WOOD FUEL: AN ALTERNATIVE ENERGY SOURCE FOR AGRIBUSINESS AND INDUSTRY

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Wood fuel is becoming increasingly more important as an alternate energy source because of price and shortages of fossil fuels. Furthermore, energy prices are expected to continue to rise in future years (U.S. Dept. of Energy, pp. 56–72). As a result, agribusiness firms in the Southeast are investigating the feasibility of utilizing wood residues or whole tree green chips for their fuel supply. Some industries may continue to rely partially on their present gas- or oil-fired systems and add a wood-fired boiler as a backup system. The availability of wood as an industrial fuel at a competitive price is one of the major concerns of these firms.

Previous studies have categorized wood fuel and impact analysis research into four broad areas (Palmer, et al., p. 2). These studies have considered (1) under-utilized resources and residues; (2) unmerchantable materials removed during cultural operations; (3) surplus growth; and (4) allocation of resources to maximize social benefits.

This study differs from the above in that it analyzes the present supply, demand, and price of wood residues through an industry survey, and then estimates quantities available from presently unused resources as price increases.

The objectives herein are: (1) to determine the supply and marketing network for wood fuels necessary to meet the weekly requirements of 14 specific firms, and (2) to estimate the cost of supplying wood fuels to several locations in the northern two-thirds of Georgia.

DATA AND METHODS

A survey of 173 firms producing wood residues in the form of bark, sawdust, shavings, mixed materials, and pulp chips was conducted during January and February, 1980, in north, central, and middle Georgia. The aggregate wood fuel supply for this area represents the quantities of wood residues and pulp chips that sawmills, veneer and plywood plants, furniture and handle plants, pallet factories, whole tree chippers, and others produced on a weekly basis during the winter. Data were collected on the weekly capacity of sawmills in board feet, seasonal variations in production, quantity, value of various wood residues, plus destinations, marketing conditions, and transportation costs for the firms in this area.

WOOD AS A FUEL

There are variations in heating value among the types of wood fuels found in the Southeast. Oven-dry loblolly pine will produce an average of 8,600 BTUs per pound; dry slash pine bark 9,002 BTUs per pound; and white oak 8,500 BTUs per pound (Arola, 1976, pp. 37, 38). However, the species of wood residue is not so important as the moisture level at which the wood fuel is burned.

Living trees usually contain large quantities of water, often more water than organic matter on a weight basis. Freshly cut whole trees would be expected to contain as much water as wood substance by weight, i.e., 100-percent moisture content on an oven-dry basis. The formula for calculating moisture content on a dry basis is the difference in the weight of wet wood minus oven-dry weight divided by the oven-dry weight and then converted to a percent value.

Wood gives off moisture from the time of cutting through delivery to the user, and often after it is in use. When wood is exposed to ambient air, but protected from rain, over a long period of time, it will stabilize at around 16-percent moisture content on an oven-dry basis. The as-fired heat value of green wood fuel at 50-percent moisture content would be only one-half its BTU value on an oven-dry basis (Arola, 1976, p. 39).

The relative heating values of bark, sawdust, shavings, whole tree chips, or pulp chips are assumed to be 8,600 BTUs per pound on an oven-dry basis; however, differences in moisture content result in the purchase of variable amounts of water with each ton of wood fuel. The moisture content values in Table 1 are typical, but can vary depending on the supply source.

The oven-dry BTU values presented in Table 1 are intended to reflect the heating value of wood

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This research was partially funded by a grant from the Office of Planning and Budget, Georgia Office of Energy Resources, Atlanta, 1980.

Contributed paper presented at the Southern Agricultural Economics Association meeting in Atlanta, Georgia, February 1–4, 1981.

TABLE 1. Equivalent Usable Heat Values for Different Types of Wood Fuels in Georgia, 1980

Fuel Type	BTUs Per Ton Oven Dry[a]	Moisture Content[b]	BTUs Per Ton[c]	Efficiency[d]	Useful BTUs Per Ton	Amount of Wood Fuel to Generate One Million BTUs
	- mil. -	- percent -	- mil. -	- percent -	- mil. -	- tons -
Bark	17.2	40	12.3	72.8	8.95	.112
Sawdust	17.2	80	9.6	67.6	6.49	.154
Shavings	17.2	15	15.0	76.1	11.42	.088
Whole Tree Chips	17.2	100	8.6	65.0	5.59	.179
Pulp Chips	17.2	90	9.0	66.3	5.97	.168

[a] The baseline BTU value is the average for Loblolly pine stemwood, oven-dry basis (Arola, 1976, pp. 37–38).

[b] Moisture content is given on an oven-dry basis. The formula for calculating moisture content oven-dry basis is wet weight minus oven-dry weight divided by oven-dry weight and converted to a percent value.

[c] The value of wood fuel in BTUs per ton when the moisture content is taken into consideration. Net BTUs = BTUs per ton − 100 + M.C.

[d] Percentage of useful heat per unit of wood fuel. The net combustion efficiency of wood fuel is the ratio of BTUs as fired to BTUs converted to steam in the boiler. The efficiency of equipment will depend upon design, maintenance and other factors. Therefore, the net percentage will deviate from one boiler situation to another.

residues available at a conventional sawmill or, in the case of whole tree chips, a portable chipper processing fuel wood. These values serve primarily to emphasize the economic impact of wood fuel selection on the cost of energy production.

PRICE, QUANTITY, AND MARKETING RELATIONSHIPS FOR WOOD RESIDUE FUELS IN THE SURVEY AREA

Supplies of mill residues suitable for fuel are currently available and extensively used by the forest products industry. Quantities of logging residues, and low-grade and under-utilized standing trees have been estimated by the U.S. Forest Service for southeastern forests, but these residues are not economically accessible at 1980 fuel prices. However, innovations in harvesting technology may lower recovery costs of these residues.

The demand for wood residues for fuel is affected by supply and demand conditions, environmental concerns, and the habits of traditional markets. Before the Environmental Protection Agency (EPA) halted the burning of wood residues in 1975, many mills simply burned their bark, sawdust, and slabs, or let them rot. Since 1975, mill operators either have found a market for their residues, stockpiled them near the mill site, or transported the residues to a landfill. Buyers of wood residue material have increased gradually over the years, and now some residues from sawmills and other primary wood industries that were once discarded are sold. Arola estimated that 26 percent of all mill residues in the U.S. were unused in 1977 (Arola, 1978, p. 111).

TABLE 2. Supply and Price of Wood Residues Available from Sawmills and Other Industries in North, North Central, and Middle Georgia, 1980

Materials	Output	Distribution	Weighted Average Price[b]
	- tons per wk -	- percent -	- $ per ton -
Other Miscellaneous Residue Materials[a]	16,555	34	4.01
Bark	10,930	22	4.02
Sawdust	17,785	36	4.14
Shavings	3,776	8	6.81
Subtotal	49,046	100	
Chips	42,487		15.92
Total	91,533		

[a] Residue materials in the "other" category include mixed sawdust, bark and wood scraps.

[b] The weighted average price was calculated as:

$$\frac{\sum \text{quantity} \times \text{price per ton}}{\text{total quantity}}$$

Analysis of the survey data for Georgia indicates that 5 to 12 percent of the residues were unused in 1980, depending upon regional demand.

In the survey area, 173 sawmills produced 49,046 tons of wood residue material per week. Approximately 36 percent of these residues consisted of sawdust, 22 percent bark, 8 percent shavings, and 34 percent other materials (Table 2). The weighted average price of wood residues ranged from a low of $4.01 per ton at the mill for miscellaneous wood residues, to a high of $6.81 per ton for shavings. The weighted average price for pulp chips, which included both pine and hardwood chips, was $15.92.

Wood residue marketing practices depend upon the type of material and the number of competing firms. Bark as a wood fuel is derived from sawmills or from whole tree chipping operations. The current market for bark produced by the surveyed firms consists of sales to papermills, agribusinesses, wood product industries, and other buyers. Some quantities of bark were either being dumped or stockpiled at a cost to the sawmill. The types of outlets for wood residues produced by firms in the survey are given in Table 3.

Sawdust was the most widely used wood residue fuel in the survey area. Papermills purchased sawdust and mixed residues consisting of bark, sawdust, and wood scraps for fuel. Nationally, pulp and papermills are about 40 percent energy self-sufficient. Nearly three-fourths of their self-generated fuel is derived from processing wastes, principally pulping liquor (Mitre Corp., p. 3). The remainder consists of wood residues and bark, making papermills important markets for wood fuels.

The trend toward wood fuel has benefited sawmill operators to a limited degree. The buyers of residues are aware of the disposal problem faced by the sawmills. The price offered for wood residues may be low because of the impact

TABLE 3. Weekly Disposal of Wood Residues by 173 Firms in North Georgia, 1980

Destination of Wood	Bark	Sawdust	Shavings	Mixed Residues	All Materials
	percent distribution				
Stockpiled	5	a	-	10	5
Papermills	16	31	1	31	25
Wood Products Industry	2	5	39	4	7
Dumped	5	8	-	12	9
Own Use	23	-	13	5	8
Agribusiness	12	24	34	12	16
Trucking Company	24	5	-	-	7
Sold, Buyer Unspecified	13	27	13	26	23
Total	100	100	100	100	100

[a] Sawmill operators were unable to provide a reliable measure of the amount of sawdust stockpiled. Stockpiled residues were often transported to an off-site location but accessible to potential buyers.

of environmental regulations, since sawmills have been faced with disposal problems that did not exist prior to those regulations. Buyers are aware of the mills' needs to dispose of their residues and consequently offer the lowest price possible. Frequently, the price of the residues will merely cover transportation costs. Occasionally, a mill operator will lose money on each load transported to the user, but accepts this loss as his disposal cost.

An important link between buyers and sellers of residues in the survey area was the independent trucker. Truckers usually deal in only one type of residue by acting as brokers; they buy residues from sawmills and find their own markets. An estimated 15 percent of the 60 independent truckers surveyed expressed an interest in expanding operations to meet the increased demand for transportation of wood residues. Independent trucking companies wanted wood fuel hauling contracts that compensated the truckers for rising fuel costs during the life of the agreement.

COST OF TRANSPORTING EQUIVALENT BTUS

One-way hauling distances for wood chips and residues in the survey region ranged from 2 to 212 miles, with an average distance of 57 miles. One factor that increased the variability of these distances was the type of business arrangement between companies and haulers. Truckers working under contract generally were willing to travel farther to obtain wood chips than were independent truckers. Company-owned mills also transported wood residues over longer distances to company-owned plants than did independent truckers.

Transportation costs obtained from the survey of the wood residue trucking industry ranged from a low of $0.90 per loaded mile to a high of $2.60 per loaded mile. Ten percent of the costs was less than $1.01; 63 percent was within the range of $1.01 to $1.50 per loaded mile; and 27 percent was greater than $1.51 per loaded mile. Costs per ton mile ranged from $0.050 to $0.068, based on a median truck capacity of 22 tons.

The potential marketing area for wood fuels is related to transportation costs, moisture content of the wood, and density or quantity of material per loaded vehicle. Loaded weight per cubic foot of cargo space is largely determined by particle size, shape, and moisture content. Because fuel users must often choose between two or more available wood fuels, it is important to know which fuel will provide the maximum usable BTUs at the least cost. This comparison is facilitated by the creation of an indifference index. The indifference index shows the value at which either commodity will serve equally well in satisfying the user's need. The indifference index for usable BTUs in Table 4 indicates that sawdust costs 1.68 times more per million BTUs to transport than bark. In terms of miles, sawdust at 60

TABLE 4. Equivalent Transportation Cost for Hauling Wood Residues, North Georgia, 1980

Fuel Type	Weight per Cu. Ft.	Tons per Load 40 ft. Van	Cost per Loaded[a] Mile	Cost Per Ton	Cost Per Mile Per MIL. BTUs	Indifference Index Usable BTUs	Indifference Index Miles
	-- lbs. --	-- tons --	- dollars-	-cents/mi.-	-cents-	----- index ----	
Bark	21	22	1.50	6.82	0.762	1.00	1.00
Sawdust	15	18	1.50	8.33	1.283	1.68	.60
Shavings	13	15	1.50	10.00	0.884	1.16	.87
W.T. Chips	32	22	1.50	6.82	1.220	1.60	.52
Pulp Chips	21	22	1.50	6.82	1.142	1.50	.67

[a] Since 63 percent of the truckers surveyed indicated a range of $1.01 to $1.50 per loaded mile, using the upper limit of transportation costs per loaded mile will influence the cost per million BTUs per mile but not the relative ranking of fuel materials in the index.
Source: Baxter, p. 37.

miles' distance will cost the same per million BTUs to transport as will bark 100 miles away.

If the price of a given wood fuel is combined with its transportation costs, its value as fuel can be determined. The average value of bark at the sawmill was $4.02 per ton, and transportation cost was $0.0682 per ton mile. The average delivered price, including transportation cost, was $7.91 per ton, assuming an average hauling distance of 57 miles. Therefore, cost for wood fuel users was $0.88 per million BTUs, assuming 8.95 million usable BTUs per ton. The average delivered price for sawdust was $8.89 per ton, or $1.37 per million BTUs. The average delivered price for hardwood pulp chips was $12.89 per ton, yielding a fuel value of $2.31 per million BTUs, assuming 5.59 million BTUs per ton.

EQUIVALENT VALUE OF WOOD AND FOSSIL FUELS

The fuel cost equivalencies of wood chips and fossil fuels can be calculated when the current or projected delivered prices for particular fossil fuels are known. Fuel equivalency calculations include a correction for combustion efficiency differences and moisture content differences, which influence the conversion ratio between wood and fossil fuels.

The appropriate BTU values and boiler efficiencies for coal, natural gas, and fuel oil are given in Table 5. The prices used in the comparisons represent market prices for wood residues as reported in the survey, whereas the prices of fossil fuels were obtained from dealers in Georgia who service the participating firms. Comparisons of delivered price per million BTUs of wood residues and fossil fuels indicate that bark, sawdust, and hardwood chips were competitive in price with coal, fuel oil, and natural gas. Hardwood pulp chips at $9 per ton was the most expensive wood fuel, but less costly than coal, fuel oil, or natural gas.

The comparative analysis indicates that bark was the least costly fuel, assuming 1980 prices and a hauling distance of 30 miles. The delivered prices of fuel from sawdust and hardwood chips were 50 and 191 percent higher, respectively, than was the price of energy from bark.

POTENTIAL SAVINGS FROM CONVERSION TO WOOD FUEL

Wood fuel requirements for 14 firms participating in the wood fuel feasibility study were calculated based on current fuel usage. Annual wood fuel costs were based on hardwood chip tonnage rather than on lower-cost wood residues, such as bark, sawdust, or mixed residues, to lend uniformity to the analysis of energy savings from wood fuel conversion. Seven of these firms could meet their wood fuel needs, a total of 1,602 tons per week, from supplies within an arbitrary 30-mile radius of their locations. If the 7 firms converted to wood fuel chips, the estimated savings in energy costs would range from 23 to 51 percent of annual fossil fuel costs in 1980 (Table 6). Annual wood fuel costs would be even lower if wood residues rather than hardwood chips were used.

The 7 firms that were unable to meet their wood fuel requirements from residue supplies within 30 miles of their plants needed 14,736 tons of wood chips per week. This is equivalent to their combined annual fossil fuel requirements of 3,477,874 million cubic feet of natural gas, 1,909,260 gallons of #2 fuel oil, 1,168,000 gallons of #6 fuel oil, and 45,213 tons of coal. Approximately 15 percent of their demand could be met from unsold sawmill residues within a 30-mile radius of their plants. Therefore, the 7 firms

TABLE 5. Cost Comparisons for Alternative Fuels in Georgia Taking Combustion Efficiency of Each Fuel into Consideration, 1980

Fuel	Unit	Cost Per Unit	BTUs per Unit	Combustion Efficiency[b]	Delivered Price Per Million BTUs
		- dollars -	- mil. -	- percent -	-- dollars --
Coal	Ton	50.12	26.00	70	2.75
#2 Fuel Oil	Gal.	.77	0.148	82.5	6.31
#6 Fuel Oil (2.7% Sulfur)	Gal.	.53	0.152	82.5	4.23
Natural Gas	M Cubic Feet	2.90	1.00	80	3.63
Wood Residues:					
Bark	Ton	4.02[c]	8.95[d]	72.8	0.68[e]
Sawdust	Ton	4.14	6.49	67.6	1.02
Hardwood Chips	Ton	9.00	5.59	65	1.98

[a] Average price of fossil fuels paid by firms participating in wood fuel study as reported to the Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, January 22, 1980.
[b] Combustion efficiency rates for energy studies from Engineering Experiment Station, Georgia Institute of Technology. The combustion efficiency for wood was already calculated in determining BTU values for wood residues.
[c] Prices of wood residues from Table 2, Column 3.
[d] Table 1, Column 5.
[e] The delivered price assumes a hauling distance of 30 miles.

TABLE 6. Estimated Wood Fuel Requirements and Current Fuel Use of 7 Firms in Georgia, 1980

Type of Firm	Current Fossil Fuel Use[a] Gas	Oil	Coal	Annual Fossil Fuel Costs	Estimated Wood Fuel Requirements[b]	Estimated Annual Wood Fuel Costs[c]	Estimated Savings in Energy Costs if Wood Fuels Were Used
- product -	- MCF/yr -	-gal/yr-	-tons/yr-	- dols/yr -	- tons/yr -	- dols/yr -	- percent -
1. Textiles	18,461	12,800 #2	--	63,393	3,120	34,476	46
2. Poultry Processing	157,500	--	--	456,750	24,232	267,764	41
3. Textiles	111,194	275,000 #2	--	534,212	23,556	260,294	51
4. Poultry Processing	82,105	91,345 #2	--	308,440	14,768	163,186	47
5. Textiles	42,300	--	--	122,670	6,500	71,825	41
6. Poultry Processing	52,000	33,000 #5	--	168,290	8,788	97,107	42
7. Flotation Devices	--	--	670	33,580	2,340	25,857	23

[a] Unpublished data, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia.
[b] The estimated weekly wood fuel requirements were determined by converting the volume of fossil fuels into BTUs. The annual fuel requirements were then converted into tons of wood chips, assuming 4,000 BTUs per pound at 50 percent moisture content.
[c] The estimated wood fuel costs were calculated at $11.05 per ton which included transportation costs for 30 miles.

would have the following options in fulfilling their remaining wood fuel needs: (1) they could compete in the market place with present buyers of sawmill residues, outbidding their competitors; (2) they could purchase logging residues that can be chipped into fuel material at a higher price; or (3) they could purchase whole tree chips for fuel.

The first two options would be the most economical solutions among potential wood fuel users' supply alternatives. Larger individual users would have to supplement residues with wood fuel chips or pay higher prices to haul residues longer distances.

Survey information seems to indicate that the least-cost method for producing additional wood for fuel would be to salvage the top bole portion of trees in conjunction with sawlog operations. Cull portions of logs could be salvaged, transported to sawmills, and converted into wood fuel chips. If these materials are available in increasing volumes in the $5 to $7 per ton price range, it

is estimated that 20 percent of the softwood cull logs, 30 percent of the upper stems, and 80 percent of the tops and branches would be available for harvesting as wood fuel.

A recent study indicated that two-thirds of the forest residue in the eastern United States, consisting of 50 percent softwood and an equal amount of hardwood, is concentrated in the South. The remaining one-third of the residue, consisting mainly of hardwood material, is located in the northeastern and north central states. This material represents a potential fuel source of 138 million dry tons per year, or 2.35 quads BTU, if efficient technology exists for removing this material from the forest (Carpenter, p. 13).

The Georgia Forestry Commission estimates that available supplies of wood fuels in Georgia could be used to provide the equivalent of at least 48 million barrels of oil each year without significantly affecting supplies of wood for conventional uses. The commission assumed a conservative estimate of utilization in which 10 percent of annual logging wastes, 10 percent of cull trees, 25 percent of excess annual growth, and 50 percent of annual processing plant wood wastes would be available for wood energy (Georgia Forestry Commission, p. 9).

DISCUSSION AND IMPLICATIONS

Although wood fuel is only a partial answer to this country's energy needs, investments in boiler facilities are being planned by the forest products industry, agribusiness firms, textile plants, utilities, and municipalities to utilize the Southeast's abundant wood fuel resources.

Arola and Dixit analyzed the capital investment needs for the installation of wood combustion systems to determine the break-even point. Arola's analysis, which compared fuel oil to bark indicated that investment in wood combustion equipment results in a break-even point of about 2.5 years for equipment, with an estimated 10-year life, assuming a 25-percent discount rate (Arola, 1976, p. 40).

Using 1980 prices, Dixit analyzed the replacement boiler costs for a typical textile firm and calculated the approximate payback period. Conventional fuel for the typical textile firm consisted of 85 percent natural gas and 15 percent fuel oil. With wood fuels at 50-percent moisture content, the estimated payback period was 2.5 to 3 years (Dixit, p. 22). These investment calculations were sensitive to changes in fuel prices, especially of fossil fuels. A 25-percent increase in fossil fuel prices would result in an increase in the expected fuel savings of at least 60 percent, while the same percentage change in wood fuel prices would reduce the energy savings by only 13 percent for a given system, other conditions remaining the same (Dixit, p. 21). The feasibility of wood fuels as an alternative energy source was enhanced if the respective plant were energy intensive.

The Mitre Corporation also analyzed the impact of a retirement tax credit and of an investment tax credit on the expansion of the use of wood fuels in the forest products industry. The retirement tax credit could provide a strong incentive for early retirement of gas- and oil-fired boilers and thereby encourage the installation of new wood-fired facilities (Mitre, p. 45). Furthermore, a firm's cash flow position, type of energy system, tax incentives, short- and long-range planning horizons, and borrowing capacity will certainly influence decisions to invest in wood combustion equipment.

In 1980, according to survey data, wood fuels were available from sawmill residues at $4 to $6 per ton in north Georgia. A total of 6,866 tons of unused mill residues was available weekly for fuel or other uses. If demand were to increase beyond currently available sawmill residue volumes, logging residues could become economically accessible for fuel use.

The estimated savings in energy costs would range from 23 to 51 percent if wood fuels were substituted for fossil fuels by firms in north Georgia. However, the prices for wood fuels are sensitive to moisture content and transportation costs. As the infrastructure for supplying and utilizing wood fuels develops, it is expected to reduce the nation's dependence on high-priced fossil fuels and to contribute to its independence from foreign sources for energy.

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