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by Leonard R. Johnson

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Quantities and Costs of Wood Biomass in Idaho

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INTRODUCTION

Biomass from wood fiber can be converted to a number of usable energy forms: steam, electricity, medium-BTU gas, fuel oil, and others. Conversion technology exists in all cases, but is more advanced and less expensive for some products than for others. The wood fiber needed to supply these processes is available from under-utilized wood and bark at wood and paper processing plants, from residue left in the woods and at landings after logging operations, and from diseased and dead trees. The principal problem with greater utilization of these materials is economic—the cost of delivering the raw material to a processing point.

Idaho contains over 15 million acres of commercial timberland (USDA Forest Serv. 1973) and supports a sizeable wood products industry. The timberland and residue created from operations on these lands are distributed as shown in Figure 1. Figure 1 also shows population centers of Idaho as they relate to timberland. Most timber in northern Idaho will be located within 50 miles of a population center; distances in central Idaho will be greater. The overview shown here tends to substantiate the statement that average haul distance for commercial timber harvest in this region is 40 miles (Grantham et al. 1974). The proximity of forest residues to population centers will affect not only the cost of delivering the fiber to a user, but also the energy product produced. If an industrial steam user is located within a reasonable distance of a forested region, then the wood can be fired to produce steam. If not, the wood may have to be burned to produce electricity or pyrolyzed to a synthetic gas or oil. Steam production can be accomplished at a higher conversion efficiency than the other two processes.

An alternative to the consumption of current stands of timber or their residuals is growth of wood fiber specifically for use as an energy source. The concept has been called an energy farm, a fuel plantation, and other similar names. The process involves cultivation of fast-growing tree species on a short rotation (harvest every 5 to 15 years). Form of the tree is not important, since the goal is the greatest volume of fiber that can be grown per unit of area. Preliminary estimates of the cost of the fuel show it to be competitive with conventional fuels. However, the plantations require large areas of land that must meet certain suitability criteria.

QUANTITIES OF WOOD RESIDUE

Estimates of quantities of wood residue were obtained from inventories conducted by the USDA Forest Service and were abstracted from a report developed for the Northwest Energy Policy Project (NEPP) (Johnson et al. 1977). Measures of cubic volume were converted to weight and energy potential at the rates of 25 dry lb/cu ft and 8500 BTU/dry lb.

The volume estimates obtained from Forest Service sources were modified to include tops, limbs, and bark. The resulting volumes for various categories of residue are shown in Table 1. It is easier to recover residue volume in some of these categories than in others. For example, mill wood and mill bark are usually available in consolidated quantities at easily accessible mill sites. The volumes of annual mortality, excess annual growth, and existing cull will be located in the woods and may not be accessible. Logging residues will be accessible through the logging roads used in the commercial timber harvest, but will be widely dispersed.

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The report prepared for the NEPP classified mill wood, mill bark, and logging residues as realistically collectable. The quantities in the other three categories were not considered collectable at the present time because of the high costs of complete recovery and the general lack of access via roads. The three recoverable categories represent an annual volume of 126×10^6 cu ft or an energy potential of 27×10^{12} BTU.

The quantities presented here represent the aboveground portions of the trees. Inclusion of the stumps and roots of the trees would add to the amount of forest residue (Lowe 1973). Logging residue would increase from 61×10^6 cu ft to 80×10^6 cu ft. Although research is continuing on methods to recover the below-ground portions of trees, they are generally not realistically collectable now, given Idaho terrain conditions and tree species.

Commercial timberland in Idaho covers 15,192,000 acres (USDA Forest Serv. 1973). The logging residue shown in Table 1 averages 4 cu ft/acre of commercial timberland. This is not an indicator of the residue volume per acre on a single logging site; that volume will be much higher. If timber harvest operations are distributed uniformly throughout all commercial timberland, however, 4 cu ft/acre represents the residue that will be available annually over the years. At this volume level a 50-MW electrical generating plant would require 4,390,000 acres of commercial timberland annually (Gardner and Gibson 1974). This implies residue delivery from an area of contiguous commercial timberland in a 47-mi radius. The annual quantities of forest residue shown in Table 1 could fuel 3.4 50-MW electrical generating facilities in Idaho.

If the existing cull shown in Table 1 could be recovered, it would be sufficient to fuel 190 MW of electrical generation for 20 years.[1] However, all of this volume will probably not be recoverable and, because of natural decay processes, will not last the full 20 years.

The energy potential of the wood residue presented in Table 1 represents the higher heating value of the wood. It cannot be converted to an energy product without some loss in conversion efficiency. Characteristically, high moisture content of the wood residue will reduce conversion efficiency in the production of steam to a range of 66 to 70 percent. Conversion efficiency in the generation of electricity will range between 27 and 30 percent. At a 66 percent conversion efficiency from wood to steam, the realistically collectable quantity of residue (mill wood, mill bark, and logging residue) represents an annual energy potential of 17.7×10^{13} BTU.

Mill wood and mill bark are currently being used for a variety of products, one of which is fuel. An inventory conducted in 1970 (USDA Forest Serv. 1973) showed 30×10^6 cu ft of mill wood and mill bark residues in Idaho being used for fuel. This represented 15 percent of the total quantity of mill residues. Paper and fiberboard products accounted for 47 percent of the mill residues, leaving 38 percent unused. Utilization of mill residues has increased in the last few years. A survey of sawmills was recently conducted in the state of Washington (Bergvall et al. 1977). In 1968 the survey showed 14 percent of the mill wood residue unused and 32 percent of the mill bark unused (Bergvall and Gedney 1970). In 1976 these figures had been reduced to 7 percent and 18 percent, respectively. The trend is likely to continue, with most utilization taking place in the forest products industry.

COST OF WOOD RESIDUE

Although availability is decreasing, mill wood and mill bark residues represent the least expensive form of wood waste. The price of these residues fluctuates with the market for their other uses (e.g., chips for paper and fiberboard production). The 1976 price on the west coast for various forms of these residues (expressed in equivalent

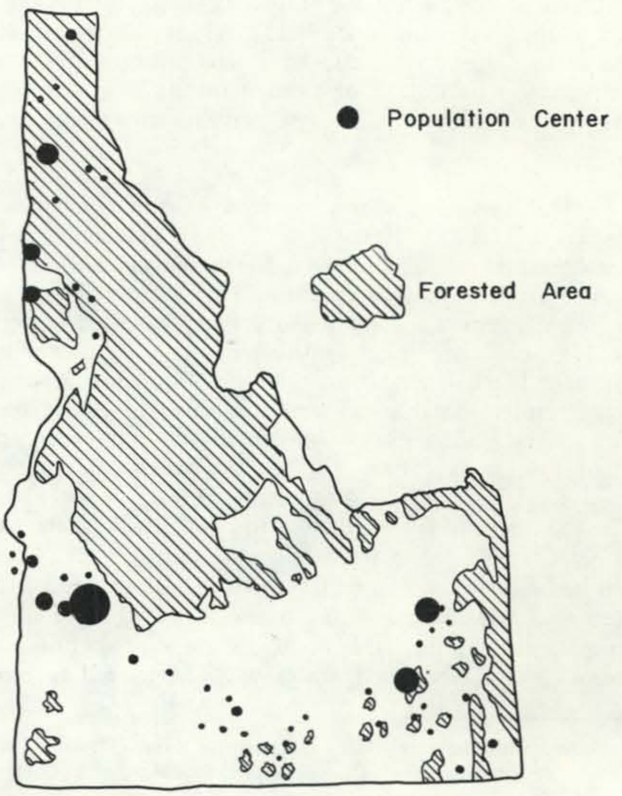

Figure 1. Overlay of population centers and forested areas in Idaho.

From Little, E.L., Jr. 1971. *Atlas of United States trees*. USDA Forest Serv. Misc. Publ. No. 1146, Vol. 1, March. Washington, D.C.

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[1] Using a plant load factor of 70% and a thermal conversion efficiency for the wood of 27.4%.

Table 1. Volume, weight, and energy potential of wood residue available annually in Idaho, by source.

	Volume (millions cu ft)	Weight[1] (millions dry tons)	Higher heat value[2] (trillions BTU)
1. Unused mill wood	41.0	.51	8.72
2. Unused mill bark	25.1	.31	5.32
3. Logging	60.5	.76	12.90
4. Annual mortality	98.5	1.23	20.90
5. Excess annual growth	146.0	1.83	31.00
6. Existing cull[3]	1956.0	24.50	416.00
TOTAL	2327.0	29.10	495.00

[1] At 25 dry lb/cu ft.

[2] At 8500 BTU/dry lb.

[3] Volume of existing cull would not be available on an annual basis.

dollars per million BTU) averaged \$.15/MMBTU[2] for sawdust, \$.34/MMBTU for bark, and \$2.23/MMBTU for chips (Howlett and Gamache 1977). The price of sawdust and bark could provide an economic incentive to convert from facilities using gas or oil to facilities fired by wood. However, the fuel-equivalent price of wood chips exceeds current prices of conventional fuels.

One of the deterrents to greater activity in converting to wood-fired facilities is uncertainty about future demands for wood and bark residues in the production of traditional wood products. If the demand for these products rises, as some projections show, the result will be an increase in the price of wood residues for fuel or any other use. The capital cost of a wood-fired system is high, and subsequent operating costs are higher than with gas or oil systems. These extra costs must be offset by fuel savings. With an increase in wood residue prices, this economic incentive for conversion to wood-fired facilities would be reduced.

Forest residues are a less economical source of fuel than mill residues because of the cost involved in delivering them to a processing point. Recovery of a non-uniform material such as forest residue is accomplished most economically when the material is broken down into a uniform size for long distance transportation. Equipment such as whole tree chippers or portable hammer hogs is available to accomplish this task, but transportation of such material still involves transport of a great deal of moisture. Systems are currently available to compress, compact, and bale chips and other forest residues. If these systems could be designed on mobile carriers and moved to locations near the residue sources, there could be savings in the total cost of such operations.

There are physical limitations to the areas where whole tree chippers and the long semi-trailers necessary for hauling chips can operate. For instance, they may not be able to operate efficiently in steep terrain where landing space is limited and roads are narrow. Some modification of existing equipment may be necessary to allow operation in the steep terrain that is characteristic of much of Idaho.

Costs of residue recovery were estimated in the NEPP report on the basis of various collection scenarios (Johnson et al. 1977). An area logged with no attempt at residue utilization will have to be completely relogged. Costs for this recovery operation will be higher than if the residues were recovered as part of the original logging operation or if all timber in the area were cut and chipped. Costs can also be reduced if the cost to move the residue to roadside is borne by the timber harvest as part of a site betterment requirement. The breakdown of costs for individual elements of the recovery process is shown in Table 2. These costs are totaled and presented in Figure 2 as a function of hauling distance.

MITRE Corporation estimated recovery costs at \$43.00 to \$61.00 per dry ton when conventional cable logging systems were used and the residue was hauled 50 miles (Inman 1977). These estimates are higher than those of NEPP. A report developed by Stanford Research Institute listed recovery costs (excluding transportation) at \$10.00 to \$17.00 per dry ton (Stanford Res. Inst. 1976). These estimates are slightly lower than those calculated in the NEPP report. One conclusion that can be drawn from this range of collection and delivery costs is that the real cost of residue collection is not known with any degree of certainty.

Recovery of forest residues requires an expenditure of energy but results in a net energy gain. Hall et al. (1976) estimate the energy expenditure at 5.7 percent of the energy recovered.

The cost of forest residues in these analyses was determined as the cost of recovery. No value was assigned to the residue itself. Since current forest practices call for the disposal of residues, this is probably a valid assumption.

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[2] 1 MMBTU = 1 million BTU.

Table 2. Breakdown of costs in dollars per dry ton and dollars per million BTU to deliver wood residue to a process point.

	$/Dry ton	$/Million BTU[1]
Deliver to landing		
Compete relogging[2]	16.50	.97
As part of sawlog operation	5.40	.32
Complete whole tree harvest[4]	8.40	.49
Pre-process (chip)[5]	4.50	.26
Haul[6]		
at 25 miles	4.25	.25
at 40 miles	6.80	.40
at 50 miles	8.50	.50
at 60 miles	10.20	.60
at 75 miles	12.75	.75
Profit[2]	6.70	.39

[1] At 8500 BTU/dry lb.
[2] Grantham et al. 1974.
[3] Johnson and Arkills. 1975.
[4] Gardner and Gibson. 1974.
[5] Average of above 3 studies.
[6] Average of above 3 studies.

However, there are three areas where unanswered questions cloud the issue of forest residue utilization. On public lands, there are the questions of how this operation would be controlled and administered, and who would pay for the cost of administration. One possible solution is for the land managing agency to assume the cost of administration in return for the benefits of slash disposal.

The second unresolved area relates to the effect of residue removal on the residual stand. Residues left on a logging site will return nutrients to the soil, and total removal of these residues could affect future site productivity. The effect of certain levels of residue removal on site productivity and the effect of residual stand damage incurred in recovery operations are not known with certainty. In addition, there are also positive effects of residue removal: reduction of fire hazard, ease in regeneration, etc., and these also must be considered in a complete analysis of the effects of this problem.

The third area relates to year-round supply of residue. Since recovery operations will be weather-dependent, the question of assuring a continuous supply of material through storage will also have to be addressed.

Once the forest residues have been delivered to a process plant, their costs and problems are the same as for mill residues.

CONVERSION COSTS

The two energy products generally discussed in conjunction with wood residues are process steam and electricity. Electricity would be produced through the use of steam-driven turbines. Other conversion processes are available that could convert the wood to a variety of liquid, solid, or gaseous fuel derivatives. However, conversion to steam or electricity is the most advanced of the technologies and currently the least costly.

The central feature of either a steam or an electric plant will be one of several styles of steam boiler in a size geared to the plant's specific requirements. Additional equipment will be required to handle the wood chips, to store an adequate supply of chips, and to control flow of the chips to the boiler. In some instances a drying facility will be installed to pre-dry chips to a certain moisture content. Air quality standards will require emission control equipment capable of trapping the particulates from combustion. If electricity is to be the primary product, a generating facility will be required.

The cost of the boiler will, logically, depend upon its size, but there is a cost break at about 100,000 lbs of

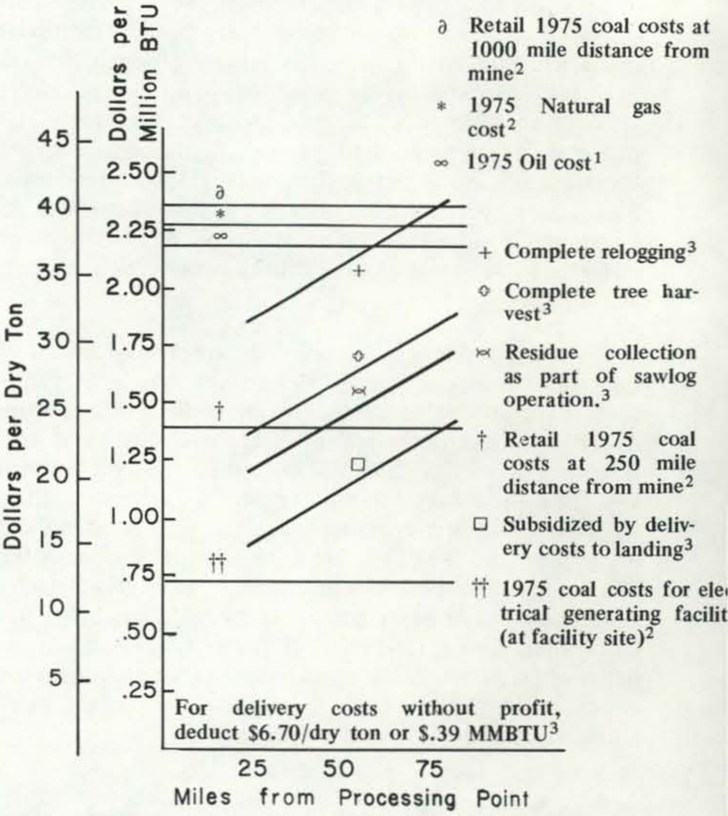

Figure 2. Delivery cost (with profit) as a function of distance from process point, using higher heating values of fuels.[1]

[1] See Table 2.
[2] McFadden 1977.
[3] Johnson, et al. 1977.

steam/hour between boilers that can be assembled at a fabricating plant and shipped complete and those that must be erected in the field (USDA Forest Serv. 1975).

It is difficult to determine an average cost of steam production because of the variability just noted. However, using data from the USDA Forest Service (1975), CH2M Hill (1976) and a Vermont Study (Hall et al. 1976), typical costs can be established for two plants, one rated at 60,000 lb of steam/hour and another at 300,000 lb of steam/hour.

Analysis performed by CH2M Hill (1976) for a solid waste plant on the southwest coast of Oregon provides the basic data for a small plant. Capital cost is set at $5.5 million, with an annual operating cost of $350,000. The plant yields 394 million lb of steam/year at a cost of $2.54/1000 lb of steam ($1.95/MMBTU).

Data for large plant costs were obtained from operating costs of a 50-MW generating plant (Hall et al. 1976) and steam plant capital costs of the USDA Forest Service (1975). Capital costs of a 300,000-lb/hour plant were set at $12.5 million dollars[3] and annual operating costs at $556,000. The plant will yield 2 billion lb of steam/year at a cost of $1.03/1000 lb ($.79/MMBTU). Costs and energy requirements of the two plants are summarized in Table 3.

The primary environmental impact resulting from the combustion of the wood residues will be air emissions. Emissions are controllable through particulate collectors and other emission equipment (these also add to the cost of the system). Wood provides a more environmentally acceptable fuel than coal, since it does not contain sulfur (Johnson et al. 1977).

The costs calculated in these two examples should not be taken as average costs or as truly representative of what process steam from wood will cost. Differences in plant size, the capability of existing facilities, and the particular equipment combination needed will cause significant differences in total costs. We can, however, extend these case studies to determine total energy costs, including fuel, when using both mill and forest residues, and to determine residue quantities and acreages that would be involved in firing steam plants of these sizes.

The small plant would require 83,000 green tons/year of wood residue or $.777 \times 10^{12}$ BTU input per year. At this rate, current volumes of mill and bark residues could fire 18 such plants in Idaho. Forest residues could supply an additional 17 plants.[4] The number of large steam plant facilities that could be supported by mill residues is 4; the number from forest residues is 3.

Table 3. Cost and energy output of two steam plants.

Rated capacity	60,000 lb/hr	300,000 lb/hr
Average output[2]	45,000 lb/hr	225,000 lb/hr
Capital cost	$5,500,000	$12,500,000
Annual cost		
Capital[3]	$650,000	$1,470,000
Operating	$350,000	$ 556,000
Total	$1,000,000	$2,026,000
Energy input		
Wood waste	83,000 green ton/yr[4]	415,000 green ton/yr[4]
	$.777 \times 10^{12}$ BTU/yr	3.88×10^{12} BTU/yr
Energy output[5]	$.513 \times 10^{12}$ BTU/yr	2.56×10^{12} BTU/yr
	394×10^{6} lb steam/yr	19.7×10^{8} lb steam/yr
Energy cost	$1.95/MM BTU	$ .97/MM BTU
	$2.54/1000 lb steam[6]	$1.03/1000 lb steam[6]

[1] CH2M Hill 1976; Hall et al. 1976 (reduced to 1975 costs at 5% per year).

[2] 75% load factor.

[3] At 10%, 20 year life.

[4] At 45% moisture.

[5] At 66% efficiency.

[6] At 1300 BTU/lb steam.

Mill and bark residues would be available at a price that fluctuates with other markets for residues. Corder (1973) set this price at $2.00 to $4.00 per 200-cu ft unit, or $.12-$.24/MMBTU. At a 40-mile haul distance, forest residues were shown to be available at from $1.05 to $1.90/MMBTU. Using these figures, the total energy costs for the two plants can be calculated and are summarized in Table 4.

Larger plants can produce steam for less than their smaller counterparts, but eventually this economy of scale will be lost in the added cost of handling the tremendous quantities of wood residue required to fire the boilers. The large plant described here has input requirements equal to a 50-MW electrical generating plant. If all residue were trucked to the plant in 12-unit chip trucks,[5] the plant would need to handle 62 trucks per day, or 6 trucks per hour on a 10-hour shift. The problems in handling this much volume per day may place an external limit on plant size.

Capital cost for a wood-fired power plant will also depend on the type of power plant currently in use and on the type of industry. If a steam user is already equipped to handle wood waste or some other bulky fuel product (e.g.,

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[3] Boiler and other equipments costs were found in CH2M Hill to be about 50% of total cost. They will be a higher percentage and total cost lower if material handling equipment is already available.

[4] See Table 1.

[5] 1 unit = 200 cu ft, or approximately 204×10^{6} BTU of wood residue per truck.

Table 4. Total energy costs for steam plant.

	Mill and bark Residue	Forest Residue
Small Plant		
Fuel cost ($/MM BTU)[1]	.18 - .36	1.59 - 2.88
Production cost ($/MM BTU)	1.95	1.95
Total cost ($/MM BTU)	2.13 - 2.31	3.54 - 4.83
Equivalent Steam Cost[2]	$2.77-$3.00/1000 lb	$4.60-$6.28/1000 lb
Large Plant		
Fuel cost ($/MM BTU)[1]	.81 - .36	1.59 - 2.88
Production cost ($/MM BTU)	.79	.79
Total cost ($/MM BTU)	.97 - 1.15	1.38 - 3.67
Equivalent Steam Cost[2]	$1.26-$1.50/1000 lb	$3.09-$4.77/1000 lb

[1] Converted from dollars per million BTU of higher heat value by dividing by 66% conversion efficiency.

[2] At 1300 BTU/lb of steam.

coal), then the steam plant investment will be reduced. If the user is not equipped in this fashion, the investment in a wood-fired facility could run at least 2 to 4 times the investment required for an oil or gas facility (Corder 1973).

Equipment requirements and basic plant configurations are similar for a process steam plant and a wood-fired electrical generating plant. The total costs in dollars per BTU for the electrical plant will be higher, however, because of higher capital costs and lower conversion efficiency.

Electrical generating plants enjoy the same economies of scale as shown for the steam plant. However, they also incur the same size limitations imposed on steam plants by material holding requirements. Grantham et al. (1974) indicate that the minimum plant size, economically, is 25 MW and that the maximum size, practically, is 50 MW. Hall et al. (1976) indicated a 200- to 250-MW maximum, but performed calculations and analysis on a 50-MW size. Plant size is usually limited by handling requirements for the wood residues, by the economical transportation distance for the residues, or by some combination of these. Economic analysis is shown here for two sizes, 50 and 100 MW. Data for the economic analysis were adapted from published reports by the Stanford Research Institute (1976) and Battelle-Columbus Labs (Hall et al. 1976).

The Battelle study considered a 50-MW plant for the state of Vermont and estimated capital costs in year 1975 at $31 million and annual operating costs at $542,000. The 100-MW plant was estimated by Witwer (1976) to cost $52 million and have operating costs of $920,000 per year. Load factor for both plants was set at 70 percent. The resulting power production and costs are outlined in Table 5.

Table 5. Production costs in year 1975 for 50- and 100-MW generating plants.

50 MW Plant:[1]		
Capital cost	$31,000,000	
Annual costs		
Capital[2]	3,641,000	
Operating	556,000	
Total	$ 4,197,000	
Energy output[3]	1.05×10^{12} BTU/yr	3.07×10^{8} KWhr/yr
Production cost	$4.00 /MM BTU	13.7 mills/KWhr
100 MW plant[4]		
Capital cost	$52,000,000	
Annual costs		
Capital[2]	$ 6,108,000	
Operating	$ 920,000	
Total	$ 7,028,000	
Energy Output[3]	2.1×10^{12} BTU/yr	6.13×10^{8} KWhr/yr
Production cost	$3.35/MM BTU	11.4 mills/KWhr

[1] Hall et al. 1976.

[2] At 10% interest, 20 year life.

[3] At 27.4% efficiency of higher heating value.

[4] Witwer 1976.

Total costs for these plants again depend upon whether mill or forest residue is used. This is shown in Figure 3.

The forest residues required to fire 50- and 100-MW plants can be matched against average residue quantities per acre to determine the number of acres required for a plant and the radius of a circle that will encompass that area (Table 6).

The greatest potential for the use of wood residue in the production of electricity probably lies in co-generation with process steam or in co-firing in a coal-fired thermal plant. Co-generation allows the user to produce both process steam and electricity. This increases the efficiency of the process, allows the user to provide both steam and electricity, and if excess electricity can be sold, provides an income incentive to help pay for the extra cost of equipment. The possibility of co-firing wood and coal is a concept that needs further investigation. A report by MITRE Corporation states that this "would enable electric utilities to burn coal without undergoing the extensive costs of sulfur oxide emission control equipment" (Inman 1977). If this is true, it could provide incentive to use both mill and forest residues in this manner.

Table 6. Truck and acreage requirements for 50- and 100-MW plants fired from forest residues.

	50 MW	100 MW
BTU/year input	3.82×10^{12}	7.64×10^{12}
Trucks per day[1]	62	125
Acres required in Idaho	43.9×10^5	87.7×10^5
Radius (miles) in Idaho	77.2	105.6

[1] At 204×10^6 BTU per 12-unit chip truck and 300 days per year operating time.

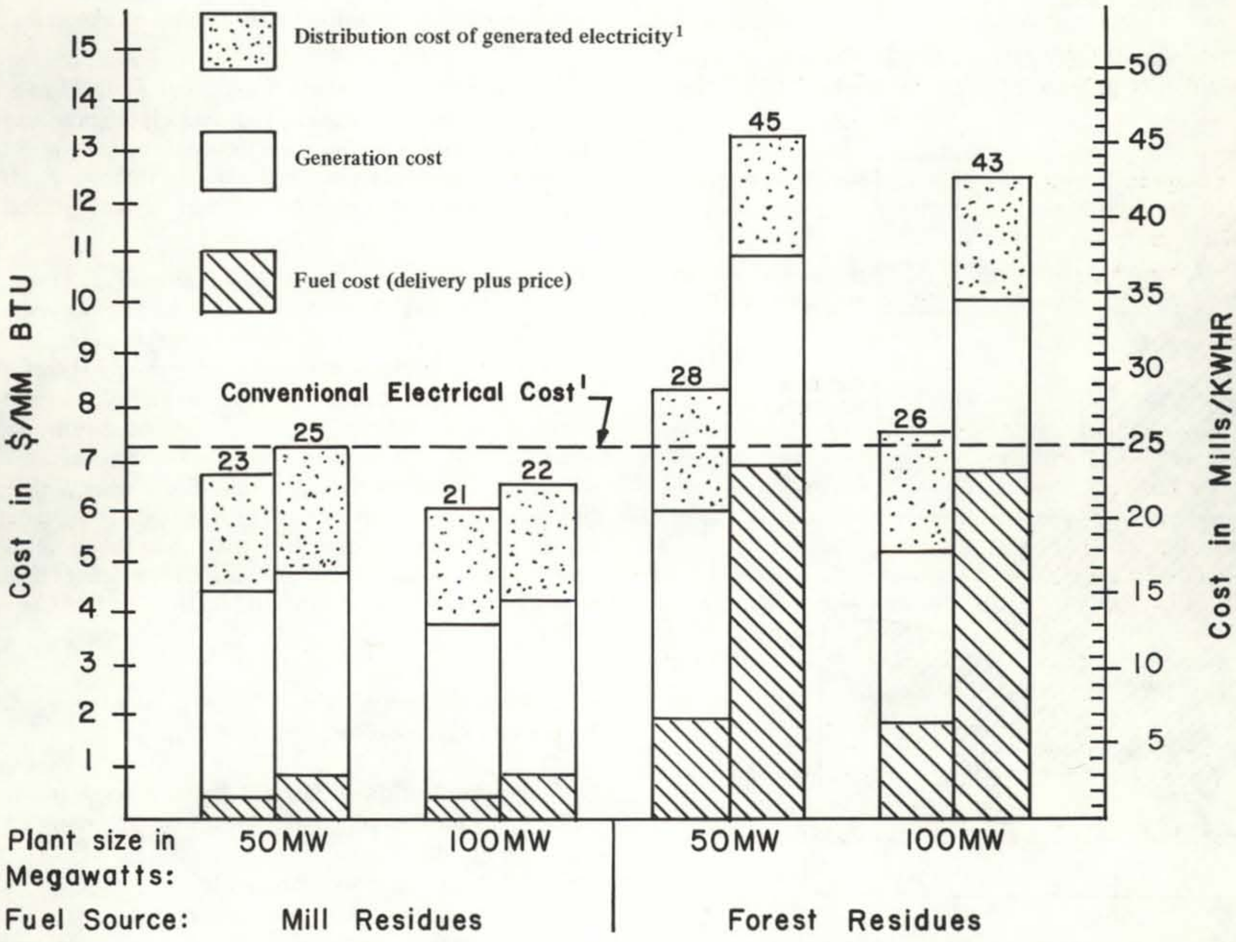

Figure 3. Electrical generation costs with wood residues.

[1] McFadden 1977.

TREE FUEL PLANTATIONS

The cost of growing trees for fuel appears to be competitive with the price of more conventional fuels. Fuel plantation costs range from $1.20 to $2.50/MMBTU (Szego 1976). The concept has not yet been field tested, however, and this testing will be needed to verify these cost estimates. Sites used for fuel plantations must meet criteria related to precipitation, soil, and terrain. Slope and rainfall conditions in Idaho generally do not meet the minimum criteria and, as a result, the potential for fuel plantations is small.

Studies conducted by two independent organizations identified regions in the United States with potential for fuel plantations. An acceptable site in the first study (Szego 1976) required slopes under 25 percent and annual rainfall of at least 16 inches, preferably 20. Maps showing general precipitation and terrain were overlayed to identify acceptable areas. The results for Idaho are shown in Figure 4. Note that the only area determined suitable for a fuel plantation by these criteria is in some of northern Idaho's prime agricultural area.

The second study (Inman 1977) called for annual precipitation of at least 25 inches, arable land according to the Soil Conservation Service classification system, and slopes less than 30 percent. On this basis the entire moun-tain region (Idaho, Montana, Wyoming, etc.) was eliminated from consideration.

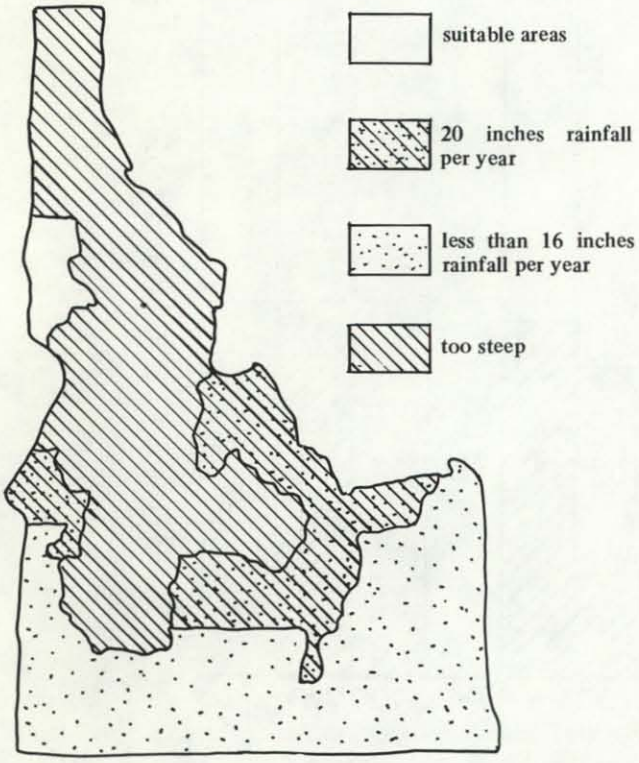

Figure 4. Areas of Idaho suitable for fuel plantations.

From Szego, G. 1976. Design, operation, and economics of the energy plantation. Proceedings, Conference on Capturing the Sun through Bioconversion. Washington Center for Metropolitan Studies. Washington, DC. 239 pp.

The analyses in these two studies were based on large-scale maps and conditions and did not attempt to consider special situations within individual states. Although their general conclusion about the state of Idaho is probably valid, there may be specific situations and locations that could be adapted to the fuel plantation concept. The impact would not be large but might meet the needs of a particular energy demand.

Originally the concept of a fuel plantation was developed to make use of marginal lands–those not used for the production of agricultural crops. However, subsequent analysis has also considered land currently under cultivation. If suitable plantation areas are identified in Idaho, they will probably be areas currently under cultivation. One issue that will require some research and analysis concerns the present and future economic tradeoffs of a shift from food production to production of a biomass fuel.

The criteria developed for fuel plantations relate to annual precipitation, terrain, and land classification of the site. Precipitation is necessary to support yields of 8 to 10 dry tons per acre per year, which Szego (1976) states is the minimum yield required to support a fuel plantation.

The plantations are designed around short-rotation crops (5-6 years). According to the MITRE Corporation report (Inman 1977), the advantages of this concept appear to be 1) higher yields per unit land area and therefore 2) lower land requirements for a given biomass output, 3) increased labor efficiency through mechanization, and 4) utilization of the capacity of most short-rotation tree species to regenerate by coppicing. Some disadvantages to this concept mentioned by MITRE include 1) higher stand establishment and management costs than for conventional forest crops, 2) site limitations, and 3) the danger involved in working with large monocultures (Howlett and Gamache 1977).

The conceptual design of a fuel plantation as outlined by the MITRE report includes the following:

1. production of 250,000 dry tons per year,
2. annual productivity per acre in the range of 5 to 13 dry tons,
3. land either purchased or leased,
4. planting at 4 ft x 4 ft spacing,
5. rotation period of 6 years,
6. irrigation during first 3 years of each rotation,
7. fertilization as needed to maintain productivity,
8. weed control operations during first year, and
9. 454 mi of work road per farm.

Table 7. Production costs for New England, California, and Illinois fuel plantation sites as reported by MITRE Corporation.[1]

	New England	California	Illinois
Land ($/acre)	260	1400	2860
Clearing ($/acre)	190	35	49
Planting ($/acre)	119	255	119
Irrigation ($/acre)			
Equipment	245	280	245
Operating	42	119	42
Total[2]			
$/dry ton	32.28	33.92	42.00
$/MM BTU	1.96	2.00	2.47

[1] Inman, et al. 1977.

[2] There are other costs not shown in this table involved in total operation.

On the basis of these criteria, they determined total current production costs, delivered to a conversion facility a maximum of 25 mi from the field, ranging from $1.21 to $2.47/MMBTU. The literature search conducted for the NEPP (Johnson et al. 1977) found production costs when no irrigation was used ranging from $.78 to $1.60/MMBTU. Irrigation costs were found to range from $.30 to $.81/MMBTU, yielding a total cost under irrigation of from $1.08 to $2.41/MMBTU.

The MITRE report also itemized production costs on ten representative sites. A closer look at the costs incurred on three of these sites might suggest the production cost range that would be incurred in Idaho (Inman et al. 1977). The New England site represented an area of low agricultural activity and relatively low productivity, 5 dry tons per acre per year. Land cost for this site was set at $260/acre and its slopes averaged 15 to 16 percent. The California site was located on prime agricultural land at a cost of $1400/acre. It required total irrigation but produced a high yield of 13 dry tons per acre per year. The Illinois site was also located on prime agricultural land and represented the highest land cost, $2860/acre. It did not require irrigation, but the yield was lower than on the California site, 8 dry tons per acre per year.

These three sites incurred the highest production costs of the ten sites selected by MITRE: $1.96/MMBTU for New England, $2.00/MMBTU for California, and $2.47/MMBTU for Illinois. The costs are given in more detail in Table 7. The high costs reflect in one instance the result of low site productivity and in the other two the result of high land costs. Since fuel plantation sites selected for Idaho would either be located on agricultural lands or be in a low yield category, production costs could be expected to be in the upper range of those shown.

SUMMARY

Mill residues are currently being used to a great extent in the production of energy or other products. The major obstacle to utilization of forest residues is economic. The cost of collecting the material is high relative to conventional fuels. One method of decreasing collection costs is to subsidize a fuel recovery operation by the amounts traditionally going to slash disposal and clean-up. This would include the amounts allocated to yarding unmerchantable material to a landing, piling brush, and burning brush piles.

Another obstacle to energy use of wood residues, primarily mill residues, is uncertainty about the continuity of supply. Predictions about the growing demand for wood fiber raise valid questions concerning future supplies of wood residue for energy. Even if economics look favorable, caution should be used in any long-range program that includes wood as a major energy source.

Fuel plantations could produce significant quantities of wood fiber at competitive costs, but they require large blocks of land that might be needed for food production. There is little land in Idaho that meets the requirements of both moisture and gentle terrain.

LITERATURE CITED

Bergvall, J.A., D.C. Bollington, and L. Gee. 1977. 1976 Washmaton Mill Survey. Rep. No. 5. State of Washington, Department of Natural Resources. 135 pp.

Bergvall, J.A., and D.R. Gedney. 1970. Washington mill survey . . . wood consumption and characteristics, 1968. Rep. No. 1. Joint study by Washington State Dept. Natur. Resources and Pac. NW Forest and Range Exp. Sta. 119 pp.

CH2M Hill. 1974. Energy recovery from solid wastes for the Oregon south coast region. Vol. I and II. Project No. C8124.0. Corvallis, OR. 150 pp.

_______. 1976. Energy recovery from solid wastes for the south coast region. Phase I Rep. Project No. C9800.AO. Corvallis, OR. 52 pp.

Corder, S.E. 1973. Wood and bark as fuel. Forest Res. Lab. Res. Bull. 14. Oregon State Univ., Corvallis. 28 pp.

Gardner, R., and D.F. Gibson. 1974. Improved utilization and disposal of logging residues. ASAE Pap. No. 74-1511. Winter meeting. Amer. Soc. Agr. Engr. Chicago. 11 pp.

Grantham, J.B., E.M. Estep, J.M. Pierovich, and T.C. Adams. 1974. Energy and raw materials potentials of wood residue in Pacific Coast states–A summary of a preliminary reasibility investigation. USDA Forest Serv. Gen. Tech. Rep. PNW-18. Pac. NW Forest and Range Exp. Sta., Portland, OR. 37 pp.

Hall, E.H., C.M. Allen, D.A. Ball, J.E. Burch, H.N. Conkle, W.T. Lawhon, T.J. Thomas, G.R. Smithson. 1976. Comparison of fossil and wood fuels. NTIS Rep. PB-251, 622. 238 pp.

Howlett, K., and A. Gamache. 1977. Silvicultural biomass farms. Vol. II. MITRE Tech. Rep. No. 7347. 136 pp.

Inman, R.E. 1977. Silvicultural biomass farms. Summary, Vol. I-IX. MITRE Tech. Rep. No. 7347. 62 pp.

Inman, R.E., D.J. Salo, and B.J. McGurk.1977. Silvicultural biomass farms. Vol. IV. MITRE Tech. Rep. No. 7347. 123 pp.

Johnson, L.R., and J. Arkills. 1975. Integration of whole tree chipping with a traditional logging operation. Pages 802-806 *in* ASAE Trans. Vol. 19. No. 5.

Johnson, L., G. Simmons, and J. Peterson. 1977. Energy supply and environmental impacts–Unconventional sources. Northwest Energy Policy Project. Final Rep. NTIS Pub. No. PB-2.68 301/W6. Study Module IIIB. 275 pp.

Lowe, K.E. 1973. The complete tree: Will it be used to supply the wood fiber needs of the future? Pulp and Paper. December:6.

McFadden, J. 1977. Energy supply and environmental impacts–Conventional sources. Northwest Energy Policy Project. Final Rep. Study Module IIIA. Portland, OR. 322 pp.

Stanford Research Institute. 1976. An evaluation of the use of agricultural residues as an energy feedstock. Vol. I. SRI Project 3520. Pages 217-238.

Szego, G. 1976. Design, operation, and economics of the energy plantation^{TM}. Proc.: Conference on capturing the sun through bioconversion. Washington Center for Metropolitan Studies. Washington, DC, March 10-12, 1976, 239 pp.

U.S. Department of Agriculture. 1973. The outlook for timber in the United States. Forest Resource Rep. No. 20. USDA Forest Serv., Washington, DC 367 pp.

U.S. Department of Agriculture, Forest Service. 1976. The feasibility of utilizing forest residues for energy and chemicals. Report NSFRA-760013 for National Science Foundation, Washington, DC. 193 pp.

Witwer, J.C. 1976. Costs of alternative sources of electricity. Pages 33-38 *in* Final Rep. SRS Project 4963-100. Stanford Research Institute, Menlo Park, CA.

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