid disposal cost by using wood wastes for fuel recovery. Good examples of industries and colleges that operate wood boilers in Nebraska are listed below:
Concordia College, Seward; Chadron State College, Chadron; Hughes Brothers Inc., Seward; Nebraska Arbor Day Foundation & Hotel, Nebraska City.
More specific information of studies appears in case studies in Appendix A.

Other Potential End Uses

Numerous other end uses for wood waste exist in addition to those describe above. For example, there could be potential markets for animal bedding and litter, compost, landfill cover, packaging filler, etc. Other uses include automotive air and oil filters using a refined fiber grade of redwood bark. In a study by Lightsey, Mitchell and Travis (1976), pine bark was examined for its effectiveness as a trickling filter medium. There is also a way of using wood chips as a biofilters for industrial odor control.

Wooden pallets have proved to be a more actively sought out wood waste product. The table below summarizes the percentage of that U.S. Wood waste processors that accept a variety of material and produce a variety of end products. The report found that pallets were the most widely accepted and handled wood waste material, with more than two-third of all the processors accepting them.

The most common wood waste end use product is wood chips and mulch for various applications. The wood chips are used in landscaping, trail building, playground underlayment, and even as flavor chips for use in barbecues. Another popular use for wood chips is animal bedding because it is a cleaner, more absorbent material. Composting operators have also found wood chips to be a good additive to their compost to improve the composting process and end product.

The greatest potential to increase utilization of wood wastes for production of products and for energy recovery probably lies mostly within the wood industry. There is also potential outside the industry to increase the use of wood as fuel for residential heating (Wood Waste Processing in Iowa, 1996).

Table 2: Percent of national processors handling wood waste material by type

Type of Material	Percent of Total Processors
Wood Pallets	66
Brush Trimmings	55
Construction Cutoffs	49
Tree Residue	42
Demolition Scrap	31
Engineered Wood	23
Preservative-treated Wood	8

Source : National Wood Recycling Directory: Darrow, 1996

4. Assessing Technology to Process Wood Waste

Processing Equipment

Wood processing equipment is evolving in response to fuel specifications and new demands for other products recovered from the wood. Equipment is readily available to grind wood wastes into chips. The city of Lincoln currently contracts with a firm to provide grinding services of tree wastes.

Grinding loosens non-wood material attached to wood waste, such as plaster, paint, or nails. The cost of grinding is approximately $13/ton based on 3 inches of wood chip size. The purchase of a potable grinder ranges from $250,000-$500,000. In order to produce a compressed wood product or fuel pellets additional grinding is generally required. Densification equipment is needed to make the finished product.

A summary of the technology associated with energy recovery from wood waste and boiler equipment appears in Appendix B.

5. Environmental and Regulatory Issues

Environmental issues

There are a number of environmental issues which should be considered when evaluating the installation of a wood processing or fueled boiler system. These issues include environmental regulations, types of pollutants, environmental impacts of the various prime movers and fuels and current emission control technology.

The following provides an overview of the primary potential environmental impacts that may be associated with waste wood processing.

a) dust

Increased truck traffic and waste wood handling activities will increase generation of dust. Maintenance of a clean site and regular watering and grading of roadways into the site can help keep dust to a minimum. In order to prevent any potential public health impacts, there should be a 500 foot buffer zone between materials handling operations and residential communities, hospitals, and nursing homes. Dust control measures can help reduce airborne transport of fungal spores.

b) noise

Noise from a waste wood processing operation can negatively impact surrounding areas. The equipment utilized to process wood, including loaders, grinders, screens, dump trucks, as well as vehicles traveling to and from the site can produce a significant amount of noise. Local codes should be reviewed to determine whether certain noise level restrictions apply to the site. Noise impacts can be limited by controlling the hours of operation.

c) surface and ground water impacts

Waste wood that is saturated or exposed to standing water for an extended period of time can generate leachate discolored with tannins, nutrients and other wood extracts that may affect surface and ground water quality. Proper site selection, design and operations guidelines can help reduce potential water pollution problems.

d) fire risk

Fire risk from vandalism or storage in large stock piles should be seriously considered. As part of fire safety precaution, outdoor storage facilities are usually required to maintain fire lanes and follow minimum height and spacing standards.

e) odor

Odor from a waste wood decomposition process can negatively impact surrounding areas as well. It also has sour smell from the fermentation process.

Regulatory and permitting Issues

A number of state and local agencies will need to review and approve any plans related to a wood processing facility. Additional requirements may need to be met if wood wastes are used for energy recovery. Some states are satisfied with enforcing the existing federal regulations while others include provisions which are more strict than those outlined by the federal government. A variety of local policy and regulatory issues affect the ability to separate, process and use wood waste for fuel. The Lincoln-Lancaster County Health Department is authorized by the Air Pollution Control Program to implement and enforce an air pollution control program consistent with the Clean Air Act, as amended (42 U.S.C. 7401 et seq.) within the corporate limits of the city and the zoning jurisdiction of the city and within Lancaster County according to the authority the city. Under the Air Pollution Control Program, wood waste fired facilities are classified as either "fuel burning equipment" or "incinerators." Permit conditions are based on federal standards established by the U.S. EPA for the Clean Air Act. Key sections in the Air Pollution Control Program Section 22 that affect emission from wood or wood waste combustion are described in Appendix C. A summary of other regulatory issues related to energy recovery appears in Appendix C as well.

6. Cost/Benefit Analysis

The city has demonstrated that there is a significant local market for landscape mulch. This demand can absorb the current 37,500 cubic yards of wood chip generated each year. It is believed however, that other alternatives need to be developed if the city should more aggressively divert wood waste from landfill disposal. The most promising alternative appears to be energy recovery.

The purpose of this section is to estimate the cost of building an energy recovery system. The total capital cost of waste wood as a fuel system depends upon the exact configuration and size of the system. The capital cost of a system will increase with size, but the cost for each unit of energy produced by a larger system generally decreases due to economies of scale. The proper selection of equipment and careful sizing to energy demand is necessary. In general, the components of capital cost can be broken down as follows:

1. Division Costs
   a) Grinding Costs
   b) Transportation Costs
   c) Storage
2. Conversion Equipment and Installation
3. Operating and Maintenance Costs

<u>1. Diversion Costs</u>

a) Grinding Costs

The processing capacity of grinders ranges from 20 to 50 tons per hour depending on the quality of the wood waste and the size of wood chip required. Depending on the chip size required by the boiler, oversize wood is fed into a grinder to reduce the size of the chip before entering the fuel feeding system of the boiler. In Lincoln and Lancaster County the cost of grinding is approximately $13.00/ton based on a chip size of 3 inches and . It is estimated that 1 or 2 inch wood chips would more than double the cost to approximately $30.00/ton.

b) Transportation Costs

The first step in assessing the cost of fuel handling is to evaluate the method for unloading the fuel from the delivery vehicles. It is estimated that the cost of transportation would be approximately $20.00/ton in Lincoln including loading and unloading.

c) Storage

Common height standards for storing wood chips are 20-30 feet. Common standards for spacing between piles are 20 feet. Where storage space is minimal or where air pollution regulation require it, some facilities store fuel in enclosed bins. The bins help control dust from the fuel and allow the facility to meter chips that are sold fairly accurately. In most cases, a 10 to 30 day fuel storage capacity is necessary to ensure an uninterrupted supply of wood chop to the wood fired boiler facility. In the case of wood chip storage for a 50,000 lbs/hr steam boiler, a pile approximately 20 feet high covering ½ acre should provide a 15 day supply (Biomass Energy System).

Open storage is a less expensive method of storing large quantities of wet or green fuel. The cost of the contingency storage shed can be approximated from Table 3.

Table 3 : Cost of Storage

	Cost (Square foot)
OPEN	
On-ground	$ .00
On-slab	$ 1.00
COVERED	
Plastic, on-ground	$ 0.02
Plastic, on-slab	$ 1.02
Silo (without conveyors)	$ 1.60/cubic foot
Open Shed	$ 5.50
Closed Shed	$ 7.00
Air Bag	$ 3.50

Source :Levi, M. and O'Grady, M.

2. Conversion Equipment and Installation

Information on the size of the system is necessary. A boiler size is based on it's size or capacity. If boiler horsepower (BoHP) is known, the conversion to pounds of steam per hour (pph) is : BoHP * 34.5 = pph. Multiplying the pph times 1,000 results in BTU(British Thermal Units) per hour.

One of the major concerns about using wood as a fuel is its relatively low BTU value. This BTU value is demonstrated in Table 4. However, the wood waste fuel can be a profitable endeavor even with the lower BTU value of wood. M.L. Smith Environmental, Inc. studied the possibilities for using wood waste as an industrial fuel and concluded that it would be very feasible, and in fact profitable, to convert existing industrial boilers to partial burners of wood waste (MLSE Report, 1995).

Table 4: Fuel and comparable cost required for equivalent heat

Fuel	Efficiency	Heat Value	Cost Required
Gas	77.8%	1,000 ft^3	$2.50/1,000 ft^3
Electricity	90.0%	253.25kWh	0.0099/kWh
Wood (dry wood-bark)	80-70%	0.06-0.12 tons	19-40/ton

Source : U.S. Forest Service Fuel Value Calculator

3. Operation and Maintenance Costs

Operation and maintenance costs include operating labor, annual routine maintenance, and overhead charges for administrative and support labor for wood boiler facilities. Estimating O&M costs is to use 10 percent of the original capital cost per year (Hughes Machinery Company, 1997).

7. The alternative in Lincoln and Lancaster County

Lincoln generates 19,000 tons of wood waste per year. Tipping fees at the landfill are $16.00 per ton. Of this, 5,000 tons of wood are ground into wood chips. In 1996, the cost of grinding the wood was approximately $45,000. Wood waste diversion extends the life of the landfill as well. Wood waste weighs approximately 729 pounds per cubic yard. The diversion of 5,000 tons of wood waste represents a savings of 13,032 cubic yards of landfill space, thereby extending the life of the landfill. Based on a value of $10.00 per cubic yard, the amount of wood wastes recycled represents $130,320 in 1996.

Several other potential benefits may be obtained by a community operating a waste wood processing facility. These benefits also include:
-- Extended landfill life
-- Avoided disposal costs
-- Projected income from tipping fees/product revenues
-- Local economic development
-- Good will generated among employees and community in conserving resources.

According to Hughes Machinery Company in Omaha which specializes in the design of wood fired boilers, a 500,000 ft^2 building would consume about 5,000 tons of wood waste per year to heat it in Lincoln and Lancaster county. The boiler would need to meet the following specifications.

New Facility -- Comparing Alternative Systems
Boiler Size : 300 BoHP = 10,350pph = 10.3 million Btu/hr.
Pressure : 125 psi
Fuel : Wood Wastes
MC : 50% wet basis
Size of wood chips : 1 - 2 inches
Fuel Heat Value :8200 Btu/lb * 2,000 lbs/ton = 16,400,000 Btu/ton
Hours of operation : 2000 - 2,500 hrs/yr (8 months between Oct. and May)
Wood Fuel Requirements : 15 - 20 tons/day or 5,000 tons/year
Ft^2 of Building : 500,000 ft^2
Estimated useful life of system : 20-30 years
Boiler cost : $155,000 (including boiler vessel, combustion, chamber, under-fired stoker fuel feed, and draft fan with ash removal separator, and breaching)
Installation Cost : $60,000
Floor fuel Storage System : $55,000
Estimated Capital Cost : $270,000 ($155,000+$60,000+$55,000)
Operating and Maintenance Cost : $27,000
Annualized Capital Cost : $43,956 (assumes 10% interest over 10 years)
Total Annualized Cost : $70,956

Table 5 : Annual Cost Comparison to Natural Gas

	Wood	Natural Gas
Fuel cost :	$50.00/ton delivered (including grinding cost $30.00/ton transportation cost $20.00/ton) $50.00* 5,000 tons = **$250,000**	$3.34/mcf (million cubic feet) 500,000 ft^2 = 80,000 mcf * $3.34 = **$267,200**

Operating costs		
Wood consumption	$250,000	0
Annual O/M costs	$27,000	$21,500
Annualized capital cost	$43,956	$35,002
Utility (gas) costs	0	$267,200
Total annual costs	**$320,956**	**$323,702**

Cash Flow Analysis

The major cost factor in using wood wastes is the initial cost of purchasing and installing a boiler. After the installation, the fuel cost is roughly the same as natural gas which affects the capital cost of the wood boiler and natural gas is approximately the same (the difference of the capital cost would be $1,746 per year). This figure does not include other cost differences such as the amount of depreciation allowed for each system and other income taxes. This figure does not include landfill space savings of approximately $150,000 per year and resource conservation which promotes good will.

Table 6 : Cash Flow

Year	1	2	3	4
gas	$323,702	$336,650	$350,116	$364,121
wood	$320,956	$333,794	$347,146	$361,032

(based on 4% annual inflation and 1997 currency basis)

Additional case studies are presented in Appendix A including several examples in Nebraska.

8. Financing

Throughout the case studies, a major assumption has been that any money used in a wood fired boiler came from a firm's own internal funds. However, it is often necessary, and can sometimes be advantageous to borrow capital money to finance a wood boiler system.

The primary concern of the creditor is to protect the investment. Creditors use various financial measures to evaluate the financial health of the potential borrower and the likelihood of a default on the loan. The three funding sources covered in this section are available to all businesses in Lincoln and Lancaster County.

Conventional Financing

Loans from commercial lending institutions are available to cover the capital costs of a wood-fired boiler system. Commercial loans from a bank represent the major source of all funding activity.

State Grant Funds

Grant funds operated from the NDEQ(Nebraska Department of Environmental Quality) and

Environmental Trust are available to the firms in Lincoln and Lancaster County. Operating wood waste for energy recovery systems saves landfill spaces and conserves other resources as well. NDEQ grants which focus on waste reduction and recycling would be available to firms that are willing to use a wood fired boiler system. Wood fired boilers also provide an end-market for wood waste which is an eligible activity for grant support.

State Energy Office

The Nebraska Energy Office provides a low-interest loan program, Climate Wise, a cooperative program that promotes a comprehensive approach to industrial energy efficiency and pollution prevention. The wood boiler system would have less pollutants than other fuel systems such as oil and coal. Energy saving loans are offered statewide by the Nebraska Energy Office and the state's lending institutions. These grant funds could aid in lowering the overall capital cost of a wood fired boiler system compared to a traditional gas-fired boiler.

9. Conclusion

Wood waste is one of our most economical, efficient, renewable and environmentally-safe sources of energy. Lincoln and Lancaster County has an underdeveloped market for handling the wood waste it generates. The lack of information, communication and market certainty all work to prevent this market from expanding. Any new uses of wood waste have not been completely developed and the economic feasibility has not yet been computed. The technology is available as is the desire to divert wood waste from Lancaster County landfills.

Opportunities to divert more wood waste is available at the city's yard waste compost facility. It costs less to grind wood waste to a 3-inch size than to landfill. A landscape mulch market for wood waste is strong in Lancaster County and is expected to continue. However, the market is not expected to absorb to the full quantity of a wood waste now being disposed of in the sanitary landfill, if the materials were diverted. A good alternative to absorb more wood waste is Energy Recovery. A co-fired wood boiler system reduces fuel costs and would have the support of local economic development and address environmental concerns. Lincoln generates 19,000 tons of wood waste per year which is disposed of in the Sanitary Landfill. It is estimated that 5,000 tons of this wood waste could be diverted and ground into wood chips. Energy recovery appears to be the best promising end use for a larger quantity of wood waste diversion.

The cost of a wood waste boiler system and natural gas system is approximately the same. However, it is estimated that landfill savings of about $150,000/yr if wood waste were used in energy recovery and it promotes resource conservation as well. Grant funds to offset a portion of the capital costs for wood fired boilers are available which may enhance the economic benefits of a wood fired boiler system.

Through greater control over the types of wood waste used as a boiler fuel or other products, the wood waste market can begin to be consistent, manageable and profitable while at the same time diverting valuable wood from landfills. Information contained in this study may stimulate further analysis on the economic and environmental costs and benefits of a wood-fired boiler system for a particular application.

Appendix A **Case Studies**

Concordia College, Seward, Nebraska

The college started operating a boiler in 1931 and spent $100,000 to modify to heat the campus in 1983. The wood boiler facility operates 8,000 Btu/lb and heats the buildings as a stand-by system. This 100 BoHP central steam boiler would heat 140,000 ft^2 of building and is an alternative source, a stand-by system. The facility uses wood waste to meet approximately 60% of the heating needs. The boiler consumes 50 tons of wood a year and cost $90/ton OCC delivered. The college mentioned that cardboard is a better product than sawdust. 6 tons of cardboard products run 6-7 days in every heating season compared to 3 tons a day for sawdust. They have an underground storage unit which could store 8 tons of wood.

Contact : Clarence
Phone # : 402 - 643 - 7422

Chadron State College, Chadron, Nebraska

The college has two physical plant facilities, wood waste fired boilers. One heats 12,000 Btu/lb of steam an hour, and the other heats 6,000 Btu/lb of steam an hour. These system heat 22 buildings at the college and use wood chips which is bark and other products at the rate of 20 tons a day. The maintenance costs about $10,000 a year. The system has completely displaced the campus's use of natural gas and electricity. The college mentioned that these systems save approximately $20,000 a month compared to using gas or electricity.

Contact : Daren Marshell
Phone # : 308 - 432 - 6227

Hughes Brothers INC., Seward, Nebraska

The Hughes Brothers is a telephone pole manufacture in Seward Nebraska. The company is generating approximately 2,600 tons of wood waste a year and operating in-house wood boiler system which would heat 240,000 ft^2 of the building. The boiler cost $20,000 with $6-7,000 installation. Due to the cost of landfill and company's good will, the company has been operating its in-house wood-fired boiler system for 5 years. The facility would cover approximately 25% of the company's total energy use. The rest of the energy sources are natural gas and electricity. The company is satisfied that the boiler produces just a little amount of ashes, however, addressed that they have to carefully check that the wood is "cleaned".

Contact : Matt Stryson
Phone # : 402 - 643 - 2991

Nebraska Arbor Day Farm Lied Conference Center, Nebraska City, Nebraska

The national Arbor Day Foundation was established in 1972 and run the fuelwood plant since 1991. One boiler operates 150 BoHP with 4,000 Btu/lb steam an hour and the other operates 200 BoHP with 8,000 Btu/lb steam an hour at 1900° F. The systems cost approximately $50,000. They consume 9-12 tons of chipped wood a day and chipped wood costs $18 per ton. The boilers heat the air-conditioning and provide hot water of 110,000 ft^2 of the building and be cleaned and operated in 30-45 days routine. Gas has been a stand-by system since they started operating wood-fired boilers. The system produces a little amount of ashes which are removed and spread on farms, composted to recycle soil nutrients or added to cement. They are proud of operating the system and do have touring

schedules for interested individuals.
Contact : Jim Stark
Phone # : 402 - 873 - 8702

North West Missouri State University, Maryville, Missouri

The campus operates 5 wood fired boilers which heat and cool its 1,700,000 ft^2 of buildings. The wood-fueled power plant went on-line for continuous use in August 1982. The boilers produce from 100,000 lb/hr of steam to 25,000 lb/hr of steam, consume about 3 tons of wood an hour and operate 24 hours a day, 7 days a week and 9 months an year between October and may, 60 to 65 tons of wood chips are used daily to meet approximately 65% of the heating and cooling needs. Wood chips produce between 4,000 and 5,000 BTUs per pound depending on the moisture content, not species, of the wood. The systems have completely displaced the campus' use of natural gas and electricity and used 4 different types of wood waste. With a steam capacity of 25,000 pounds per hour, the use of wood chips decreases the use of oil and natural gas by 65%. The total annual savings is natural gas amount to 1,911,907 ccf or an oil savings of 1,275,938 gallons.

M.C. Dixon Lumber Company, Eufaula, Alabama

M.C. Dixon Lumber Company of Eufaula, Alabama produces about 85,000 boards feet of lumber per week. The company decided to install a cogeneration system using its waste wood as fuel. The system has completely displaced the company's use of natural gas and purchased electricity. The system cost about $2 million. The company raised funds through an Industrial Revenue Bond issue. From a storage silo the fuel flows to a 60,000 lb/hr boiler. Part of the steam output (300 psig, 500° F) goes to four lumber drying kilns. The rest of the steam powers two condensing steam turbine generators. One is rated at 1500 kW; the other, 1000kW. The boiler operates 24 hours a day, 6 days a week, powering the kilns. Costing savings were about $373, 000/yrs., leading to a payback of 5.3 years.

Colortile Manufacturing Company, Melbourne, Arkansas

Colortile Manufacturing Company is a division of Colortile Supermart, Inc., that produces hardwood flooring for sale. The plant began operation in 1980. About 60% of the raw lumber used in manufacturing becomes waste. Disposal would cost $75,000 - $100,000 per year. The boiler produces about 31,000 lb/hr of steam at 450 psig and 725 °F. The system cost about $420,000. Costing savings were $272,000/yr for process steam, $150,000 for electricity, and $75,000 -$100,000 for waste disposal, leading to payback of about 1.6 years. It costs $24,000/year for maintenance parts and material. In 1986 the company upgraded its generators to 2000kW to meet the plant's power needs during the work week.

Young Manufacturing Company, Inc., Beaver Dam, Kentucky

Young Manufacturing is a millwork company located in Beaver Dam, Kentucky. It is a small business that produces about 2 million board feet of product per year. The company added a wood-fired cogeneration system in 1974. In 1987 and 1991 the company replaced the steam piston engines with turbine/ generators. The system supplies 100% of the plant's heat load and about 35% of its electric load. A boiler cost $250,000, the generators $100,000. Operating and maintenance costs were $70,000 and electricity costs were $24,000/yrs. Annual savings after startup were at least $196,000, leading to a payback of 1.8 years. The company received an award from the EPA for its excellent emissions record.

DeSoto Hardwood Flooring Company, Memphis, Tennessee

DeSoto Hardwood Flooring Company has been a manufactures of oak flooring and hardwood lumber since 1912. The company has burned wood waste in boilers since the early 1920s. The boilers produce steam to heat the company's dry kilns. The company decided in early 1984 to install a steam turbine generator and had it on line in July 1984. About 20,000 lb/hr of steam (150 psig) power a back pressure turbine that runs a 300 kW generator. Electric bills dropped from $16-18,000/month to $12-13,000/month, saving $48-60,000/year. A turbine-generator cost $70,000 to install and $4800/year in operating and maintenance costs. The payback was less than 1.5 years.

Appendix B Technology for Energy Recovery and Boilers

Wood waste can be converted either into heat/thermal energy which is used to generate steam, or into gaseous fuels, which can be used to operate internal combustion engines or gas turbines. The most common form of conversion is direct combustion to produce heat by burning wood in any one of a number of types of furnaces. Conversion to gaseous fuels is accomplished either by heat in a gasifier or by anaerobic digestion. In addition, wood residues can be processed prior to conversion by densification or into alcohol fuels.

Combustion

Direct combustion, the simplest method, is a proven technology that combines molecules of hydrogen and carbon with oxygen, resulting in thermal oxidation. In the process, solid wood residues are converted to gases and ash and heat are released from the thermal/chemical reaction.

Gasification

Gasification is the thermal conversion of a solid fuel to a gaseous fuel that can be used to produce heat or power or in chemical synthesis. Gasifiers generally burn cleaner than direct combustors.

Carbonization

Carbonization is the conversion of wood into charcoal. Charcoal and tar manufacturing is the oldest of all chemical wood-processing methods. Charcoal can be made from any wood species, although denser species are preferred because yields are in direct relationship to density. Charcoal can be made from solid wood as well as chips, shavings or sawdust and can be used directly in a crude form or briquetted for transportation.

Densified Wood

Densification is the process by which residues are compressed under pressure and heat into uniformly sized particles. Densified wood products come in a variety of shapes and sizes for use as fuel, such as logs, pallets and briquettes. Densified wood products are clean, easy to kindle and provide abundant heat in a short time.

Alcohol

Cellulose form sawdust and chips can be converted directly into alcohol fuels.

-- Ethanol : It is produced by converting corn cobs, a starchy crop, into sugar, which can be fermented into alcohol.

-- Methanol : It can be produced with wood residues as the feedstock.

The equipment to energy through wood-fired boiler are as follows:

Pile burner

-- Dutch Oven
-- Conifer Furnace
-- Horizontal Return Tubular Industrial Boiler
-- Modified Firebox Industrial Boiler
-- Firetube boiler/Watertube Boiler

Cyclone or Suspension burner

-- Injection Suspension Burning
-- External Direct-Fired Suspension Burning

Fluidized bed combustion system

Wood Gasifiers

Hot Air Furnace

Appendix C Regulatory Issues

Federal regulations

Although the state environmental agencies are the primary ones to contact in determining the required pollution control equipment and regulatory steps necessary to gain approval for an energy facility, including a source of wood waste, in rare instances you may also want to contact the Environmental Protection Agency (EPA) regional office responsible for the area in which the cogeneration facility is to be built.

Three major laws establish the Federal policy and regulatory approach that applies to the use of wood waste for fuel and other purposes.

a) Resource Conservation and Recovery Act (RCRA), which is the major Federal law addressing the management and disposal of solid and hazardous waste in the U.S.

b) Clean Air Act (CAA), which is the major Federal law addressing emissions of air pollutants from stationary sources, such as wood-fired facilities. Most industrial, commercial, institutional and utility wood-burning facilities are required under the CAA to obtain a permit to emit air pollutants.

Major regulations that impact wood-fired facilities include the:

- National Ambient Air Quality Standards (NAAQS);
- Prevention of Significant Deterioration (PSD) regulations;
- Non-Attainment Areas (NAA) and Lowest Achievable Emission Rate (LAER) regulations;
- New Source Performance Standards (NSPS); and
- National Emission Standards for Hazardous Air Pollutants (NESHAPS).

States must prepare State Implementation Plans (SIPs) that carry out the intent of the CAA. The SIPs must be approved by EPA.

c) National Energy Policy Act of 1992 (EPACT), which identifies specific goals and activities for managing the nation's energy demand and for meeting future energy requirements. As a renewable resources, wood waste can help achieve goals of EPACT that address solid fuels and feedstocks that produce liquid or gaseous biofuels.

Air emissions characterization

In wood-fired boiler plants, the air pollutant of primary concern is particulate matter. Removal of sulfur oxides is required only when large amounts of high-sulfur coal or oil, together with wood waste, are burned. Generally, nitrogen oxide emissions can be controlled by boiler design; however, in some locations, regulations have required the installation of nitrogen oxide emission control systems. If demolition debris which can contain plastics, paint, glues, synthetics, wire, cable, insulation, etc is part of the wood waste fuel, additional air pollution control equipment may be required, depending on what and how much is burned.

Actual emissions include:

--Composition of the wood waste fuel and its variability
--Type and amount of fossil fuel burned in combination with the wood waste
--Firing method and type of furnace
--Extent of carbon reinjection
--Air pollution control system

Water quality

Various agencies regulate the withdraw, allocation and use of water. The requirements are determined by whether the water will be pumped from groundwater, withdrawn from a natural body of water or supplied by a municipal wastewater system.

A cogeneration plant may require use of hazardous materials such as ammonia, sulfuric acid and caustic soda for regenerating boiler feedwater demineralizers. For plants that incorporate a cooling tower, biocides are considered as pesticides and must be registered and approved by the EPA for the specific use that appears on the label.

Air quality

Regulations for air quality at the Federal level include a variety of rules and regulations. Air quality permits are issued by a state to enforce limitations of both federal and state air quality emissions. A wood-fueled cogeneration plant may or may not require an air quality permit, depending on the exact type and amount of anticipated emissions and the location of the plant. A permit will be required if the plant emits a sufficient amount of any of the seven critical air pollutants, emits for which National Emissions Standards for Hazardous Air Pollutants (NESHAPS), locates within a Non-Attainment area or significantly impacts either a Non-Attainment area or a Class 1 area which includes National parks, wilderness areas, national memorial parks. Most areas in the U.S. belong to the Class 2 including Lincoln.

Air pollution control measures

Air pollution control equipment designed to remove particulate will be principal focus. Particulate control equipment used on wood-fired boilers generally falls into one of four categories:

a) mechanical collector
b) wet scrubbers
c) electrostatic precipitators (ESPs) - dry and wet
e) filters

Air pollution control equipment able to meet today's stringent air regulations is readily available for wood waste combustion facilities. The following alternatives are possible:

a) The use of limestone in a fluid-bed boiler
b) A spray dryer acid-gas removal reactor using a lime slurry
c) A packed tower absorber using a sodium-based scrubbing solution
d) A lime/limestone injection system

Permits and regulatory agencies

To install a new boiler one must obtain a permit to construct, a permit to operate and possibly other permits, depending upon the State and local requirements. It will be necessary to submit a Prevention of Significant Deterioration (PSD) permit application if the plant will emit more than 100 tons/year of a criteria pollutant or if the plant will emit pollutants at levels considered significant (See Table 7).

Table 7 : Emission Level Considered Significant Under PSD Regulations

Pollutant	Emissions Rate (tons/year)
Carbon monoxide	100
Nitrogen oxides	40
Sulfur dioxide	40
Particulate matter	25
Ozone (volatile organic compounds)	40
Lead	0.6
Asbestos	0.007
Beryllium	0.0004
Mercury	0.1
Vinyl chloride	1
Fluorides	3
Sulfuric acid mist	7
Hydrogen sulfide (H_2S)	10
Total reduced sulfur (including H_2S)	10
Reduced sulfur compounds (including H_2S)	10

Source: SERBEP 1993

Air Pollution Control Program Section 22

This section 22 can be found in the page 84 of the 1995 Lincoln-Lancaster County Health Department Air Pollution Control Program. The Air Pollution Control Program is to implement and enforce an air pollution control program consistent with the Clean Air Act within the corporate limits of the city and the zoning jurisdiction of the city and within Lancaster County according to the authority the city.

SECTION 22 INCINERATOR EMISSION

(A) All category I incinerators shall comply with the following requirements:

(1) No person shall cause or permit emissions of particulate matter from any incinerator to be discharged into the outdoor atmosphere to exceed 0.10 grains per dry standard cubic foot (gr/dscf) of exhaust gas, corrected to 12 % carbon dioxide. The exhaust gases contributed by the burning of a liquid or gaseous fuel shall be excluded.

(2) The burning capacity of an incinerator shall be the manufacturer's or designer's guaranteed maximum rate or such other rate as may be determined by the Director in accordance with good engineering practice.

(3) Waste burned during performing testing required by paragraph (4) below shall be representative of the waste normally burned by the Affected facility and shall be charged at a rate equal to the burning capacity of the incinerator. Copies of any additional operational data recorded during the test shall be submitted to the Department together with the completed test report forms.

(4) Instructions for proper operation of each incinerator shall be posted on site and written certification that each operator has read these instructions, understands them and intends to comply, shall be kept on record by the owner.

(B) All category II incinerators shall comply with the following requirements:

(1) Design

(a) Automatically controlled auxiliary burners capable of heating and maintaining the combustion in the primary combustion chamber at a minimum temperature of 1300°F for two seconds residence time at an oxygen concentration greater that 7% by volume measured on a dry basis.

(b) A fugitive emissions control system for the waste incinerator and its pollution control device including double doors on the feed chamber with interlocks to prevent both doors from being opened at once.

(c) A door lockout mechanism which prevents charging of waste between the manufacturer's designated burn cycle and which prevents charging if primary or secondary chamber temperatures fall below designated minimum temperature and/or carbon monoxide levels exceed designated shutdown criteria and /or excess visible emissions occur.

(d) A pollution control system containing at a minimum either an acid gas scrubber and a particulate control device, or a dry sorbent injection and fabric filter, shall be in place and in working order with a maximum emission gas temperature of 300 F continuously monitored and recorded exiting from the pollution control system.

(2) Emission Standards

(a) A particulate matter emissions limit of 0.03 grains per dry standard cubic foot adjusted to 7% oxygen.

(b) Acid gases - hydrochloric acid emissions shall be no greater than 50 parts per million by volume corrected to 7% oxygen on an hourly average or shall be reduced 90% by weight of uncontrolled emissions on an hourly average, whichever is less stringent. Sulfur dioxide emissions shall be no greater than 100 parts per million by volume corrected to 7% oxygen hourly average or shall be reduced to 70% by weight of uncontrolled emissions on an hourly average, whichever is less stringent.

(c) Carbon monoxide - carbon monoxide emissions shall be no greater than 50 parts per million by volume corrected to 7% oxygen on a dry basis as a 4 hour average.

(d) Opacity - the opacity of all emissions except un-combined water shall not exceed 5% for a six minute running average in accordance with the EPA Method 9.

(e) Dioxins/furans shall be limited to no greater than 30 nanograms per dry standard cubic meter (dscm).

(f) Mercury shall be limited to no greater than 50 micrograms per demonstrating compliance with a particulate matter emissions limit equal to or less than 0.015 grains per dry standard cubic foot at 7% oxygen.

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