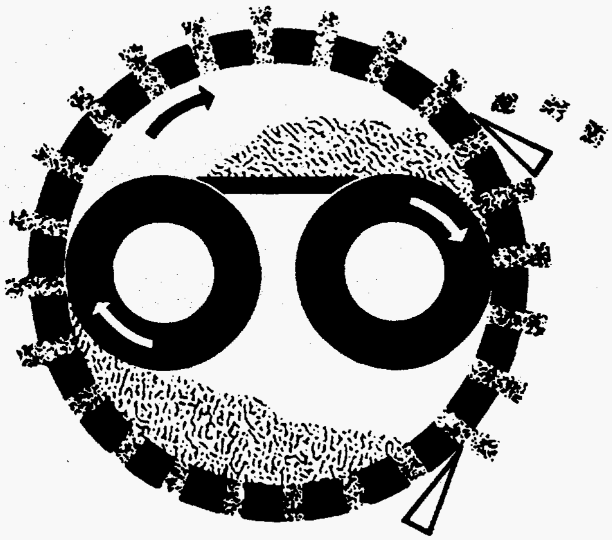
A Handbook For
Small-Scale Densified Biomass Fuel (Pellets) Manufacturing
For Local Markets



Prepared for:

United States Department of Energy
Bonneville Power Administration
1002 N.E. Holladay
Portland, Oregon 97232
Contract # DE-A179-87BP66088

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July, 1992

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A Handbook For
Small-Scale Densified Biomass Fuel Manufacturing (Pellets)
For Local Markets

HANDBOOK SUMMARY

Audience

Small to medium-sized wood products company managers
Independent logging contractors
Solid waste disposal company managers
Farmers interested in residue-to-energy conversion
Pellet fuel and pellet stove manufacturers
Biomass fuel researchers

Topics

Pellet Fuel Industry Assessment
Directories of Fuel, Equipment and Stove Manufacturers
Case Study of Browning Cut Stock Company
Laboratory and Stove Testing of Pellet Fuels
Preliminary Feasibily Spreadsheet (DENSEFUEL)

Summary

This handbook has been prepared to assist potential small-scale manufacturers of densified biomass fuel with preliminary investment, processing and local marketing decisions. It presents an overview of the industry, documents the operation of an actual small-scale pellet fuel manufacturing business and provides an interactive spreadsheet for examining cash flow from hypothetical plant layouts.

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Part I. SMALL-SCALE DENSIFIED WOOD FUEL MANUFACTURE AND UTILIZATION: An Industry Assessment

NATIONAL PERSPECTIVE ON WOOD ENERGY POTENTIAL IN THE UNITED STATES

In 1981, the U.S. consumed a total of about 78 quads of energy. Of this total, approximately three quads or four percent were from wood. Industrial consumption, mainly by the forest products industry, used nearly two quads of the supply which it generated by direct combustion of mill residues as a manufacturing by-product. The remainder, about one quad, was used for residential heating and was produced from burning firewood (Slinn, 1984). [A quad is defined as one quadrillion BTU of heat. Since a barrel of crude oil contains about six million BTU, a quad is equivalent to approximately 167 million barrels of crude oil.]

Table 1 presents the potential sources and amounts of wood energy from existing inventories, stand growth and harvest/utilization.

Table 1. WOOD ENERGY POTENTIAL IN THE UNITED STATES IN CONJUNCTION WITH FOREST INVENTORY, GROWTH, HARVEST AND UTILIZATION (Steinhagen, 1986)

Inventory	
commercial forest land	352 quads
non-commercial forest land	80 quads
total inventory	432 quads
Net Growth (less mortality)	
commercial forest land	7 - 14 quads/year
non-commercial forest land	1 quad/year
total growth	8 - 15 quads/year
Harvest and Utilization	
harvest converted to finished products	1.7 quads/year
harvest converted to wood fuel	1.5 quads/year
harvest not utilized	2.2 quads/year
total harvest and utilization	5.4 quads/year

An important conclusion that may be drawn from Table 1 is that inventory data indicate a surplus and potential energy supply, just from growth, of approximately five to twelve quads per year.

The national pattern of wood energy use in 1982 within the forest products industry was as follows (Slinn, 1984):

- hog fuel	8.0%
- bark	5.4%
- spent liquor (from pulping)	37.4%
- fossil fuels, electricity and other	49.2%
totals	100.0%

Estimates of potential sources of annual available forest biomass (in million dry tons) for energy conversion by the year 2000 are summarized in the following table (Table 2).

Table 2. ESTIMATED FOREST BIOMASS FOR ENERGY BY THE YEAR 2000 (DOE, 1981)

Biomass Source	Million Tons Dry Biomass	Million Tons Dry Biomass For Energy	Quads of Potential Gross Energy	Quads of Potential Net Energy
mill residue	200	100	1.70	1.08
logging residue	205	50	0.85	0.50
thinnings (TSI)	70	35	0.60	0.35
unharvested mortality/growth	310	30	0.51	0.30
non-commercial wood residue	55	55	0.94	0.55
wood energy plantations	10	8	0.17	0.10
totals	850	278	4.47	2.88

Total U.S. energy demand by the year 2000 in quads per year within various demand sectors for a variety of fuel sources is projected by two scenarios, A and B, in Tables 3 and 4 for a variety of fuel sources. In spite of the likelihood of a surplus of wood energy supply in the U.S. by the year 2000, demand is expected to increase only slightly or remain relatively constant throughout the period (Davis, 1991). In addition, a re-definement of "available" wood energy supplies due to national timber supply issues such as endangered species and new forestry is a certainty and may reduce the available supply.

Table 3. SCENARIO A (DOE, 1979)

	DEMAND				SUPPLY	
Fuel	Residential Commercial	Industrial	Trans-portation	Elec-tricity	Domestic	Imported
oil & NGL	3.0	5.0	21.0	2.0	22.0	10.0
natural gas	9.0	12.0	--	--	19.0	2.0
coal	--	9.0	--	30.0	39.0	--
nuclear	--	--	--	17.0	17.0	--
hydro-electric	--	--	--	4.0	4.0	--
biomass	0.5	2.5	--	--	3.0	--
solar	1.0	1.0	--	--	2.0	--
totals	13.5	29.5	21.0	53.0	106.0	12.0

Table 4. SCENARIO B (OTA, 1979)

oil & NGL	1.0	2.0	16.0	--	15.0	4.0
natural gas	4.5	11.5	0.5	0.5	16.0	1.0
coal	--	9.0	--	21.0	30.0	--
nuclear	--	--	--	7.0	7.0	--
hydro-electric	--	--	--	4.0	4.0	--
solar	1.5	1.0	--	1.5	4.0	--
syn fuels	--	1.5	3.5	1.0	6.0	--
biomass	0.5	2.5	--	--	3.0	--
totals	7.5	27.5	20.0	35.0	85.0	5.0

POTENTIAL SUPPLY OF WOOD FIBER IN THE REGION FOR ENERGY

Introduction

In addition to harvesting the standing forest resource, a large segement of the region's (Figure 1) forest products industry is based on the utilization of wood residue as a by-product of lumber and panel manufacturing. In fact, over 95 percent of the mill residue generated in Idaho and Montana comes from sawmills and plywood plants (Keegan, 1988). Major uses include paper and reconstituted board manufacture, energy generation and process steam for drying. Large industry users located in Idaho alone are dominated by a kraft paper mill, a particle board plant and a generating facility. Other significant regional residue users include a generating facility and a paper mill in eastern Washington, a fiberboard producer, a particleboard plant and a paper mill in western Montana, and two particleboard plants in eastern Oregon.

In the following discussion, residue types are examined for availabilty with the objective in mind to find if there are supplies considered to be surplus and available for wood pellet manufacturing.

Types of Residue

Sawmills and plywood plants generate three types of wood residue: 1) coarse or chipper residue composed primarily of slabs, edgings, and trim from lumber manufacturing, log ends from sawmills and plywood mills, and peeler cores and veneer waste from plywood plants; 2) fine residue in the form of planer shavings and sawdust from sawmills and sander dust from plywood plants; and 3) bark from sawmills and plywood mills.

Trends in Residue Production and Consumption

In 1985, Idaho sawmills and plywood mills were producing approximately 2.0 million bone dry units (BDU) of manufacturing residue, a decline from 2.7 million in 1969 and 2.5 million in 1979 (Keegan et al, 1988). [A BDU is defined as 200 cubic feet in volume of wood chips at oven-dry conditions and weighing approximately 2400 pounds.] Utilization of this residue, however, increased significantly from 63 percent of the total available in 1969 and 89% in 1979 to 94% in 1985. Table 3 is a reflection of the trend for utilization of wood residue by Idaho forest industry in 1969, 1979 and 1985.

Figure 1. Intermountain West Region for Small-Scale Densified Wood Fuel Manufacture

Table 5. ESTIMATED VOLUME OF WOOD RESIDUE GENERATED BY IDAHO SAWMILLS AND PLYWOOD PLANTS - 1969, 1979 and 1985 (Keegan et al, 1988)

	Estimated Volume (million BDU)			Percent of Total	
Residue	Utilized	Unutilized	Total	Utilized	Unutilized
chipped					
1969	0.830	0.268	1.098	76	24
1979	0.987	0.021	1.008	98	2
1985	0.976	0.014	0.990	99	1
fines					
1969	0.621	0.353	0.974	64	36
1979	0.739	0.078	0.817	90	10
1985	0.596	0.039	0.635	94	6
bark					
1969	0.254	0.393	0.647	39	61
1979	0.473	0.174	0.647	73	27
1985	0.282	0.073	0.355	79	21
totals					
1969	1.705	1.014	2.719	63	37
1979	2.199	0.273	2.472	89	11
1985	1.854	0.126	1.980	94	6

Residue Supplies and Utilization in the Intermountain West

Coarse residue has the greatest demand within the forest industry. Most of this residue type is currently being used in pulp and paper manufacturing. In 1985, approximately 990,000 BDU were available of which 99% was utilized. Of the total 990,000 BDU available, the pulp and paper industry consumed about 930,000 or 94%, hog fuel for steam boilers in sawmills took approximately 28,000 or 3%, and other industry requirements were about 18,000 or 2%. Approximately 14,000 BDU or 1% of coarse residue remained unutilized.

Over 94% of the fine residue was used in 1985 compared to about 90% in 1979 and 64% in 1969. Sawdust made up the greatest proportion of this used residue type, about 308,000 BDU or 93%, and planer shavings accounted for approximately 288,000 BDU or 94%. Board plants and pulp mills used the greatest amount of planer shavings, about 128,000 BDU, while 155,000 went into hog fuel and 5,000 ended up as bedding for livestock. In 1985, only about 17,000 BDUs or 7% remained unutilized.

Of the total sawdust generated by the wood industry, 176,000 BDU or 53% was consumed by pulp mills and board plants, 115,000 or 35% went into hog fuel, and 17,000 or 5% found other uses. In 1985, 7% of the total sawdust residue that was still available for use.

The utilization of bark has steadily increased from 1969 levels. In 1985, 79% of the bark was used compared to less than 39% in 1969. The total generated was approximately 355,000 BDU. Of this volume, 263,000 or 74% was used as hog fuel and 19,000 or 5% went for animal bedding or mulch. The remaining 73,000 BDU or 21% was either burned or piled for later disposal.

Table 4 shows a comparison of the utilized and unutilized volumes of residue in north and south Idaho in 1985 (Keegan et al, 1988).

Table 6. AMOUNT OF RESIDUE GENERATED IN IDAHO BY REGION - 1985 (Keegan et al, 1988)

	Estimated Volume (million BDUs)		
	utilized	unutilized	total
chipped			
north Idaho	0.768	0.010	0.778
south Idaho	0.208	0.004	0.212
planer shavings			
north Idaho	0.203	0.017	0.220
south Idaho	0.085	---	0.085
sawdust			
north Idaho	0.236	0.020	0.256
south Idaho	0.072	0.002	0.074
bark			
north Idaho	0.178	0.068	0.246
south Idaho	0.104	0.005	0.109
totals			
north Idaho	1.385	0.115	1.500
south Idaho	0.469	0.011	0.480
grand totals	1.854	0.126	1.980

Other Regional Sources of Wood Residue for Wood Pellet Manufacturing

primary wood processors

Although large primary manufacturers of solid wood products generate the largest volume of wood residue, there are many small and medium primary processors that, collectively, are significant producers. Firms in Idaho, numbering approximately 185 (Govett and Miller, 1988), include small sawmills, and cut stock, house logs, cedar products, and post and pole manufacturers. There are currently no accurate estimates of the total residue these firms generate, however, only a small amount is sold and surplus may be stockpiled, incinerated, or landfilled. Negative operating costs accompanied by environmental risk are incurred when wood wastes are stockpiled, incinerated or landfilled (Folk and Campbell, 1990). Viable markets include livestock bedding, organic material for nurseries, garden mulch and firewood.

secondary wood products processing

Gorman (1989), Morgans (1989) and the Montana Department of State Lands (1990) identify over 200 secondary wood processors in Idaho, 13 in eastern Oregon and 87 in western Montana that generate potential raw material for wood pellet fuel. Detailed information about secondary manufacturers in eastern Washington is not complete but a cursory assessment is made from the directory commonly used by buyers and sellers in the forest products industry (Random Lengths, 1987).

Of the total, about 115 processors in Idaho, 40 in western Montana, 5 in eastern Washington and 5 in eastern Oregon manufacture moulding and millwork, prefabricated buildings, log homes, pallets and boxes, log and western furniture, novelties, lath and survey stakes or operate a resaw and remanufacturing facilities. These processors would produce a clean, bark and contaminant-free residue with a low moisture content.

Another supply source composed of 20 specialty cedar products manufacturers in Idaho, 3 in western Montana, 6 in eastern Washington and 1 in eastern Oregon could also provide a clean, dry raw material. Processing difficulties with densification due to the oils present in the wood can be eliminated when cedar is pelleted in combination with other species.

A third raw material source is 65 Idaho, 44 western Montana, 2 eastern Washington and 7 eastern Oregon manufacturers of cabinets, furniture, posts and poles however, contamination is likely. Abrasives, adhesives and overlays such as formica and vinyl used in furniture and cabinet manufacturing will damage pelleting equipment, are non-combustible and can cause slagging. Wood preservatives and coatings are potentially corrosive and volatilize when heated. Processing and combustion characteristics of contaminated residues should be thoroughly examined before these sources are used as a residential pellet fuel feedstock.

Forest Land and Timber Inventories in Idaho

Idaho supports a large commercial forest land base from which wood for energy could be obtained. Tables 7 and 8 present an overview of forest land acreage by region and ownership classification and a projection of volume growth for this ownership.

Table 7. COMMERCIAL FOREST LAND WITHIN THE STATE OF IDAHO - 1975 (Hatch et al, 1976)

Region	Ownership Classification		Acreage (thousands)
North Idaho	National forest		4,208.7
	other public		778.7
	forest industry		777.6
	other private		1,808.6
		total:	7,573.6
South Idaho	national forest		6,125.0
	other public		568.2
	forest industry		169.1
	other private		265.5
		total:	7,127.8
North and South Idaho (all classifications)			14,701.4

Table 8. PROJECTED ANNUAL GROWTH OF IDAHO FORESTS - 1975 (Hatch et al, 1976)

Year	Million cubic feet/year (net) National Forest	Other Public	Forest Industry	Other Private
		North Idaho		
1980 - 1990	119.00	27.97	45.35	41.15
1990 - 2000	127.32	29.62	50.60	41.73
2000 - 2010	132.68	30.71	57.90	41.33
2010 - 2020	135.85	31.50	55.75	40.66
2020 - 2030	137.42	32.07	56.47	40.04
2030 - 2040	137.77	32.45	56.54	39.58
2040 - 2050	137.89	32.68	56.36	39.31
		South Idaho		
1980 - 1990	74.62	5.80	7.89	3.82
1990 - 2000	81.00	5.88	8.25	3.84
2000 - 2010	85.65	5.88	8.44	3.83
2010 - 2020	88.86	5.85	8.54	3.80
2020 - 2030	90.85	5.79	8.57	3.71
2030 - 2040	92.00	5.72	8.57	3.71
2040 - 2050	92.50	5.66	8.55	3.67

To summarize, the forest products industry in the region is consuming nearly all the coarse and much of the fine residue that is available. It is a result of the competition for utilization of this residue primarily by the panel and, pulp and paper industry. Large sawmills and plywood mills significantly impact residue supply and residue utilization fuel to provide process steam for lumber and veneer drying. In addition, a reduction in the forest land base, a decline in lumber production due to mill closings or economic downturn can only place further pressures on the supply of clean wood residues (Keegan and Blatner, 1991). Given this economic constraint, there is little excess for other uses such as wood pellet manufacturing. Wood pellet manufacturing must be expected to generate a higher economic return than current uses for clean residues if supplies are to be made available for energy.

Other small residue producerss in secondary wood processing however, may be potential sources but these firms have not been adequately inventoried and are scattered throughout the region. Bark /hog fuel continue to be available but with existing technology, it is undesirable from a product quality point-of-view for producing densified wood fuel pellets for the current residential pellet appliance market. The recovery of logging slash could supply material for new residue utilization. However, the recovery, processing and handling costs of the material are expensive. The commercial forest land base throughout the state is substantial, particularly in north Idaho where total growth per year for the region is in excess of 230 million cubic feet. Net cubic foot volume growth for the state as a whole (average of both regions) is projected to increase approximately 16 percent over the next 70 years. This would suggest an increasing wood resource that could meet raw material requirements for an expanding forest products industry. An expansion should translate to additional supplies of clean residue and opportunities for expansion in the pellet fuel industry.

RAW MATERIAL RECOVERY AND IN-THE-WOOD PROCESSING FOR ENERGY PRODUCTS

Nearly all the supply of raw material for existing pellet mill capacity now comes from wood processing residue in the form of sawdust, shavings and chips. But if wood pellets are to become a growing source of energy, alternative raw material sources must be located and utilized. Alternative sources under consideration are from recovered logging residue, unmerchantable trees from thinning and timber stand improvement, and utilization of cull and standing-dead trees and cull logs in conjunction with timber harvesting operations. Recovery of logging residue implies simultaneous processing or a post-logging entry to recover the residue from landing slash piles and scattered accumulations in a logged area. Utilization of unmerchantable material usually means whole-tree processing, sometimes from pulp grade trees, and processing green slash produced during logging.

Wood pellet manufacture requires roundwood or residue to be broken down into sawdust, shavings or chips and eventually to particles for pelleting. There are many ways to achieve this, either through stationary (on-site) or mobile (in-the-woods) chippers, hogs, shredders, chunkers and hammermills. One method to produce energy products is to chip in-the-woods and then transport the chips to the pellet manufacturer. Another approach is to use a stationary chipper at or near the pellet mill and transport the raw material to the chipper site. Available chipping equipment covers a wide range of prices depending on the desired chip quality, the machine capacity and mobility, and materials handling options.

One reason that current manufacturing interest and wood pellet research continues to focus on logging residue recovery is that residue is already delivered to or generated at landings during harvesting. Utilization of logging residue can increase revenues from logging and benefit other forest management activities. Studies have shown that the use of logging residue for energy is not feasible in most operations because of inefficiency in using large capacity chippers, long hauling distances and low hog fuel prices. Other research suggests that residue recovery with an ongoing harvesting operation, using a small chipper and 129 mile hauling distances, would be profitable for fuel chip prices of $30 per dry ton (Dean, 1983).

There is need with chipper operations to match skidder production, volume and residue size to the chipper capacity (Keller, 1983). A major problem with in-the-woods chipping is over-capacity of the equipment which raises the per ton cost of the chips. A study with a large capacity chipper showed that efficiency was raised from approximately 50 to 75 percent by using two skidders, instead of one, to supply material (Dean, 1983). This increased production from 4.6 tons to 8.5 tons per scheduled machine hour and lowered the cost of skidding and chipping the material from $24.71 to $21.60 per green ton. [A scheduled machine hour is defined as the planned operating time period for a piece of equipment disregarding downtime.]

Efficiency of operation using chippers is a continuing problem that has many ramifications. A study comparing three models of chippers on three different logging operations revealed a chipper efficiency that ranged from 28% to 52%. Cited as major delays were chippers waiting on skidders for residue delivery, chippers waiting for vans to load, and chipper downtime. The latter was due to knife changing, especially with sliding boom, infeed equipment. In the same study, when chipping costs alone were considered, whole tree-processing with large chippers was found to be less expensive than residue recovery with small capacity equipment (Dean, 1983). This was a direct result of larger chippers being utilized more economically from larger piece volumes and from less mechanical downtime due to cleaner raw material. This information suggests a point where logging residue would be cost prohibitive for producing chips if it were below a certain quality. Total system costs for harvesting, skidding and processing whole trees in the previously mentioned study, ranged from $8.16 per green ton of energy wood with a large capacity chipper to $25.14 per green ton for a small capacity machine in residue recovery. Overall, larger chippers with an 18-inch or greater capacity were found to be better suited for whole tree processing, and small chippers 14 inches or less, better for salvage operations and residue recovery.

The Forest Engineering Research Institute of Canada (FERIC) in Prince George, British Columbia, examined hauling logging residue to a central site for processing (Powell, 1982). A front-end loader with a high capacity, self-feeding chipper were utilized. The loader emptied trucks and placed material within reach of the chipper. Production of the chipper averaged 277.75 green tons per day or 36.33 green tons per productive machine hour. Costs of the loader and chipper were estimated at $8.54 (U.S.) per green ton. [U.S. dollars have been determined from the Canadian dollar at an exchange rate of 78%.] Cost delivered to the mill, including logging and hauling, and the chipping costs were estimated at $39.04 (U.S.) per green ton. Records show that birch and aspen, while green, were the easiest to process, and dry softwood species were the most difficult. The chipper was also found to be sensitive to dirt and incurred excessive downtime for knife replcement with material from landing slash piles. It was concluded that shredders or hogs that are less sensitive to dirt would be a better alternative for processing this type of raw material.

Even though it is probably more economical, in most cases, to utilize mill waste for pellet manufacturing, an expanding pellet market will make the utilization of alternative raw material sources a necessity. Two likely sources identified are logging residue or slash left after harvesting and unmerchantable trees from thinnings and on-going logging operations. Whereas chippers may be economical for whole-tree processing, more research is needed in the area of utilizing the residue from slash piles. Chipper downtime in dry, contaminated residue due to mechanical problems will be an economical constraint. Availability of large supplies of this residue type, however, make it a problem worthy of a solution. Efficiency in any chipping operation is of primary importance with typical problems that include scheduling vans for loading, matching equipment to volumes and sizes of the raw material and mechanical downtime costs. If future raw material supplies are expected to lean heavily on logging residue, machine development considerations for another type of processor, such as a shredder, hog or hammermill, are prudent.

In-the-woods manufacture of pellet fuel using a punch-press concept was pioneered in 1988 (HSI, 1988). A prototype module operated by hydraulic pressure was constructed and sucessfully tested with a wide variety of wood and agricultural residue materials that included western redcedar, newspaper, mesquite, rapeseed meal, ponderosa pine, cabinet shop wood waste, plywood trim, dead white pine, red alder, sander dust and balsa. During the evolution of the prototype to a production machine, however, portability was not included and the mobility concept was abandoned for fixed-site production. Since the pelleting process requires a target mositure content of 15-18% (OD basis) for the feedstock, mobil biomass drying would also have to be developed. In-the-woods pelleting would bring a new dimension to the densified fuel industry by adding value to the raw material close to the source and by improving materials transportation and handling.

DENSIFICATION PATENTS, PROCESSING AND EQUIPMENT

Pelleting Patents

The first recorded patent for using biomass material as an energy source dates to 1864 (U.S. Patent #43,112) and William Halstead. It was manufactured by combining sawdust, tar, wood cuttings or chips, water, and coal tar to form an artificial fuel. About one hundred years later, improved techniques were used to shape wood waste material into an energy product known as a briquette.

Another important process to produce pellets was invented by Rudolf Gunnerman in 1977 (U.S. Patent #4,015,951). A raw material of random particle size such as sawdust or other wood product waste with a non-uniform water content is carried by pneumatic conveyor to a hammermill. The pneumatic conveyor separates rocks, tramp metal and other foreign material from the wood. At the hammermill, particle size is adjusted to a uniform maximum dimension which is approximately 85% or less of the minimum thickness of the pellet to be produced. The product from the hammermill is transported to a rotary drum type dryer where the moisture content of the uniformly dimensioned wood particles is reduced to a range of 16 to 28% (dry basis). The particles are then moved by conveyor to a pellet machine where the material is fed into a hopper and pressed through a ring-shaped die to the desired shape and diameter for the product. The pellet mill die and roller assembly must be capable of producing compression within the die to cause the temperature of the woody material to reach 325-350 degrees F. Pellet mill load pressures may vary from 8,000-40,000 pounds per square inch and depends largely on die design.

During the extrusion process, the lignin component in the cellulose material is caused to flow and and migrate to the pellet surface. During cooling, the lignin forms a surface skin on the pellet that protects it from shattering and from any rapid change in moisture content before the fuel is used.

Wood pellets emerging from the mill are spread over a moving, endless belt conveyor where air fans adjust the temperature to ambient level. The product, now with a low, uniform moisture content, may be stored safely or used immediately. The equilibrium moisture content of the pellets will usually be within the range of seven to eight percent, oven-dry basis, depending on the humidity in storage.

Products from the Gunnerman process are comoustible, organic, fibrous pellets, having a symmetrical configuration with a maximum cross-sectional dimension of not more than one-nalf inch and a pellet density greater than 65 pounds per cubic foot. Pellets burn uniformly and release approximately 8,500 to 9,000 BTU per pound. It is not necessary to add a binder material to the particles, provided the pressure during pelleting is sufficient to produce the necessary 325-350 degrees F. temperature. Materials such as waxes may be added to the fibrous material to supplement the lignin which serves as a natural binding substance within the wood.

Other processes were developed during the 1980's that used different types of binders. By doing so, a calorific value approaching that of coal was obtained. These binders not only improved the ignition and burning characteristics of the pellet but also lubricated and extended the life of the pellet mill die. One such example was a 1980 development by Ian F. Johnston who invented a fuel pellet with a minimum dimension of at least 3/16-inch to ease handling. The pellet was comprised of approximately 50 to 99% by weight of natural cellulosic material and from one to 50% by weight of a synthetic, polymeric, thermoplastic material (U.S. Patent #4,236,897). A thermoplastic material was chosen because it solidified at a temperature of approximately 200 degrees F. The thermoplastic served to bind the pellet together by encapsulating the wood particles, increased the heating value of the pellet, lubricated the pellet mill die, and improved the ignition and burning characteristics of the fuel. The pellets were easily ignited, burned evenly, resisted changes in humidity, and generally produced a gross heating value in excess of 9,000 BTU per pound.

The natural cellulosic material used to manufacture pellet fuel by the Johnston process can be woody material such as sawdust, wood shavings, sanderdust, hog fuel, peat and bark. Agricultural waste such as banana and papaya stalks, straw, bamboo, jute, bagasse, corn cobs and husks, cotton "gin trash", sisal, seed hulls and peanut hulls can also be processed. The synthetic thermoplastic material can be polystyrene, polyethylene, polypropylene, acrylonitrile-butadienestyrene, acetal copolymer, acetal homopolymer, acrylic, polybutylene and combinations of these.

A process developed by Charles J. Reilly in 1983 (U.S. Patent #4,398,917) modified the cellulose and renders it more pliable and soft. The cellulose could then flow easily into the pellet mill to be processed with less mechanical power. Since the modified cellulose particles were less abrasive than unmodified material, die life was extended. The Reilly process was directed at producing fuel pellets that were derived in whole or in part from at least one cellulose-based material. The only requirement for the material was that it can be softened by the enzyme, cellulase. The form of the cellulose could be paper, sawdust, roundwood, wood chips, wood waste, peat, bark and urban or municiple waste in the form of paper or paper derivitives. The preferred moisture content of the processed material could not exceed 15-25% by weight.

As a description of the Reilly process, cellulose material is hogged by rotary knives, grinders, shredders or hammermills to comminute the material to a desired particle size. The preferred particle size for wood is approximately 3/4-inch. After comminuting the cellulosic material, it is sieved to produce uniform size particles. At this stage and depending again on the raw material pelleted, it may be desirable to pre-condition the material before bringing it in contact with enzymes. Pre-conditioning can be effected by a variety of methods including acid, alkali and steam treatment.

Pre-conditioning is followed by modifying the cellulose structure with the enzyme cellulase. The enzyme is applied over the material at the rate of about one to two pounds per ton of cellulose. The reaction requires from one-half to eight hours. The modified material is then ready for pelleting by using any of the types of densification equipment presently on the market.

Pellets from the Reilly process have a bulk density of 35 pounds per cubic foot, compared to approximately five pounds per cubic feet for the enzyme-treated feedstock prior to pelleting. The calorific value is rated at about 7,500 BTU per pound. The pellets produced are reported to be acceptable for home heating or for use in commercial and industrial boilers.

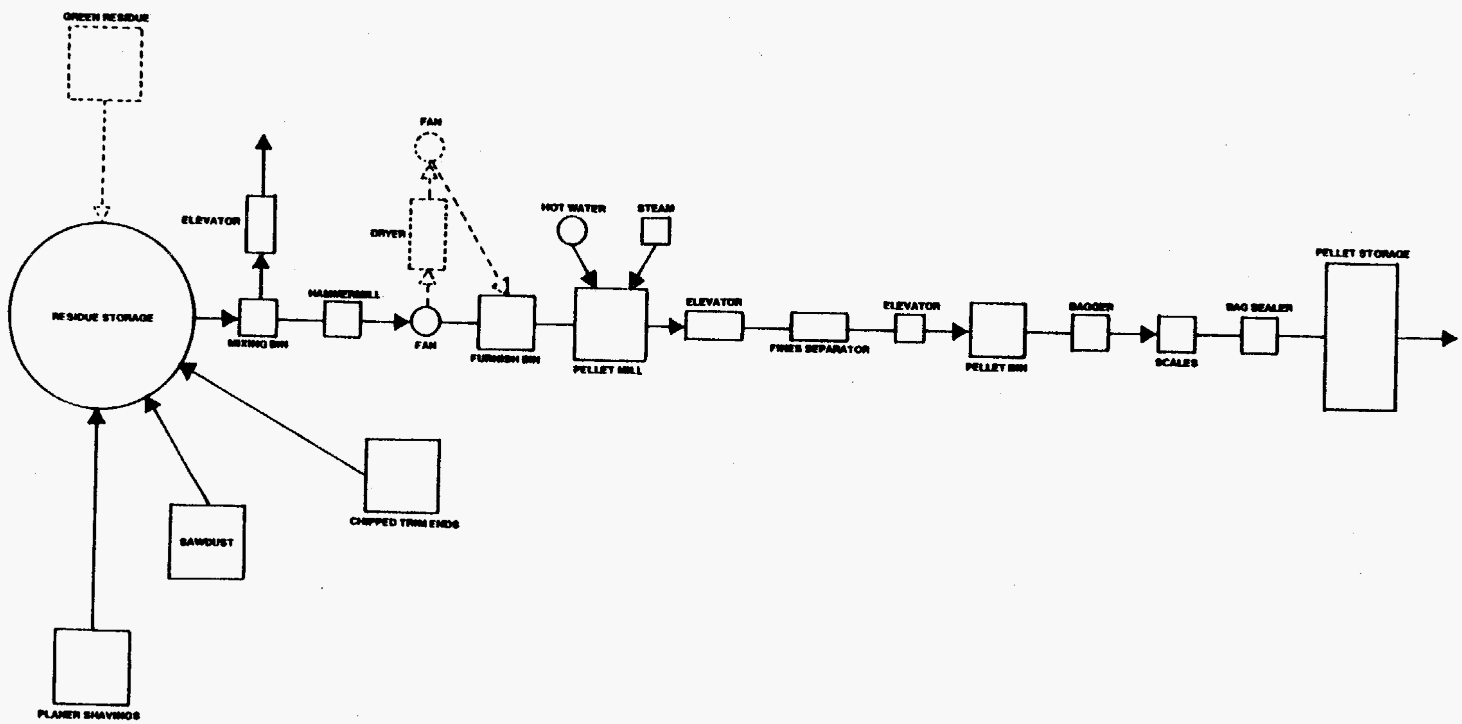
A further review of the U.S. Patent Office record by Resch (1982) that follows lists processes and equipment that are key contributions to the development of the densified fuel industry in the United States:

W.H. Smith	Densification of sawdust for fuel, #233,887, 1880
G.B. Norman	Extrusion-consolidated die, #2,902,715, 1959
E.N. Meakin	Means for extruding moldable material having viscous properties, #2,902,949, 1959
E.N. Meakin	Extrusion mill feed assembly, #2,908,038, 1959
E.N. Meakin	Pellet mill die assembly, #2,958,900, 1960
E.N. Meakin	Extrusion mill assembly, #2,961,700, 1960
E.N. Meakin	Method of extruding material which is adversely affected by heat, #2,974,371, 1961
E.N. Meakin	Contamination free extrusion mill, #3,010,150, 1961
E.N. Meakin	Floating die type pellet mill, #3,280,426, 1966
E.N. Meakin	Apparatus for cooling material adversely affected by heat of extrusion, #2,870,480, 1959
E.N. Meakin	Horizontal cooler, #2,982,029, 1961
R.W. Gilman	Axial extrusion mill, #3,422,748, 1969
R.W. Gilman	Adjustable feed deflector, #3,538,546, 1970
R.W. Gilman	Walking die pellet mill and improvements thereof, #3,559,238, 1971
R.W. Gilman	Extrusion mill with roller adjustment means, #3,679,343, 1972
A.M. Alessio	Traversing roll type extruder, #3,743,462, 1973
R.W. Gilman	Quick-change die and roller assembly, #3,825,387, 1974
R.W. Gilman	Deflector and impelletor combination, #3,826,475, 1974
R.W. Gilman	Quick-change die and roller assembly, #3,911,550, 1975
A.D. Livingston	Process for treating municipal wastes to produce a fuel, #4,015,951, 1977

Process Flow and Manufacturing Equipment

A flow chart of a small-scale densified wood fuel manufacturing facility (Figure 2) shows the primary processing equipment and production steps. A directory of principal manufacturers of small to medium-scale processing equipment are given in Appendix D by major function categories that include in-the-woods raw material processing, raw material transport, residue handling and classifying, storage, grinding, drying, densification and packaging.

Figure 2. Flow Diagram of a Small-Scale Densified Wood Fuel Manufacturing Facility



raw material storage and handling

In small-scale manufacturing facilities, a common objective is to utilize a high quality raw material, primarily clean wood residues with low moisture content. This allows for safe raw material storage over extended periods if necessary, eliminates or simplifies drying requirements, and reduces investment in expensive storage facilities, metal detection, handling equipment and grinding. Storage may be an open-air pile, covered pole building, gravity-fed bin or self unloading silo. Uncovered storage piles of wood residue to be used for energy, as noted by Springer (1985) and Harris (1988), show that fuel characteristics including moisture content, fiber content, heat value and spontaneous ignition temperature are adversely affected. This storage method should be avoided.

Thoroughly mixed raw materials types (sawdust, shavings, chips etc.), particulary where species, particle size and moisture content may vary, is critical to a uniform feedstock for successful pelleting. A mixing bin allows some "buffering" to occur between particles of different moisture content. Any special physical or chemical characteristic of the wood due to species (pitch, volatiles, lignin, oils), either beneficial or detrimental, are also distributed in the feedstock during mixing. A mixing bin allows the introduction of additives. If an attached elevator is included, additives may be introduced and raw materials off-loaded for other uses. Shop-built mixing bins and, elevators and screw conveyors are sometimes used.

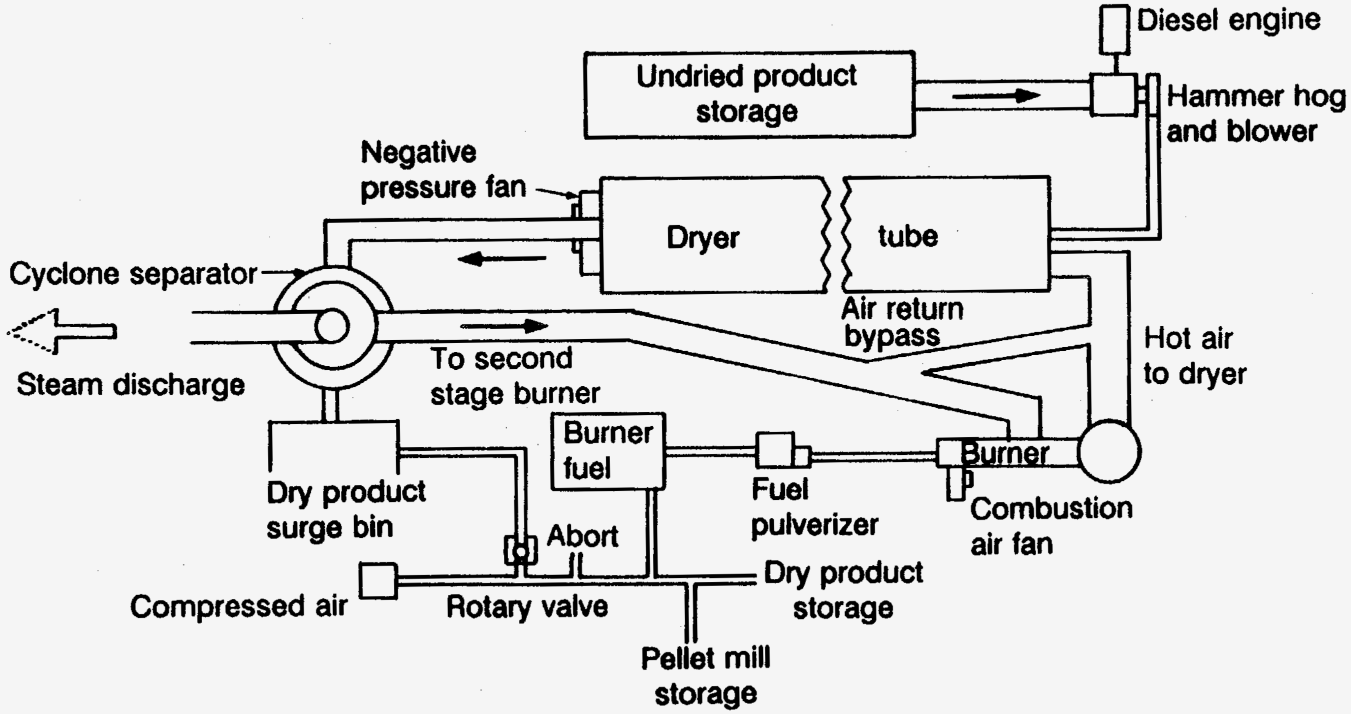
raw material grinding

The grinding process may begin prior to raw material storage with a chipper, hog or shredder to reduce oversize materials. A hammermill is needed to arrive at a uniform, target particle size for pelleting. A common screen size for a pellet plant hammermill is 3/16-inch. The raw material is delivered to the hammermill by elevator or screw conveyor.

feedstock drying

If dry or low moisture material is the feedstock, a biomass dryer may be eliminated from the process. Moisture content before pelleting needs to be 12-18 percent minimum on an oven-dry basis. Feedstocks at lower moisture contents may be brought to target levels by adding water in the form of steam or hot water. If a dryer is necessary, rotary drum technology is the most common choice in the pellet fuel industry. Rotary drum drying in small to medium-scale pellet manufacturing, however, is excessive from a capacity and investment point-of-view and is likely to require extensive modifications to the dryer. A new dryer purchased from a manufacturer could exceed $300,000. Modification costs for used, medium-sized equipment are reported to be in excess of $146,000. Figure 3 presents a product flow diagram of a rotary drum dryer and layout modified for a medium-sized pellet manufacturing operation (Roether, 1991). Note that the energy source to operate the dryer is reject pellet fuel that is pulverized and mixed with combustion and return air in the burner section of the drum.

Figure 3. Flow Diagram of a Modified Rotary Drum Dryer for Densified Wood Fuel Manufacture (Roether, 1991)



The dry feedstock is then moved by blower fan to a surge bin, often shop-built, located above the pellet machine. The bin should be enclosed and able to control wood dust generated by the flow into the bin.

densification

A ring-die extrusion or die and roller mill is the most widely used machine type in wood pelleting although punch and die technology has also been recently developed (HSI, 1989). Other types include disk pelletizers or "flying saucers", drum and rotary cylinder pelletizers, tablet presses, compacting and briquetting rolls, piston-type briquetters, cubers and screw extruders. Each densification method will be suited to specific materials and end products. Method selection is influenced by factors such as needed capacity, abrasiveness, plasticity, finished particle appearance, size and shape, need and tolerance for lubricants and binders, and the material's adaptability to the process.

In the United States, pellet mills are produced by three companies and were initially designed to pellet alfalfa and other grasses and grains for livestock feed. Modifications to livestock feed equipment is necessary for pelleting wood feedstocks and will include increasing motor, shaft and bearing sizes, using a die designed for wood and developing a method to introduce steam, hot or cold water or other conditioning agent into the mixing chamber. New equipment by one U.S. manufacturer contains factory engineered changes for wood pelleting.

The feedstock enters the supply auger housing of the pellet mill by gravity where supply rate to the mixing chamber is regulated by controlling the auger motor. Furnish entering the mixing chamber may be conditioned or softened. Steam, and hot or cold water are commonly used as conditioning agents and are introduced into the mixing chamber. Some feed mill machines have been factory-fitted to add binders and feed additives such as molasses, starch and sugar. The amount of conditioning is determined by the mill operator through trial and error.
Mixed furnish enters the center of the ring-shaped, perforated die where die rotation against one, two or three rollers press the furnish through the perforations (Figure 4). As Leaver (1988) illustrates, a die design that includes proper bore diameter, number of perforations, die thickness and shape (effective length and counterbore area) is critical to controlling residence time, heat and densification of the wood (Figure 5). The adjustment of the rollers against the die surface effects the furnish rate entering the die and the pressure forcing the wood through the die chamber.

Pellets should leave the die in long strands that are cut to length by an adjustable knife held against the rotating die. With wood pelleting, however, heat and pressure will often cause the pellet to break while exiting. This commonly occurs with conifer feedstocks containing extractives such as pitch that volatilize under pressure. Manufacturers often develop a raw material recipe containing a mixture of wood species found to reduce this problem and, at the same time, improve process control or enhance other fuel characteristics such as heat value and appearance.

Figure 4. The Ring-Die Extrusion Process (Leaver, 1988)

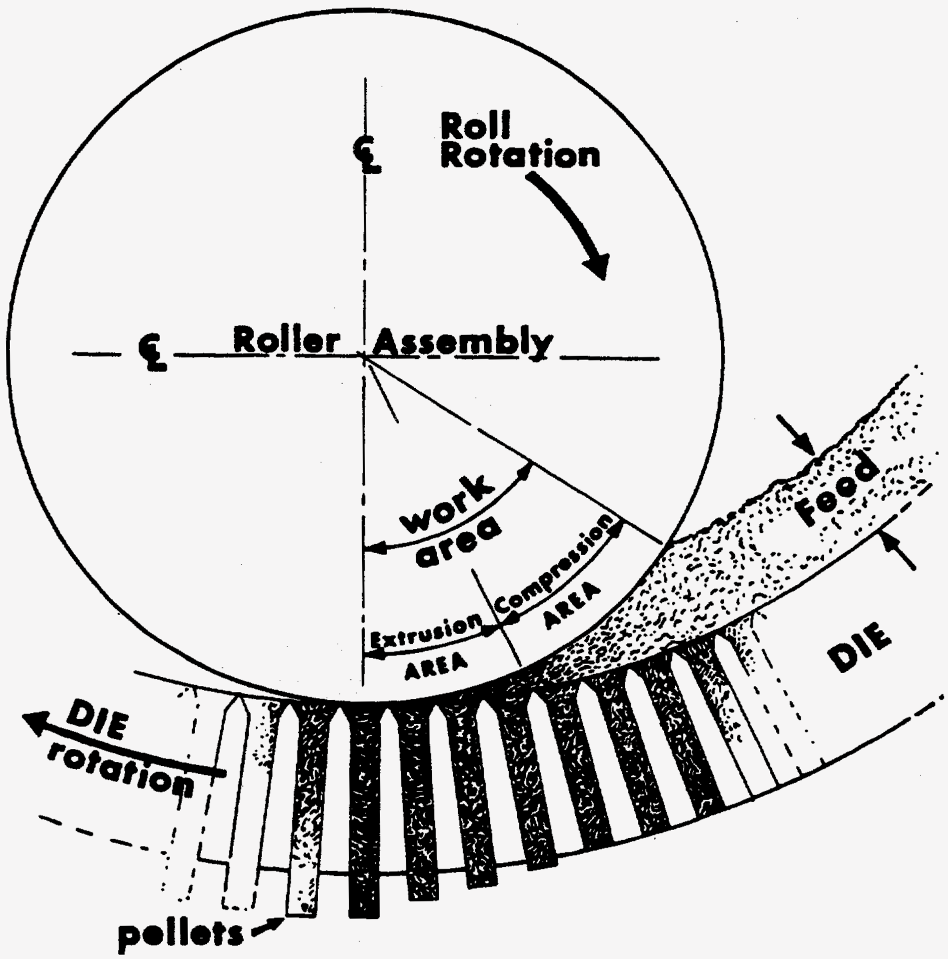
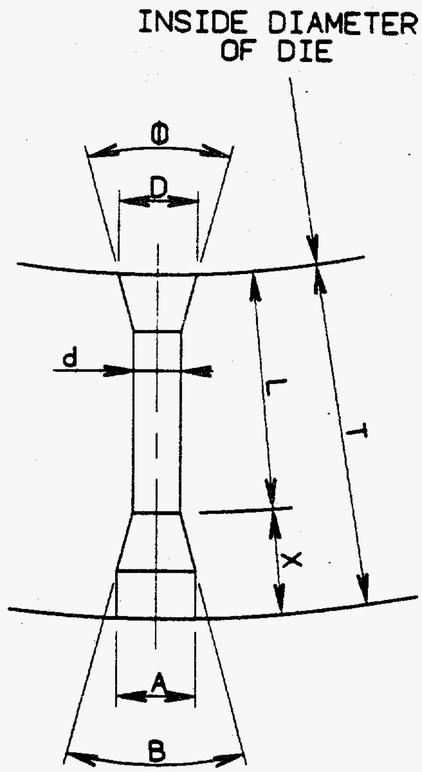


Figure 5. Die Design for Wood Pellet Manufacture (Leaver, 1988)



d=PELLET DIAMETER
L=EFFECTIVE LENGTH
T=TOTAL THICKNESS
D=INLET DIAMETER
Φ=INLET ANGLE

X=COUNTERBORE DEPTH
B=COUNTERBORE ANGLE
A=COUNTERBORE DIAMETER
COMPRESSION RATIO= $\frac{D^2}{d^2}$
$\frac{L}{d}$ =PERFORMANCE RATIO

cooling and fines removal

Wood pellets leaving the die should be cooled as qickly as possible to retain integrety and permit handling and packaging. Fines are generated by the pellet mill and the movement of pellets from the mill to storage. Commercial vacuum systems and pellet coolers are available technology but fans and shop-built screens are common.

bagging and pellet storage

Pellets are transferred to permanent bulk storge, directed to a surge bin for bagging or both. Bulk storage may be on a concrete floor of a covered stall or in a pellet surge bin. Bins are often shop-built but fitted with a commercial weight-dispensing bagger. Translucent polyethylene bags containing the manufacturers logo and net contents (40 or 50 pounds) are heat sealed and check-weighed. A few manufacturers who consistently produce a product with low fines and a light or golden color use clear polyethylene as a marketing strategy. Bagged fuel may be manually stored or placed on pallets and handled by forklift or pallet jack. Covered storage is essential for protection from moisture and mechanical damage.

process control systems

The "artistic" side of pellet fuel manufacturing is often evident with the methods used in controlling the process. For example, pellet mills in small-scale facilities are often operated by maintaining a desired load on the drive motor using an amp gauge. Through a visual examination of the product as it is being made, furnish supply rate and conditioning, roller clearance and drive motor speed is adjusted. Electrical service and a control panel for the pellet machine are usually separated from the raw material storage and handling, feedstock preparation and pellet fuel handling and storage sides.

PRODUCT QUALITY, PROCESS PATENTS AND END USES

Pellet Fuel Testing and Standards

National, but not necessarily regional, development of manufacturing standards for the wood pellet industry can be described as in the early stages. Two manufacturing organizations, the Association of Pellet Fuel Industries (APFI) and the Fiber Fuels Institute (FFI), have become established in recent years to promote the densified fuel industry in the Northwest and the Lake States, respectively. Membership in either organization currently represents less than one-half the total producers in the United States and Canada. Actual product standards, as shown later, vary within and between organization membership in order to accomodate significant differences in raw material types, species, processing equipment, product end use, combustion equipment, air quality requirements and industry expansion.

Five reasons are important for establishing high, well-defined standards for wood pellet manufacturing. First, it is necessary to clarify and standardize the terminology and definitions used in research and development, and manufacture and use of pellet fuel. For example, the basis used for expressing physical characteristics of wood products can be "oven-dry", "green" or at a "specified moisture content". In many cases, research and development rely on oven-dry data, while manufacturers relate to wood in the green condition and end users identify the product according to as the product is received. In the wood pellet industry, the raw material and product are only dealt with on an "as received" basis, thereby introducing potential for confusion and misunderstanding of product characteristics.

Next, pellet quality standards provide the consumer with product identification. If the product is often not visible or cannot be closely examined, how can the consumer be confident of what is bought? All wood pellets "are not created equal" and standards can be used to differentiate an all-wood product from bark and agricultural ones, hardwood feedstocks from softwood, and fuels with additives from fuels without. Product differentiation with wood, agricultural biomass, paper and RDF (refuse-derived fuel) products is not widely followed in the industry. Products containing combinations of these feedstocks are not separately identified.

Third, quality testing and product standards provide manufacturer and consumer protection, particularly in the areas of weights and measures, and from combustion of potentially toxic materials. For example, in the Intermountain West region, the net contents of bagged fuel from eighteen manufacturers showed a 3-15% excess weight, translating to loss of potential profits. Nationally, potentially harmful additives and feedstock raw materials in use include: plastics, mixed waste paper, phenol and urea formaldehyde adhesives, poly-vinyl-chloride, sanderdust, and paper mill and agricultural crop processing by-products. These materials have not been adequately tested for volatiles driven off during manufacturing, emissions given off during combustion or environmental effects from ash disposal.

Product standards serve as a basis for comparison in the marketplace for pellet fuel manufacturers. How does Manufacturer A who makes a product from all wood compete with Manufacturer B who makes a pellet from all bark, when both are manufacturing pellet fuel? There is a widely held belief by pellet manufacturers that the market will absorb wide variation in pellet fuel products, regardless of cost of production, price or performance.

Finally, quality standards will provide for thorough, stepwise development of this energy technology, ensure the longevity or product life, and emphasize the engineering advantages of wood pellets.

There are distinct advantages of closely associating wood pellets as a product of the wood processing industry rather than the energy industry. Product testing methods in the wood industry are specifically outlined, physical characteristics affecting processing are well documented, and performance is understood and predictable. Wood pellet fuel is a product of the timber growing and wood processing industries, and is a renewable resource. Pellets can be marketed as a commodity or as a specialty product and, as a by-product, can compliment the product array of these industries. As a product of the energy industry, pellet fuel is identified as an alternative - a choice between one fuel or another. Other economic and social distinctions such as renewability, value-added and resource recovery can become disconnected and overshadowed.

Grades and Specifications

Wood pellets are used as an energy source for commercial/industrial and residential applications. In general, pellets are three-sixteenths to one-half inch in diameter and one-half inch long (Zerbe, 1978). There are no widely accepted standards by fuel and stove manufacturers, or consumers for densified wood fuel. However, fuel specifications adopted by the APFI in 1988 recognize a residential grade pellet fuel, that shall meet or exceed the following:

1. calorific value of not less than 8,200 BTU per pound
2. bulk density of at least 40 pounds per cubic foot
3. moisture content of not more than 8 percent
4. ash content of not more than 1 percent
5. diameter between 0.235 and 0.35 inches
6. length not to exceed 1.5 inches
7. fines content of not more than 1 percent passing through a 1/8-inch screen

All pellet specifications are measured on an "as received" basis.

In 1984 the FFI adopted two grades of fuel pellets, premium and choice, and both having the same specifications <u>except</u> ash content. The specifications were:

1. calorific value of not less than 8,000 BTU per pound (as received)
2. bulk density of not less than 36 pounds per cubic foot
3. moisture content, as received, of not more than 10 percent

4. ash content of not more than 2.75 percent for premium grade or 4 percent for choice grade
5. diameter between 0.375 and 0.50 inches
6. length not to exceed 0.75 inches
7. fines content, as received, of not more than 10 percent passing through a 1/8-inch screen

There are numerous pitfalls associated with fuel specification categories, levels set as floors and ceilings, or lack of them. A calorific value on an "as received" basis provides the manufacturer and consumer with an estimate of usable heat only if differences in moisture content and the contributions from additives are also taken into account. Since moisture content less than 10 percent is low compared to stored conditions, pellet fuel could have a tendency to absorb moisture. In addition, absorption is encouraged by pellet geometry in currently manufactured products because pellet ends have exposed, rough surfaces and good formation of an outside skin is not always achieved. Calorific value based on oven-dry basis would eliminate potential confusion from moisture effects and give the calorific value of the wood content and additives. The integrity and energy contribution of these components are the energy basis for the fuel.

Pellet density is actually bulk density, defined as weight per unit volume and is used to measure the amount and, sometimes, strength or durability, of a product that is aggregated. Since the amount of void space within the given volume effects the weight, we should assume that individual pellets are relatively uniform in size. This is not the case at all with products currently manufactured in the region. Pellets tested for bulk density from regional manufacturers show bulk densities ranging from 36 to 42 pounds per cubic foot. Values greater than 40 pounds per cubic foot are usually associated with pellets that are 1/4-inch in diameter. Pellet fuel density should be specified for each pellet diameter. Pellet length should show only minor variability.

With bulk density, any association with strength or durabilty is misleading since bulk density will automatically be increased by increasing pellet diameter. A larger diameter pellet may actually be softer and less durable than a smaller one. The American Society for Testing and Materials (ASTM) has developed a test method for pellet durability (E 1288-89), but neither that method or another standard has been accepted by any pellet manufacturer or manufacturing association. Without a clearer definition of the term "as received" by manufacturers, durability measured at the plant where cash and carry sales are conducted will be very different from that measured at an intermediary such as a wholesaler or retailer or at the consumer's location. Durability also indicates hardness, a characteristic that could adversely effect the operation of the pellet burning appliance. Long pellets that are too hard could damage the stove's auger. If too soft, fines generated during handling or during movement within the stove may obstruct the auger housing.

High moisture content of pellet fuel is a legitimate source of concern by the consumer, when a common practice by manufacturers is to perforate the sealed plastic bag to improve stacking for storage on pallets. Two methods that can be used to improve stacking ability is to expel trapped air before sealing using the same method for preparing food to be frozen in plastic bags or by applying vacuum. Data collected from current regional manufacturers describe a product ranging from 3 to 8 percent moisture content (oven-dry basis) at the plant.

Percentage of non-combustibles (primarily ash) is a primary concern with consumers and pellet appliance manufacturers in the region. Another concern regards formation of "clinkers". At temperatures above 900 degress F., non-combustibles within the pellet can slag then re-solidify to form clinker. Formation usually occurs near the orifices in the combustion chamber that supply underfire and overfire air. Periodic removal of clinker is essential for safe and efficient appliance operation. Although ash will fall by gravity into an ash pan, it will also be circulated and deposited in the heat exchanger and on the door glass by combustion air. Intermountain pellet manufacturers currently offer the lowest ash pellet in the industry, ranging from 3/10 to 3/4 percent. Other regions of the United States will have difficulty meeting this level because their pellet fuel industries are based on hardwood residues and feedstocks with significant bark content. Unless pellet stove manufacturers are able to design an appliance with capability to combust contaminated pellet products safely and efficiently, there can be no substitute for low ash pellet fuel. Modifications to the appliance will need to include a significant increase in combustion air, high temperature fabrication and a larger ash pan. With an increase in operating temperature, slagging will become more problematic. With an increase in combustion air, stack particulates are likely to increase. These design changes will lead to higher appliance costs, added operating requirements and increased maintenance.

Pellet size (diameter and length) is a characteristic within the pellet manufacturing industry with a wide range of acceptable values, even though an earlier explanation for manufacturing a uniform pellet size would be more desirable. Without a minimum length, pellet fragments in the shape of a coin will be accepted during screening (greater than 1/8-inch) even though these "coins" can cause problems with appliance operation. Long pellets create a problem known as "bridging" where the fuel supply is interrupted or interferes with auger operation. Damage to the auger or shutdown can result.

Equally important as ash content is fines content of wood pellet fuel. Coin-shaped fragments should be rejected as fines during screening but to do this, a screen size larger than 1/8-inch is required. Even if a 1/4-inch screen were used, only "coins" thinner than 1/32-inch would be rejected in the pellet products from all diameter classes now manufactured. These coin-shaped fragments that are easily retained on a 1/8-inch screen, will migrate and collect at the bottom of the bag where they rapidly disintegrate during handling and storage.

In addition to characteristics and specifications that are recognized as measures of quality, some pellet specifications and characteristics that have not been recognized are of equal or perhaps greater importance. Besides examining durability, adding by-products to enhance particle binding, equipment lubrication, combustion and appearance should be listed on the package, and combustion tests of these additives should be made available to the consumer by the manufacturer upon request. Currently, no labeling is required. The area of emissions testing, so long as wood pellets are wood-based, is well documented for other wood-based energy products such as roundwood, hog fuel and chips. Manufacturing with additives, or pelleting contaminated feedstocks, enters a new dimension of increased environmental risk that could result from processing, stack emissions during combustion and disposal of combustion residues. Research data needs to be obtained regarding processing and combusting potentially hazardous feedstocks in residential appliances, such as: sander dust, panel trim, pulp and paper waste streams, agricultural residues and refuse-derived waste materials.

Patented Processes

Examples of pellet products manufactured by the patented processes listed below offer a general description of the type and quality of these products.

1) Woodex
   Woodex is refined from almost any organic, fibrous material including wood waste, bagasse, agricultural waste and peat. The manufacturer reports that the product has a moisture content of 10 percent, a low ash content, virtually no sulfur content, and carbon dioxide emissions equal to the carbon dioxide released into the atmoshere if the raw material were left to naturally decompose. Natural resins serve as binders for these pellets. Woodex pellet bulk density is approximately 35 pounds per cubic foot and delivers about 9,000 BTU per pound (Blackman, 1978; Carpenter, 1981; Pearson, 1981).

2) Lignetics
   Lignetics is a densified wood fuel manufactured by a proprietary process from wood waste including sawdust, wood shavings, bark, hog fuel, and trash wood. A small amount of a polystyrene additive, estimated at approximately one percent by volume, is used to facilitate the formation of dust-free pellets, lubricate the dies in the pellet machine, increase the calorific value and accelerate the burning rate. Lignetics pellets are reported by the manufacturer to produce about one percent ash when burned, have a moisture content of less than 10 percent (oven-dry basis), and produce 8,500 to 9,000 BTU of energy per pound of wood fuel (Lignetics, 1986). The product is sold by the ton in bulk or in 40 pound bags to residential and commercial/industrial customers.

3) Roemmc
   Roemmc fuel pellets may be used as a heating fuel for residential and commercial/industrial applications. Reported specifications by the manufacturer are that (1) pellets may be made from any biomass including wood, straw, nut hulls, bagasse, corn cobs, and peat, (2) moisture content may not exceed 12 percent, (3) ash content may not exceed five percent, (4) average bulk density is about 40 pounds per cubic foot, and (5) the average BTU content is 8,500 per pound (Guaranty, 1986). The product is sold by the ton in bulk or in 20 and 50 pound bags.

4) Pelletized Sludge
At the Abitibi-Price hardboard plant in Alpena, Michigan, sludge collected by a dissolved air flotation process is dried and pelletized. The pellets are burned as a supplemental fuel in combination with coal and reduce the amount of coal used by about 15 percent. The BTU content of the pelletized sludge is approximately two-thirds that of coal or 8,600 BTU per pound. Moisture content of the sludge pellets ranges from 7 to 8 percent and pellet size varies from 1/16 to 3/16-inch in diameter (American Logger & Lumberman, 1981).

Industrial and Municipal/Institutional Use

For an industry considering the use of densified wood pellets as a fuel substitute, there is some question as to whether the added expense of processing is justified by the increased ease of handling and the improved combustion efficiency of the end product. Where high sulfur emissions from coal are a problem, burning sulfur-free wood pellets in combination with coal may be a solution (Johnson, 1982). Having to choose between installing expensive scrubbers or burning sulfur-free fuel, a hospital in Oregon changed to wood pellets without expensive boiler modifications. A study in one lumber mill revealed that wood pellets may provide greater efficiency and fewer stack emissions than conventional mixtures of dry wood and manufacturing waste, and hog fuel (Zerbe, 1978). However, another indicated that where hog fuel is available to a mill within a 25-mile radius, the economic advantages of pellets may be nullified (Pearson, 1981).

Wood pellets can be used to fuel large industrial boilers, such as factory-assembled package boilers up to 1,200-horse power (Guaranty, 1986). Pellet fuel can be burned in a standard, stoker-spreader furnace or it can be used in a suspension burner by reducing the pellets to powder with a hammermill and burning the particles in suspension.

Wood pellets can be easily handled by conveyor equipment. Short duration, outdoor storage using covers, silos or bins reportedly will not adversely affect the moisture content. One study, however, involving delivery and storage of wood pellets for a small-scale consumer showed that degradation during handling produced an unacceptable problem with fuel dust (Brandon and Wright, 1982).

In the Intermountain West region, commercial, industrial or institutional use of wood pellet fuel is at a modest level. Since no industrial grades are manufactured in the region, residential quality fuel is burned. On the commercial/industrial side, heating greenhouses has become a viable alternative to roundwood, electricity, LP gas and fuel oil. Fruit orchard space heaters known as "salamanders" have been modified to replace the kerosene generator with an add-on pellet burner. Pellet fuel acceptance in the institutional market has shown the most progress and include schools, hospitals and penal institutions. Data collected during a boiler survey of Idaho facilities in 1988 by the Idaho Department of Water Resources identifies, from fuel(s) used, boiler size and type, age and operating condition, and energy application, existing and potential institutional users for pellet fuel.

Current users were one hospital with two boilers, and four schools with four boilers.

Potential pellet fuel users are identified by fuel type now used and age and condition of the boiler. Facilities using coal, electricity or LP gas in heating systems which are in in fair or poor condition and where natural gas is unavailable would have the highest potential. Coal supplies are shipped to Idaho from neighboring states and do not contribute significantly to any multiplier effect in Idaho's economy. Those boiler facilities burning wood as sawdust, chips or roundwood in systems rated as good, fair or poor, and where natural gas is unavailable would be the next highest potential. These facilities contend with problems such as fugitive dust, storage space, variable fuel moisture content, tramp metal, and frozen material. Some fuels handling and storage equipment is in place and knowledge of wood as a fuel exists. Third priority facilities are those heated with fuel oil in heating systems rated as poor, and where natural gas is unavailable. Facilities in this category would be likely to replace a furnace or boiler in the very near term and pellet fuel could be an alternative.

High priority facilities in Idaho are two hospitals with three heating systems, five armories with five systems, one school for the deaf and blind with three systems and twenty four other schools with twenty four systems. Second priority facilities are eight schools with eight systems and a third priority facility is a state office building with one heating system.

A list of industrial/commercial wood pellet combustion system manufacturers has been compiled (see Appendix B). With older stoker coal equipment, adjustment of the fuel delivery rate may be the only modification necessary. Add-on equipment that supplies pellet fuel through the furnace door and replacement pellet fuel burn rings are available to retrofit existing furnaces.

Residential Use

An exploratory study of residential wood pellet use was conducted in 1986 using a judgement sample of selected stove dealers. Information on pellet stoves and wood pellets was obtained through telephone and face-to-face interviews that concentrated on the residential user's acceptance of the wood pellet technology. Three geographical areas in Idaho and Washington were canvassed by the telephone survey (Boise, Coeur d'Alene and Spokane). A face-to-face interview of wood pellet and pellet stove dealers was conducted in Spokane.

telephone survey description

A 1986 telephone survey asked retail dealers a series of predetermined questions to find out whether or not they sold pellet stoves and wood pellets, and to gather information from their opinions as to their acceptance and knowledge of the wood pellet technology. If dealers sold pellet stoves, brand names and sales prices were requested. If wood pellets were sold, the supplier or manufacturer and retail prices were recorded. After the initial series of sales-related questions, dealers were asked to comment on customer satisfaction and to give their personal opinion of wood pellet fuel as an energy technology. A summary of the results of the telephone survey is given in Table 9.

Table 9. SUMMARY OF TELEPHONE SURVEY RESULTS

Area	Number Surveyed	Number of Responses	Sell Pellet Stoves	Sell Wood Pellets
Spokane	15	10	6	2
Coeur d'Alene	9	6	3	1
Boise	3	3	2	1
other	3	3	2	1
totals	30	22	12	5

Dealers were selected from the yellow pages of telephone directories. The difference between the number surveyed and the number of responses was due to disconnected telephone service, and dealers who had changed location or had gone out of business.

The survey showed that of 22 dealers responding, 12 sold wood pellet stoves as part of their line of wood burning appliances. Of those 12 dealers, seven displayed pellet stoves in their show rooms. The remainder stated that they would have them on display by the end of July, 1986.

The survey further indicated that only five of the 12 dealers who handled pellet stoves also sold wood pellets. Quantity sold by the five wood pellet suppliers ranged from 40-pound bags to bulk delivery. The seven dealers not carrying wood pellets stated that they would act as an intermediary for pellet sales with the manufacturer or other suppliers, but had no intentions at this time of keeping pellets on inventory.

wood pellet stove availability

Table 10 is a summary of the manufacturers brand names and prices for wood pellet stoves in the telephone survey areas.

Table 10. BRAND NAMES AND RETAIL PRICES OF PELLET STOVES - 1986

brand	average cost	price range
Whitfield	$1,289	$1,200 - 1,500
Traeger	$1,336	$1,200 - 1,800
Collins	$1,330	$1,300 - 1,390
Sweet Home	$1,500	$1,200 - 1,800
Everlasting	$ 475	-
other	$1,300	-

The majority of the dealers selling pellet stoves carried more than one brand name in their show rooms. Three dealers displayed as many as three different brand names at one time. Whitfield, Traeger, Collins and Pellifier were the three most frequently carried brand names. A listing of current residential wood pellet stove and furnace manufacturers has been compiled (Appendix C). Sweet Home is currently marketed under the tradename, Solitaire, by Sierra Manufacturing Co., Harrisonburg, Virginia. The brand name listed as "other" in Table 8 is now marketed under the tradename, Crossfire, by Thermic Inc., Spokane, Washington.

Dealers had varying opinions as to their popularity. Some felt that pellet stoves were the most efficient stove, had lower maintenance requirements and were easier to install. The Sweet Home was a newer stove and only two of the dealers contacted carried it. The Everlasting stove was less expensive because it was an "add-on" pellet burning device. As the name implies, an add-on appliance is located in or adjacent to an existing furnace or boiler and uses the duct-work to deliver the heat generated by the add-on (Pursley, 1980). An add-on usually allows the homeowner to switch back and forth from the pellet fuel device to the primary heating system. Add-ons will fit into most primary heating systems usually by modification of the furnace door and fire pot.

wood pellet availability and distribution

Pellet stove dealers who carried wood pellets did so because they felt that customer satisfaction with their appliance was important and that selling pellets was one way to insure this. Table 11 indicates price differences between bag and bulk supplies.

Table 11. PELLET DISTRIBUTION AND PRICE - 1986

quantity	price	units
40-pound bag	$2.50 - 2.85	bag
40-pound bag	$110 - 132	ton
bulk	$ 65 - 110	ton

The amount charged by dealers for 40-pound bags was fairly consistent. If the consumer bought the bags in orders of 1 ton or more, the price would be reduced to approximately $2.20 per bag. Bulk purchase would require the consumer to store the bags and may not be desirable in some residential applications.

The wide range in price for bulk sales was due to differences in markup with the $65 per ton quotation being direct from the manufacturer. The bulk retail price of $110 per ton reflected the additional cost of shipping, handling and storage by the retail dealer. One retail dealer offered a free ton of wood pellets with the purchase of a pellet burning stove.

Retail dealers reported a major problem with consumer acceptance of pellet burning appliances: a concern about price and availability of pellets. Since pellet prices were largely determined by the costs and profit margin of the pellet manufacturer, dealer prices of pellet burning appliances, supplies and services were perceived to be too closely tied to pellet prices. Although wood pellet prices currently allowed the dealer to sell pellets and pellet stoves, the dealer felt that if prices were to increase, wood pellet stove sales would slow or might stop completely. At the time of the study, obtaining a pellet supply was not a problem for the dealers contacted. Two dealers, however, expressed concern with future availability and cost as demand increased. No widespread concern was expressed concerning pellet quality, although one retail wood stove dealer not handling pellet stoves stated that some pellets would not burn well.

A retail dealer at Post Falls, Idaho, stated that 50% of last year's stove sales were wood pellet burning equipment. Since first opening for business, he had sold a total of 131 units and felt that sales would increase. Another dealer at Hayden Lake, Idaho, reported that 98% of the people inquiring about new or add-on energy systems asked about wood pellet burning stoves. Pellet stoves sales for this dealer had almost doubled since last year.

Another dealer stated that a customer should base the decision to buy a wood stove or a pellet stove on only one criteria: is there access to firewood? If the homeowner lived relatively close to a forested area containing an available supply of firewood, firewood should be used. Otherwise, wood pellets would probably be less expensive and troublesome.

Two stove dealers stated that they would never consider carrying wood pellet stoves. Both felt that pellet stove engineering had some definite mechanical problems such as burn-back and clinker formation and that the stoves did not burn very well. One retailer stated that a wood pellet stove was not traditional and that its dependence upon electricity was a limitation.

The majority of dealer opinion indicated that in the future, the wood pellet stove was the only way to meet our energy needs. One dealer went so far as to say that the wood pellet burning stove had reached the theoretical limits of efficiency.

face-to-face interview description

A 1986 face-to-face survey of all retail stove dealers in the city of Spokane, Washington, asked the same pre-determined questions used in the telephone survey. The intent was to determine whether or not these retailers sold pellet stoves and wood pellets, and to gather information with regard to their acceptance and knowledge of the wood pellet technology. If dealers sold pellet stoves, brand names and prices were requested. If wood pellets were sold, the supplier or manufacturer and retail prices were recorded. After the initial series of sales-related questions, dealers were asked to comment on customer satisfaction and to give their personal opinion of wood pellet fuel as an energy technology.

wood pellet stove availabilty

Of the dealers visited, half currently sold pellet stoves. Several of the dealers intended to sell or manufacture pellet stoves in the future. The major reasons given by the stove dealers for not selling wood pellet stoves were:

1. Current stove technology was unacceptable to the stove dealers.
2. Pellet quality and availability was questionable.

3. In the opinion of the dealers, pellet stoves currently on the market were unattractive.

Since 1981, pellet stove sales had consistently increased. Dealers were anticipating sales of the pellet stoves to increase in the future. All pellet stove dealers kept pellet stoves in stock for inspection by potential customers. Sales were generally to first-time customers. It appeared that nearly all customers were installing pellet stoves as a primary source of residential heat (mortgage regulations from many sources of funds often require a backup source of heat other than a wood-based system). Sales of wood pellet stoves were geared to smaller homes (900 to 1000 square feet range). Dealer markup was higher for pellet stoves than conventional wood stoves. However, dealers stated that there was often more profit potential on conventional wood stove sales due to installation costs and the sale of accessory items. Pellet stove customers reportedly felt that stoves were clean and inexpensive to operate. The major concerns with wood pellet stoves voiced to the dealers by their customers were:

1. problems with stove technology which include auger maintenance, plugging of the exhaust pipe, exhaust fan maintenance, and miscellaneous minor mechanical problems,
2. pellet quality, and
3. stove safety (burn-back into fuel hopper).

wood pellet availability and distribution

All pellet stove dealers contacted had pellets in stock and sold wood pellets primarily to their stove customers. The package size sold in greatest quantity was the 40-pound bag and the greatest quantity purchased was one ton. One ton of pellets represents a 30 to 50-day supply of fuel. The major complaints concerning pellet quality were:

1. dirty fuel containing bark and contaminates which resulted in variable pellet quality and "klinker" buildup in the stove, and
2. widely varying pellet length resulting in numerous augering problems.

The following comments summarized the views and opinions of the dealers contacted during a face-to-face interview:

1. The technology of wood pellet stoves was not well developed.
2. There was a lack of knowledge and safety codes regarding the installation and use of chimneys for pellet burning equipment.
3. The future of wood pellet sales appeared optimistic as there was a growing proportion of the wood heat stove sales in pellet stoves.
4. Sales of wood pellets should be geared to geographic areas where pellets were manufactured and readily available.
5. There was greater profit in conventional wood stove sales compared to pellet stoves.

wood pellet manufacturers

In 1985, wood pellet manufacturing plants within the Intermountain West region were located at Ravalli, Bozeman, Eureka and Darby, Montana, Sandpoint, Idaho, and at Omak and Brewster, Washington. Two additional plants were planned to be in operation the following year in Spokane, Washington and Julietta, Idaho. There are currently 19 wood pellet fuel manufacturers in the region; five in Idaho, six in western Montana, five in eastern Washington and three in eastern Oregon. Three neighboring regions account for 23 manufacturers with 42 producers in the four remaining U.S./Canadian regions (see Appendix A). Average production capacity in the Intermountain West region in 1991 is an estimated 680 tons per 8-hour shift with an annual capacity of approximately 170,300 tons. Intermountain region pellet production in 1991 is estimated at 143,650 tons per year.

Whitney (1991) reports that across the United States, some producers may be working more than one shift, however, this is not likely occurring in the Intermountain West when considering the production figures. There is unused capacity in the Intermountain West region. The amount, estimated at 26,650 tons, could be true unused capacity in that production is keeping up with demand. Or, manufacturers may be having difficulty getting the production from their equipment. Modifications to pellet mills and mill operation are as much an art as a science in the industry, with considerable trial and error that result in delays and downtime.

Capacity may also be overestimated. Difficulty in determining machine capacity is a common problem in pellet manufacturing because machine manufacturer's specifications, often used by the producer, have been based on production of feed pellets rather than wood fuel. An accurate determination of capacity is probably a combination of both capacity scenarios.

DENSIFIED WOOD FUEL MARKETS AND MARKETING

Introduction

The industrial manufacturing sector is a large energy consumer and uses large bulk volumes at any given site. As a consequence, it became the first market for targeting wood pellet production. Wood pellets have many advantages over some other conventional fuels in that they are relatively clean to handle and burn. Wood pellets may be burned in gas or oil furnaces with certain modifications or in a conventional stoker-spreader furnace without modification. With a substantially higher usable heat compared to round wood, less pollutants as compared to coal and lower cost per therm compared to electricity, LP gas and fuel oil, the savings achieved from using wood pellets is attractive to most industrial space heating applications (Spangler, 1977; Pursley, 1980; Pearson, 1981; Johnson, 1982).

On the other hand, wood pellets face stiff competition from other sources of more expensive and inexpensive energy, and readily available fuels. An example is hogfuel which can be used to fire furnaces without being compressed into pellets.

Hydro-elctric power and natural gas are strong competitors with wood pellets in some areas of the country. While this might seem to eliminate the Intermountain West from being a potential wood pellet market, the outlook is perhaps not that bleak. Many believe that reasonable energy costs for industrial customers of hydro-electric and natural gas is only temporary and that imposition of more stringent air and water quality regulations are likely. This will further discourage the utilization of fuels such as coal (Pearson, 1981).

Despite competition, the industrial sector has remained attractive to wood pellet manufacturers for several reasons. Only a few industrial contracts (each with a large volume) can keep a pellet plant at desired production capacity. Serving a few customers further reduces the sales efforts required and other logistics problems such as distribution and delivery. There are, however, some disadvantages related to industrial sales. Dependence on just a few customers can be equated to "putting all the eggs in one basket" and large volume, bulk sales are associated with low profit margin.

Sales efforts are being increasingly directed toward residential heating in recent years as a market segment offering a higher profit margin (Spangler, 1977; Pursley, 1980). An objective of this discussion is to examine these potential market segments and marketing approaches.

Identification of Market Segments

There are a number of steps to marketing a product, and some initial steps are categorized accordingly:

- identification of the market segments
- selection of the most promising segment(s)

- formulation of marketing approaches and allocation of resources

When identifying market segments, fuel pellet consumers can be generally grouped under three major segments - industrial, residential, and municipal/institutional. Industrial consumers of wood pellets can be further sub-divided into two classes: those that consume energy principally for generating process heat (steam or hot water) and those that use the energy for interior (space) heating (Pursley, 1980; Pearson, 1981).

In most cases, residential (including small businesses and offices) consumption of heat energy is almost exclusively for space heating. There are, however, certain differences that warrant further sub-division of this segment. One method of differentiating the sub-groups of residential consumption is according to a readiness to convert to using wood pellets. By applying this classification, four sub-divisions are identified (Pursley, 1980):

- residences with existing coal or wood heating systems, or other types of furnaces or boilers that could be easily converted, with little or no modification to burn pellets;
- residences that are contemplating an "add-on" or an additional furnace to connect into existing duct work;
- residences having existing or seeking additional supplemental, appliances, including all non-central systems;
- new residences installing central or non-central heating systems, and older residences considering replacement of old furnaces or boilers.

The municipal/institutional consumer category uses energy primarily for interior heating although some institutions such as hospitals also require fuel to generate steam or supply hot water. Consumption by these customers is normally much larger than those of a residential consumer.

Ranking the importance of these segments might differ among geographical regions. Detailed market segment research could be too costly for some wood pellet manufacturers, however, a basic marketing investigation can help in avoiding serious mistakes with formulating marketing approaches.

Selecting Market Segments

There are several factors to be considered before a market segment is selected for use in determining the approach to selling wood pellets. Geographical constraints, production capacity, and the availability and cost of techniques and equipment for conversion of existing devices for burning pellets are very important.

While many pellet manufacturers feel that a hauling distance with a 100-mile radius is generally feasible (Pearson, 1981), market studies suggest that a distribution area with a 50-mile radius or less, especially for distribution to residential consumers, is more profitable. Within the region, however, manufacturers have recently demonstrated the ability to supply customers beyond a 200-mile radius and maintain profitability.

The rationale behind these conflicting statements seems to closely relate to the volume of consumption of each customer, over time, with the concentration of these customers, competition, and price of alternate fuels.

There are a number of ways that production capacity or proposed capacity might affect the selection of the market segments. First, while it is critical to determine the availability of potential consumers for the manufactured product, the quantity that consumers can absorb will largely determine the viable capacity. This viable capacity will also depend on the ability of this new product to penetrate the market of an established product. Immediate market penetration of full production capacity would be unlikely for any new venture, so aside from other production logistics, a legitimate design capacity will need to be tied to market penetration within a specific geographical region.

Available technology and cost of engineering and equipment needed to convert existing facilities to burn wood pellets varies among market segments. For large volume consumers such as industrial and municipal/institutional users, the savings that could be realized should be sufficiently attractive to commit investment in such conversions. For residential consumers, the return on investment may be quite different.

There are many other factors that contribute to the final selection of viable market segment. Different segments require different distribution and delivery methods. Large volume consumers in the industrial and municipal/institutional segments will typically require bulk delivery under a long term contract price on a payment schedule, while the residential market may prefer packaged supplies that are cash and carry. Furthermore, delivery requirements will not only vary in terms of quantity but also with consistency of delivery. While process heating systems will need fuel all year round, space heating requirements will be restricted to a specified period each year. A seasonal supply requirement adds complexity to wood pellet fuel distribution, inventory and storage. Other factors that will influence manufacturing decision making are budgetary constraints and required profit margins. Large volume sales will usually require less marketing effort with lower profit margin than individual, small volume sales to residential consumers. Some form of additional regulation with respect to particulate emissions by environmental agencies, especially for large volume consumers, may also be expected. Regulatory approval can take up to a year to obtain (Spangler, 1977).

Market research, besides being necessary for market segmentation and segmentation identification, should be designed to collect information in order to select the most promising segements. Before formulating a marketing approach, information to include potential wood pellet consumption, types of existing furnaces, available local suppliers of needed combustion equipment and auxilliary hardware, and available contractors with knowledge of furnace modifications are important to selecting these segments.

Formulating Pellet Fuel Marketing Approaches and Allocating Resources

Initial stages in market segment identification and selection are market survey and analysis activities often performed in marketing research. After data are obtained and analyzed, the next step is to formulate approaches and allocate resources needed to sell the product. This will include the areas of promotion, consumer education, the sales approach, establishing distribution networks and delivery systems, and many other related activities. Again, market segments have widely varying characteristics and will call for different approaches to marketing wood pellets. Similarly, resource requirements will also vary according to the complexity of each segment, residential being the most complex followed by municipal/institutional and finally, the industrial segment.

Marketing Programs For Different Market Segments

With the variability among the three main groups of potential consumers, marketing programs with different approaches should be designed for each market segment. Programs should follow a somewhat standard format, with components such as selecting a sales or marketing agent, planning out promotion and consumer education programs, and establishing a distribution network and delivery system. Component emphasis is given according to the target group. Approaches that have been proven to be effective are outlined below, according to segment.

industrial segment

Either selecting a sales or marketing agent or recruiting and training a sales and marketing team have advantages and disadvantages. While an experienced marketing agent is more likely to do a better marketing job, it may not be feasible to have an agent devoted solely to one product. An agent will usually handle more than one marketing program at the same time. If the programs are for similar products from different manufacturers, there may be consumer confusion. Since industrial wood pellet sales, as a rule, are small in terms of numbers of accounts, continuing marketing functions with promotion and sales can be handled by company employees at the plant.

Promotional approaches to selling wood pellets may include:

- advertising in trade journals, technical periodicals and newsletters that are targeted towards industrial plant managers, plant engineers, physical plant supervisors, and boiler and furnace operators,
- mailing out a technical pamphlet or newsletter to plant managers, plant engineers and other industry representatives,
- calling plant managers or their technical staffs to arrange participation in promotional, yet technical, seminars that advertise the advantages of using wood pellets over other conventional fuels,

- contacting plants to test-fire wood pellets in their facility. (This would simultaneously promote a product and educate a potential user. Test-firing information could then be included in promotional literature or the test could be video-taped and made available at seminars, trade shows or for mailings.)
- participating in trade fairs, exhibitions and other promotional shows, particularly in conjunction with and heating equipment manufacturers.

Devising a distribution network for marketing wood pellets to industrial segment may not be necessary since sales are usually direct between the manufacturer and the industrial customer. Establishing a delivery system will probably be in the form of bulk shipping, direct to customer storage, on a year-round basis.

Although these approaches are logically sound for marketing wood pellets to industrial consumers, the need to carry them out has been questioned. It has been argued that pellets are a bulk energy product and cannot be separated from the family of bulk energy commodities in a marketing scheme (Bossel, 1985). Pellets therefore do not become more attractive by creative packaging or advertising. In all liklihood, persuading a plant to operate with pellets on a trial basis may be all that is needed to "push" the product (Spangler, 1977; Pursley, 1980).

<u>residential segment</u>

Hiring a marketing or sales agent or recruiting one versus using an in-house team has similar problems with cost and loyalty as with the industrial segment. A professional agent, however, may be better able to handle some of the complexities of residential marketing than a plant employee and vice versa. Residential pellet fuel promotion might be approached by:

- advertising in the media (television, newspaper, and magazine) as well as other household literature (this may be cost prohibitive for the small manufacturer),
- participating in consumer trade fairs, home shows and exhibitions,
- mailing promotional pamphlets of the pellet product to retailers of combustion equipment and accessories (pellet stove dealers, home heating contractors, and hardware stores) that might provide display space or could become potential outlets for wood pellets,
- using sales personnel to contact potential retailers for accounts by offering seasonal and quantity discounts, and providing assistance with advertising and pricing,
- conducting and evaluating the use of pellets in residences, videotaping and documenting results and providing the tapes and literature to pellet stove dealers.

The distribution network for serving the residential segment will be longer and more complicated than the industrial network, and may require intermediaries such as a warehousing wholesaler and a retailer. Since wood pellet demand is likely to be seasonal, detailed planning for inventory control and establishing a delivery system is critical. Pellet fuel should be marketed to customers in a package size that is safe and convenient to handle with 50 pounds as maximum. Federal OSHA safety regulations regarding employee lifting limits would apply with an employee handling the product. Bagged fuel is often manually loaded into a pick-up truck or car trunk of cash and carry customers. Accomodating several bag weights will require additional investment by the manufacturer for packaging and storage. Packaging could be performed at the intermediary level although it is now not a function of wholesalers or retailers. Bulk delivery direct to residential customers, not now a function of the manufacturer, is unlikely since an individual customer sale is typically less than one ton with retail value less than $100.

municipal/institutional segment

This segment can be treated with marketing approaches that are similar to those listed for the industrial segment. Consumption by customers are usually in large volumes except that part of the segment demand used mainly for space heating is seasonal. Interruption of supply is a critical concern from municipal/institution customers.

Proposed Marketing Strategy

Characteristics of the three market segments outlined have been summarized in the following table to indicate a marketing startegy for wood pellet fuel sales and distribution.

Table 12. MARKET SEGMENT CHARACTERISTICS OF WOOD PELLETS

market segment	demand mode	delivery mode	marketing	profit margin
industrial	year round	bulk	simple, direct sales	low
residential	seasonal	packaged	complicated	high
municipal and institutional	mixed	bulk	simple, direct sales	low

A rational approach to be followed for a manufacturer entering the wood pellet market and serving these market segments will be to: (1) obtain one or more large volume industrial customers, (2) or expand into the municipal/institutional segement, (3) using the excess or slack production capacity to serve the residential segment. This approach may be modified when the desired level of initial market penetration has been established.

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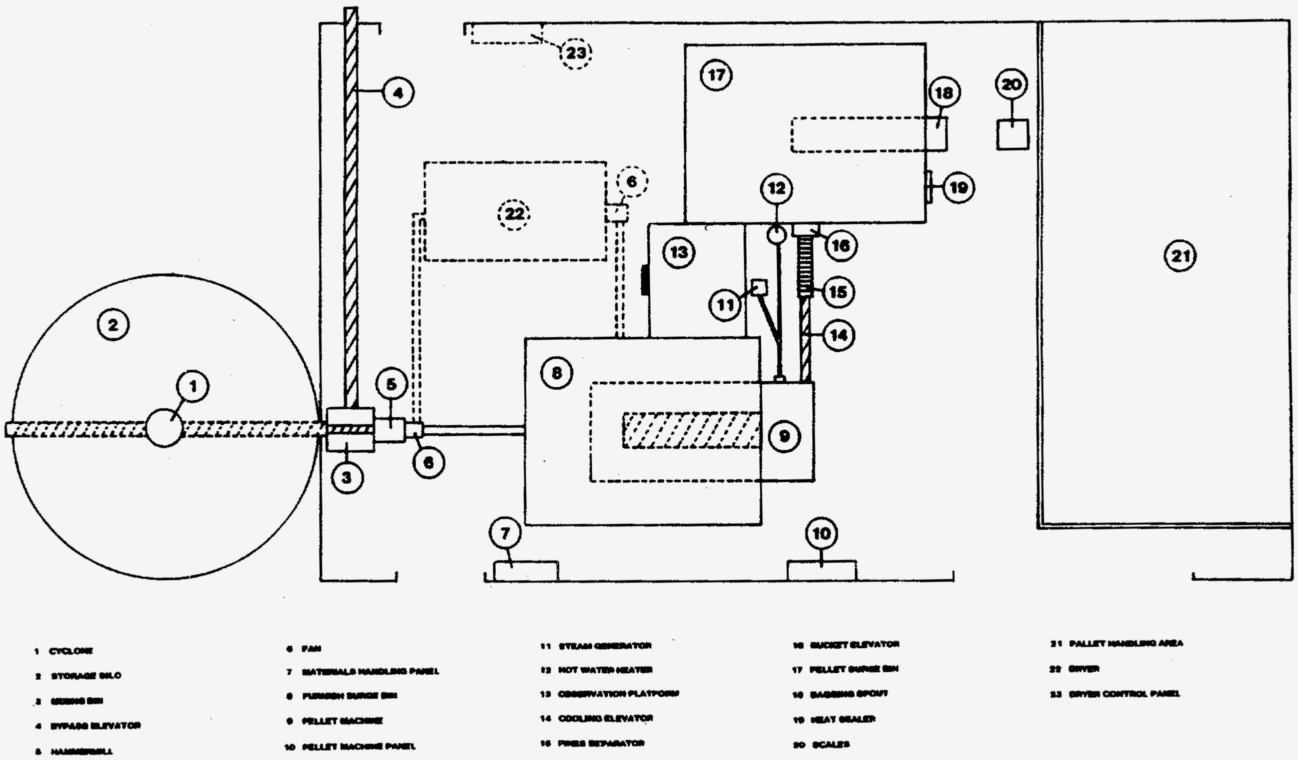
Part II. TECHNICAL FEASIBILITY AND LOCAL MARKETING WITH SMALL-SCALE DENSIFIED BIOMASS FUEL (PELLETS) MANUFACTURE: A Case Study



INTRODUCTION AND BACKGROUND

Biomass from the Forest

Substantial but widely dispersed quantities of residue and waste wood originating from forest land may be found within the Intermountain West region. Coarse and fine residue from forest products processing (slabs, edgings, sawdust, and shavings) generated by large forest industry corporations are largely utilized. Bark, however, is underutilized (Keegan et al, 1988). Medium and, particularly, small-sized primary and secondary processors generate green and dry residue (edgings, trim ends, sawdust and shavings) that are largely unused. In most cases, these producers do not have wood waste in a quantity or form that can be readily sold or directly consumed either in the martketplace or by the company. In some cases, the producers are simply not aware of alternative conversion of their residue to an energy product or cannot afford to conduct the research to investigate the technical and economic aspects of equipment layout, processing, markets and marketing. Small wood processing companies generally use conventional residue disposal methods such as giving it away, incinerating it in open burners, stock piling or landfilling. There are economic, social and environmental costs associated with these disposal methods; methods that are often expensive and unnecessary. Long term use of such disposal methods may pose an environmental risk and the probabilty for regulation.

Green residue generated from primary wood processing must be dried to a very low moisture content before pelleting; a cost that becomes prohibitive in small-scale densified biomass fuel manufacturing. On the other hand, secondary manufacturing residues are usually free from bark and dirt, and are already at a low moisture content. Compared to primary manufacturing, secondary processing usually generates less residue per unit volume of product output. Consequently, scale and capacity of a pellet manufacturing operation is immediately critical to the investment.

Estimates of in-the-woods waste wood from timber harvesting have been reported to range from 20-40 tons per acre (Johnson et al, 1987). In many cases, the waste wood is found concentrated along haul roads and near landings. Since the cost of collecting logging residue is already borne with the log, only the cost of conversion to pellet fuel and hauling the fuel remains, if processing is carried out on-site. Mechanical, in-the-woods processors (whole-tree-chippers) are now available that separate much of the bark from the wood, converting logging residue into a high quality biomass energy raw material. At least one manufacturer of punch-press pelleting equipment has designs for a portable machine, however, a full scale model has not been built or tested. Ring-die extrusion equipment is not portable and would be unlikely to profitably operate with even the smallest amount of contamination in the raw material.

Whole-tree-chips from standing dead trees do offer a raw material supply with certain desirable characteristics for pelleting; less contamination and lower moisture content. However, as with logging residue, on-site pelleting is undeveloped.

Biomass From Agricultural Residue

Accepted agricultural practices with grain crops are to bale and sell residue, plow it under, leave it in place and plant the next crop in the stubble (no-till), or broadcast burn it. Other potential biomass pellet raw materials from agricultural residue are the dry fibrous stems and stalks of plants such as straw, corn, rapeseed, sorghum and sunflowers. These types of residues provide little organic value when returned to the soil and therefore should present little or no environmental impact on short or long term soil productivity. These residues are difficult to incorporate using machinery.

Since harvesting the agricultural product requires the residue to be pre-processed, part of the cost of densified biomass fuel manufacturing is absorbed by the marketed crop. Residue handling and processing can be simplified by using conventional farming equipment such as balers, elevators and, silage choppers and hammermills.

Once an agricultural crop has been harvested, by-products may be generated during processing, spoilage during storage can occur and surpluses may require disposal. Examples of common processing by-products in agriculture are: corn cobs, nut hulls and husks, peelings, oil seed meals, and gin trash. Examples of spoiled and surplus products are seed potatoes and seed corn, grass seed and grains.

Biomass From Municipal Solid Waste

Municipal solid waste from biomass origin, such as lawn and garden residue, and newspaper represent biomass wastes that are usually buried or sometimes burned at the landfill. In the case of newspaper, demand for use as a recycled material exists in the marketplace where large quantities are used in the building products (e.g. insulation) and the pulp and paper industry (e.g. paper and board products and mailing envelopes). The composition of newspaper printing inks are three ingredients: vehicles, coloring agents and additives. Vehicles serve as carriers and binders, and may be derivitives of phenolic resins, cellulose or rubber. Coloring agents are pigments rather than dyes, composed of clay, calcium, magnesium and carbon. Additives are waxes and polyethylene. Never-the-less, newspaper does show considerable technical promise as a biomass pellet fuel feedstock with its high cellulose and lignin content and few chemicals compared to other paper waste streams.

CASE STUDY FACILITY DESCRIPTION

Operating History

Browning Cut Stock Company is an incorporated, family owned and managed, secondary wood processing business, founded in 1964 by Jack G. Browning, the current President. As a manufacturer of pine cut stock and specialty wood products that include window and door parts, moulding, finger-jointed millwork, toy blocks, and paper mill roll plugs, Browning Cut Stock is a major forest products industry employer in southern Latah County. The plant is located approximately 1 mile south of Juliaetta, Idaho, and employs 30 workers from the nearby communities of Juliaetta, Kendrick, Southwick, Troy, Deary and Bovill. Manufacturing materials are exclusively kiln dried, shop grade, ponderosa pine lumber. Moisture content, dry basis, averages 12 percent or less and total annual lumber useage is approximately 1.5 million board feet. An estimated 500 tons of fine residue and hogged waste wood from narrow edgings, fine sawdust, shavings, and trim containing knots, pitch pockets and wane are produced annually. Prior to 1987, Browning Cut Stock Co. periodically sold small quantities of fine residue (sawdust and shavings) for animal bedding and gave away coarse residue (edgings and trim) and reject cut stock pieces for firewood. The majority of the residue, however, was burned in two open incinerators, and the remainder was landfilled on adjacent company property.

In 1987, Browning Cut Stock Co. purchased a Hyflo pellet mill manufactured by California Pellet Mill Company, along with several dies and spare parts. The pellet mill had been used to produce alfalfa pellets for cattle feed. The mill was modified by Browning employees. These modifications included: a new drive motor, heavy main shaft bearings, new rollers and roller bearings, a rebuilt supply auger, and a new main drive gear. The mill was installed on site in a new steel building but independent of the cut stock operations. A self-unloading, steel grain silo was attached to one end of the building to store residue produced at the different cut stock machine centers. Initially, end trim continued to be given away or landfilled while only shavings and sawdust were moved by fans through metal blower pipe to the silo for pelleting. During late summer 1988, a rotary hog was added to reduce the trim to chips, and a 12-inch diameter residue collection line was installed to move the hogged material to the silo.

Browning Cut Stock Co. began manufacturing wood pellets from their own residue in late 1987, first using a 1/4-inch diameter feed die and then a new 1/4-inch wood die. One employee was trained to operate and service the mill. The pellets were of exceptionally high quality (very low fines content, durable, very low ash content) but production and maintenance on the pellet machine was unacceptable. In 1988, a 5/16-inch wood die was installed in the pellet macnine that successfully increased production and reduced operating and maintenance costs on the mill. Pellet quality, particularly durability and fines content, were somewhat adversely effected by the die change but the product remained residential grade. However, adding knotty trim to the feedstock created a processing problem not encountered with sawdust and shavings: pelleting residue containing high concentrations of pitch. A solution to the problem was found when steam and hot water were added to condition the feedstock prior to entering the pelleting chamber. In mid to late 1988, the company went into full production of densified wood fuel and has made only minor changes to their process since then. A partial overhaul of the pellet machine (shaft aligned and balanced with the die) in early 1989 has put the machine in it's best operating condition since purchase, producing a wood fuel pellet similar in quality to the 1/4 inch product made with a wood die.

Equipment Description and Materials/Product Flow

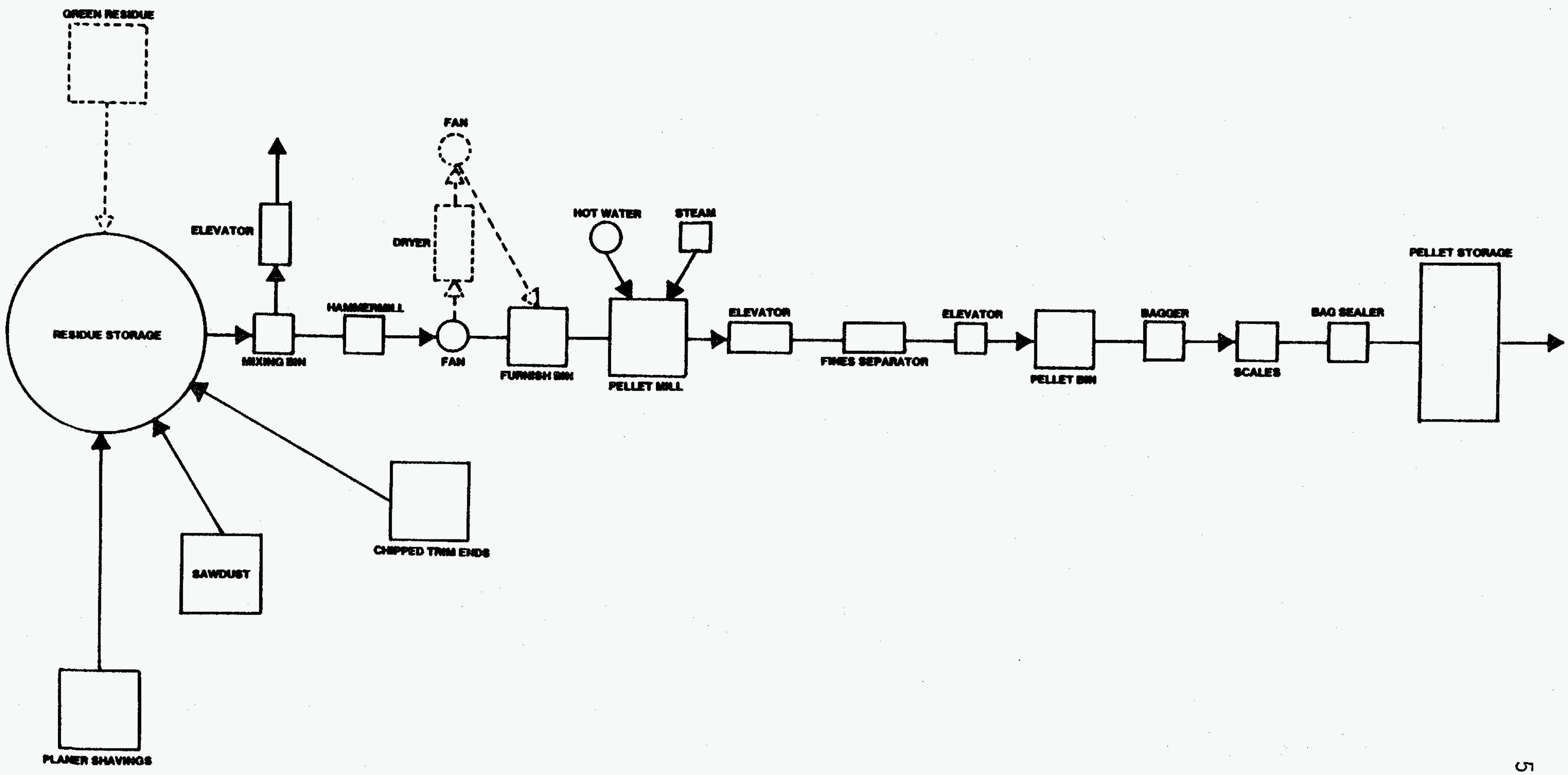
As shown by the flow chart in Figure 1, dry residue produced by the cut stock side is moved by fan and blower pipe to a 24 x 24 feet round, steel storage silo. Moisture content of the residue is reduced to approximately 9 percent (oven-dry basis) from movement through the pipe. Fans, blower pipe, cyclones and electric controls for hogging the trim and handling the material were purchased and installed by the company. All other residue collection and handling equipment (2 fans and 150 feet of blower pipe) were already in place from use with the incinerator. The silo may also be filled through the silo roof by elevator.

The facility containing the pelleting side is an insulated, steel building that measures 52 feet long, 24 feet wide, and stands 15 feet high, and rests on a 6-inch thick, reinforced concrete slab. Three phase, 220-volt service is installed; 440-volt service is not available. Lighting for the building is supplied by five florescent fixtures, and two electric space heaters provide temporary heat for the pellet mill operator during startup. Heat generated during pelleting is given off into the building.

Residue is unloaded from the silo by an auger running through the center of the silo that is installed in the concrete foundation. The auger is elevated approximately 3 1/2 feet from the base of the silo to remain in-line with the blending hopper. Stored material is unloaded into a shop-built blending hopper with a surge capacity of approximately 60 cubic feet. An off-loading elevator connected to one side of the blending hopper allows residue to be unloaded from the silo and sold as mulch and animal bedding. The elevator is reversing and can be used to supply other residues for pelleting or introduce additives to the residue in the hopper should the opertor choose this option. [A permanent magnet or other metal detecting device is usually installed in the outfeed side of the blending hopper to locate tramp metal. However, the high quality of the residue generated by cut stock (edgings, shavings, sawdust and trim) usually precludes the need for one.] A shop-built auger, 11 feet long, carries the residue from the bottom of the hopper to a hammermill powered by a 30-hp, 220-volt, 3-phase motor. Productive capacity of the hammermill is approximately 200 pounds of dry wood per hour through a 3/16-inch screen. A built-in, permanent magnet is located near the throat of the hammermill.

The hammered material or feedstock is transported by fan and blower pipe to a shop-built, surge bin located above the pellet machine. The surge capacity of the bin is approximately 350 cubic feet. A cloth cover, sealing the blower pipe to the bin, reduces wood dust in the building. [If green residue were being pelleted, a biomass dryer would be installed after the hammermill to lower the moisture content of the furnish to the target level of 15-18 percent].

Figure 1. Flow Diagram of a Small-Scale Densified Biomass Fuel Manufacturing Facility



The feedstock is gravity fed into a ring-die extrusion pellet mill (a vertical die, horizontal main shaft machine with two rollers) powered by a 50-hp, 3-phase, 220-volt electric motor. A built-in, permanent magnet is located in the pellet mill just before the feedstock enters the pellet chamber. Two additional 3-phase, 220-volt motors independently operate the auger and the mixer. The production capacity of the machine for manufacturing alfalfa pellets is rated at 6 tons per hour, however, wood pellet production ranges from 400 to 900 pounds per hour. Steam and hot water are introduced into the mixing chamber to condition the feedstock before extrusion. A shop-built steam generator consists of a steel casing, water inlet and baffle, 220-volt heating element and a float-solenoid switch. Steam flows from an outlet on the generator into the mixing chamber casing of the pellet machine through high pressure hose. Hot water may also be injected into the mixing chamber using an industrial furnace spray nozzle. One side of the spray head is connected to a 52 gallon hot water heater and the other to a 220-volt air compressor supplying 40 pounds per square inch of air to produce a "fan-shaped" mist of water inside the mixing chamber.

Pellets and pellet fines exit from the base of the pellet machine, move by a 7 feet long, shop-built auger and are deposited into the open end of a rotating barrel screen or "trundle" measuring 2 feet in diameter and 30 inches long. The screen size is 1/4 inch. Pellet cooling begins in the auger and continues during movement through the trundle. Pellet fines pass through the screen into a fan housing and are blown back into the storage silo where they are mixed with new residue. [In a green residue process, fines could be burned as fuel for the rotary drum dryer.] The trundle is inclined at a 30-degree angle, allowing the pellets to be screened the entire length of the barrel.

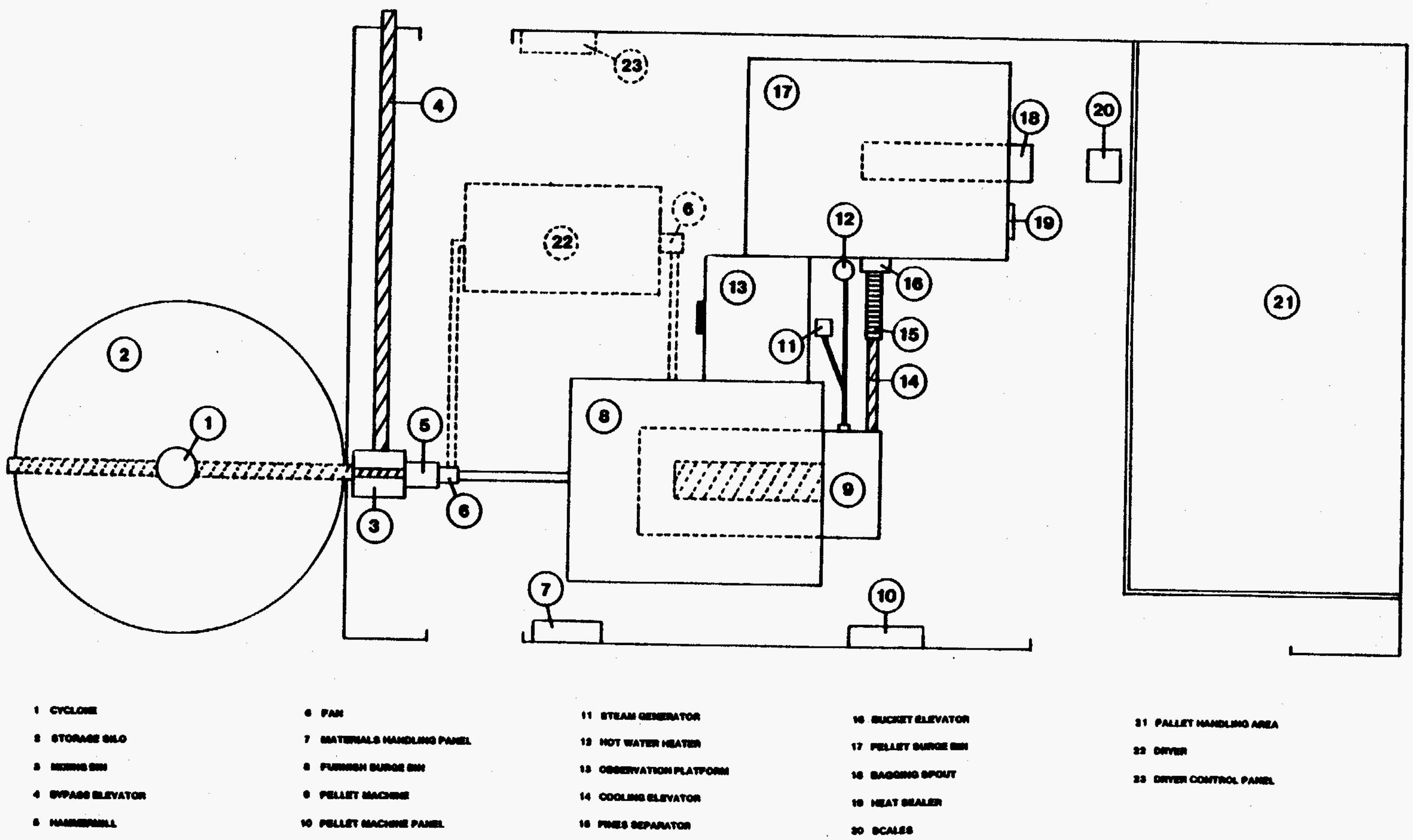
Pellets leave the open end of the trundle and fall into a bucket elevator, carrying them a vertical distance of 14 feet to a fan and blower pipe used to fill the pellet surge bin. The pellet surge bin is a farm combine bin with a surge capacity of 170 cubic feet. The bin outlet has been modified to accomodate a commercial, weight-dispensing bagger. Two grain bin cooling fans are mounted in the base of the pellet surge bin to bring the pellet fuel to room temperature.

All pellet fuel produced at Browning Cut Stock Co. is packaged in clear polyethylene bags, check-weighed on a beam balance (additional product may be added) and sealed with a 24" impulse sealer. Bagged fuel is loaded on pallets where each pallet contains 20, fifty-pound bags or one-half ton. Shrink-wrap packaging is used to seal the contents of each pallet. A 5,000 pound capacity pallet jack moves loaded pallets to an overhead door in the building where a propane powered fork lift transports and stacks the product in a 24′ x 24′ x 15′ high, enclosed storage shed. The capacity of the shed is approximately 48 bagged tons.

Plant and Equipment Layout and Costs

Figure 2 gives the pellet plant layout at Browning Cut Stock Co. and includes the location of optional residue drying equipment. A complete list of the equipment, purchase prices, and cost of set-up labor and materials for putting the facility on stream is given below.

Figure 2. Plant Layout of a Small-Scale Densified Biomass Fuel Manufacturing Facility



residue preparation, handling and storage

used rotary hog (unknown manufacturer) w/40 hp, 3 phase, 220 volt, 98 amp motor	$ 2,224
electrical service for hog	$ 545
used fan and 15′ blower pipe (unknown manufacturer) w/5 hp, 3 phase, 220 volt, 13.4 amp motor	$ 488
used fan and 150′ blower pipe (unknown manufacturer) w/30 hp, 3 phase, 220 volt, 70 amp motor; 3 used cyclones	$ 9,000
new Scafco grain silo (24′ x 24′) w/1/2 hp, 3 phase, 220 volt, 13.4 amp motor; concrete foundation and auger housing	$15,328
new R&M steel building (52′ x 24′ x 15′); concrete; lighting; space heaters; electric service	$15,100
shop-built blending hopper and 11′ auger w/1 hp, 3 phase, 220 volt, 4.4 amp motor	$ 407
shop-built off-loading elevator w/5 hp, 3 phase, 220 volt, 14.6 amp motor	$ 1,570
new electrical service for residue handling and processing, and pellet handling and storage	$ 2,090

residue grinding

shop-built hammermill screw auger	$ 112
used Sears-Roebuck Model 241/1000 hammermill w/new 30 hp, 3 phase, 220 volt, 76.6 amp motor	$ 1,119
used fan and 18′ blower pipe (unknown manufacturer) w/1/3 hp, 1 phase, 115 volt, 5.0 amp motor	$ 350

pelleting and pellet handling

shop-built furnish surge bin (350 cubic feet)	$ 4,500
new California Pellet Mill Company wood dies (1/4" and 5/16")	$ 2,400

used CPM Hyflo pellet mill w/3/4 hp, 3 phase, 220 volt, 3.8 amp auger motor; 15 hp, 3 phase, 230 volt, 38 amp mixer motor; new 50 hp, 3 phase, 220 volt, 128 amp drive motor; 2 feed dies; extra rollers and auger	$ 2,720
shaft/die alignment and balancing	$ 1,225
shop-built "steam jenny" w/220 volt heating element	$ 500
new Eagle Deluxe 52 gallon hot water heater w/4000 watt upper and lower elements	$ 377
new air compressor (manufacturer unknown) w/5 hp, 220 volt, 15 amp motor	$ 500
new industrial furnace spray head (manufacturer unknown)	$ 550
shop-built steel platform, stairs and railing	$ 2,700
shop-built 7' auger w/1/3 hp, 3 phase, 220 volt, 1.5 amp motor	$ 143
shop-built 30" trundle w/1/8 hp, 1 phase, 115 volt, 2.5 amp motor	$ 70
used fan and 25' blower pipe w/1/2 hp, 1 phase, 115 volt, 7.8 amp motor	$ 391
new Universal bucket elevator w/3/4 hp, 3 phase, 220 volt, 3.8 amp motor	$ 1,300
used fan and 5' blower pipe w/1/3 hp, 1 phase, 115 volt, 5.0 amp motor	$ 383
electric service for pellet machine	$ 2,090

<u>pellet cooling and storage</u>

shop-built pellet surge bin (170 cubic feet)	$ 4,500
two new Scafco cooling fans w/.75 hp, 1 phase, 115 volt, 11.6 amp motor	$ 900
new Taylor bagger	$ 430
used U.S. Standard beam type weigh scales	$ 116

new 24" Clamco impulse heat sealer	$ 1,280
used pallet jack (manufacturer unknown)	$ 555
used Clarke 5 ton capacity propane fork lift	$ 6,500
20′ x 20′ x 15′ enclosed storage shed	$ 6,776

other miscellaneous

miscellaneous construction and assembly labor	$12,500
Grand total:	$101,739

Labor Costs

The entire pellet manufacturing facility is operated by one employee at the rate of $10.48 per hour, including benefits. Work days are Monday thru Friday, 5 days per work week, 250 work days per year (5 paid holidays and 5 paid vacation days). Daily work hours are from 8:00 am to 5:00 pm with 1 hour for lunch and two, 15 minute breaks (7.5 working hours).

Operating and Maintenance Costs

The largest operating expense is for electricity to power the facility. Electricity use is summarized for each electric motor operated at 75% capacity:

40 hp	- 3 phase	- 220 v.	- 98.0 a.	- 8 hrs./day:	180 kWH
5 hp	- 3 phase	- 220 v.	- 13.4 a.	- 8 hrs./day:	22.5 kWH
30 hp	- 3 phase	- 220 v.	- 70.0 a.	- 8 hrs./day:	135 kWH
1.5 hp	- 3 phase	- 220 v.	- 4.8 a.	- 4 hrs./day:	3.4 kWH
1 hp	- 3 phase	- 220 v.	- 4.4 a.	- 6 hrs./day:	3.4 kWH
30 hp	- 3 phase	- 220 v.	- 76.6 a.	- 12 hrs./day:	202.5 kWH
1/3 hp	- 1 phase	- 115 v.	- 5.0 a.	- 12 hrs./day:	2.3 kWH
3/4 hp	- 3 phase	- 220 v.	- 3.8 a.	- 6.9 hrs./day:	2.9 kWH
15 hp	- 3 phase	- 220 v.	- 38.0 a.	- 6.9 hrs./day:	58.2 kWH
50 hp	- 3 phase	- 220 v.	- 128.0 a.	- 6.9 hrs./day:	194.1 kWH
1/3 hp	- 3 phase	- 220 v.	- 1.5 a.	- 8 hrs./day:	1.5 kWH
1/8 hp	- 1 phase	- 115 v.	- 2.5 a.	- 8 hrs./day:	0.6 kWH
3/4 hp	- 3 phase	- 220 v.	- 3.8 a.	- 8 hrs./day:	3.4 kWH
1/2 hp	- 1 phase	- 115 v.	- 7.8 a.	- 8 hrs./day:	2.3 kWH
1/3 hp	- 1 phase	- 115 v.	- 5.0 a.	- 8 hrs./day:	1.5 kWH
5 hp	- 1 phase	- 230 v.	- 15.0 a.	- 2 hrs./day:	5.6 kWH
3/4 hp	- 1 phase	- 115 v.	- 7.0 a.	- 8 hrs./day:	3.4 kWH
3/4 hp	- 1 phase	- 115 v.	- 7.0 a.	- 8 hrs./day:	3.4 kWH
n/a	- 1 phase	- 240 v.	- 8000 w.	- 8 hrs./day:	48 kWH
n/a	- 1 phase	- 110 v.	- 660 w.	- 2 hrs./day:	1 kWH
n/a	- 1 phase	- 115 v.	- 1100 w.	- 8 hrs./day:	6.6 kWH
n/a	- 1 phase	- 220 v.	- 10000 w.	- 6.9 hrs./day:	51.7 kWH

daily total:	933.3 kWH
cost/kWH:	$0.03897
daily kWH cost:	$ 36.37
daily basic charge:	$ 34.41
total daily cost:	$ 70.78

A cost of $0.38 is incurred for each polyethylene bag and $3.20 per pallet (includes shrink-wrap).

Maintenance at the facility is performed by the pellet mill operator for an average of 1 1/2 hours per week (0.3 hrs./day) at a daily cost of $4.19, including benefits. Parts are obtained from scrapped equipment and materials at the facility.

Office Overhead, Sales and Transportation Costs

Browning Cut Stock Co. maintains a sales and accounting office staffed by the company president, who serves as sales manager and purchasing agent for all company business, and by a part-time accountant and payroll clerk. Office overhead and sales costs from the pellet manufacturing side do not contribute any significant added expense to the principal business of the company, cut stock, and are not separated from the cut stock side. The company owns and operates two, tractor truck and flat bed trailer combinations that deliver cut stock orders as far east as Minnesota and to the west coast. Pellet fuel deliveries made to wholesale purchasers are within a 100-mile radius of the plant and are loaded along with cut stock orders and delivered enroute when space is available. Transportation expenses for pellet fuel are therefore not separated from the cut stock freight costs. Cash and carry customers from five local communities, purchasing one bag to several tons at a time, account for more than 75% of pellet fuel sales. The company's yard foreman or the company president loads the bagged fuel for the customer, accepts payment and sees that the sale is recorded at the office by the end of the day. Employees may purchase pellet fuel from the company at a discount. The retail price for bagged fuel sold at-the-plant is $2.35 per 50 lb. bag. The delivered, wholesale pellet cost is $115 per bagged ton. Unbagged, bulk sales are not made.

Markets and Marketing

The most widely used local market distribution channel is at-the-plant to cash and carry customers. The company also sells to pellet stove appliance shops, building suppliers, and feed and seed stores located in the larger towns and cities of Lewiston, Orofino, and Moscow, Idaho, and Pullman, Washington. Although they must keep a supply of pellets on hand to promote pellet stove sales, stove shops often lack storage space for large inventories and are not able to take advantage of quantity discounts. Some building supply companies see pellet fuel as a compliment to their array of building materials and wood products. Feed and seed stores, farm supplys and garden centers all have warehouse space for large inventories, mechanized handling equipment and can usually provide their own transportation. These purchasing advantages lead to a cost savings in freight, labor and the wholesale price of pellet fuel.

Product quality, type of packaging, color of the fuel, size of the bag, logo, and listing of contents have all been used as a marketing strategy. Browning Cut Stock Co. emphasises fuel color and low fines content by using clear packaging to allow the contents of the bag to be examined and to take advantage of the clean, light colored appearance of ponderosa pine. Other manufacturers see advantages in fuel advertised on the bag as "100% wood", "all natural" or "clean burning" (to separate their product from manufacturers that use additives or bark). The weight of the bag is an important consideration with consumer marketing. The Occupational Safety and Health Administration (OSHA) has set the safe lifting limit in the workplace at 50 pounds. This limit will be too heavy for many people including: the elderly, some women, the handicapped and consumers that carry their purchases any distance or on stairs. Condition of the bag, such as tears and punctures, are widely recognized by wholesale customers and retail consumers as poor quality merchandise.

CASE STUDY METHODS

Case Study Plan

The purpose of this study was to observe and document the operation of a small-scale, densified biomass fuel facility located at the Browning Cut Stock Company, Juliaetta, Idaho. The company produces pine cut stock where residue generated from the cut stock side is used to manufacture biomass fuel pellets in small-scale equipment for local markets.

The principal residue types selected to use in a production run analysis included waste wood from ponderosa pine (Pinus ponderosa) edgings, sawdust, shavings and trim ends, whole-tree-chips, stalks from the winter rapeseed plant (Brassica napus L.) and newspaper. Combinations of wood and whole-tree-chips, and wood and rapeseed stalks were also examined. The assessment included documenting residue preparation, examining materials flow through the system, identifying any special processing or handling problems, (particularly those associated with small volumes, contamination, shipping and product identification), identifying any "bottlenecks" in the system and recording production levels. While operating the facility, a sensitivity analysis was performed to identify production variables that effect cost, output and pellet fuel quality, and market and marketing variables that effect sales.

Case Study Methods

100% wood feedstock

Fine and coarse wood residues generated at the case study facility were selected as a principal production run material. Five hundred pounds of freshly hogged sawdust, planer shavings and trim from ponderosa pine were collected, weighed to the nearest tenth of a pound and bagged. After the inside of the pellet mill was cleaned and the system purged from the pellet mill to the bagger, a portion of the pellet surge bin exposing the auger was partitioned off and a length of blower pipe installed to link the hammermill directly with the pellet machine auger. The blower pipe from the pellet fines fan (receives fines from the trundel screen) was disconnected and a cloth bag was attached to collect the fines. With the equipment operating, approximately 100 pounds of 100% wood residue was added to the system at the hammermill and was pelleted in order to heat the die and allow the mill operator to make adjustments to the steam and hot water supply, furnish supply rate and roller clearance. After warm-up, the system was again purged (except for the pellet machine die) and the production run was started by adding pre-weighed bags of wood residue into the hammermill.

One observation made during warm-up was that residue reduction at the hammermill was not sufficient to keep up with the pellet machine by a factor of two. The blending hopper auger also supplied residue to the hammermill in quantities that could cause it to plug. This required the mill operator to regularly attend the blending hopper and hammermill. In order to properly test the remainder of the system, the pre-weighed residue sample used in the production run was first put through the hammermill and into the furnish surge bin before pelleting.

The starting and ending times for pelleting were recorded. Production run fuel pellets collected in the pellet surge bin were cooled, bagged and weighed to the nearest tenth of a pound using a digital balance. Pellet fines were removed from the cloth bag and weighed. The production rate was determined by the weight of the fuel produced within the time required to pelletize all the feedstock in the pellet machine surge bin. Pellet recovery or the percentage of the feedstock actually pelleted was calculated from the difference between the pellet weight and residue weight. The pellet fuel was later laboratory and appliance tested at the University of Idaho, Department of Forest Products.

WTC and Wood/WTC feedstocks

Whole-tree-chips (WTC) representing waste wood from logging slash and unmerchantable trees were selected as a principal production run material. A partial pickup load of whole-tree-chips (35 cubic feet and weighing approximately 875 lbs.) composed of stem, limb and branchwood from a mixture of conifer species and some hardwoods, was processed at the University of Idaho using a 12-inch capacity Morbark Eeger Beever chipper. Production time was calculated to be 1.3 tons per hour for a 3/4-inch chip size. The 3/4-inch chips were too large to be processed in the hammermill and were pre-prepared at the case study facility with a 1 1/2-hp, Sears Chipper-Shredder. The cut stock hog located at Browning's facility was adequate to prepare the whole-tree-chips for the hammermill, however, it was not possible to shut it down or divert hogged WTC directly to the pelleting operation at the time of the study. This was due to equipment line-up and other physical constraints.

The production rate for the shredder-chipper was 122 pounds per hour. After a five hundred pound supply had been processed, a 100-pound sample was again run through the hammermill and into the pellet machine surge bin for pelleting. Moisture content of 100% whole-tree-chips, measured later to be 41% (oven-dry basis), was found to completely inhibit the pelleting process, terminating the production run.

A substitute residue type made from mixing 50% ponderosa pine and 50% whole-tree-chips was then processed in the hammermill. After roller clearance in the pellet mill had been set and a sub-sample again pelleted, the production run was completed in the same manner as for 100% wood.

Rape and Wood/Rape feedstocks

Rape stalk was selected as a principal production run material. As a coarse, fibrous, agricultural crop residue, it returns little nutrient value to the soil and has a high cost of tillage. Approximately 1 1/2 tons of rape stalk were collected from University of Idaho Experimental Farm using conventional hay/straw baling equipment. The rape stalk was pre-processed using a 1 1/2 hp-Sears Chipper-Shredder. As with whole-tree-chips, the cut stock hog at Browning's facility was adequate but could not be modified for the study. A pre-processing rate through the shredder for rape stalk was 160 pounds per hour but a noticeable amount of fines and irritating dust was produced. After 500 pounds have been bagged and weighed, approximately 100 pounds were run through the hammermill for pellet mill adjustment.

An observation made during the adjustment period was a requirement for greater amounts of steam and hot water in pelleting, and the visible amount of fines and irritating dust in the air.

With the system purged, pre-weighed bags of 100% rape stalk residue were processed at the hammermill and transfered to the pellet machine surge bin. Hammermill output was noticeably increased over wood or whole-tree-chips. The production run was conducted in the same manner as with previous furnish types. A residue type composed of 50% wood and 50% rape stalk was also processed and following pellet machine adjustment, a production run with a pre-weighed sample was completed.

100% newspaper (NP) feedstock

Newspaper was selected as a principal production run material, representing a municipal solid waste with a biomass origin. Newspaper pre-preparation was completed by feeding rolled, newspaper "logs" into a 25-hp Black-Clawson Rechipper located at Washington State University and reprocessing the shredded paper through the 3/8-inch screen of a 40-hp, silage hammermill. Newspaper logs were also fed directly into the hammermill but with only marginal success.

The action of the hammermill significantly increased the volume of residue by a factor of about 10 to 1 and the carbon black on the paper particles were given a static charge. Fine particles of carbon and paper were visible in the air and attached themselves to every nearby surface. The rotary hog at the case study facility again was acceptable for shredding newspaper, however, the hammermill was found to be underpowered during the pre-production run adjustment period.

The large volume-to-weight ratio of the feedstock produced by the hammermill created several problems with pelleting that are a reflection of the feedstock supply rate, auger operation and furnish conditioning in the mixing chamber. The newspaper's fine particle size and large surface area required additional moisture for proper heat transfer and binding, but the auger and mixing systems were unable to function when the furnish thickened from the addition of moisture. When conditioned feedstock was introduced directly into the pelleting chamber, successful extrusion and densification resulted. Adjustments to make the feedstock flow independently through the pellet machine were totally unsuccessful. The production run was terminated due to equipment breakdown that resulted when wet newspaper jammed the auger.

Case Study Results

100% Wood

1. The production rate for the pellet machine was 527 pounds of fuel pellets per hour (based on a 1/2 hour production run). The recovery of pellets from the residue was 88%.
2. Based on the wood residue supply generated annually by the case study facility ard operating the pellet machine 7.2 hours per 8 hour shift, a minimum of 250 operating days per calendar year will be

needed to utilize all cut stock residues. This number of annual operating days is typical for small, wood products processors.

3. The inability of this 30-hp hammermill to keep up with the pellet mill was a "bottleneck".
4. A 10 to 20 minute warm-up period was needed to heat the die and adjust the pellet machine for the furnish being pelleted.
5. Applying steam to the mixing chamber of the pellet mill to condition the wood feedstock before it enters the pellet chamber improved pellet recovery (reduced fines removed by the trundle screen).
6. Extractives driven off during pelleting were significant eye irritants.

100% WTC

1. Green whole-tree-chips with a moisture content of 41% or greater could not be pelleted in the ring-die extrusion equipment at the case study facility.
2. The 30-hp hammermill was unacceptable for processing 3/4-inch chips produced by a whole-tree-chipper.
3. A portable chipper was adequate to preprocess in-the-woods waste wood from stems, limbs and branches from harvested and unmerchantable trees for pellet fuel manufacturing.

50% Wood and 50% WTC

1. The production rate for the pellet machine was 247 pounds of fuel pellets per hour with a recovery of 58%.
2. No steam or hot water was needed to condition the furnish.
3. The production rate for the hammermill was inadequate.
4. Fuel pellets exhibited signs of significant swelling after leaving the pellet mill.

100% Rape Stalk

1. The production rate for the pellet machine was 493 pounds of fuel pellets per hour with a recovery of 78.5%
2. Fines and dust generated during residue processing were significant eye and respitory system irritants and should be avoided.
3. Particle size of the feedstock produced by the hammermill varied, with noticeable amounts smaller than 3/16-inch.
4. A large amount of steam and hot water was needed to successsfully pellet the residue type, compared to wood-based feedstocks.

50% Wood and 50% Rape Stalk

1. The production rate of the pellet machine was 582 pounds of fuel pellets per hour with a recovery of 87%.
2. Fines generated during residue processing was a significant eye and respitory system irritant and should be avoided.

100% Newspaper

1. Hammermilled newspaper (3/8-inch particle size) could not be pelleted in the ring-die extrusion equipment at the case study facility. The furnish would not flow through the pellet machine because of the static charge of the particles, the large volume-to-weight ratio and difficulties with moving the furnish by auger when steam and hot water were added. Pelleting was successful when the conditioned feedstock was introduced directly into the pelleting chamber.
2. The size of rotary hog at the case study facility was acceptable for shredding newspaper.
3. The hammermill was underpowered for processing whole newspapers, or converting shredded newspaper with a 3/8-inch particle size to a 3/16-inch particle. A mill larger than 40-hp could perform both tasks.
4. Processing newspaper into a feedstock released paper and carbon particles into the air that were significant respitory system irritants.

Case Study Discussion and Conclusions

The amount of wood residue generated at the case study facility and the pellet mill production for wood fuel indicate that the pellet machine will need to operate at or above the production run output throughout the normal business year if all cut stock residues are utilized. Using a 50/50 wood and rape stalk furnish would not permit full utilization of wood residue within the annual number of operating days with one shift operation. A pellet machine with greater operating capacity (and some excess) is needed to prevent a permanent production loss and from having to continuously operate the pellet mill at peak output.

A major "bottle-neck" at Browning Cut Stock Co. is operating a hammermill with a production rate for wood feedstock that is half the output of the pellet machine. Although the feedstock supply problem may be solved by running the mill during off hours (during the lunch hour, work breaks and after 5:00 pm), the hammermill still has a tendency to plug if not periodically tended by the operator. Plugging results from an over-supply of residue fed to the mill by the blending hopper auger. The drive pulley on the auger motor can be reduced in size and prevent plugging, however, this will not solve the miss-match of the hammermill to the pellet machine. Most hammermills can be modified to increase output by adding additonal hammers, but a corresponding increase in horsepower will be required. A motor rating between 40 and 50-hp (3-phase, 220-volt) would match the hammermill to this pellet machine. The higher end of the range should allow direct processing of other residue types, such as whole-tree-chips and newspaper, and enough capacity to accomodate a larger pellet machine.

Applying steam to condition the furnish increases pellet production by improving heat transfer and bonding between particles, and reduces fines generated during pelleting. Small particles of the feedstock will require more moisture within the feedstock matrix because of greater surface area and bonding sites. Uniform particle size is an advantage to bonding, reduces pellet fines and increases output. Short-fibered biomass such as rape stalk and other agricultural materials present a problem in maintaining uniform particle size where large particles (at least particles greater than 3/16") are desirable in the furnish. Short fibers tend to disintegrate into fine particles on impact with the hammers and pass directly to the furnish bin without being screened.

Vapors and dust particles from residue processing and pelleting may be irritating to the eyes, skin and respiratory system of pellet plant employees. Acceptable levels in the workplace have been set by OSHA for wood dust resulting from machining. Residue processing in a hammermill may be interpreted as machining. Wood residue (except cedar) should be less of a concern with dust particles, but volatiles from feedstocks released during pelleting are eye and respitory irritants. Ventilation above the pellet machine would relieve most vapor problems. Although not wood dust, particles from rape stalk and newspaper processing are very likely to effect the health of plant employees. Consequently, even where dust collection or air circulation is provided, a dust mask should be worn when working in conditions of this type.

Pelleting a furnish composed, in part, from whole-tree-chips shows promise for pellet manufacturers using a dry residue process (without a rotary drum dryer). When mixed with a residue that is approximately 40% moisture content (dry basis), processed through a hammermill, and pelleted (without steam or hot water), there is enough "buffering effect" by the dry residue to produce an acceptable biomass fuel pellet. Excessive fines are also produced by the pellet machine, probably due to a lack of uniform moisture within the feedstock matrix and poor heat transfer. Pellets that swell and burst after leaving the machine indicate excessive moisture in the fuel and identify what may be the moisture limit of this machine for pelleting feedstock mixtures of green and dry residues. It should be noted that whole-tree-chip moisture content is certain to exceed 41% (dry basis), require more dry material in the mixture and probably reduce pellet recovery.

Pre-preparation of newspaper with a knife chipper or rotary hog is an acceptable method for reducing this bulky material. Newspapers that are rolled into logs form to fit the chipper infeed chute opening, result in the continuous pre-processing of shredded paper. Processing newspaper with a hammermill provides a uniform particle size but creates the problem of a large volume-to-weight ratio. Not only is there difficulty in augering newspaper furnish in dry form, it is difficult for the pellet machine to auger it rapidly into the die and roller area. When steam or water is added to the feedstock in sufficient quantity to obtain binding and extrusion in the die, it thickens in the auger or mixer and plugs the machine. Another approach to pelleting newspaper may be to pre-process the residue with a hog and to use a shear to slice the shredded material into particles. This would reduce static charge and air-borne carbon particles and improve the volume-to-weight ratio. It may be possible to auger the larger, uniform paper particles through the machine and apply steam just before the furnish enters the pelleting chamber. Still another consideration is to redesign the auger and mixer to move paper in a pulp form. In either case, a large amount of steam or hot water will be needed in the extrusion process because of the increased surface area and low moisture content of paper.

Case Study Marketing Concerns

The residential pellet fuel consumer is restricted by the current design and operation of pellet burning appliances from using biomass pellets with high moisture content (solids) or a high percentage of non-combustibles (ash and slag). Pellet fuel made from wood and whole-tree-chips could almost certainly be directed into the residential market at a price lower than 100% wood pellets since bark pellets have been sold in the residential market. If ash content was acceptable (1-2%), residential customers might accept the product, especially if other fuel performance characteristics favorably compare with all-wood fuel (e.g. heat value) and were listed somewhere on the bag for the consumer to examine. An appeal to the consumer for utilizing waste from harvested trees, as from Wood/WTC pellets, might be exploited in a logo or phrase on the bag (e.g. WHOLE-FUEL, NO WASTE, WHOLE-TREE). Since a light colored fuel is more appealing to most consumers, Wood/WTC pellets should be sold in opaque packaging. Package size is constrained by a safe lifting weight of 50 pounds and should not exceed this weight.

Fuel performance, color, odor, and other consumer preferences and expectations are likely to direct production of non-wood pellet fuels from a cut stock facility into industrial or municipal/institutional market segments that are more competitive, distant and not yet expanding in the local market of this case study facility. Creating a market for biomass fuel pellets means replacing a fuel that may be non-renewable, degrades air quality, is destined for regulatory control or is increasing in cost. It might also mean providing a fuel that can be used in inexpensive retrofits (e.g. stoker-spreader systems) and boiler replacements (e.g. firewood) where natural gas and coal are not available. Entering the market with pellet fuel means producing an inexpensive fuel in quantity and guaranteeing uninterrupted delivery perhaps in unbagged bulk. Browning Cut Stock may not be able to supply a large school or hospital while maintaining current pellet fuel sales to residential fuel consumers and residue sales to other customers. If surplus residues were available, pellet machine capacity would not be sufficient. Unbagged, bulk delivery would mean an additonal equipment purchase (truck with a dump body) and the ability to load directly from the pellet surge bin (re-design and relocation of the bin). Although more of a concern with residential grade fuel, pellet quality for industrial and municipal/institutional users would still be specified in a sales contract with provisions and penalties from testing. The manufacturer would be required to perform his own testing or have it done under contract to prevent a penalty.

LABORATORY TESTING METHODS AND RESULTS

Laboratory Testing Methods

Biomass pellet fuel characteristics listed below are currently recognized by pellet fuel manufacturers, pellet stove manufacturers, the forest products industry, and by university and government energy researchers as important measures of fuel quality. They are not, however, a complete listing of every recognized characteristic. It is only an overall assessment of quality and a means of comparing pellet fuels manufactured at the case study facility with other producers. The characteristics are:

- moisture content (dry basis)
- percent ash (wet and dry basis)
- bulk density (wet and dry basis)
- specific gravity/density (dry basis)
- percent fines (wet basis)
- heat value or BTU content (wet and dry basis)

Properties and characteristics of wood and wood-based materials may be expressed as a function of the moisture conditions in the material as it is used (known as wet basis), conditions at a specified moisture content, or when all moisture has been removed (dry basis). Pellet fuel properties specified on wet basis are important in assessing the fuel's expected performance, as received, in a pellet burning appliance. Characteristics expressed on dry basis provide a means of comparing one fuel with another and represent, in many instances, theoretical ceilings. Dry basis is often used in the forest products research because the dry condition in wood can be achieved with inexpensive laboratory equipment and is repeatable.

Testing methods for most pellet fuel characteristics have been established by the American Society For Testing and Materials (ASTM). ASTM methods provide a description of the testing equipment, as well as a step-by-step outline of the testing procedure. Additional methods have been developed by individual pellet fuel and pellet stove manufacturers, pellet fuel manufacturing associations, private testing laboratories and independent researchers. Biomass pellet fuel properties and characteristics in this category include pellet diameter and length, fines content, durability, ash analysis, ash fusion temperature (slagging temperature), analysis of volatile matter and, proximate and ultimate analysis.

The pellet fuel characteristics listed in the beginning paragraph have the following testing method identification:

- moisture content (ASTM E 871-82)
- percent ash (ASTM D 1102-84)
- bulk density (ASTM E 873-82)
- specific gravity (ASTM D 2395-69, Method D, reapproved 1977)
- percent fines <1/4-inch (University of Idaho)
- percent fines <1/8-inch (Association of Pellet Fuel Industries and the Fiber Fuels Institute)
- calorific value (ASTM D 2015-77, reapproved 1978)

Laboratory Testing Results

100% Wood

moisture content (dry basis)	8.0 %
ash content (wet basis)	0.21 %
ash content (dry basis)	0.23 %
bulk density (wet basis)	37.0 lbs./cu. ft.
bulk density (dry basis)	34.3 lbs./cu.ft.
sp. gr./density (dry basis)	1.12/69.9 lbs./cu. ft.
percent fines < 1/4"	3.3 %
percent fines < 1/8"	0.8 %
heat value (wet basis)	8,363 BTU/lb.
heat value (dry basis)	9,091 BTU/lb.

50% Wood/50% WTC

moisture content (dry basis)	8.7 %
ash content (wet basis)	1.95 %
ash content (dry basis)	2.12 %
bulk density (wet basis)	39.2 lbs./cu. ft.
bulk density (dry basis)	36.1 lbs./cu. ft.
sp. gr./density (OD basis)	1.05/65.7 lbs./cu. ft.
percent fines < 1/4"	4.9 %
percent fines < 1/8"	1.8 %
heat value (wet basis)	7,991 BTU/lb.
heat value (dry basis)	8,752 BTU/lb.

50% Wood/50% Rape Stalk

moisture content (dry basis)	9.4 %
ash content (wet basis)	2.88 %
ash content (dry basis)	3.15 %
bulk density (wet basis)	38.2 lbs./cu. ft.
bulk density (dry basis)	34.9 lbs./cu. ft.
sp. gr./density (dry basis)	1.17/73.3 lbs./cu. ft.
percent fines < 1/4"	3.3 %
percent fines < 1/8"	0.8 %
heat value (wet basis)	7,536 BTU/lb.
heat value (dry basis)	8,318 BTU/lb.

100% Rape Stalk

moisture content (dry basis)	9.9 %
ash content (wet basis)	5.80 %
ash content (dry basis)	6.38 %
bulk density (wet basis)	40.7 lbs./cu. ft.
bulk density (dry basis)	37.0 lbs./cu. ft.
sp. gr./density (dry basis)	1.19/74.4 lbs./cu. ft.
percent fines < 1/4"	1.4 %
percent fines < 1/8"	0.7 %
heat value (wet basis)	6,769 BTU/lb.

heat value (dry basis)	7,512 BTU/lb.

100% NP

moisture content (dry basis)	14.8 %
ash content (wet basis)	1.34 %
ash content (dry basis)	1.54 %
sp. gr./density (dry basis)	1.23/76.8 lbs./cu. ft.
heat value (wet basis)	7,192 BTU/lb.
heat value (dry basis)	8,427 BTU/lb.

100% whole-tree-chip (WTC) pellets could not be successfully produced without a biomass dryer and 100% newspaper (NP) fuel pellets could not be manufactured in sufficient quantity during production runs at the case study facility to even perform all laboratory tests.

Lab Testing Conclusions

1. Moisture content of biomass fuel pellets produced ranged from 8% with wood-based residues (100% Wood and 50% Wood/50% WTC), to 10% with wood/crop residues (50% Wood/50% Rape Stalk and 100% Rape Stalk) and 15% with municipal solid waste (100% NP).
2. Bulk density (green basis) of all pellet products covered a narrow range within 40 pounds per cubic foot.
3. Specific gravity/density was higher for pellets containing crop residue or newspaper compared to wood based residue.
4. Percent fines <1/4-inch and <1/8-inch was greater for pellets containing wood-based residue compared to crop residue.
5. Calorific value of fuel pellets made from wood-based residue was higher than pellets containing crop residue or newspaper.

Lab Testing Discussion

The densification process that takes place in ring-die extrusion equipment is a function of feedstock characteristics and machine operation. Feedstock particle size is important in that surface area of the particle effects heat transfer that causes lignin to flow and become a binder. Small particles provide more contact sites, however, additional moisture is needed to provide a sufficient medium for heat transfer. Air spaces act as insulation. Particle size of pellets manufactured at Browning Cut Stock from wood-based residues are coarser than those containing crop residue or newspaper, requiring less moisture to transfer enough heat to aid in binding these larger particles. This suggests that small particle size, inherent with the pre-preparation of agricultural residues such as rape stalk and other short fiber biomass, will require a higher feedstock moisture content for pelleting. Consequently, the pellet product will provide less usable heat unless the chemical and mechanical makeup of the residue has combustion advantages over wood or, additives with a high calorific value are used in pelleting.

Bulk density (wet basis), a measure of the weight of moisture, solid wood and air space of a specified volume (usually 1 cubic foot) of loose product, varies within a narrow range for pellets of similar length and diameter. Residue type and pellet machine set-up have less effect on bulk density than pellet size. Differences in total amount of air space or solid wood due to pellet sizes (e.g., 1/4-inch, 5/16-inch 3/8-inch, 7MM, 8MM) contribute more to the variation in weight per cubic foot than physical properties of the feedstock or reasonable adjustments to the pellet machine to increase extrusion pressure. With respect to the case study pellet fuels, comparing bulk densities of similar size products indicates that wood and wood-based pellet fuels are lighter than fuels manufactured all or in part from crop residues. The commonly accepted standard in the industry for pellet fuels of similar size, 40 lbs./cu. ft., will therefore require close control of moisture content and particle size to achieve and maintain this level. Without this control, increased power consumption and higher maintenance costs on the pellet machine will result.

An insufficient volume of 100% newspaper pellets was produced for measuring bulk density, however, specific gravity/density data can be obtained from small amounts of a sample. In addition, specific gravity/density is positively correlated with strength, providing a broad assessment of durability. From specific gravity/density tests, a comparison of the products showed higher specific gravity/density and, therefore, greater durability, for fuel pellets containing crop residue and newspaper. This result was is further substantiated by a higher percentage of fines generated in manufacturing pellets from wood-based feedstocks compared to crop-based feedstocks. Newspaper pellets are therefore likely to produce less fines than wood or crop residue pellets, a conclusion reached from other pellet product testing of specific gravity/density relationships with durability (Folk, 1989).

Since the usable heat in a biomass fuel pellet is largely influenced by moisture content, a comparison of heat values (wet basis) is indicative of how the case study fuels are likely to perform in a pellet burning appliance. Lower moisture content coupled with less noncombustibles (ash) show wood-based pellets (100% Wood and 50% Wood/50% WTC) as the fuels with higher calorific value. If the effects of moisture are removed and only the physical and chemical properties of the fuels are considered by using heat value (dry basis), wood-based pellets again contain a higher heat value. Newspaper, still being manufactured using a mechanical process, now contains more colored ink (mineral pigments), binders (oils and resins) to improve legibility, and additives (waxes and polyethylene). These compounds will increase the noncombustible component.

In conclusion, physical and chemical properties of wood-based biomass fuel pellets are higher in heat value than pellets made at the case study facility from 50% Wood/50% Rape Stalk, 100% Rape Stalk, or 100% Newspaper. Unless crop residues provide superior calorific value due to physical and chemical properties or unless these residues or newspaper can be pelleted at a low moisture content, they show no advantage as a feedstock in small-scale biomass pellet fuel manufacture for the residential market.

STOVE TESTING BIOMASS PELLET FUELS

Stove Testing Methods

A representative sample weighing 3303 grams (approximately 7.3 pounds) was drawn from a supply of four pellet fuels manufactured at the case study facility. Each fuel type was placed into the hopper of the pellet-testing appliance; a Welenco Model P-1000W. The appliance has 14 different combinations of fuel feed rate, as well as variable control of combustion air.

The test stove was located in a 15 feet x 23 feet unheated room where the temperature was brought to 55 degrees F. before each test burn. The room, built on a 4-foot thick concrete slab was well insulated and contained no windows. An exterior and an interior door were weather stripped and contained no windows.

After igniting the fuel with a propane torch, the stove was gradually staged through the fuel feed rate and combustion air settings until optimum combustion was observed. Optimum conditions were recorded when room temperature, monitored near the appliance with laboratory thermometers, had maximized and other favorable combustion characteristics were visible in the appliance's combustion chamber (flame color and intensity, ash deposit on the glass, size of ash particles ejected by new fuel being augered into the burn pot) and stack emissions (smoke color and density). Once optimum stove settings were reached (within one hour), they were maintained throughout the remainder of the burn (usually a three to five hour period) until the stove was out of fuel. After a "cool down" period of two hours, the burn chamber was brushed clean, the ash pan removed, and the contents weighed and recorded. The burn pot was then scraped to remove slag deposits and finally vacuumed to remove slag and any unburned pellets from the burn pot and the auger housing. The vacuumed contents were screened to separate unburned fuel from slag, ash and unburned fines. Unburned fuel was identified as pellets and pellet fragments unable to pass through 1/8-inch square mesh. The unburned fuel was weighed separately from the slag and unburned fines.

Ash content (wet basis) of pellet fuel was determined by adding the ash, slag and unburned fines weight, and dividing the sum by the original sample weight less the unburned pellet weight,

$$\% \text{ ash} = \frac{\text{ash + slag + unburned fines weight}}{\text{3303 - weight of unburned pellets}} \times 100$$

Results reported below and conclusions reached regarding fuel quality were a combination of measured and observed data.

Stove Testing Results

100% Wood

ash	6.8 grams
slag & unburned fines	18.0 grams
unburned pellets	76.6 grams
% ash (wet basis)	0.8 %

50% Wood - 50% WTC

ash	27.6 grams
slag & unburned fines	26.3 grams
unburned pellets	73.4 grams
% ash (wet basis)	1.7 %

50% Wood - 50% Rape Stalk

ash	28.2 grams
slag & unburned fines	45.9 grams
unburned pellets	169.1 grams
% ash (wet basis)	2.4 %

100% Rape Stalk

ash	99.2 grams
slag & unburned fines	39.0 grams
unburned pellets	416.8 grams
% ash (wet basis)	4.8 %

WTC and NP pellets were not successfully produced in sufficient quantity during the case study to perform stove testing.

Stove Testing Conclusions

1. Fuel rate and combustion air settings on the test stove ranged from a high fuel rate with Wood, to a medium rate with Wood/WTC, and to a very low rate with Wood/Rape and Rape pellets.
2. Room temperature at optimum operating conditions was 72, 68, 68 and 64 degrees F., respectively, for Wood, Wood/WTC, Wood/Rape and Rape pellets.
3. Visible smoke and particulates from the stack after start-up were negligible from Wood, slightly visible from Wood/WTC, and highly visible from Wood/Rape and Rape pellets.
4. Solids (creosote and other volatiles in the fuel) buildup in the stove's burning chamber and on the glass was negligible with Wood, slightly noticeable with Wood/WTC, and very noticeable with Wood/Rape and Rape pellets.
5. Percent ash (wet basis) was 0.8, 1.7, 2.4 and 4.8 percent respectively, for Wood, Wood/WTC, Wood/Rape and Rape pellets.
6. The amount of unburned fuel remaining in the stove after cooling using Wood/Rape and Rape pellets was more than double and nearly six times, respectively, than the unburned amounts from Wood and Wood/WTC pellets.
7. The amount of ash, slag and unburned fines remaining in the burn pot after cooling from Wood/Rape and Rape pellets was more than double the unburned amounts from either Wood or Wood/WTC pellets.
8. With the exception of biomass fuel pellets made from Wood, stove testing results for percent ash (wet basis) were consistently lower than laboratory testing results for Wood/WTC, Wood/Rape and Rape pellets.

Stove Testing Discussion

Densified biomass fuel manufactured from all wood at Browning Cut Stock Co. performs better with respect to usable heat, stove maintenance and visible smoke, compared to all other case study pellet fuels that were stove tested. Biomass pellets made from 50% wood and 50% whole-tree chips show potential as a lower grade fuel that could be used in current residential pellet appliances but with some disadvantages. From a manufacturing point-of-view, Wood/WTC pellets make it possible to use a wet residue that can be "buffered" by adding dry material. Biomass fuel pellets made from rapeseed stalks, alone or in combination with wood, exhibit poor combustion characteristics and will result in excessive maintenance, solids build-up in the stove and stack, and increased particulates in stack emissions. Although the percent ash from stove testing is lower than that from laboratory testing (except 100% Wood), this likely resulted from releasing significant amounts of ash out the stack as particulates. Burning all wood pellet fuel produced noticeable smoke only during start-up. Ash loss from the stack as particulates was probably insignificant during peak operation since smoke was barely visible. Unless stack particulates are accounted for, percent ash determined by stove testing will be artificially low compared to that determined by laboratory testing methods.

COST COMPARISON OF SOLID, LIQUID AND GASEOUS FUELS

Chart Explanation

The residential energy cost comparison chart (Table 1) compares the energy cost for fuels commonly used in the Intermountain West at local prices. Only the cost to produce and deliver the energy is represented by the cost per therm; the capital investment in the heating system is not included. Cost per therm has been calculated using the formula,

$$\text{COST/THERM} = \frac{1}{\text{Higher Heat Value} \times \text{Combustion Efficiency}} \times 100{,}000 \times \text{Cost/Unit}$$

Energy costs for biomass fuel pellets produced during the case study are included.

The higher heat value shown in the formula is defined as the amount of energy available when the fuel is burned. A combustion efficiency adjustment is then applied to arrive at the recoverable or usable BTU; a result of heat loss from water evaporation, fuel vaporization and flue gas. A 5% boiler inefficiency is also included in the adjustment for all fuel types. Clearly, firepalce and stove inefficiency from using some of the solid fuels listed may increase to more than fifty percent and result in a significant increase in the cost per therm for these fuels.

The cost per unit for wood pellets is the current cash and carry sales price from Browning Cut Stock, including profit, while other pellet fuels, not currently manufactured, reflect the expected sales price and profit. Newspaper pellets reflect purchasing the raw material at $.02 per pound.

From the chart, cost per therm for wood pellets ($.654) compares favorably with #2 furnace oil ($.648) and represents a substantial savings when compared to electricity ($1.327 and $1.475). Firewood ($.455 and $.492), coal ($.479) and natural gas ($.523) are lower cost alternatives, however, supply, environmental concerns and regulatory action are likely to impact the future availability, development and use. Compared to wood pellets, however, small diameter firewood from species of low specific gravity and high moisture content dramatically increases cost per therm, even when the price per cord is reduced.

Energy costs for combinations of wood and rapeseed stalk feedstocks ($.693 and $.724) also show a savings when compared to electricity, but current residential heating equipment may not perform well using these pellet fuels. Agricultural residue pellets from rapeseed stalk ($.753) may be promising if processing and combustion problems can be overcome.

The high energy cost of newspaper pellets ($1.229) may not accurately represent the actual cost per therm since the case study production run was terminated before enough data was collected. Significant processing problems with newspaper, however, must first be solved before a realistic evaluation of this pellet fuel product can be made.

Table 1. RESIDENTIAL ENERGY COST COMPARISON CHART FOR THE INTERMOUNTAIN WEST

Fuel Type	Delivered Cost/Unit	Higher Heat Value	Combustion Efficiency	Cost/Therm
electricity	$0.0453/kwh	3,413 BTU/kwh	90%	$1.475
electricity	$0.0453/kwh	3,413 BTU/kwh	100%	$1.327
#2 furnace oil	$0.749/gal	140,000 BTU/gal	82.5%	$0.648
kerosene	$1.25/gal	134,000 BTU/gal	82.5%	$1.131
propane	$0.79/gal	89,536 BTU/gal	78.7%	$1.121
natural gas	$0.0042/cuft	1,035 BTU/cuft	77.8%	$0.523
soft coal	$110/ton	27,000,000 BTU/ton	85%	$0.479
charcoal (5% MC)	$250/ton	26,000,000 BTU/ton	94%	$1.023
pres-to-logs (5% MC)	$128/ton	16,500,000 BTU/ton	94%	$0.977
larch firewood (18% MC)	$80/80 cuft	22,644,000 BTU/cord	77.7%	$0.455
larch firewood (35% MC)	$80/80 cuft	21,565,000 BTU/cord	75.4%	$0.492
WOOD PELLETS (8% MC)	$94/ton	18,182,000 BTU/ton	79%	$0.654
WOOD/WTC PELLETS (8.7% MC)	$102/ton	17,864,000 BTU/ton	78.9%	$0.724
RAPE PELLETS (9.9% MC)	$100/ton	15,780,000 BTU/ton	78.8%	$0.753
WOOD/RAPE PELLETS (9.4% MC)	$92/ton	16,848,000 BTU/ton	78.8%	$0.693
NEWSPAPER PELLETS (14.8% MC)	$152/ton	15,836,000 BTU/ton	78.1%	$1.229

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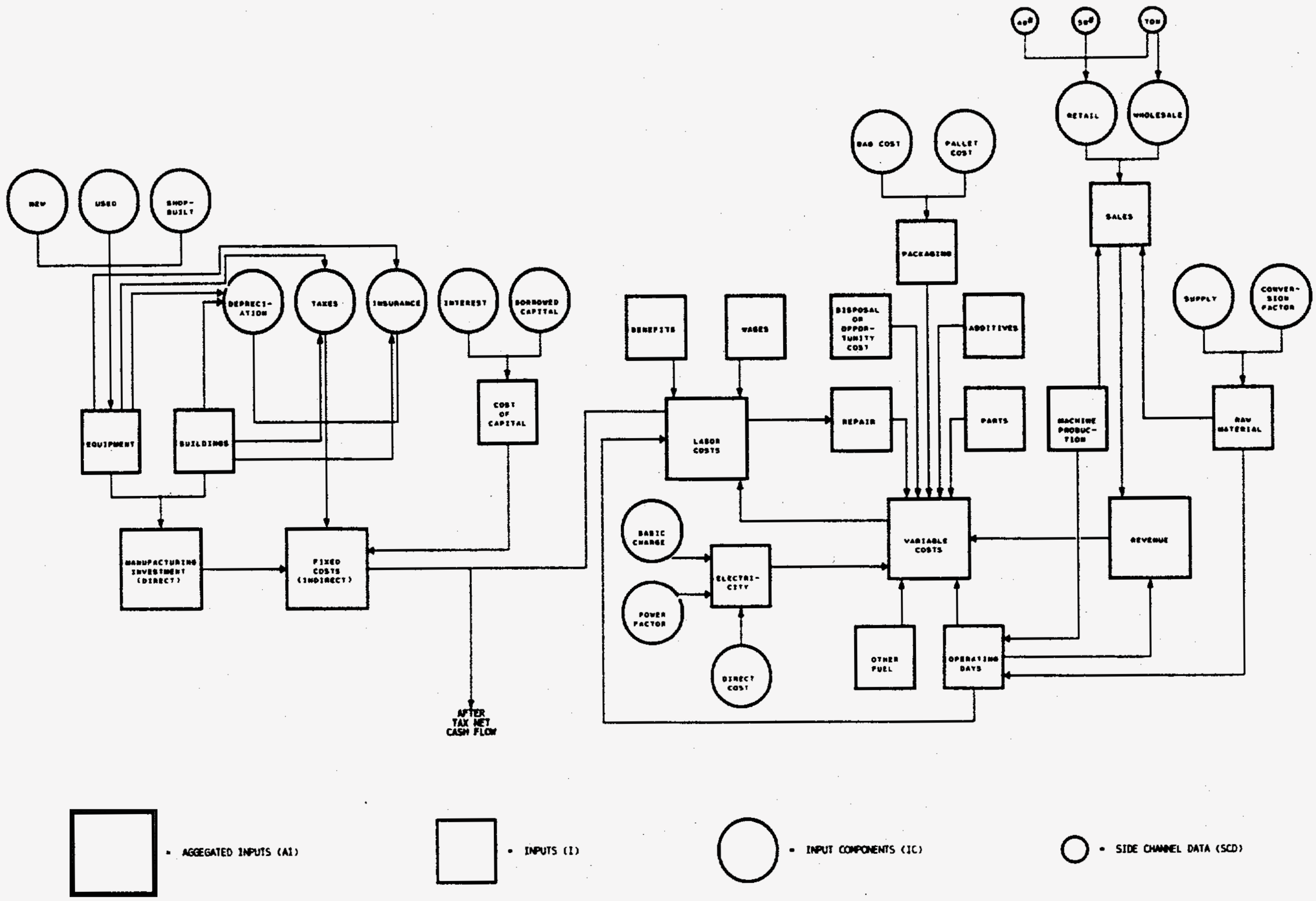
Part III. DENSIFIED BIOMASS FUEL MANUFACTURING PROGRAM (DENSEFUEL): A Preliminary Investment Model for Small-Scale Wood Pellet Manufacture



INTRODUCTION

Wood pellet manufacturing in the Intermountain West is a recently founded and rapidly expanding energy industry for small-scale producers. Within a three-year period, the total number of manufacturers in the region has increased from seven to twelve (Folk et al., 1988). Small-scale industry development is evolving because a supply of raw materials from small and some medium-sized primary and secondary wood processors that has been largely unused. For the residue producer considering pellet fuel manufacturing, the wastewood generated from primary products often carries a cost associated with residue disposal when methods are stockpiling, landfilling or incinerating. Regional processors use these methods for a variety of reasons, including the relatively small amounts of residue produced, residue form, mixed residue types, high transportation costs and lack of a local market, convenience and absence of regulation. Direct costs associated with residue disposal include the expenses required to own and operate residue handling equipment, costs for operating and maintaining a combustor and tipping fees charged to accept wood waste at public landfills. Economic and social costs related to environmental concerns may also be incurred to include local air and water quality degradation from open-air combustion and leachate movement into streams and drinking water.

Small-scale pellet fuel industry establishment and expansion is also occurring due to increasing consumer demand. The demand is a result of consumer preference for alternative energy that is less expensive than electricity, less energy dependent than fossil fuels, and more efficient and convenient than firewood. Increasing use of wood pellet fuel also simultaneously addresses important environmental issues by being derived from a renewable natural resource, less polluting that many energy alternatives, and a recyclable waste.

There are more than 185 small primary and over 300 secondary wood products processors in the region producing an undetermined quantity of wood waste that could be utilized to potentially enhance profitability of these companies (Klug, 1990; Gorman, 1989; Hill, 1989; Govett and Miller, 1987). Conducting detailed technical and economic feasibility studies to aid in decision-making is often cost prohibitive for these manufacturers. As an added disincentive, each small-scale pellet fuel manufacturing facility is, in many cases, a one-of-a-kind system containing modified and shop-built processing equipment with a process control by trial and error. There is considerable critical but privileged processing information held by pellet fuel and commercial pelleting equipment manufacturers, such as: pellet mill modifications, pellet mill adjustment, die design, raw material mixture and additives used. Access to this information effects the time period and investment costs for putting a pellet fuel manufacturing facility on stream.

The objective of this investment model is to provide a simplified, interactive, step-by-step investment method analysis that a small to medium-sized wood products processor with a residue surplus can use as an aid in designing a pellet fuel manufacturing addition. Estimated after tax net cash flow for directing wood waste into densified wood fuel is calculated by the model. The model has been validated using a side-by-side comparison of the same numbers entered into the model with those from hand calculations.

PROGRAM EXPLANATION

The densified biomass fuel manufacturing program DENSEFUEL is a preliminary investment model that provides the user with a decision-making tool to examine small-scale manufacturing and local marketing opportunities for fuel pellets. The program requires use of personal computer spreadsheets, however, the interactive logic allows its use by persons who have only minimal computer background.

The model is based on several assumptions generally considered to be valid with small-scale wood products manufacturing in the Intermountain West region. Pellet fuel manufacturing in this analysis is assumed to be an "add-on" facility to an existing forest products business (primary or secondary processing). Consequently, the model assumes land purchase is not necessary, and office space, labor and equipment that conduct the primary business of the company are already in place. Other assumptions of the model are as follows: One employee operates the pellet manufacturing side of the company with responsibility for production (residue handling, preprocessing and processing, pelleting, packaging and maintenance). Product storage and loading, and customer service activities are performed by other yard and office employees during "slack time" or as a minimal part of the business day of the primary company. An 8-hour shift with two, 15 minute breaks is the basis for a work day. Waste wood generated by primary operations should be treated as a negative cost if a disposal method has been the alternative to utilization. If residue has been sold, the selling price should be treated as an opportuniuty cost.

DENSEFUEL is a spreadsheet designed to run on Lotus 123 (Version 2.0), a registered trademark, and other spreadsheet software that are fully compatible in importing and running Lotus 123 (Version 2.0) files. This model provides a generalized approach that, by its nature, cannot accurately reflect the unique business operations of all small forest products companies. Consequently, the daily CASH FLOW statement or "income statement" serves only as a preliminary investigative tool and does not necessarily reflect use of generally accepted accounting principles by the company. An example would be the simplified treatment of depreciation expense which may not necessarily reflect how the company may depreciate the equipment for tax purposes. The program is designed to give the decision maker a "first look" at small-scale manufacturing possibilities for densified wood fuel. As such, detail in the model is focused on identifying and considering the relavent fixed and variable costs related to raw materials, equipment purchase, equipment operation, product sales etc., rather than detailed pro-forma financial information that may be be confusing to potential program users. Use of the model is not a substitute for appropriate business planning normally required by a company for an investment of this size and nature, which may include analyses such as cash flow projections and marketing studies.

PROGRAM LOGIC

Model Diagram

Figure 1 is a branched diagram outlining the logic, the decision-making considerations and alternatives for the model. Principal considerations known as aggregated inputs (AI) include manufacturing investment (direct), fixed costs (indirect), labor costs, variable costs and revenue and are shown by the large squares. Small squares represent secondary considerations or inputs (I). Large circles are input components (IC) and small circles are component side channel data (SCD).

Manufacturing Investment (Direct)

There are two inputs, building and equipment, represented by this aggregated input. Under equipment, input categories include residue handling and processing, feedstock handling and pelleting, pellet handling and processing and pellet storage. Equipment input components have options of investing in new, used or shop-built equipment. The model provides a list of the necessary equipment for categories of inputs and input component options with a spreadsheet address where costs are entered. Other equipment may be accomodated at the end of each listing, not to exceed three additions. The total manufacturing investment (direct) is calculated after this consideration is satisfied.

Fixed Costs (Indirect)

The aggregated input, fixed costs (indirect), is represented in the model by input categories that include taxes, insurance, cost of capital and depreciation. The taxes input is further separated into property and income taxes. An address identified as PTRATE is for entering the fixed rate per $100 of assessed value at 100% fair market value.

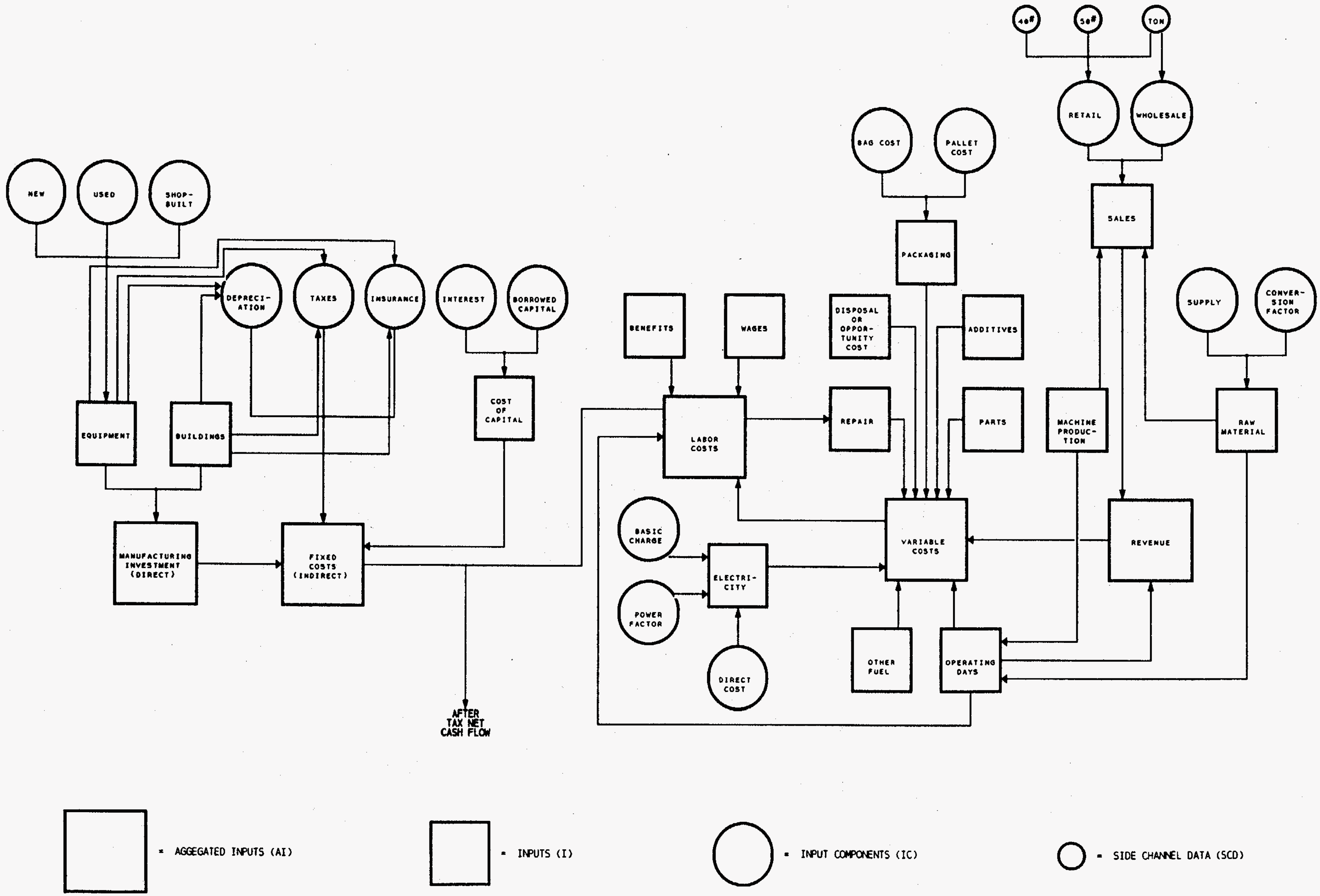
Income tax is determined from annual net income and an appropriate tax bracket but only an estimated bracket can be entered at the beginning. The user is advised to return to the address identified as BRACKET and make revisions if necessary. A default bracket of 50% (0.50) is assessed.

An annual insurance premium is based on a fixed rate per $100 of assessed value using the replacement cost method to arrive at the assessed value. A daily rate is calculated from the fixed rate (INRATE).

The cost of borrowed capital (INTEREST) uses the compounded, effective annual rate. The amount to be borrowed (BORROW) and the rate (RATE) are entered under their respective addresses and the interest is calculated.

Depreciation expense is determined from the Modified Cost Recovery System (MACRS), straight line method, by grouping assets according to useful life categories specified by the Internal Revenue Service. The useful life categories are 5-year property (rolling stock), 10-year property (mill equipment and machines) and 20-year property (buildings). New, used and shop-built options are treated independently. A SUGGESTED TOTAL for the

Figure 1. Branched Diagram of the DENSEFUEL Model



assets in each life category are calculated from the building and equipment lists. The user may elect to use these amounts or enter different values (YOUR TOTAL).

Labor Costs

The labor cost aggregated input is based on an hourly rate (PAYRATE), including all benefits, and hours worked (HOURS). The model provides for more than one employee. An unweighted average payrate (UNWEIGHTED AVERAGE PAYRATE) is determined for 1-3 employees before calculating total labor costs (LABOR).

Variable Costs

The aggregated input, variable costs, is comprised of inputs that include: electricity consumption, other fuel consumption, repair and maintenance, bags and pallets, residue disposal and additives. Since electricity consumption is a major operating cost, the model requires entering the horsepower rating of each electric motor then applying the kilowatt rate for industrial customers available from the public utility. The model provides for listing specifications, horsepower (HP) and operating hours (HOURS) for up to 25 electric motors. The energy cost for each motor is calculated then totaled.

Other electricity costs that include lights, heaters or appliances are determined by entering the watt rating (WATTS) and the operating hours (HOURS). The model provides for listing 10 appliances, calculates each energy cost and gives a total for other electricity use.

A basic charge (BASIC), demand cost (DEMAND) and power factor charge (POWER) are partly a function of power demand. Flat chages and multipliers for factor charges need to be obtained from the public utility company then applied to the total electricity demand from electric motors and other appliances.

Other fuel costs (OTHERFUEL) such as gasoline or propane for rolling stock must be entered directly to the model as an annual expense.

Equipment repair and maintenance consist of labor rates, labor hours and repair parts. Labor (LABOR) is determined from the unweighted average pay rate and the designated number of hours per week (HOURS) to be spent on repair and maintenance. Since designated maintenance periods during the work day are commonly used in wood products processing, the model uses this approach. Parts and supplies (PARTS) are estimated at a value of one-half the labor. A total repair and maintenance cost (REPAIR) is calculated from the labor value, length of the designated maintenance period and parts and supplies.

Packaging and handling require an expenditure for bags and possibly pallets. Since total cost will be determined by pellet production, the cost for each bag (BAGS) and pallet (PALLETS) is entered for use in later calculations.

If wood waste produced from primary product manufacturing represents a disposal cost, the model treats it as a negative cost with a positive influence on pellet manufacturing profitability. If residue is being sold, the residue represents an opportunity cost with a negative influence on profitability. As further explanation, if residue is sold resulting in a positive net cash flow to the company, diverting the residue to pellet manufacturing will require that we forego the opportunity to sell it. The residue thus diverted is valued as if it were purchased at a cost equal to the price at which it could have been sold. On the other hand, there may be costs associated with disposal (e.g. stockpile, landfill, combustion). In this situation, residue is treated as having a negative cost that would be equal to the cost of disposal. The price per ton is used as the basis for the disposal cost calculation (DISPOSE).

Extra ingredients such as polystyrene, lubricants and other additives may be purchased to improve processing or product performance. Additive costs are also a function of pellet production but are introduced to the model by entering the cost per pound (ADDCOST) and the percent by weight (PERCENT) to be used in pellet feedstock.

Revenue

Revenue considerations are explained by the categories raw material supply, pellet machine production, product price and gross sales. Raw material supply (RESIDUE) is entered in tons per day with a conversion made from tons of residue to pounds of pellets (PELLETS). The conversion uses a 1 to 1.1 ratio of residue (less than 10% moisture content, dry basis, with an average weight of 6.5 pounds per cubic foot) to pellets that are greater than 10 percent when packaged and weighed. There may be a net gain in pellet moisture content from conditioning the furnish in the pellet mill with steam or water followed by a net loss during storage. Gross income from product sales is a function of pellet production in three common unit measurement quantities (40-, 50-pound bags and by the ton) and the unit sales price. The model allows for a mix between retail and wholesale volume with income (INCOME) calculated from the percent directed into each market for the unit quantities.

Pellet machine production rates for pelleting wood fuel feedstocks should be used in the revenue formula and not the rated capacity of the pellet mill to manufacture feed pellets. Estimated production (RATE) in tons per hour and actual daily production (DAYPROD), automatically adjusted for repair and maintenance, are the basis for the calculation.

Operating Days

Consideration for the number of operating days (MAXDAYS) for pellet manufacturing is calculated from the daily pellet production and the residue supply. Either the calculated value (may have to operate during holidays or scheduled vacations) or a lesser number of days (ACTUAL) may be selected.

Income Statement

The final section in the model presents a simplified pro-forma income statement and cash flow for the manufacturing facility during an 8-hour shift. As shown in the sample income statement in Table 1, total revenues are projected from pellet production and sales price inputs. Total fixed costs include taxes, insurance, interest on borrowed capital, depreciation and cost of residue disposal or opportunity cost. Variable costs include electricity, other fuel, repair and maintenance, packaging and additives. Labor costs for the operator are calculated separately. The sum of revenues, fixed costs, variable costs and labor determine before tax income. By applying the tax bracket rate, after tax profit is calculated. Profit is adjusted by depreciation to obtain after tax net cash flow. Since it is assumed that the pellet manufacturing facility is an "add-on" to an exisiting company, the full amount of earned depreciation is added to after tax profits to calculate after tax net cash flow.

Table 1. Simplified Income Statement and Cash Flow For Small-Scale Densified Biomass Fuel Manufacture (8-hour shift)

REVENUES	$ 222.20
FIXED COSTS	
Property Taxes	($ 29.98)
Interest on Borrowed Capital	($ 0.00)
Insurance	($ 10.34)
Depreciation	($ 35.22)
Residue Disposal	$ 56.91
LABOR (base pay and all benefits)	($ 83.84)
VARIABLE COSTS	
Electricity	($ 72.43)
Other Fuel	($ 0.00)
Repair and Maintenance	
labor	($ 3.14)
parts/supplies	($ 1.57)
Packaging	
bags	($ 34.03)
pallets	($ 3.58)
Additives	($ 0.00)
INCOME BEFORE TAXES	$ 4.97
TAXES	$ 2.49
AFTER TAX PROFIT	$ 2.49
DEPRECIATION	$ 35.22
AFTER TAX NET CASH FLOW	$ 37.70

DISCUSSION/CONCLUSIONS

The densified biomass fuel manufacture program DENSEFUEL is an interactive model that offers a preliminary investment analysis for adding pellet fuel manufacturing to an existing forest products business. Products within a mix that are often complimentary in a product line mix such as: furniture and shipping crates, window parts and wood toys, and dimension lumber and electricity generation, may better enhance the overall profitability of the company as products produced in combination rather than singly. These mixes may be difficult or impossible to identify without an investment tool with which to conduct a simple examination regarding what investment considerations should be made, what are the components of the production process and what level of profit might be anticipated.

Within the constraints of the DENSEFUEL model, an after-tax net cash flow is projected. An important constraint is that wood waste generated from manufacturing the primary product is treated as a cost. If the wood waste is currently utilized elsewhere in the business or sold, this must be considered as an opportunity cost. If the waste has no value or other use, there is a disposal cost that is incurred. Those costs may be associated with stockpiling, incinerating, landfilling or even giving the waste away.

The model places no cash value on environmental improvements to air and water quality, benefits that may include special discounts to consumers who are company employees, in-house sales or free supplies of reject fuel, local economy impacts from pellet stove sales, good will or beneficial effects from serving a municipal/institutional customer such as a school or hospital. These advantages to the company considering the investment are not necessarily economic but they represent benefits to others or society in general none-the-less.

The value in the DENSEFUEL model is that it is tailored to the small-scale pellet producer who may not have the resources, time or even the expertise to conduct a detailed feasibility study. A modest investment level by these potential pellet fuel manufacturers is essential and can be achieved through creative approaches to equipment fabrication, process control, labor use and serving several local market segments. The model provides for consideration of these approaches, approaches that are unique to small and some medium-sized forest products processors who may contemplate becomming small-scale densified biomass fuel manufacturers.

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Klug, J. 1990. 1990 Directory of Montana's Forest Products Industry. Montana Department of State Lands, Service Forestry Bureau, 85p.

APPENDIX A

WOOD PELLET MANUFACTURERS IN THE U.S. COASTAL WEST & WESTERN CANADA

Ag-Pro Grain Company Ltd.
Creston, British Columbia, Canada
Chris Harland
(604) 428-7061

Evergreen Forest Products, Inc.
620 S.W. Stearns Lane
Oakland, Oregon 97462
Ray Palm
(503) 459-9664

Gold Country Pellet Fuel
9720 East Mach Street, P.O. Box 639
Plymouth, California 95669
Ron McKinney
(209) 245-6340

Johnson Pellet Mill
P.O. Box 4
Sultan, Washington 98294
S. Johnson
(206) 793-3133

Kaaland Mill
P.O. Box 533
Hamilton, Washington 98255
Don Kaaland
(206) 826-4344

Manke Lumber Company
1717 Marine View Drive
Tacoma, Washington 98422
Milt Farvor
(206) 572-6252

Modoc Energy Products
P.O. Box 257
Klamath Falls, Oregon 97601
Kurt Schmidt
(503) 884-3177

Natural Resources Recovery, Inc.
2300 2nd Street, P.O. Box 250
Columbia City, Oregon 97018
Christopher Sharron
(503) 397-6908

Northwest Pellet Mills, Inc.
34401 Lake Creek Drive
Brownsville, Oregon 97327
Dan Knight
(503) 466-5115

Pacific Densified Fuels
P.O. Box 3589
Arlington, Washington 98223
M. Kuhlman
(206) 334-5018

PEP Fuel Products
5551 Eastside Road, P.O. Box 4704
Redding, California 96099
Dan Prielipp
(916) 246-0965

Presto-Flame
1250 Glenshire Road
Victoria, British Columbia, Canada V8X3X2
(604) 474-6200

Recycle King
808 "G" Street
Fresno, California 93706
Chuck Balo
(209) 485-2154

Seattle-Tacoma Box Company
23400 71st Place South
Kent, Washington 98032
Ferd Nist
(206) 854-9700

Swan Lake Pellets
Route #2, Box 809-S
Klamath Falls, Oregon 97603
Ken Jesperson
(503) 882-2915

The Wood Pellet Company
P.O. Box 86
Oakville, Washington 98568
John Sharp
(206) 273-6982

West Oregon Wood Products
Box 249
Columbia City, Oregon 97018
Christopher Sharron
(503) 397-6707

Wood Fuel Processing, Inc.
5079 South Township Road
Yuba City, California 95991
R. Farrell
(916) 895-1806

WOOD PELLET MANUFACTURERS IN THE U.S. INTERMOUNTAIN WEST

Agri-Systems
1300 Minnesota Street
Agri-Trade Center
Billings, Montana 59101
Steve Wojciechowski
(406) 245-6231

Bear Mountain Forest Products Inc.
751 Frankton Road
Hood River, Oregon 97031
Robert Sourek
(503) 386-4799

Belgrade Wood Products
251 Arden Drive
Belgrade, Montana 59714
John Topp
(406) 388-8866

Bitterroot Timber Products
Box 57
Darby, Montana 59829
Winston Wanstrath
(409) 821-4428

Blackfoot Forest Products
P.O. Box 188
Lincoln, Montana 59639
Ginny Carey
(406) 362-4868

Browning Cut Stock Company, Inc.
P.O. Box 439
Juliaetta, Idaho 83535
Jack Browning
(208) 276-3494

C.D. Pellet Company
Box 3185
Omak, Washington 98841
Cherrie Moomaw
(509) 826-2059

Coeur d'Alene Fiber Fuels
3550 West Seltice Way
Coeur d'Alene, Idaho 83814
Bob Cauley
(208) 765-0608

Eureka Pellet Mills
P.O. Box 667
Eureka, Montana 59917
Gregory Schmid
(406) 296-3109

Firetech Wood Products, Inc.
P.O. Box 883
Union, Oregon 97883
Andrew Short
(503) 562-5057

Great Western Pellet Mills
708 Golf Course Road
Enterprise, Oregon 97828
Dave Anderson
(503) 426-4515

Hoo Doo Mountain Pellets
1870 South Highway 2
Libby, Montana 59923
Lee Disney
(406) 293-5019

Jensen Lumber Company, Inc.
P.O. Box 6
Ovid, Idaho 83260
Robert Jensen
(208) 847-0889

Lignetics of Idaho
P.O. Box 1706
Sandpoint, Idaho 83864
Kenneth Tucker
(208) 263-0564

M.J.M. Pellet Mill
Route 1, Box 104
Brewster, Washington 98812
Matthew Michaels
(509) 689-3188

Panorama Wood Products
P.O. Box 250
Kettle Falls, Washington 99141
Richard Fannan
(509) 738-2161

Rocky Mountain Mills
Box 46
Ravalli, Montana 59863
Allen (Bud) Zempel
(406) 745-2492

Simmons Densified Fuels, Inc.
2318 South 1st Street, #3
Yakima, Washington 98903
Ronald Simmons
(509) 453-6008

Spokane Pres-To-Logs
North 3124 Flora Road
Spokane, Washington 99216
Derald Kuhnhausen
(509) 924-2807

Ten Gs
Box 146
Union, Oregon 97883
(503) 562-5057

WOOD PELLET MANUFACTURERS IN THE U.S. ROCKY MOUNTAIN & CENTRAL CANADA

CNZ Corporation
932 Kroe Lane
Sheridan, Wyoming 82801
Orrin Connell
(307) 672-9797

Little River Lumber Company
Piedmont, South Dakota 57769
Arlin Bates
(605) 787-4836

Northern Combustion
Prince Albert, Saskatchewan, Canada
Jerry Seufert
(306) 763-4500

R & R Enterprises
P.O. Box 1075
Sturgis, South Dakota 57785
M. Ringer
(605) 347-4556

Rocky Mountain Forest Products Corporation
P.O. Box 777
Laramie, Wyoming 82070
Butch Keadle
(307) 745-8924

South and Jones
North Highway 89
Evanston, Wyoming 82931
Dan South
(307) 798-2398

Westway Trading Corporation
P.O. Box 40
Mapleton, North Dakota 58059
Jeff Olson
(701) 282-5010

WOOD PELLET MANUFACTURERS IN THE U.S. SOUTHWEST

B & K Packaging, Inc.
Tulsa, Oklahoma
Cliff Kuns
(918) 585-9136

Pellet Fuels of Texas
690 Lindbergh Drive
Beaumont, Texas 77707
Stan Price

Precision Pellet Manufacturing
P.O. Box 368
Heber, Arizona 85928
David Tenney
(602) 535-5356

Wood Recyclers, Inc.
Tulsa, Oklahoma
Kent Burkett
(918) 446-0023

WOOD PELLET MANUFACTURERS IN THE U.S. MIDWEST

Agri-Mass
80 East Road
Rockville, Indiana 47872
(317) 569-3151

Claycamp's
R.R. #4, Box 132
Seymore, Indiana 47274
(812) 522-7136

East Perry Lumber Company
Highwat "C" & "A", P.O. Box 105
Frohna, Missouri 63748
B. Lorenz
(314) 824-5272

Hammon Products Company
217 Hammon Drive, P.O. Box H
Stockton, Missouri 65785
J. Jones
(417) 276-5181

Heatilator, Inc.
Muscatine, Iowa 52761
Rob Perrenoud
(800) 247-6798

Pennington Seed Co.
P.O. Box 338
Greenfield, Missouri 65661
Keith Hankins
(417) 637-5978

Tecor, Inc.
HCR5, Box 40
Houston, Missouri 65483
Jerry Stricklin
(417) 967-4838

WOOD PELLET MANUFACTURERS IN THE U.S. & CANADIAN GREAT LAKES REGION

Alberta Dehydrating Company Ltd.
138 Argyle Street North
Renfrew, Ontario, Canada K7V4A6
Allan Lindsay
(613) 432-3614

American Bio-Energy, Inc.
P.O. Box 635
Gilbert, Minnesota 55741
(218) 749-1818

Anderson Industrial Products
P.O. Box 119
Maumee, Ohio 43537
N. Peiffer
(419) 893-5050

Biomass Fuel Supply, Inc.
112 West Spring Street
Marquette, Michigan 49855
(906) 228-9150

BioShell, Inc.
P.O. Box 547
Hearst, Ontario, Canada POL1NO
Jacques Lecours
(705) 362-4264

Dynamic Resources, Inc
R.R. #3, Box 277
Bagley, Minnesota 56621
(218) 657-2501

Forest Fuel Corporation
RR #2, Box 205-BL
Mason, Wisconsin 54856
(715) 746-2452

Gilman Forest Products
400 North 1st Avenue
Gilman, Wisconsin 54430
Tom Slaugther
(715) 447-8221

Grand Rapids Wholesalers
P.O. Box 101
Grand Rapids, Minnesota 55744
(218) 326-9477

Khoury, Inc.
2201 East Industrial Park Drive
Iron Mountain, Michigan 49801
Steve Johnson
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LaCross Milling
Box 86
Cochrane, Wisconsin 54622
(608) 248-2222

Martha Wood Shaving Supply
6752 State Highway 107 North
Marathon, Wisconsin 54448
Jerry Natzke
(715) 842-9200

Maust Fiber Fuels
Highway 52 & 16 North
Preston, Minnesota 55965
Mark Maust
(507) 765-2126

Montcalm Fiber Corporation
6244 Henkel Road
Howard City, Michigan 49503
James Trent
(616) 235-2800

Neo-Wood Products Company
447 Wall Street
Tiffin, Ohio 44883
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Nordheim Roofing & Sheet Metal
P.O. Box 188
Bemidiji, Minnesota 55601
(218) 751-3923

Northern Bio-Fuel
P.O. Box 28
Pequot Lakes, Minnesota 56472
(218) 568-8616

N.S. Bauman, Ltd.
Route 3
Wallenstein, Ontario, Canada N802S0
Willard Bauman
(519) 669-5447

Rapid River Co.
P.O. Box 458
Baudette, Minnesota 56623
(218) 634-2041

Rivard's Quality Seeds
P.O. Box 303
Argyle, Minnesota 56713
Ken Schuster
(218) 437-6638

S-W Mills, Inc.
P.O. Box 162
Archbold, Ohio 43502
I. Wyse
(419) 445-5206

Thronson Management, Inc.
P.O. Box 424
Menominee, Michigan 49858
Don Thronson
(906) 863-1208

U.P. Bio-Energy, Inc.
Highway #41 & Brigdecreek Road
Menominee, Michigan 49858
(906) 863-7853

Valley Forest Resources
Star Route, Box 27
Marcell, Minnesota 56657
John Fisher
(218) 832-3600

WOOD PELLET MANUFACTURERS IN THE U.S. NORTH & EASTERN CANADA

Bioshell, Inc.
6070 Sherbrook Street
Montreal, Quebec, Canada H1N1C1
Roger Paquet
(514) 252-8300

BioShell, Inc.
Lac-Megantic, Quebec, Canada
B. Paradis
(819) 583-5131

Great Lakes Fuel Pellets
6831 County Road 34
Naples, New York 14512
R. Gardner
(716) 374-2021

Green Mountain Pellet, Inc.
P.O. Box 4327
Burlington, Vermont 05401
Pat Irish
(802) 862-9228

Jim C. Hamer Company
Kenova, West Virginia 25530
J.P. Hamer, II
(304) 453-6381

Kingsford Products Company
P.O. Box 464
Parsons, West Virginia 26287
Richard Stokes
(304) 478-2911

Manus Company
200 Park Avenue, Pan Am Building, Suite 303 East
New York, New York 10016
(212) 986-2515

Mapleleaf Technologies
7 Halliday Street
Westmont, Nova Scotia B1R1A8

New England Soli-Fuel
P.O. Box 184
Derby, Vermont 05829
(802) 334-5733

Wood Pellets, Inc.
Summerhill, Pennsylvania 15958
Donna Nolan
(814) 495-9335

WOOD PELLET MANUFACTURERS IN THE U.S. SOUTH

Anderson Peanut Co.
P.O. Box 26
Goshen, Alabama 36035
(205) 484-3441

Bio-Plus, Inc.
Industrial Drive
Ashburn, Georgia 31714
J. Myers
(912) 567-3566

Blakely Peanut Company
P.O. Box 708
Blakely, Georgia 31723
R. Smith
(912) 723-3701

Consolidated Pelletizers
P.O. Box 129
Damascus, Georgia 31741
Joann Simpson
(912) 725-3303

Fiber Resources, Inc.
P.O. Box 8727
Pine Bluff, Arkansas 71611
J.R. Weaver
(501) 535-1759

Modular Energy Company
Route #2, Box 389-2
Bealton, Virginia 22712
Jack Warf
(703) 439-1482

North Carolina Wood Fuels, Ltd.
P.O. Box 289
Cleveland, North Carolina 27013
(704) 278-2213

Southern Energy, Ltd.
P.O. Box 14-H
Bristol, Florida 32321
(904) 643-2292

Sycamore Pellets
P.O. Box 2502
Asburn, Georgia 31714
(912) 567-3566

Union Camp Corporation
P.O. Box 178
Franklin, Virginia 23851
J. Lawler
(804) 569-4620

APPENDIX B

INDUSTRIAL/COMMERCIAL WOOD PELLET COMBUSTION SYSTEM MANUFACTURERS

Aqua-Chem Inc. - Energy Systems Division
P.O. Box 421
Milwaukee, WI 53201
tradename: BMS Series
(414) 961-2872

Cresswood Stove Works
4504 Ellwalk Rd.
Courtland, IL 60112
tradename: Cresswood
(815) 758-7171

Decton Iron Works, Inc.
5200 N 124th St.
Milwaukee, WI 53225
tradename: Decton
(414) 462-5200

Eshland Enterprises, Inc.
P.O. Box 8A
Greencastle, PA 17225
tradename: Wood Gun
(717) 597-3196

Fire-View Products, Inc.
9003 A West Evans St., P.O. Box 370
Rogue River, OR 97537
Multi-Flue
(503) 582-3351

G & S Mill Co., Inc.
75 Otis St.
Northborough, MA 01532
tradename: G & S
(508)393-9266

Messersmith Manufacturing, Inc.
1260 Highway #2 & #41, P.O. Box 68
Bark River, MI 49807
tradename: Messersmith Dragon
(906) 466-9947

Northwest Iron Fireman
Fargo, ND 58102
tradename: Sidewinder
(701) 237-4096

PMC Corporation
Drawer S
Sheridan, WY 82801
tradename: Prill Ring-O-Fire
(307) 672-5801

The Will-Burt Company
169 S. Main St.
Orrville, OH 44667
tradename: Will-Burt
(216) 682-7015

Tryco Manufacturing Co., Inc.
SouthSide Dr.
Decatur, IL 62525
tradename: Bioflamm
(217) 428-0901

APPENDIX C

RESIDENTIAL WOOD PELLET STOVE AND FURNACE MANUFACTURERS

Alternate Energy Northwest, Inc.
16311 Smokey Point Blvd.
Arlington, WA 98223
tradename: Turbo-Fire
(206) 653-1067

Alternate Heating, K.A.E.S. Ltd.
Box 2445
Creston, British Columbia, Canada V0B1G0
tradename: Pelstar
(604) 428-3466

American Road Equipment - Nordic Division
4201 N 26th St.
Omaho, NB 68111
tradename: Erik Elite-M
(402) 451-2575

Attala Stoves
Highway 35 N
Kosciusko, MS 39090
tradename: Attala
(601) 289-6004

Boston Boiler Works
Boston Post Rd.
Enosburg Falls, VT 05450
tradename: Boston Boiler

Chippewa Trading, Ltd.
1610 Industrial Rd.
Salt Lake City, UT 84104
tradename: Chippewa
(801) 972-4488

Collins Enterprises, Inc.
P.O. Box 8
Belgrade, MT 59714
tradename: Collins Hopper
(406) 587-0544

Country Flame, Inc.
1200 Industrial Park Dr., P.O. Box 151
Mt. Vernon, MO 56712
tradename: Country Flame
(417) 466-7161

Decton Iron Works, Inc.
5200 N 124th St.
Milwaukee, WI 53225
tradename: Decton
(414) 462-5200

Deeze, Inc.
E 5317 Trent Ave.
Spokane, WA 99212
tradename: Freeland Flame
(509) 534-6974

Earth Stove Marketing, Inc.
19700 SW Teton St.
Tualatin, OR 97062
tradename: HomeWarmer
(503) 682-3384

Energie Nouvelle Engineering
401 16th Ave.
Deux-Montagnes, Quebec, Canada J7R4P9
tradename: Energie Nouvelle
(514) 473-4634

Essex Thermodynamics Corp.
P.O. Box 817
Essex, CT 06426
tradename: Essex
(203) 767-2651

FABCO
P.O. Box 6
Eagle, Idaho 83616
tradename: Briarwood

Fabridyne, Inc. - Viking Heating Division
P.O. Box 1040
Litchfield, MN 55355
tradename: Eagle
(612) 693-7251

Forge Stove Co.
3275 N Main St.
Logan, UT 84321
tradename: Augermatic
(801) 753-8787

Harman Stove Systems
R.D. 1, Box 619
Halifax, PA 17032
tradename: Harman
(717) 362-9080

Hawke Manufacturing Co.
Ball Park Rd., P.O. Box 507
Marietta, SC 29661
tradename: UltraFlame
(803) 836-8008

Heritage Stoves, Inc.
352 South Main St.
Clearfield, UT 84120
tradename: Heritage
(801) 773-8606

Hi-Teck Stoves, Inc.
2985 S 3600 St. W
Salt Lake City, UT 84119
tradename: Jamestown
(801) 975-0548

Horizon Research, Inc.
180 W. Dayton St., Suite 201
Edmonds, WA 98020
tradename: Eclipse
(206) 670-6533

Horstmann Industries
301 2nd St., P.O. Box 66
Elroy, WI 53929
tradename: Royal
(608) 462-8431

Humble Manufacturing Co., Inc.
Highway 43 N
Rushford, MN 55971
tradename: Humble
(507) 864-2525

Hunter Enterprises Orillia, Ltd.
P.O. Box 400
Orillia, Ontario, Canada L3V6K1
tradename: Hunter
(705) 325-6111

Ithaca Manufacturing Company
1210 Avenue A, P.O. Box 78
Ithaca, Michigan 48847
tradename: A-MAIZE-ING HEAT
(517) 875-4949

Kaniksu Heating Equipment
Rt. 1, Box 479
Bonners Ferry, ID 83805
tradename: Kaniksu
(208) 267-2755

King Coal Furnace Corp.
P.O. Box 2162
Bismark, ND 58502
tradename: King Coal
(701) 255-6406

Leaders Heat Products
8518 W Main St.
Kalamazoo, MI 49009
tradename: Leaders
(701) 372-1072

Longwood Manufacturing Corporation
Box 223
Gallatin, MO 64640
tradename: Longwood
(816) 663-2185

Martin Industries
P.O. Box 128
Florence, AL 35630
tradename: Pellifier
(205) 767-0330

Messersmith Manufacturing, Inc.
120 Hwy. #2 & #21
1260 Highway #2 & #41, P.O. Box 68
Bark River, MI 49807
tradename: Messersmith Dragon
(906) 466-9947

National Steelcrafters of Oregon, Inc.
P.O. Box 2501
Eugene, OR 97402
tradename: Breckwell
(503) 683-3210

New Buck Corp.
1265 Bakersville Hwy., P.O. Box 69
Spruce Pine, NC 28777
tradename: Peltron
(704) 765-6144

Pellet Inc.
P.O. Box 4308
Burlington, VT 05401
(802) 862-9287

PMC Corp.
Drawer S
Sheridan, WY 82801
(307) 672-5801
tradename: Prill Ring-O-Fire

Pyro Industries
11625 Airport Rd.
Everett, WA 98204
tradename: Whitfield
(206) 348-0400

RSF Energy, Ltd.
P.O. Box 3637
Smithers, BC, Canada V0J2N0
tradename: RSF
(604) 847-4301

Scott Stoves, Inc.
P.O. Box 1033
Hayden Lake, ID 83835
tradename: Scott
(208) 772-7310

Sherwood Industries Ltd.
6820 Kirkpatric Circle
Victoria. BC, Canada V8X3X1
tradename: Enviro Fire
(604) 652-6080

Sierra Manufacturing Co.
1680 Country Club Rd.
Harrisonburg, VA 22801
tradename: Solitaire
(703) 434-3800

Slant/Fin Corp.
100 Forest Dr.
Greenvale, NY 11548
tradename: Slant/Fin
(516) 484-2600

TEC
Box 23
Lewiston, ID 83501
tradename: Pellet Star
(208) 843-7297

Thelin-Thompson Co.
P.O. Box 847
Nevada City, CA 95959
tradename: Thelin-Thompson
(916) 265-2121

Thermic Inc.
605 N Fancher St., P.O. Box 11986
Spokane, WA 99211
tradename: Crossfire
(509) 535-0140

Thermo-Rite Sales of Minnesota
110 6th St. NE
Minneapolis, MN 55413
tradename: Thermo-Rite

Traeger Industries
1385 E College St.
Mt. Angel, OR 97362
tradename: Traeger
(503) 845-9234

Tryco Manufacturing Co., Inc.
South Side Drive, P.O. Box 1277
Decatur, IL 62525
tradename; Bioflamm
(217) 428-0901

Vector Corp.
2720 Roosevelt Blvd.
Eugene. OR 97402
tradename: Convector
(503) 461-2141

Volcanic Glow Stoves, Ltd.
R.R. #2
Elmira, Ontario, Canada N3B2Z2
tradename: Volcanic Glow
(519) 669-1733

Waterford Irish Stoves, Inc.
Rivermill Complex
85 Mechanic St.
Lebanon, NH 03766
tradename: Waterford

Welenco/Enerpel, Inc.
533 Thain Rd.
Lewiston, ID 83501
tradename: Welenco, Pellet Master
(208) 753-5525

Woodcutters Manufacturing, Inc. - Blaze King of Montana
3301 Isaccs St.
Walla Walla, WA 99362
tradename: Auto-Light
(509) 529-9820

APPENDIX D

MOBILE WHOLE TREE PROCESSOR MANUFACTURERS

Bruks Mekaniska Aktiebolag
P.O. Box 46
S-82010 Arbra, Sweden
0278/40500

Chipharvestors, Inc.
P.O. Box 1000
Winn, MI 48896
(517) 866-2381

M-B Company Inc. of Wisconsin
1200 Park St.
Chilton, WI 53014
(414) 849-2313

Nicholson Manufacturing Co., Inc.
3670 E Marginal Way S
Seattle, WA 98134
(604) 385-6757

Peterson Pacific Corp.
4253 Franklin Blvd.
Eugene, OR 97403
(503) 746-3177

Precision American Corp.
Rt. #3, P.O. Box 360
Leeds, AL 35094
(205) 640-5181

Strong Manufacturing Co.
498 Eight Mile Rd.
Remus, MI 49340
(517) 561-2280

TILT DUMP AND CHIP VAN MANUFACTURERS

Air-O-Flex Equipment Co.
3030 East Hennepin Ave.
Minneapolis, MN 55413
equipment: tilt dumps
(612) 331-4925

Lear Siegler, Inc. - Peerless Division
610 Mill St., P.O. Box 760
Paragould, AR 72450
equipment: tilt dumps, chip vans
(501) 236-7753

Chiparvestors, Inc.
Winn, MI 48896
equipment: tilt dumps
(517) 866-2381

Phelps Industries
1700 E 9th St.
Little Rock, AR 72202
equipment: tilt dumps
(501) 375-1141

Walco National Corp. - Husky Hydraulics Division
P.O. Box K
Two Harbors, MN 55616
equipment: tilt dumps
(218) 834-2274

Wesco Trailer Manufacturing
1960 East Main St.
Woodland, CA 95695
equipment: chip vans
(916) 662-9606

RESIDUE/PELLET STORAGE EQUIPMENT MANUFACTURERS

Atlas Systems Corp.
E 6416 Main Ave.
Parkwater Sta., P.O. Box 496
Spokane, WA 99211
(509) 535-7775

Baker/Rullman Manufacturing, Inc.
104 W Main St., P.O. Box 67
Watertown, WI 53094
(414) 261-0708

Butler Manufacturing Co.
Box 26
Salina, KS 67401
(913) 825-1611

Clarke's International, Inc.
660 Canyon St., P.O. Box 2428
Eugene, OR 97402
(503) 343-3395

Sprout-Andritz
Muncy, PA 17756
(717) 546-1495

Laidig, Inc.
4535 Dragoon Tr.
Mishawaka, IN 46544
(219) 256-0204

Lear Sieglar, Inc. - Peerless Division
P.O. Box 760
Paragould, AR 72450
(501) 236-7753

McConnell Industries
3539 Mary Taylor Rd., P.O. Box 5
Trussville, AL 35173
(205) 655-3261

Memphis Concrete Silo
2665 Princeton Ave.
Memphis, TN 38112
(901) 452-5416

Miller-Hofft, Inc.
2415 W Thompson Rd.
Indianapolis, IN 46217
(317) 787-9385

Wellons, Inc.
P.O. Box 381
Sherwood, OR 97140
(503) 625-6131

RESIDUE HANDLING, SCREENING AND CLASSIFYING EQUIPMENT MANUFACTURERS

ABCO Engineering Corp.
801 2nd Ave. SE
Oelwein, IA 50662
equipment: conveyors
(319) 283-5652

Acrowood Corp.
P.O. Box 1028
Everett, WA 98206
equipment: screens
(206) 258-3555

American Fabricators, Inc.
2519 N Front St.
Woodburn, OR 97071
equipment: conveyors
(503) 982-8500

Buffalo Hammer Mill Corp.
222 Chicago St.
Buffalo, NY 14204
equipment: blowers

Bulk Handling Systems, Inc.
1040 Arrowsmith
Eugene, OR 97402
equipment: conveyors
(503) 485-0999

Carrier Vibrating Equipment, Inc.
P.O. Box 37070
Louisville, KY 49233
equipment: conveyors
(502) 969-3171

Carter Day Co.
500 73rd Ave. NE
Minneapolis, MN 55432
equipment: cyclones
(612) 571-1000

Chiparvestors, Inc.
Winn, MI 48896
equipment: conveyors, portable screens, blowers
(517) 866-2381

Clarke's International, Inc.
660 Conger St., P.O. Box 2428
Eugene, OR 97402
equipment: conveyors, classifiers
(503) 343-3395

Sprout-Andritz
Muncy, PA 17756
equipment: conveyors, screens, cyclones, air locks, classifiers
(717) 546-1495

Eriez Magnetics
Ashbury Rd.
Erie, PA 16514
equipment: conveyors, magnets
(814) 883-9881

General Kinematics Corp.
777 Lake Zurich Rd.
Barrington, IL 60010
equipment: conveyors, screens
(312) 381-2240

Hobbs-Adams Engineering
1100 Holland Rd., P.O. Box 1833
Suffolk, VA 23434
equipment: conveyors, separators, blending hoppers
(804) 539-0231

Jay Bee Manufacturing, Inc.
P.O. Box 986, 522 North Beverly St.
Tyler, TX 75701
equipment: conveyors, blending hoppers
(214) 597-9343

Lear Siegler, Inc. - Peerless Division
610 Mill St., P.O. Box 760
Paragould, AR 72450
equipment: conveyors
(501) 236-7753

Precision American Corp.
Rt. #3, P.O. Box 360
Leeds, AL 35094
equipment: conveyors, screens
(205) 640-5181

Progress Industries Inc.
P.O. Box 353
Trussville, AL 35173
equipment: cyclones, conveyors, surge bins, screens, metal detectors
(205) 655-8875

The Read Corp.
25 Wareham St., P.O. Box 1298
Middleboro, MA 02346
equipment: screens
(508) 946-1200)

Recovery Systems Technology Incorporated
18012 Bothell Everett Hwy.
Bothell, WA 98102
equipment: trommel screens

Rens Manufacturing Co.
P.O. Box 37
Creswell, OR 97426
equipment: metal detectors
(503) 895-2172

Screw Conveyor Corporation
700 Hoffman St.
Hammond, IN 46327
equipment: conveyors
(219) 931-1450

Triple/S Dynamics
1031 S Haskell Ave.
Dallas, TX 75223
equipment: conveyors, screens, cyclones, air locks,
fans, classifiers
(214) 828-8600

West Salem Machinery Co.
665 Murlark Ave. NW
Salem, OR 97304
equipment: screens
(503) 364-2213

ON-SITE CHIPPER, SHREDDER, HOG AND HAMMERMILL MANUFACTURERS

Acrowood Corp.
P.O. Box 1028
Everett, WA 98206
equipment: chippers, debarkers
(206) 258-3555

Bruks Mekaniska Aktiebolag
P.O. Box 46
S-82010 Arabra, Sweden
equipment: chippers
0278/40500

Buffalo Hammermill Corp.
222 Chicago St.
Buffalo, NY 14204
equipment: hammermills

C W Manufacturing, Inc.
14 Commercial St., P.O. Box 246
Sabetha, KN 66534
equipment: tub grinders
(913) 284-3454

Combustion Engineering, Inc.
Sprout-Bauer
Muncy, Pennsylvania 17756
equipment: hammermills
(717) 546-1495

Haybuster
Box 1940
Jamestown, ND 58402-1910
equipment: tub grinders
(701) 252-4601

Hobbs-Adams Engineering
1100 Holland Rd., P.O. Box 1833
Suffolk, VA 23434
equipment: hammermills
(803) 539-0231

Jay Bee Manufacturing, Inc.
522 North Beverly St., P.O. Box 986
Tyler, TX 75701
equipment: hammermills, grinders
(214) 597-9343

Montgomery Industries International, Inc.
2017 Thelma St., P.O. Box 3687
Jacksonville, FL 32206
equipment: hammermills, shredders, hogs, chippers
(904) 355-5671

Morrison-Knudsen Forest Products Co., Inc.
P.O. Box 7808
Boise, ID 83729
equipment: hogs
(208) 386-6510

Precision American Corp.
Rt. #3, P.O. Box 360
Leeds, AL 35094
equipment: chippers, debarkers, grinders
(205) 640-5181

Triple/S Dynamics
1031 S Haskell Ave.
Dallas, TX 75223
equipment: shredders
(214) 828-8600

Tryco International
1160 S. Monroe St., P.O. Box 1277
Decatur, IL 62525
equipment: grinders, shredders
(217) 428-0901

West Salem Machinery Co.
665 Murlark Ave. NW
Salem, OR 97304
equipment: hogs, chippers
(503) 364-2213

ROTARY DRUM DRYER MANUFACTURERS

Aeroglide Corp.
7100 Hillsborough Rd., P.O. Box Aeroglide
Raleigh, NC 27602
(919) 851-2000

Baker/Rullman Manufacturing, Inc. - Dehydration Div.
3000 W Montana St.
Milwaukee, WI 53201
(414) 261-8107

M.E.C. Co.
P.O. Box 330
Neodosha, KS 66759
(316) 325-2673

McConnell Industries, Inc.
3539 Mary Taylor Rd., P.O. Box 5
Trussville, AL 35173
(205) 655-3261

Productization, Inc.
1120 E Main St., P.O. Box 1086
Independence, KS 67301
(316) 331-0025

Rader Companies, Inc.
P.O. Box 20128
Portland, OR 97220
(503) 255-5330

Stearns Roger, Inc.
P.O. Box 5888
Denver, CO 80217
(303) 770-6400

Westec America, Inc.
10580 SW McDonald St.
Tigard, OR 97223
(503) 639-9050

PELLET MILL AND PELLET COOLER MANUFACTURERS

Amandus Kahl Nachf
Dieselstr. 5
Postfach 1246
D-2057 Reinbek bei Hamburg
011-4940-727-71-0

California Pellet Mill Co.
1114 E Wabash Ave.
Crawfordsville, IN 47933
(317) 362-2600

Sprout-Andritz
Muncy, PA 17756
(717) 546-1495

Ferro-Tech
467 Eureka Rd.
Wyandotte, MI 48192
(313) 282-7300

Landers Machine Co.
207 E Broadway
Fort Worth, TX 76104
(817) 336-5653

BAGGING, WEIGHING AND PALLETIZING EQUIPMENT MANUFACTURERS

Clamco Corp.
12900 Plaza Dr.
Cleveland, OH 44130
equipment: heat sealers
(216) 267-1911

Detecto Scale Co.
P.O. Box 191
Webb City, MO 64870
equipment: scales
(417) 673-4638

Hobbs-Adams Engineering
1100 Holland Rd., P.O. Box 1833
Suffolk, VA 23434
equipment: baggers, packers
(804) 539-0231

O/K International - Packaging Equipment Division
169 Pine St.
Natick, MA 01760
equipment: heat sealers
(617) 651-1498

Vaagen Timber Products, Inc.
565 W. 5th St.
Colville, WA 99114
equipment: pallet forks
(509) 684-6334

Walco National Corp. - Husky Hydraulics Division
P.O. Box K
Two Harbors, MN 55616-0511
equipment: pallet forks
(218) 834-2274

APPENDIX E

```
A1: PR '                              DENSEFUEL
A2: PR '                     An Investment Spreadsheet For
A3: PR 'Small-Scale Densified Biomass Fuel Manufacturing For Local Markets
A4: PR '                                 by
A5: PR '                  Richard L. Folk & Robert L. Govett
A6: PR '            College of Forestry, Wildlife & Range Sciences
A7: PR '                     Department of Forest Products
A8: PR '                          University of Idaho
A9: PR '                                 1989
A12: PR '    Welcome to DENSEFUEL, an interactive investment spreadsheet that
A13: PR 'provides you with a decision-making tool to examine small-scale
A14: PR 'manufacturing opportunities for densified biomass fuel pellets.
A15: PR 'When using the spreadsheet, you will be prompted by a series of
A16: PR 'questions and instructions.  Enter your response in the space that has
A17: PR 'been provided.
A18: PR '    The use of this model is founded on several assumptions that the
A19: PR 'authors believe to be valid with small-scale pellet fuel manufacturing
A20: PR 'in the Northwest.  The pellet manufacturing side is assumed to be an
A21: PR '"add-on" facility to an existing forest products business (primary or
A22: PR 'secondary processing), agri-business or municipal soild waste disposal
A23: PR 'company.  Consequently, land purchase is not necessary and office space,
A24: PR 'labor and equipment are already in place from the primary business of
A25: PR 'the company.  One employee usually operates the pellet manufacturing
A26: PR 'side of the company with responsibility for the production end
A27: PR '(residue handling, preprocessing and processing, pelleting, packaging
A28: PR 'and maintenance).  Product storage and loading, and customer service
A29: PR 'activities are performed by other yard and office employees during
A30: PR '"slack time" or as a minimal part of the business day of the primary
A31: PR 'company.  An 8-hour shift with two, 15 minute breaks is the basis of a
A32: PR 'work day.  The residue that is generated by the primary company is
A33: PR 'treated as a negative cost if disposal has been the alternative
A34: PR 'method up until now.  If residue has been sold, the selling price is
A35: PR 'treated as an opportunity cost.
A37: PR '                                IMPORTANT !!
A38: PR 'This spreadsheet has been designed to serve only as a preliminary
A39: PR 'evaluation tool in determining if further analysis of small-scale pellet
A40: PR 'fuel manufacturing may be warranted.  Under no circumstance should the
A41: PR 'model be used as a foundation for an investment decision.  This model
A42: PR 'provides a generalized approach that cannot accurately reflect the
A43: PR 'unique business operations of all small forest products companies.  The
A44: PR 'daily CASH FLOW statement or "income statement" serves only as an
A45: PR 'illustrative learning tool and does not totally reflect generally
A46: PR 'accepted accounting principles.
A48: PR '---------
B48: PR '---------
C48: PR '---------
D48: PR '---------
E48: PR '---------
F48: PR '---------
G48: PR [W18] '------------------
```

```
A49: PR 'You are now ready to begin !!  The first section of DENSEFUEL examines
A50: PR 'your investment.  One category of investment has been identified as
A51: PR 'Manufacturing Investment (Direct) and includes:
A53: PR '               1. Buildings (complete)
A54: PR '               2. Equipment (includes modification & set-up)
A55: PR '                  a. residue handling and processing
A56: PR '                  b. furnish handling and pelleting
A57: PR '                  c. pellet handling and processing
A58: PR '                  d. pellet storage
A60: PR 'You may choose to purchase new or used equipment or to custom-build
A61: PR 'your own.  For each building type and piece of equipment, enter your
A62: PR 'total expected outlay (e.g. 15100 for $15,100) under the column labeled,
A63: PR 'COST, opposite the type of building or equipment.  Please continue !!.
A65: PR 'A.  MANUFACTURING INVESTMENT (DIRECT)
G65: PR [W18] "COST
A66: PR '     1.  Buildings
A67: PR '                  (1) wooden, pelleting building
G67: (C2) U [W18] 0
A68: PR '                  (2) steel, pelleting building
G68: (C2) U [W18] 15100
A69: PR '                  (3) self-unloading storage silo
G69: (C2) U [W18] 15328
A70: PR '                  (4) residue storage pole shed
G70: (C2) U [W18] 0
A71: PR '                  (5) wooden, pellet storage building
G71: (C2) U [W18] 6776
A72: PR '                  (6) steel, pellet storage building
G72: (C2) U [W18] 0
A73: PR '                  (7) other _________________________
G73: (C2) U [W18] 12500
A74: PR '                  (8) other _________________________
G74: (C2) U [W18] 0
A75: PR '                  (9) other _________________________
G75: (C2) U [W18] 0
A76: PR '                                       Total Buildings:
G76: (C2) PR [W18] @SUM(G67..G75)
A78: PR '     2a. New Equipment (Residue Handling & Processing)
A79: PR '                  (10) front end loader
G79: (C2) U [W18] 0
A80: PR '                  (11) knife or rotary hog
G80: (C2) U [W18] 0
A81: PR '                  (12) main hog fan, pipe & cyclones
G81: (C2) U [W18] 0
A82: PR '                  (13) metal detector
G82: (C2) U [W18] 0
A83: PR '                  (14) blending hopper or mixing bin
G83: (C2) U [W18] 0
A84: PR '                  (15) silo elevator
G84: (C2) U [W18] 0
A85: PR '                  (16) off-loading or bypass elevator
```

```
G85: (C2) U [W18] 0
A86: PR '                   (17) hammermill screw conveyor
G86: (C2) U [W18] 0
A87: PR '                   (18) hammermill
G87: (C2) U [W18] 0
A88: PR '                   (19) hammermill fan & blower pipe
G88: (C2) U [W18] 0
A89: PR '                   (20) rotary drum dryer
G89: (C2) U [W18] 0
A90: PR '                   (21) dryer fan and blower pipe
G90: (C2) U [W18] 0
A91: PR '                   (22) electric panels and controls
G91: (C2) U [W18] 545+2090
A92: PR '                   (23) other _________________________
G92: (C2) U [W18] 0
A93: PR '                   (24) other _________________________
G93: (C2) U [W18] 0
A94: PR '                   (25) other _________________________
G94: (C2) U [W18] 0
A95: PR '                                              Total New:
G95: (C2) PR [W18] @SUM(G79..G94)
A97: PR '        Used Equipment (Residue Handling & Processing)
A98: PR '                   (26) front end loader
G98: (C2) U [W18] 0
A99: PR '                   (27) knife or rotary hog
G99: (C2) U [W18] 2224
A100: PR '                   (28) main hog fan, pipe & cyclones
G100: (C2) U [W18] 9488
A101: PR '                   (29) metal detector
G101: (C2) U [W18] 0
A102: PR '                   (30) blending hopper or mixing bin
G102: (C2) U [W18] 0
A103: PR '                   (31) silo elevator
G103: (C2) U [W18] 0
A104: PR '                   (32) off-loading or bypass elevator
G104: (C2) U [W18] 0
A105: PR '                   (33) hammermill screw conveyor
G105: (C2) U [W18] 0
A106: PR '                   (34) hammermill
G106: (C2) U [W18] 1119
A107: PR '                   (35) hammermill fan & blower pipe
G107: (C2) U [W18] 350
A108: PR '                   (36) rotary drum dryer
G108: (C2) U [W18] 0
A109: PR '                   (37) dryer fan and blower pipe
G109: (C2) U [W18] 0
A110: PR '                   (38) electric panels and controls
G110: (C2) U [W18] 0
A111: PR '                   (39) other _________________________
G111: (C2) U [W18] 0
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A112: PR '                    (40) other _________________________
G112: (C2) U [W18] 0
A113: PR '                    (41) other _________________________
G113: (C2) U [W18] 0
A114: PR '                                            Total Used:
G114: (C2) PR [W18] @SUM(G98..G113)
A116: PR '          Shop-Built Equipment (Residue Handling & Processing)
A117: PR '                    (42) blending hopper or mixing bin
G117: (C2) U [W18] 407
A118: PR '                    (43) silo elevator
G118: (C2) U [W18] 0
A119: PR '                    (44) off-loading or bypass elevator
G119: (C2) U [W18] 1570
A120: PR '                    (45) hammermill screw conveyor
G120: (C2) U [W18] 112
A121: PR '                    (46) rotary drum dryer
G121: (C2) U [W18] 0
A122: PR '                    (47) other _________________________
G122: (C2) U [W18] 0
A123: PR '                    (48) other _________________________
G123: (C2) U [W18] 0
A124: PR '                    (49) other _________________________
G124: (C2) U [W18] 0
A125: PR '                                      Total Shop-Built:
G125: (C2) PR [W18] @SUM(G117..G124)
A128: PR '     2b. New Equipment (Furnish Handling & Pelleting)
A129: PR '                    (50) furnish surge bin
G129: (C2) U [W18] 0
A130: PR '                    (51) ring-die pellet machine
G130: (C2) U [W18] 0
A131: PR '                    (52) punch-press pellet machine
G131: (C2) U [W18] 0
A132: PR '                    (53) other pellet machine
G132: (C2) U [W18] 0
A133: PR '                    (54) steam generator
G133: (C2) U [W18] 0
A134: PR '                    (55) hot water heater
G134: (C2) U [W18] 377
A135: PR '                    (56) industrial furnace spray head
G135: (C2) U [W18] 550
A136: PR '                    (57) air compressor
G136: (C2) U [W18] 500
A137: PR '                    (58) electric panels and controls
G137: (C2) U [W18] 2090
A138: PR '                    (59) other _________________________
G138: (C2) U [W18] 2400
A139: PR '                    (60) other _________________________
G139: (C2) U [W18] 0
A140: PR '                    (61) other _________________________
G140: (C2) U [W18] 0
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A141: PR '                                          Total New:
G141: (C2) PR [W18] @SUM(G129..G140)
A143: PR '        Used Equipment (Furnish Handling & Pelleting)
A144: PR '                  (62) furnish surge bin
G144: (C2) U [W18] 0
A145: PR '                  (63) ring-die pellet machine
G145: (C2) U [W18] 2720
A146: PR '                  (64) punch-press pellet machine
G146: (C2) U [W18] 0
A147: PR '                  (65) other pellet machine
G147: (C2) U [W18] 0
A148: PR '                  (66) steam generator
G148: (C2) U [W18] 0
A149: PR '                  (67) hot water heater
G149: (C2) U [W18] 0
A150: PR '                  (68) industrial furnace spray head
G150: (C2) U [W18] 0
A151: PR '                  (69) air compressor
G151: (C2) U [W18] 0
A152: PR '                  (70) electric panels and controls
G152: (C2) U [W18] 0
A153: PR '                  (71) other __________________________
G153: (C2) U [W18] 1225
A154: PR '                  (72) other __________________________
G154: (C2) U [W18] 0
A155: PR '                  (73) other __________________________
G155: (C2) U [W18] 0
A156: PR '                                         Total Used:
G156: (C2) PR [W18] @SUM(G144..G155)
A158: PR '        Shop-Built Equipment (Furnish Handling & Processing)
A159: PR '                  (74) furnish surge bin
G159: (C2) U [W18] 4500
A160: PR '                  (75) steam generator
G160: (C2) U [W18] 500
A161: PR '                  (76) other __________________________
G161: (C2) U [W18] 2700
A162: PR '                  (77) other __________________________
G162: (C2) U [W18] 0
A163: PR '                  (78) other __________________________
G163: (C2) U [W18] 0
A164: PR '                                   Total Shop-Built:
G164: (C2) PR [W18] @SUM(G159..G163)
A167: PR '    2c. New Equipment (Pellet Handling & Processing)
A168: PR '                  (79) pellet screw or belt conveyor
G168: (C2) U [W18] 0
A169: PR '                  (80) fines separator or screen
G169: (C2) U [W18] 0
A170: PR '                  (81) fines fan & blower pipe
G170: (C2) U [W18] 0
A171: PR '                  (82) pellet cooler
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G171: (C2) U [W18] 0
A172: PR '                  (83) pellet bin bucket elevator
G172: (C2) U [W18] 1300
A173: PR '                  (84) pellet bin
G173: (C2) U [W18] 0
A174: PR '                  (85) grain bin cooling fans
G174: (C2) U [W18] 900
A175: PR '                  (86) pellet bin fan & blower pipe
G175: (C2) U [W18] 0
A176: PR '                  (87) bagging head
G176: (C2) U [W18] 430
A177: PR '                  (88) weighing scale
G177: (C2) U [W18] 0
A178: PR '                  (89) impulse bag sealer
G178: (C2) U [W18] 1280
A179: PR '                  (90) other __________________________
G179: (C2) U [W18] 0
A180: PR '                  (91) other __________________________
G180: (C2) U [W18] 0
A181: PR '                  (92) other __________________________
G181: (C2) U [W18] 0
A182: PR '                                             Total New:
G182: (C2) PR [W18] @SUM(G168..G181)
A184: PR '        Used Equipment (Pellet Handling & Processing)
A185: PR '                  (93) pellet screw or belt conveyor
G185: (C2) U [W18] 0
A186: PR '                  (94) fines separator or screen
G186: (C2) U [W18] 0
A187: PR '                  (95) fines fan & blower pipe
G187: (C2) U [W18] 391
A188: PR '                  (96) pellet cooler
G188: (C2) U [W18] 0
A189: PR '                  (97) pellet bin bucket elevator
G189: (C2) U [W18] 0
A190: PR '                  (98) pellet bin
G190: (C2) U [W18] 0
A191: PR '                  (99) grain bin cooling fans
G191: (C2) U [W18] 0
A192: PR '                 (100) pellet bin fan & blower pipe
G192: (C2) U [W18] 383
A193: PR '                 (101) bagging head
G193: (C2) U [W18] 0
A194: PR '                 (102) weighing scale
G194: (C2) U [W18] 116
A195: PR '                 (103) impulse bag sealer
G195: (C2) U [W18] 0
A196: PR '                 (104) other __________________________
G196: (C2) U [W18] 0
A197: PR '                 (105) other __________________________
G197: (C2) U [W18] 0
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A198: PR '                    (106) other _________________________
G198: (C2) U [W18] 0
A199: PR '                                                Total Used:
G199: (C2) PR [W18] @SUM(G185..G198)
A201: PR '        Shop-Built Equipment (Pellet Handling & Processing)
A202: PR '                    (107) pellet screw or belt conveyor
G202: (C2) U [W18] 143
A203: PR '                    (108) fines separator or screen
G203: (C2) U [W18] 70
A204: PR '                    (109) pellet cooler
G204: (C2) U [W18] 0
A205: PR '                    (110) pellet bin bucket elevator
G205: (C2) U [W18] 0
A206: PR '                    (111) pellet bin
G206: (C2) U [W18] 4500
A207: PR '                    (112) other _________________________
G207: (C2) U [W18] 0
A208: PR '                    (113) other _________________________
G208: (C2) U [W18] 0
A209: PR '                    (114) other _________________________
G209: (C2) U [W18] 0
A210: PR '                                          Total Shop-Built:
G210: (C2) PR [W18] @SUM(G202..G209)
A213: PR '    2d. New Equipment (Pellet Storage)
A214: PR '                    (115) pallet jack
G214: (C2) U [W18] 0
A215: PR '                    (116) propane fork lift
G215: (C2) U [W18] 0
A216: PR '                    (117) tractor w/forks
G216: (C2) U [W18] 0
A217: PR '                    (118) other _________________________
G217: (C2) U [W18] 0
A218: PR '                    (119) other _________________________
G218: (C2) U [W18] 0
A219: PR '                    (120) other _________________________
G219: (C2) U [W18] 0
A220: PR '                                                 Total New:
G220: (C2) PR [W18] @SUM(G214..G219)
A222: PR '        Used Equipment (Pellet Storage)
A223: PR '                    (121) pallet jack
G223: (C2) U [W18] 555
A224: PR '                    (122) propane fork lift
G224: (C2) U [W18] 6500
A225: PR '                    (123) tractor w/forks
G225: (C2) U [W18] 0
A226: PR '                    (124) other _________________________
G226: (C2) U [W18] 0
A227: PR '                    (125) other _________________________
G227: (C2) U [W18] 0
A228: PR '                    (126) other _________________________
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G228: (C2) U [W18] 0
A229: PR '                                              Total Used:
G229: (C2) PR [W18] @SUM(G223..G228)
A231: PR '        Shop-Built Equipment (Pellet Storage)
A232: PR '                (127) other ___________________________
G232: (C2) U [W18] 0
A233: PR '                (128) other ___________________________
G233: (C2) U [W18] 0
A234: PR '                (129) other ___________________________
G234: (C2) U [W18] 0
A235: PR '                (130) other ___________________________
G235: (C2) U [W18] 0
A236: PR '                (131) other ___________________________
G236: (C2) U [W18] 0
A237: PR '                (132) other ___________________________
G237: (C2) U [W18] 0
A238: PR '                                        Total Shop-Built:
G238: (C2) PR [W18] @SUM(G232..G237)
A241: PR 'Your grand total MANUFACTURING INVESTMENT (DIRECT) is:
G241: (C2) PR [W18] +G76+G95+G114+G125+G141+G156+G164+G182+G199+G210+G220+G229+G238
A243: PR '---------
B243: PR '---------
C243: PR '---------
D243: PR '---------
E243: PR '---------
F243: PR '---------
G243: PR [W18] '------------------
A244: PR 'You are now ready to calculate your expected daily Fixed Costs
A245: PR '(Indirect) that include these categories:
A247: PR '              1. Taxes
A248: PR '                 a. property tax
A249: PR '                 b. income tax
A250: PR '              2. Insurance (e.g. fire, liability)
A251: PR '              3. Cost of Capital (interest)
A252: PR '              5. Depreciation (MACRS)
A253: PR '                 a. 5 year property (mobile equipment)
A254: PR '                 b. 10 year property (wood manufacturing machines)
A255: PR '                 c. 20 year property (buildings)
A257: PR 'Property taxes for DENSEFUEL are based on a fixed rate per $100
A258: PR 'of assessed value where the assessment is 100% of fair market.  For now,
A259: PR 'enter your property tax rate (e.g. 7.25 for $7.25) in the space directly
A260: PR 'under the label, PTRATE.  When additional information is entered later
A261: PR 'on, daily property tax will be calculated for you and shown in the cash
A262: PR 'flow summary at the end of the spreadsheet.  Please continue !!
A264: PR 'B.  FIXED COSTS (INDIRECT)
A265: PR '    1a. Property Taxes
G265: PR [W18] "PTRATE
G266: (C2) U [W18] 7.25
A268: PR 'Income tax, using DENSEFUEL, is determined from annual net income by
A269: PR 'multiplying the expected net income by your tax bracket.  Other
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A270: PR 'calculations, however, must first be made.  For now, enter your tax
A271: PR 'bracket (e.g. 50%) in the space directly under the label, BRACKET.  You
A272: PR 'may want to return to this section and change the BRACKET value.  Please
A273: PR 'continue !!
A275: PR '    1b. Income Tax
G275: PR [W18] "BRACKET
G276: (F2) U [W18] 0.5
A278: PR 'The annual insurance premium using DENSEFUEL is based on a fixed
A279: PR 'rate per $100 of assessed value.  Replacement cost is used to arrive
A280: PR 'at the assessed value.  Enter your insurance rate (e.g. 2.5 for
A281: PR '$2.50) in the space directly under the label, INRATE.  When additional
A282: PR 'information is entered later on, daily insurance costs will be
A283: PR 'calculated for you and shown in the cash flow summary at the end of the
A284: PR 'the spreadsheet.  Please continue !!
A286: PR '     2. Insurance
G286: PR [W18] "INRATE
G287: (C2) U [W18] 2.5
A289: PR 'The annaul cost of borrowed capital (interest) from DENSEFUEL is based
A290: PR 'on a compounded, effective annual rate.  Enter the amount you will
A291: PR 'borrow (e.g. 15000 for $15,000) under the label, BORROW, and the
A292: PR 'effective annual interest rate (e.g. 10.5%) under the label, RATE.
A293: PR 'The calculation will be made for you and shown directly under the label,
A294: PR 'INTEREST.  Please continue !!
A296: PR '     3. Interest
D296: PR "BORROW
F296: PR "RATE
G296: PR [W18] "INTEREST
D297: (C0) U 0
F297: (F5) U 0.105
G297: (C2) PR [W18] (+D297)*(+F297)
A299: PR 'Depreciation expense using DENSEFUEL is calculated with the Modified
A300: PR 'Accelerated Cost Recovery System (MACRS), straight line method, by
A301: PR 'grouping assets according to the useful life categories specified by
A302: PR 'the IRS.  These categories are 5-year property (rolling stock), 10-year
A303: PR 'property (mill equipment and machines) and 20-year property (buildings).
A304: PR 'New, used and shop-built designations are treated separately.  The
A305: PR 'suggested totals of the assets for each life category have already been
A306: PR 'calculated for you from the building and equipment list.  You may elect
A307: PR 'to use these or enter your own totals.  Either way, re-enter the
A308: PR 'SUGGESTED TOTAL values or enter your total values (e.g. 6500 for $6,500)
A309: PR 'in the spaces opposite the label, YOUR TOTAL.  Please continue !!
A311: PR '     4. Depreciation
D311: PR "5-YEAR
E311: PR "10-YEAR
F311: PR "20-YEAR
C313: PR 'NEW
D313: (C0) PR +G79+@SUM(G215..G219)
E313: (C0) PR @SUM(G80..G94)+@SUM(G129..G140)+@SUM(G168..G181)+G214
F313: (C0) PR @SUM(G67..G75)
C315: PR 'USED
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D315: (C0) PR +G98+@SUM(G224..G228)
E315: (C0) PR @SUM(G99..G113)+@SUM(G144..G155)+@SUM(G185..G198)+G223
C317: PR 'SHOP
D317: (C0) PR @SUM(G232..G237)
E317: (C0) PR @SUM(G117..G124)+@SUM(G159..G163)+@SUM(G202..G209)
A319: PR '        SUGGESTED TOTAL:
D319: (C0) PR +D313+D315+D317
E319: (C0) PR +E313+E315+E317
F319: (C0) PR +F313+F315+F317
A320: PR '             YOUR TOTAL:
D320: (C0) U 6500
E320: (C0) U 45535
F320: (C0) U 49704
A322: PR '---------
B322: PR '---------
C322: PR '---------
D322: PR '---------
E322: PR '---------
F322: PR '---------
G322: PR [W18] '------------------
A323: PR 'C.  LABOR COSTS
A325: PR 'Labor cost in DENSEFUEL is hourly pay (including ALL benefits) for the
A326: PR 'employee(s) that work only in the pellet manufacturing side to operate
A327: PR 'and service the equipment.  First, enter the number of paid, daily work
A328: PR 'hours for each employee (e.g. 8.0) in the space opposite the employee
A329: PR 'number and directly under the label, HOURS.  Then enter the rate per
A330: PR 'per hour (e.g. 10.80 for $10.80), including All benefits, in the space
A331: PR 'directly under the label, PAYRATE.  The daily cost of labor will be
A332: PR 'calculated for you and shown in the spaces directly under the label,
A333: PR 'LABOR.  Please continue !!
A335: PR '     1. Labor Costs
D335: PR "HOURS
F335: PR "PAYRATE
G335: PR [W18] "LABOR
A337: PR '        EMPLOYEE #1
D337: (F1) U 8
F337: (C2) U 10.48
G337: (C2) PR [W18] +$F$337*$D$337
A339: PR '        EMPLOYEE #2
D339: (F1) U 0
F339: (C2) U 0
G339: (C2) PR [W18] +$F$339*$D$339
A341: PR '        EMPLOYEE #3
D341: (F1) U 0
F341: (C2) U 0
G341: (C2) PR [W18] +$F$341*$D$341
A343: PR '            Totals:
D343: (F1) PR +D337+D339+D341
F343: PR '    ***
G343: (C2) PR [W18] +$G$337+$G$339+$G$341
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A345: PR '                UNWEIGHTED AVERAGE PAYRATE:
F345: (C2) PR @IF(F341>0,(@AVG(F337..F341)),(@IF(F339>0,@AVG(F337..F339),F337)))
A347: PR '---------
B347: PR '---------
C347: PR '---------
D347: PR '---------
E347: PR '---------
F347: PR '---------
G347: PR [W18] '------------------
A348: PR 'D.  VARIABLE COSTS
A350: PR 'Another category of expenses has been identified as Variable Costs
A351: PR 'and includes the following:
A353: PR '                1. Electricity Consumption
A354: PR '                   a. electric motors
A355: PR '                   b. other electricity
A356: PR '                   c. basic charge
A357: PR '                   d. demand cost
A358: PR '                   e. power factor charge
A359: PR '                2. Other Fuel Consumption
A360: PR '                3. Repair and Maintenance
A361: PR '                   a. labor
A362: PR '                   b. parts/supplies
A363: PR '                4. Bags and Pallets
A364: PR '                5. Residue Disposal
A365: PR '                6. Additives
A367: PR 'Electicity cost is a function of the energy charge, basic charge, demand
A368: PR 'cost and power factor charge of your utility company.  These rates and
A369: PR 'charges are fixed and must be obtained from your utility company.
A370: PR 'First, enter the cost per kilowatt charged by your utility company
A371: PR 'in the space directly under the label, KWRATE (e.g. .03897 for $.03897).
A372: PR 'To calculate the energy charge, list the horsepower (5.75 for 5 3/4 hp)
A373: PR 'for each electric motor on the pellet side in the space directly across
A374: PR 'from the label, MOTOR# and directly under the label, HP.  Then enter
A375: PR 'the number of hours per day (6.5 for 6 1/2 hours) that each motor will
A376: PR 'actually operate, under the label, HOURS.  The total daily cost will be
A377: PR 'calculated for you and shown directly under the label, ENERGY.  Energy
A378: PR 'charge is based on the motor operating at 75% capacity.  Please
A379: PR 'continue !!
A381: PR '    1a. Electric Motors
D381: PR "MOTOR#
E381: PR "HP
F381: PR "HOURS
G381: PR [W18] "ENERGY
A382: PR '        (energy charge)
D383: PR "1
E383: (F2) U 40
F383: (F1) U 8
G383: (C2) PR [W18] +E383*0.75*F383*$B$385*0.75
B384: PR "KWRATE
B385: (F5) U 0.03897
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D385: PR "2
E385: (F2) U 5
F385: (F1) U 8
G385: (C2) PR [W18] +E385*0.75*F385*$B$385*0.75
D387: PR "3
E387: (F2) U 30
F387: (F1) U 8
G387: (C2) PR [W18] +E387*0.75*F387*$B$385*0.75
D389: PR "4
E389: (F2) U 1.5
F389: (F1) U 4
G389: (C2) PR [W18] +E389*0.75*F389*$B$385*0.75
D391: PR "5
E391: (F2) U 1
F391: (F1) U 6
G391: (C2) PR [W18] +E391*0.75*F391*$B$385*0.75
D393: PR "6
E393: (F2) U 30
F393: (F1) U 12
G393: (C2) PR [W18] +E393*0.75*F393*$B$385*0.75
D395: PR "7
E395: (F2) U 0.67
F395: (F1) U 12
G395: (C2) PR [W18] +E395*0.75*F395*$B$385*0.75
D397: PR "8
E397: (F2) U 0.75
F397: (F1) U 6.9
G397: (C2) PR [W18] +E397*0.75*F397*$B$385*0.75
D399: PR "9
E399: (F2) U 15
F399: (F1) U 6.9
G399: (C2) PR [W18] +E399*0.75*F399*$B$385*0.75
D401: PR "10
E401: (F2) U 50
F401: (F1) U 6.9
G401: (C2) PR [W18] +E401*0.75*F401*$B$385*0.75
D403: PR "11
E403: (F2) U 0.33
F403: (F1) U 8
G403: (C2) PR [W18] +E403*0.75*F403*$B$385*0.75
D405: PR "12
E405: (F2) U 0.13
F405: (F1) U 8
G405: (C2) PR [W18] +E405*0.75*F405*$B$385*0.75
D407: PR "13
E407: (F2) U 0.75
F407: (F1) U 8
G407: (C2) PR [W18] +E407*0.75*F407*$B$385*0.75
D409: PR "14
E409: (F2) U 0.5
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F409: (F1) U 8
G409: (C2) PR [W18] +E409*0.75*F409*$B$385*0.75
D411: PR ^15
E411: (F2) U 0.33
F411: (F1) U 8
G411: (C2) PR [W18] +E411*0.75*F411*$B$385*0.75
D413: PR ^16
E413: (F2) U 5
F413: (F1) U 2
G413: (C2) PR [W18] +E413*0.75*F413*$B$385*0.75
D415: PR ^17
E415: (F2) U 0.75
F415: (F1) U 8
G415: (C2) PR [W18] +E415*0.75*F415*$B$385*0.75
D417: PR ^18
E417: (F2) U 0.75
F417: (F1) U 8
G417: (C2) PR [W18] +E417*0.75*F417*$B$385*0.75
D419: PR ^19
G419: (C2) PR [W18] +E419*0.75*F419*$B$385*0.75
D421: PR ^20
G421: (C2) PR [W18] +E421*0.75*F421*$B$385*0.75
D423: PR ^21
G423: (C2) PR [W18] +E423*0.75*F423*$B$385*0.75
D425: PR ^22
G425: (C2) PR [W18] +E425*0.75*F425*$B$385*0.75
D427: PR ^23
G427: (C2) PR [W18] +E427*0.75*F427*$B$385*0.75
D429: PR ^24
G429: (C2) PR [W18] +E429*0.75*F429*$B$385*0.75
D431: PR ^25
G431: (C2) PR [W18] +E431*0.75*F431*$B$385*0.75
D433: PR ^26
G433: (C2) PR [W18] +E433*0.75*F433*$B$385*0.75
D435: PR ^27
G435: (C2) PR [W18] +E435*0.75*F435*$B$385*0.75
D437: PR ^28
G437: (C2) PR [W18] +E437*0.75*F437*$B$385*0.75
D439: PR ^29
G439: (C2) PR [W18] +E439*0.75*F439*$B$385*0.75
D441: PR ^30
G441: (C2) PR [W18] +E441*0.75*F441*$B$385*0.75
A442: PR '                    Column Totals:
E442: PR +E383+E385+E387+E389+E391+E393+E395+E397+E399+E401+E403+E405+E407+E409+E411+E413+E415+E417+E419+E421+E423+E42
5+E427+E429+E431+E433+E435+E437+E439+E441
F442: (F1) PR +F383+F385+F387+F389+F391+F393+F395+F397+F399+F401+F403+F405+F407+F409+F411+F413+F415+F417+F419+F421+F42
3+F425+F427+F429+F431+F433+F435+F437+F439+F441
A443: PR '                     Total Motors:
G443: (C2) PR [W18] @SUM(G383..G441)
A445: PR 'Other electricity costs from the pellet side can be calculated by first
A446: PR 'entering the wattage of the equipment (i.e. lights and heaters) opposite
A447: PR 'the label, OTHER#, and in the space directly under the label, WATTS.
```

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A448: PR 'Next, enter the number of hours per day the under the label, HOURS.
A449: PR 'Your energy charge will be calculated for you and shown under the label,
A450: PR 'ENERGY.  Please continue !!
A452: PR '    1b. Other Electricity
D452: PR "OTHER#
E452: PR "WATTS
F452: PR "HOURS
G452: PR [W18] "ENERGY
A453: PR '          (energy charge)
D455: PR "1
E455: (F0) U 8000
F455: (F1) U 8
G455: (C2) PR [W18] (+E455/1000)*F455*0.75*$B$385
D457: PR "2
E457: (F0) U 660
F457: (F1) U 2
G457: (C2) PR [W18] (+E457/1000)*F457*0.75*$B$385
D459: PR "3
E459: (F0) U 1100
F459: (F1) U 8
G459: (C2) PR [W18] (+E459/1000)*F459*0.75*$B$385
D461: PR "4
E461: (F0) U 10000
F461: (F1) U 6.9
G461: (C2) PR [W18] (+E461/1000)*F461*0.75*$B$385
D463: PR "5
G463: (C2) PR [W18] (+E463/1000)*F463*0.75*$B$385
D465: PR "6
G465: (C2) PR [W18] (+E465/1000)*F465*0.75*$B$385
D467: PR "7
G467: (C2) PR [W18] (+E467/1000)*F467*0.75*$B$385
D469: PR "8
G469: (C2) PR [W18] (+E469/1000)*F469*0.75*$B$385
D471: PR "9
G471: (C2) PR [W18] (+E471/1000)*F471*0.75*$B$385
D473: PR "10
G473: (C2) PR [W18] (+E473/1000)*F473*0.75*$B$385
A474: PR '                        Column Totals:
E474: (F0) PR +E455+E457+E459+E461+E463+E465+E467+E469+E471+E473
F474: (F1) PR +F455+F457+F459+F461+F463+F465+F467+F469+F471+F473
A475: PR '              Total Other Electricity:
G475: (C2) PR [W18] +G455+G457+G459+G461+G463+G465+G467+G469+G471+G473
A477: PR 'The basic charge is a monthly flat fee set by your utility company.
A478: PR 'Enter the amount (e.g. 200 for $200) in the space directly under the
A479: PR 'label, CHARGE.  The daily basic charge will be calculated for you on
A480: PR 'the basis of 20 working days per month and shown directly under the
A481: PR 'label, BASIC.  Please continue !!
A483: PR '    1c. Basic charge
E483: PR "CHARGE
G483: PR [W18] "BASIC
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E484: (C0) U 200
G484: (C2) PR [W18] +E484/20
A486: PR 'The demand cost is determined by taking the horsepower from motors
A487: PR 'and watts from other electricity uses and multiplying the total
A488: PR 'kilowatts by a daily demand cost factor.  Enter the monthly demand cost
A489: PR 'factor (e.g. 2.6 for $2.60) supplied by your utility company, in the
A490: PR 'space directly under the label, FACTOR.  The calculation will be made
A491: PR 'for you from the list of motors and other equipment and shown directly
A492: PR 'under the label, DEMAND.  Please continue !!
A494: PR '    1d. Demand Cost
E494: PR "FACTOR
G494: PR [W18] "DEMAND
E495: (C2) U 2.6
G495: (C2) PR [W18] (((+E442+(E474/1000))-50)*E495)/20
A497: PR 'Power factor charge is a daily cost calculated by dividing the monthly
A498: PR 'power cost factor supplied by your utility, by 20.  Enter the power
A499: PR 'cost factor (e.g. 123.75 for $123.75) in the space directly under the
A500: PR 'label, FACTOR.  The calculation will be made for you and shown in the
A501: PR 'space directly under the label, POWER.  Please continue !!
A503: PR '    1e. Power Factor Charge
E503: PR "FACTOR
G503: PR [W18] "POWER
E504: (C2) U 123.75
G504: (C2) PR [W18] +E504/20
A506: PR '                              Total Electricity Cost:
G506: (C2) PR [W18] +G443+G475+G484+G495+G504
A508: PR 'Other fuel costs such as fuel to operate a biomass fuel dryer, and
A509: PR 'gasoline or propane for rolling stock must be estimated.  Enter your
A510: PR 'anticipated annual cost for other fuels in the space directly under the
A511: PR 'label, OTHERFUEL.  The daily expense will be calculated for you when
A512: PR 'operating days per year are determined.  Please continue !!
A514: PR '    2. Other Fuel Costs
G514: PR [W18] "OTHERFUEL
G515: (C2) U [W18] 0
A517: PR 'DENSEFUEL allows for repair and maintenance on equipment in the
A518: PR 'categories of labor and parts/supplies.  Labor costs are determined by
A519: PR 'designating a total number of hours per week to be spent on repairs
A520: PR 'and maintenance.  Enter the number of hours (e.g. 3.0) in the space
A521: PR 'directly under the label, HOURS.  The daily amount for labor will be
A522: PR 'calculated for you using an average labor cost value, and shown in the
A523: PR 'space directly under the label, LABOR.  Parts/supplies cost are
A524: PR 'estimated at a value of 1/2 the labor.  Parts/supplies cost will be
A525: PR 'calculated for you and shown directly under the label, PARTS.  Total
A526: PR 'repair cost will also be calculated for you and shown directly under the
A527: PR 'label, REPAIR.  Please continue !!
A529: PR '    3. Repair and Maintenance
E529: PR "LABOR
F529: PR "PARTS
G529: PR [W18] "REPAIR
E530: (C2) PR ((+$F$345)*($B$532/40))*8
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F530: (C2) PR +$E$530*0.5
G530: (C2) PR [W18] +$E$530+$F$530
B531: PR "HOURS
B532: (F1) U 1.5
A534: PR 'The cost of bags and pallets for packaging and handling product are
A535: PR 'calculated on a daily basis by multiplying the cost per bag by the
A536: PR 'daily production, expressed in numbers of bags of fuel.  Pallet capacity
A537: PR 'is 1/2 ton.  Production will be examined later but for now, enter your
A538: PR 'cost for each bag and pallet (e.g. .38 for $.38) directly under the
A539: PR 'labels, BAGS and PALLETS.  Please continue !!
A541: PR '     4. Packaging
E541: PR "BAGS
F541: PR "PALLETS
E542: (C2) U 0.38
F542: (C2) U 3.2
A544: PR 'Since residue generated by your plant may represent a disposal problem,
A545: PR 'there is a negative cost associated with disposal using DENSEFUEL.  For
A546: PR 'now, enter your disposal cost per ton of residue (e.g. 18.5 for $18.50)
A547: PR 'in the space directly under the label, DISPOSE.  If you are currently
A548: PR 'selling your residue, enter the price you receive per ton as a negative
A549: PR 'value (e.g. -4.50) in the space directly under the label, DISPOSE, to
A550: PR 'reflect the opportunity cost.  Please continue !!
A552: PR '     5. Residue Disposal
G552: PR [W18] "DISPOSE
G553: (C2) U [W18] 28
A555: PR 'Extra ingredients such as plastic, lubricants and other additives may be
A556: PR 'purchased to improve processing or product quality.  For now, enter the
A557: PR 'cost per pound (e.g. .02 for $.02) in the space directly under the
A558: PR 'label, ADDCOST, and the percent by weight (e.g. 2%) that is added to
A559: PR 'the furnish, under the label, PERCENT.  Please continue !!
A561: PR '     6. Additives
E561: PR "ADDCOST
F561: PR "PERCENT
E562: (C2) U 0
F562: (F3) U 0
A564: PR 'You have just completed Manufacturing Investment (Direct), Fixed Costs
A565: PR '(Indirect), Labor Costs and Variable Costs using DENSEFUEL.  The next
A566: PR 'part of the spreadsheet, Revenues, will calculate income from
A567: PR 'anticipated sales and will be used to determine costs that have
A568: PR 'already been mentioned but not yet shown.  Please continue !!
A570: PR '---------
B570: PR '---------
C570: PR '---------
D570: PR '---------
E570: PR '---------
F570: PR '---------
G570: PR [W18] '------------------
A571: PR 'The second section of DENSEFUEL examines revenue, useing the following
A572: PR 'categories to arrive at gross daily revenue:
A574: PR '                  1. Raw Material Supply
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A575: PR '                 2. Pellet Machine Production
A576: PR '                 3. Product Price & Gross Sales
A578: PR 'Raw material supply is treated in the spreadsheet as tons of dry
A579: PR '(less than 12% MC), clean, hogged residue.  The average weight per cubic
A580: PR 'foot for this material is 6.5 pounds.  A 1 to 1.1 conversion of
A581: PR 'residue to pellet fuel is used.  To calculate the daily production of
A582: PR 'pellet fuel, enter your supply of hogged residue (e.g. 477 for 477
A583: PR 'tons) in the space directly under the label, RESIDUE.  The conversion
A584: PR 'from tons of residue to pounds of pellet fuel will be made for you and
A585: PR 'shown in the space directly under the label, PELLET.  Please continue !!
A587: PR 'E.  REVENUE
A588: PR '    1. Raw Material Supply
E588: PR "RESIDUE
F588: PR "PELLET
G588: PR [W18] "
E589: (F0) U 500
F589: (F0) PR +$E$589*2000*1.1
A591: PR 'Pellet machine production rates should be used for the residue being
A592: PR 'pelleted and not for the rated capacity of the mill making animal feed.
A593: PR 'Enter the estimated production in tons per hour (e.g. .2500 for 1/4 ton)
A594: PR 'in the space directly under the label, RATE.  Actual daily production
A595: PR '(adjusted for repair and maintenance) will be calculated for you in
A596: PR 'pounds of fuel and shown directly under the label, DAYPROD.  Please
A597: PR 'continue !!
A599: PR '     2. Pellet Machine Production
E599: PR "RATE
F599: PR "DAYPROD
E600: (F3) U 600/2000
F600: (F0) PR (+$E$600*2000)*(7.5-($B$532/40))
A602: PR 'Gross income from the sale of your product will be a function of
A603: PR 'production, expressed in unit size (40 lb. bags, 50 lb. bags, ton), and
A604: PR 'the unit sales price.  Gross income will depend on the number of units
A605: PR 'sold of each unit size.  Enter the unit prices (e.g. 2.35 for $2.35 per
A606: PR '50 pound bag) for your unit size(s) in the space directly under the
A607: PR 'labels, 40LB, 50LB and TON.  Then determine the percent of sales that
A608: PR 'you anticipate making to retail and wholesale customers.  Retail prices
A609: PR 'are usually given for bagged fuel while wholesale prices are quoted by
A610: PR 'the ton.  Enter the percent sales (e.g. 75%) in the spaces directly
A611: PR 'under the labels, RETAIL and WHLSALE.  Daily gross income will be
A612: PR 'calculated for you and shown directly under the label, INCOME.
A613: PR 'Please continue !!
A615: PR '     3. Product Price & Gross Sales
B617: PR "RETAIL
C617: PR "WHLSALE
D617: PR "40LB
E617: PR "50LB
F617: PR "TON
G617: PR [W18] "INCOME
B618: (F2) U 0.75
C618: (F2) U 0.25
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D618: (C2) U 0
E618: (C2) U 2.35
F618: (C2) U 115
G618: (C2) PR [W18] (((+$F$600*$B$618)/40)*$D$618)+(((+$F$600*$C$618)/2000)*$F$618)+(((+$F$600*$B$618)/50)*$E$618)
A620: PR '---------
B620: PR '---------
C620: PR '---------
D620: PR '---------
E620: PR '---------
F620: PR '---------
G620: PR [W18] '------------------
A621: PR 'F.  OPERATING DAYS
A623: PR 'Operating days are determined by the amount of hogged residue that you
A624: PR 'generate and the production from the pellet mill that you purchase.
A625: PR 'From the daily pellet production and hogged residue supply that you have
A626: PR 'already entered, the maximum number of operating days have been
A627: PR 'calculated for you and is shown in the space directly under the label,
A628: PR 'MAXDAYS.  You may use the calculated value (may mean operating during
A629: PR 'holidays and scheduled vacation) or you can enter a smaller value due to
A630: PR 'holidays and vacation.  Either way, re-enter the calculated number or
A631: PR 'enter your number (e.g. 250) in the space directly under the label,
A632: PR 'ACTUAL.  Please continue !!
A634: PR '     1. Operating Days
D634: PR "MAXDAYS
F634: PR "ACTUAL
D635: (F0) PR +F589/F600
F635: (F0) U 246
A637: PR '---------
B637: PR '---------
C637: PR '---------
D637: PR '---------
E637: PR '---------
F637: PR '---------
G637: PR [W18] '------------------
A638: PR 'The final section of DENSEFUEL is designed to automatically return to
A639: PR 'the data you have entered and provide you with an analysis of your
A640: PR 'proposed pellet manufacturing facility.  Please continue !!
A642: PR 'G.  CASH FLOW FROM SMALL-SCALE DENSIFIED BIOMASS FUEL MANUFACTURING
A643: PR '    DURING AN 8-HOUR SHIFT
A645: PR '    Revenues
G645: (C2) PR [W18] +$G$618
A647: PR '    Costs
A648: PR '       property taxes
G648: (C2) PR [W18] (((+$G$241/100)*$G$266)/$F$635)*-1
A649: PR '       insurance
G649: (C2) PR [W18] (((+$G$241/100)*$G$287)/$F$635)*-1
A650: PR '       interest on borrowed capital
G650: (C2) PR [W18] (+$G$297/$F$635)*-1
A651: PR '       depreciation
G651: (C2) PR [W18] ((($D$320/4)/($F$635))+(($E$320/10)/($F$635))+(($F$320/20)/(F$635)))*-1
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A652: PR '      residue disposal
G652: (C2) PR [W18] ((+$E$589*$G$553)/$F$635)
A654: PR '    Labor
A655: PR '      base pay and all benefits
G655: (C2) PR [W18] (+$G$343)*-1
A657: PR '    Variable Costs
A658: PR '      electricity
G658: (C2) PR [W18] (+$G$506)*-1
A659: PR '      other fuel
G659: (C2) PR [W18] ((+G515/F635)*-1)
A660: PR '      repair and maintenance
A661: PR '        labor
G661: (C2) PR [W18] (+E530)*-1
A662: PR '        parts and supplies
G662: (C2) PR [W18] (+$F$530)*-1
A663: PR '      packaging
A664: PR '        bags
G664: (C2) PR [W18] (@IF(+$D$618=0,($F$600/50)*$E$542,($F$600/40)*$E$542))*-1
A665: PR '        pallets
G665: (C2) PR [W18] (((+$F$600/1000)*$F$542)*$C$618)*-1
A666: PR '      additives
G666: (C2) PR [W18] ((+$F$562*$F$600)*$E$562)*-1
A668: PR '                                 Income Before Taxes
G668: (C2) PR [W18] @SUM(G645..G666)
A670: PR '    Taxes
G670: (C2) PR [W18] @IF(+G668<=0,0,G668*$G$276)
A672: PR '                                 After Tax Profit
G672: (C2) PR [W18] +G668-G670
A674: PR '    Depreciation
G674: (C2) PR [W18] (($D$320/4)/($F$635))+(($E$320/10)/($F$635))+(($F$320/20)/(F$635))
A676: PR '                                 After Tax Net Cash Flow
G676: (C2) PR [W18] +G672+G674
A678: PR '                                        NOTE !!
A679: PR 'Since we have assumed that the small-scale pellet facility being
A680: PR 'examined is an "add-on" to an existing, profitable operation, the full
A681: PR 'amount of earned depreciation is added to after tax profits to arrive at
A682: PR 'after tax net cash flow.
A684: PR '---------
B684: PR '---------
C684: PR '---------
D684: PR '---------
```