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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
Approved Technical Article

Potentials of Wood For Producing Energy

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ABSTRACT-Rising prices of fuels and energy have evoked proposals for increased use of wood as an industrial fuel and as a chemical feedstock. The fuel potential of the entire U.S. annual timber harvest is small compared to the energy produced yearly from fossil fuels. It appears unfeasible to supply large steam-electric plants or chemical plants from standing timber, mill residue, or logging residue. The chief obstacles are lack of assured long-term supplies, high costs of collection and inherent disadvantages of wood compared to those of fossil fuels. A further deterrent is the increasing value of wood chips, sawdust and shavings for the manufacture of pulp and particleboard. However, use of bark and wood residues for production of process steam and electricity at forest products plants may be highly advantageous. The great potential contribution of wood to solve our energy problems probably lies in improved timber processing and efficient wood products design.

Rapid inflation in prices of fuel and energy has stimulated an expanding search for alternatives to high-cost oil and dwindling natural gas reserves. Some proposals suggest converting wood wastes to chemical feedstocks and growing wood specifically as a source of fuel. These proposals are of particular interest to land managers as a means to reduce problems of logging residue. They also should interest forest industry leaders who seek market outlets for mill wastes but may fear competition from new users of raw material. From a policy standpoint, however, questions arise. Can wood contribute substantially to the nation's energy supply? Is the use of wood as fuel or feedstock technically feasible if compared with coal and other fossil fuels? What are the relative values of using wood for energy compared to other uses?

Perspectives on U.S. Energy Requirements

In 1971, the United States consumed the equivalent of 69 quadrillion Btu's (*Table 1*), a quantity scarcely comprehensible (20). More importantly, energy consumption is projected to triple by the year 2000. Opinions differ widely whether rising fuel prices will slow the rate of increase in consumption and whether it will be technically, environmentally and socially feasible to develop these huge amounts of energy.

Demands for petroleum and natural gas will be especially difficult to meet since the United States has become less and less self-sufficient in these resources. The anticipated sources of oil and gas in 1985 and 2000 (Table 2) illustrate the drastic reduction envisioned in domestic oil and gas production, thus the corresponding increase in imports (*10*). In March 1974, S. Stanley Katz, deputy director for international policy, U.S. Department of Commerce, estimated that the cost for imported oil and petroleum products in 1974 would rise to $24 billion compared to $7.5 billion in 1973 and $4.3 billion in 1972 (9). Katz suggested that the long-term price for mideastern oil would be $8 to $10 per barrel instead of the former $2 to $3. Others have maintained that domestic shale oil and Canadian tar sand can be developed at a low enough cost to bring prices down somewhat (3, 12). In any event, the present outlook is one of very high prices for imported fuels, which is a strong impetus to search for alternative domestic resources.

Wood as an Energy Source

Per capita consumption of fossil fuels in the United States is about six times that of all forest products (*Figure 1*) (*11*). Since the average heat value of wood is far less than the average values for petroleum and natural gas, and is about two-thirds that of most coal, burning the nation's entire annual timber harvest obviously would contribute relatively little to our total energy requirements.

A proposal that captured the imagination of many people was to fuel large electric power plants with wood from "fuel plantations." Szego and Kemp (*14*) calculated that a 400-megawatt steam-electric plant might be supported by a plantation of 370 square miles. They suggested that using improved crop strains might allow a 1,000-megawatt plant to be supported by that much land. Harold Tarkow, assistant director of the Forest Service's Forest Products Laboratory, Madison, Wi., estimated that at least 2,000 square miles would be necessary for a 1,000-megawatt plant, assuming a growth rate of 2 cords per acre per year. Regardless of the assumption of yield, the obvious drawback to fuel plantations would be the enormous land requirements for any significant addition to energy supplies. Total U.S. electrical generating capacity in 1971 was about 387 million kilowatts. Fueling even 1 percent of this capacity would require between 1 and 5 million acres, depending on growth rates and conversion efficiency.

Another fuel source might be forests that have low harvest-to-growth ratios because of poor market demand for particular species, sizes, or grades of timber. Stands of low-quality hardwoods in the East and lodgepole pine in some areas of the Rocky Mountains might offer the most likely opportunities. However, it seems doubtful that public sentiment, already dis-

[1] Personal communication to National Science Foundation.

Table 1. Energy consumption in the United States, 1971 (actual) and year 2000 (projection).[1]

Year	Consuming sector	Coal[2]	Petroleum[3]	Natural gas	Nuclear power	Hydro-power	Total gross energy input	Final distribution[4]
		Trillions of Btu's						
1971	Household and commercial	400	6,500	7,300	—	—	14,300	17,400
	Industrial	4,500	5,400	10,400	—	—	20,300	22,600
	Transportation	—	16,100	800	—	—	17,000	17,000
	Electrical generation	7,700	2,400	4,100	400	2,800	17,400	—
	(conversion loss)	—	—	—	—	—	—	(11,900)
	Total	12,600	30,500	22,700	400	2,800	69,000	57,000
2000	Household and commercial	—	11,100	10,800	—	—	21,900	39,600
	Industrial	6,700	14,700	17,900	—	—	39,300	57,800
	Transportation	—	40,000	2,600	—	—	42,600	42,700
	Electrical generation	17,500	5,000	2,600	49,200	6,000	80,400	—
	(conversion loss)	—	—	—	—	—	—	(49,600)
	Synthetic gas	7,100	600	—	—	—	7,700	—
	(conversion loss)	—	—	—	—	—	—	(2,200)
	Total	31,400	71,400	34,000	49,200	6,000	191,900	140,100

[1]Adapted from Department of the Interior (*20*).
[2]Includes anthracite, bituminous and lignite.
[3]Petroleum products refined and processed from crude oil, including still gas, liquified refinery gas and natural gas liquids.
[4]Adjusted for distribution of electricity and synthetic natural gas, after conversion losses. Electrical production converted to Btu's on the basis of 3,412 Btu/kWh and synthetic gas converted on basis of 1,000 Btu/ft^3.

Table 2. Projected oil and gas consumption, 1970-2000.[1]

Fuel consumption and source	1970 (actual)	1985	2000
Oil consumption (billion barrels per year)[2]	5.37	9.45	15.52
Source (percent)			
Domestic, exluding North Slope	78.6	37.4	18.8
North Slope	0	7.7	7.1
Net imports	21.4	52.9	57.6
Oil shale	0	1.2	7.1
Coal	0	.8	9.4
	100.0	100.0	100.0
Gas consumption (trillion cubic feet per year)	21.37	24.0	33.5
Source (percent)			
Lower 48 states production	96.2	66.6	36.7
Alaskan supply	.6	5.8	12.5
Net imports	3.2	15.9	23.9
Petroleum liquids	0	7.1	2.4
Coal	0	4.6	24.5
	100.0	100.0	100.0

[1]Adapted from Library of Congress (*10*, p. 44).
[2]Excluding liquid for gas production.

posed to question traditional harvesting in many areas, would favor substantial increases in logging to fuel either power or chemical plants.

A more practical consideration is whether use of logging residue and mill residue in conjunction with urban wastes could meet a significant portion of the country's fuel needs. A recent estimate suggests that conversion of all collectible organic wastes to energy would provide less than 2 percent of our requirements (*2*). Nevertheless, environmental benefits would be substantial from improved disposal systems that could involve limited production of power or chemicals. Furthermore, wood manufacturing residue, logging residue and dead timber could be an important energy source to forest-based industries that in 1971 purchased almost $1.2 billion of fuels and electricity (16). Conversion of wastes to energy not only could reduce environmental problems, but would make these forest-based industries less dependent on interruptible gas or oil supplies and release fossil fuels for use elsewhere.

Wood Residue Volumes—Residue volume estimates compiled from several sources are summarized in Table 3. The table is incomplete because few data are available on logging residue from nongrowing-stock sources, on bark residue and secondary-manufacturing residue. Volumes of material actually available at reasonable cost for energy production could be considerably smaller than is suggested by Table 3.

Table 3. Estimated logging residue and forest products manufacturing residue in the United States, 1970.[1]

Region	Logging residue		Unused primary manufacturing residue		Unused secondary manufacturing residue
	From growing stock	From other sources	Wood	Bark	
	Millions of cubic feet[2]				
Coastal Alaska	39	27	8	—	—
Douglas-fir subregion	347	247	133	—	—
Ponderosa pine subregion	34	45	46	—	—
California and Hawaii	106	268	152	—	—
Pacific Coast subtotal	526	587	339	213	30
Northern Rocky Mountain	84		93	66	—
Southern Rocky Mountain	19		46	23	—
South	483		343	165	—
North	283		172	180	—
Total U.S.	1,595		993	624	—

[1]Based on U.S. Forest Service (*18*), Howard, *et al.* (*8*), and from numerous Forest Service reports, working tables and communications.
[2]To convert to bone-dry tons, assume an average weight of 30 lb/ft^3 and multiply the above figures by 0.015; e.g., 1,595 million ft^3 = 23.9 million tons.

Conversion Possibilities

Principal suggestions for producing energy from wood have included direct combustion for process steam and electric power generation, bioconversion via anaerobic bacteria, chemical reduction and pyrolysis.

Direct Combustion at Forest Industry Plants—Wood wastes long have been used as fuel by forest industries and, to a limited extent, by utility companies. About 19 percent of all residue produced in 1970 at the nation's primary wood-processing plants was used for industrial fuel (18). According to the American Paper Institute, 37 percent of the 1972 energy requirement of the pulp and paper industry was met through combustion of bark and spent pulping liquors. Pulpmills, sawmills and plywood plants face growing interruptions in natural gas and increasing difficulty in obtaining adequate standby supplies of fuel oil or propane. Thus, new furnace installations at pulpmills or at large wood manufacturing centers generally are designed to burn wood or bark although wood-fired industrial furnaces are three to four times as expensive as gas-fired furnaces. Much of the added cost is for equipment to control particulate emissions.

Large manufacturing centers, such as pulpmills, use much process-steam and electricity. Thus, steam generated from wood or bark can power a steam turbine-electric generator set and exhaust to process steam rather than to a condenser. When an industry has such a desirable combination of steam and electrical power demand, the relative efficiency of heat recovery from steam can be almost 75 percent compared with the 38 percent at a modern facility generating electricity.

Many smaller wood manufacturing plants are replacing gas- or oil-fired furnaces with wood-fired units to produce hot gas or steam for drying. Burning in suspension with tangential firing or burning in a fluidized bed are new techniques that allow these installations to meet rigorous air-quality standards.

Direct Combustion at Electric Power- Generating Plants—Conversion of wood to electric power by utility companies requires large daily inputs of bulky fuel equivalent to about 1 bone-dry ton (2 tons, wet) per megawatt hour of electrical energy. Utilities prefer new plants with rated capacities of about 1,000 megawatts, a size that would require 2,000 tons of wet wood or bark per hour. Most large pulpmills require a wood supply equivalent to only about 125 to 250 tons per hour; this amount represents the major output of the forest—not residue alone.

A recent study (6) indicated that a facility generating 25 to 50 megawatts of electricity was the smallest that could produce electricity competitively. Further, the study suggested that a 50-megawatt plant was probably the maximum size that could be supplied economically with fuel from wood residue. A 50-megawatt plant operating 6,000 hours per year would require about 100 tons of wood per hour or 600,000 tons of wet fuel per year. By comparison, new coal-fired plants may have one or more units, each capable of producing 500 to 900 megawatts of power; therefore, they usually will be located near a coal bed.

Bioconversion, Chemical Reduction and Pyrolysis—Wood and most other organic materials can be converted to high-energy methane or low-energy gas, to high- or low-energy liquids, to char and to charcoal.

Bioconversion, using anaerobic bacteria to digest organic wastes and produce methane, is a possibility under investigation primarily for animal manures and

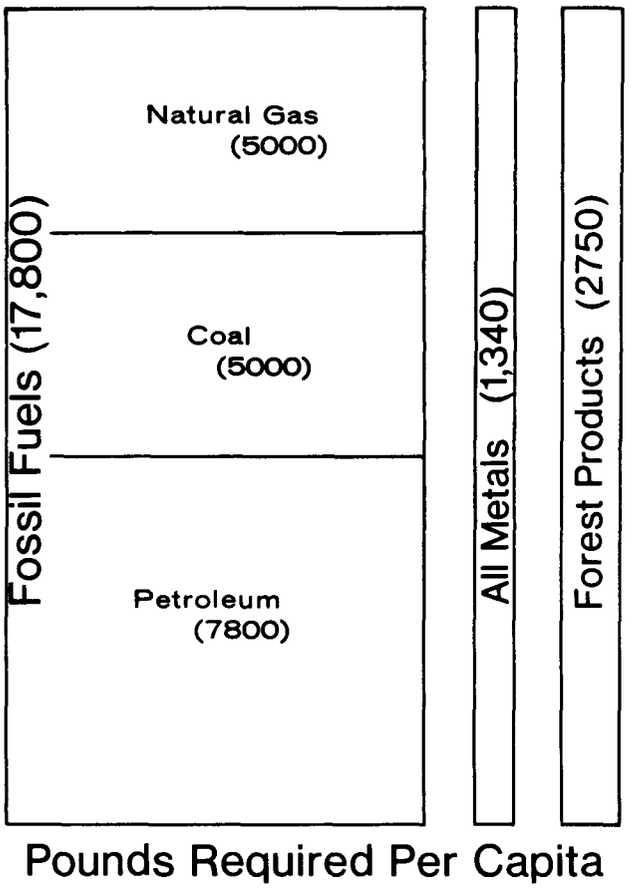

Figure 1. Comparison of forest products with fossil fuels and metals—1972 per capita use of new basic raw materials. [Adapted from National Materials Policy Commission (*11*).]

municipal wastes. Long a part of municipal sewage treatment processes, bioconversion well may be applicable to disposal of unwanted forest products residue, especially cellulosic pulpmill and papermill wastes. However, many technical problems remain to be solved before this process can beoperated feasibly (*15*).

The U.S. Bureau of Mines recently designed a pilot plant for chemical reduction of wood chips to oil, and expected to take bids on construction in the spring of 1974. With a capacity for 3 tons (assuming 44 percent moisture content) of wood chips per day, the bureau expects a yield of about 2 barrels of oil per day. Municipal refuse and bark could be converted at the plant, along with wood residue.

Pyrolysis has been studied intensively for converting municipal solid wastes to clean fuel (*1*). Depending on process conditions, pyrolysis can yield varying proportions of gas, oil and char (a dry residue that can be used as fuel). Small pilot plants have operated at LaVerne, Ca., St. Louis, Mo., and Tarrytown, N.Y., and larger facilities are under construction, including a 1,000-ton-a-day plant in Baltimore, Md.

Obstacles to Large-Scale Conversion of Wood to Fuels

The major obstacles to utilizing logging and mill residues for commercial production of fuels and power are difficulty in assuring a large-volume supply for a 20- to 40-year investment amortization period; high costs of collection (especially for logging residue); and inherent disadvantages compared with other fuels.

Long-term Availability and Cost—In 1970, about three-fourths of all primary residue from wood manufacturing was used as furnish for pulp, particleboard, other commodities and for fuel (*18*). Projected demands for these products suggest that little of this residue will go unused in the future. In fact, a survey of primary processors in the State of Washington showed that 92 percent of all wood residue was used in 1972 (*13*).

The high demand for wood byproducts was evidenced by spring 1974 prices of $50 and more per bone-dry ton for wood chips delivered to pulpmills in the Columbia River area of Oregon and Washington. At the same time, sawdust and shavings prices in the area were $10 and higher per bone-dry ton. Substantial volumes of bark, however, have gone unused in many areas.

Logging residue, although larger in volume than mill residue (*Table 3*), is far less concentrated, and would be a much costlier source of raw material. The largest concentration and presumably the least costly volumes of logging residue would be on national forests of the Douglas-fir region. A sample of 1969 clearcut logging operations in that region indicated gross volumes of 4,548 cubic feet (57 bone-dry tons) and net (sound wood fiber) volumes of 3,127 cubic feet (40 bone-dry tons) per acre in pieces 4 feet long or longer and 4 inches or larger in diameter (7). Two-thirds of the gross volume was in pieces 12 feet or longer and 8 inches or more in diameter.

If the large material (12 feet and 8 inches) were gathered by relogging clearcut areas, the cost likely would be high—perhaps more than $30 per dry ton delivered to a plant and preprocessed for hogged fuel. Removal in conjunction with ongoing harvests would cost considerably less, and may be quite feasible, particularly if credits for slash disposal are applied.

Comparison with Coal—For large-scale commercial uses, wood fuel costs must be compared with those for conventional fuels—petroleum, natural gas and coal. If petroleum and natural gas become prohibitively expensive or unavailable in the next several decades, a vast supply of coal will be available in the United States.

Principal deterrents to increased use of coal have been: (1) availability of low-cost convenient alternative fuels-oil and gas; (2) difficulties in meeting air pollution standards; (3) transportation problems; and (4) stricter environmental and safety regulations for mining. The present high prices for oil and the continuing scarcity of natural gas have brought new attention to coal. Huge deposits of lignite and subbituminous coal in the West do not bear the high sulfur content that has somewhat discouraged the use of bituminous coal in eastern states. Problems of particulate emissions apparently are no greater for coal than they are for wood fuels. Transportation problems have been met recently by siting electrical generating facilities at mine locations. Even when long-distance shipping is necessary, transportation costs for coal tend to be less than those of collecting and shipping equivalent volumes of wood.

Environmental and safety problems related to coal production appear particularly difficult. Wood residue removal generally would improve the forest environment, whereas surface mining detracts significantly from aesthetic, watershed and other land values. Deep mining is less destructive environmentally but much more hazardous to workers. The economic potential of our abundant coal reserves, however, is so great that increased development is certain.

Typical carbon contents and heat values of wood and three types of coal, dry basis, are:

Material[1]	Total carbon	Heat value (Btu/lb)
Wood	49-54	8,500- 9,500
Bark	47-57	8,500-10,000
Lignite	64-65	11,000-12,000
Subbituminous coal	62-73	10,500-14,000
Bituminous coal	73-86	13,000-16,000

[1]Lignite and Coal (*19*); Wood and Bark (*5*)

Because of higher carbon content and heat value, coal is generally preferable to wood for large-scale chemical conversion or for fuel. Another major advantage of coal is availability in very large deposits that far exceed volumes of wood residue available at most locations. Although, in some areas, surplus mill residue has been available for the cost of hauling, the amount of unwanted mill waste is dwindling. Logging residue would be considerably more expensive than coal:

Fuel (average)	Cost per ton (moist basis) (dollars)	Cost per million Btu's (dollars)	Source
Coal, U.S., Nov. 1973	9.70	0.44	(*4*)
Pacific Coast, Nov. 1973	6.65	.35	(*4*)
Rocky Mt., Nov. 1973	4.38	.23	(*4*)
Unused mill residue, largely bark, 1973	1.65-2.50	0.20-0.30	(Estimate)
Logging residue, Douglas-fir region national forests, 1973	10-20	1.25-2.50	(Estimate)

Role of Wood in Energy Conservation Strategies

A fact that even foresters may forget is that the nation's annual consumption of wood products is far larger than that of all metals combined (Figure 1). A recent suggestion is that wood processing is relatively energy-efficient, especially compared to the manufacture of competitive materials for structural uses. The Atomic Energy Commission in a December 1973 report (15) to the President made recommendations to:

> . . . maximize specific energy efficiency in buildings by developing and demonstrating improved design, construction techniques and practices, operational methods and maintenance practices, and the use of materials that require less energy for production. . . .

The commission also recommended a similar approach to conserve energy in industrial processes.

In a 1973 report (17) the Environmental Protection Agency suggested strategies to promote use of energy-saving materials in manufacturing and construction. The report noted that synthetics and plastics generally required more energy than the natural materials they replaced, e.g., paper.

Data sufficient to estimate with precision the energy efficiency of alternative materials, including total energy costs in extraction, processing and application are not available. For many uses, however, wood products appear to have a relatively low energy cost. Improvements in processing technology and wood products design will further reduce this cost.

Conclusions

Wood probably will not be a major source of energy for commercial power production or for chemical feedstock. Although some residue from forest products manufacturing plants may be included with municipal solid wastes at combined disposal and power-generating facilities, practically all mill residue will be used for fiber products or fuel within the forest industry. Logging residue generally will be too expensive for use as fuel only, but is a potentially attractive source of material for products.

Although the quantity of forest products consumed annually in the United States is twice that of metals, it is small compared to that of fossil fuels. Except at forest products plants, coal generally will be cheaper than wood fuels, and will be accessible in far larger quantities.

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