Biomass 12 (1987) 27-36

Use of Wood Energy in the United States – An Opportunity

John W. Koning, Jr

Program Coordinator, Engineering Professional Development Department,
College of Engineering, University of Wisconsin, Madison, WI, USA

and

Kenneth E. Skog

Research Forester, National Timber Products Requirements Staff,
USDA Forest Service, Forest Products Laboratory,* One Gifford Pinchot Drive,
Madison, WI 53705-2398, USA

(Received 15 December 1986; accepted 30 December 1986)

ABSTRACT

The use of wood for energy – including the burning of solid wood and black liquor from pulping – has been growing at a rate significantly greater than that for all other uses such as lumber, pulp, or particleboard. in the United States, the end of most wood is not lumber or pulp and paper but feed for energy. In 1983, 155·5 M Mg of wood were used for energy. This could threaten to increase the price of wood for those other uses, or it can stimulate us to seek more creative ways of using untapped wood resources for fuel.

on the basis of estimates of heavy wood energy use relative to other uses for wood, and estimates of continuing high costs for fossil fuels, we suggest here the feasibility of meeting the demand for fuelwood through small-scale cooperatives. Such an approach can improve forestry practices and can avoid unduly increasing the cost of wood for other end uses.

Key words: Energy, fuelwood, forestry, chipping, economics.

*The Laboratory is maintained in cooperation with the University of Wisconsin. Madison.

INTRODUCTION

The primary use of wood in the world today is for energy, with most of it being used as a cooking fuel. Use for cooking fuel is greatest in less developed countries, and levels of supplies have reached crisis conditions in some places. However it might come as a surprise that, in the United States, the end use of most timber is not lumber or pulp and paper but fuel for energy, and this energy use has been growing at a substantial rate (Fig. 1). Wood energy use estimates for 1972-83 are given in Table 1 and shown in more detail for 1983 in Table 2.

Though these wood energy *use* estimates are surprisingly high, they are conservative because they may underestimate the wood burned by industrial firms outside the forest industry; relatively little information about that component is available.[4]

Wood is burned both in solid form and in the form of black liquor from the pulping process. Even if the substantial black liquor tonnage used for energy is subtracted, the amount of wood used for energy is still more than the use of wood for all other wood products combined.

Such a continued increase in the use of wood for energy could increase the cost of certain wood materials and challenges foresters and woodland managers to look more carefully at available sources of fuelwood.

Currently we have ample unused hardwood and waste wood for fuel in the United States;[7] their production exceeds use. But, if the rate of use

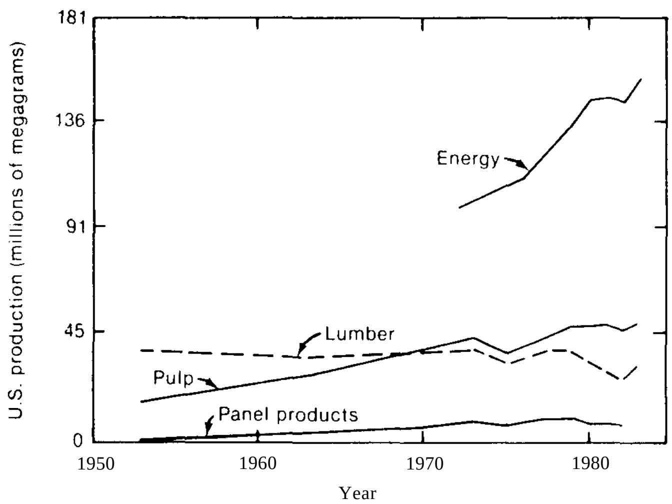

Fig. 1. Major end uses of timber and bark in the United States. Values for lumber and panel products are from Ref. 1. Values for pulp are from the American Paper Institute as reported in *Paperboard Packaging.*[2]

TABLE 1
Wood Energy Use, 1972-83

Use	*Estimated consumption of wood or wood equivalent*								
	1972	*1974*	*1976*	*1978*	*1979*	*1980*	*1981*	*1982*	*1983*
	Million megagrams at 15% MC[a]								
Lumber and wood products industry[b]	21·5	22·8	24·1	25·6	26·3	27·1	25·0	20·9	25·0
Pulp and paper industry[c]									
As hog fuel	2·7	3·7	4·8	6·0	6·4	7·4	9·2	10·2	13·2
As bark	5·4	5·4	5·4	5·7	5·6	6·2	6·2	6·7	7·1
As black liquor	42·5	44·3	45·4	49·2	48·5	49·2	49·2	46·7	49·8
Other industry[d]	2·3	2·4	2·4	2·7	2·7	2·8	2·8	2·6	2·9
Residential[e]	24·2	23·7	30·7	39·6	46·4	52·1	52·6	56·7	55·9
Commercial[f]	0·5	0·5	0·7	0·9	1·1	1·3	1·3	1·4	1·4
Utilities[g]	0·2	0·1	0·1	0·1	0·1	0·3	0·2	0·2	0·2
Totals	99·3	102·9	113·6	129·8	137·1	146·4	146·5	145·4	155·5

[a] Megagrams x 1·102 = ton (2000-lb basis) or tons x 0+0·9072= megagrams.
[b] Amounts for 1980 through 1983 are million ovendry tons (MMODT) (Ref. 4, p. 7)x 1·15. Amounts for 1972 through 1979 are computed assuming a constant rate of increase from 19·4 MMODT in 1970 (Ref. 5, p. 46) to 26 MMODT in 1980 (Ref. 4, p, 7).
[c] *Amounts* of hog fuel and bark are MM tons at 50% moisture content (Ref. 3)x (1·15 + 2·00). Black liquor is (quads from (Ref. 3) ÷ (17·2 MM Btu/ODT)) x 1·1 5.
[d] Other industry consumption is computed as 3% of total industry consumption (Ref. 4, p. 17).
[e] Amounts for 1980 through 1983 are MM cords (Ref. 4, p. 27)x 1·16 ODT/cord (this is ((29·1 OD lb/ft^3) x (80 ft^3/cord)) ÷ 2000 lb/ton) x 1·15 (See fn *b* of Table 2). To compute amounts for 1972 through 1979: MMODT (Ref. 6, p. 95)x 0·86 cord/ODT (Ref. 4, p. 27) converts the DOE estimate to a correct cord estimate. Second, x 1“16 ODT/cord to obtain a correct ODT estimate. Next, x 1·15. Finally ÷ 0·95 to account for an under-estimate (Ref. 4, p. 59).
[f] Amounts for 1980 through 1983 are MMODT (Ref. 4, p. 43) x 1·15. Amounts for 1972 through 1979 are MMODT (Ref. 6, p. 111) ÷ 0·8 (this is a correction factor (Ref. 4,p.61))x1·15.
[g] Amounts for 1980 through 1983 are MMODT (Ref. 4, p. 43)x 1·15. Amounts for 1972 through 1979 are MMODT (Ref. 6, p. 122)x 1·15.

TABLE 2
Wood Energy Use in 1983 by Five Measures

Use	*Estimated wood energy use in 1983*					*Wood use from primary data source*	
						Amount	*Source*
	MM megagrams (15% MC)[a]	*MM tons (15% MC)*[b]	*MMODT*	*MM cords*[c]	*Quads*		
Lumber and wood products industry	25·0	27·6	24·0	20·7	0·40[d]	24·0 MMODT	(*4*)
Pulp and paper industry							
As hog fuel	13·2	14·6	12·7	10·9	0·21	12·7 MMODT	(*3*)
As bark	7·1	7·8	6·8	5·9	0·12	6·8 MMODT	(*3*)
As black liquor	49·8	54·9	47·7[e]	41·1	0·82	0·82 Quads	(*3*)
Other industry	2·9	3·2	2·8	2·4	0·05	2·8 MMODT	(*4*)
Residential	55·9	61·6	53·6[f]	46·2	0·92[g]	46·2 MMcords	(*4*)
Commercial	1·4	1·5	1·3	1·1	0·02[h]	1·3 MMODT	(*4*)
Utilities	0·2	0·2	0·2	0·1	—[i]	0·15 MMODT	(*4*)
Total	155·5	171·4	149·1	128·4	2·54		

[a] 1 Mg = 0·9072 ton (2000-lb basis).
[b] 1983 ODT estimates × 1·15.
[c] 1983 ODT estimates ÷ (1·16 ODT/cord), except for residential use. 1·16 ODT/cord = (29·1 OD lb/ft^3 × 80 ft^3/cord) ÷ 2000 lb/ton. Hardwood is 32·8 OD lb/ft^3, softwood is 27·4 OD lb/ft^3. Estimating 31% of wood harvested is hardwood and 69% is softwood, then (32·8 × 0·31) + (27·4 × 0·69) = 29·1 OD lb/ft^3. Wood at 15% MC contains 1·15 × 1·16 ODT/cord = 1·33 ton (15% MC)/cord.
[d] 1983 ODT estimate × 17·2 MM Btu/ODT.[4]
[e] 1983 quad estimate ÷ 17·2 MM Btu/ODT.[4]
[f] 1983 cord estimate × 1·16 ODT/cord.
[g] 1983 cord estimate × 20 MM Btu/cord.
[h] 1983 ODT estimate × 17·2 MM Btu/ODT.[4]
[i] Less than 0·005 quad.

of wood for energy shown in Fig. 1 continues in a linear fashion, this nation could face fiber cost increases depending on local abundance of wood by the year 2000 — 13 years from now — because of increased competition for wood. Higher wood prices would support better forestry, but the payoff in more timber growth would take many years. If the linear trend continues we will use over 254 M Mg (280 M tons) per year (15% moisture content (MC))(216 M ovendry Mg) for fuelwood by the year 2000. This represents less than 1·5% of the total weight of above-ground tree biomass presently on commercial forest land (254 M Mg divided by 18·8 billion Mg (15% MC)).[8]

The United States Department of Agriculture, Forest Service, projections made for energy in the early 1980s suggest that roundwood used directly from forests for energy (excludes mill waste) may increase from 42.6 M Mg per year (15% MC) in 1977 to 177 M Mg in the year 2000.[9]

Although both these projected increases are probably high due to the present low fossil fuel prices, the likely prospect of increased natural gas and oil prices and increased fuelwood consumption remains.

Recent projections suggest that, if oil imports are constrained, then prices for natural gas and oil (without inflation) may be 15 to 30% higher in 1995 than in 1984.10 Under these conditions commercial and industrial users of natural gas and oil could afford $15·18 to $21·80/cm^3 stacked wood* ($55 and $75/cord) (1985 dollars) in 1995 *versus* $11.86 to $18.21 in 1984 ($43 to $66/cord) (Table 3). These cubic meter costs must, of course, cover any higher costs to store wood and to build and operate woodburning plants. Wood is much less likely to replace low-priced coal used by large plants to make steam. However, one midwest utility is conducting prefeasibility analyses for a large wood burning power plant to compete with coal on the basis of cost and environmental impact.

Of the 155·5 M Mg (15% MC) used for fuel in 1983, only that for residential use (55·9 M Mg (15% MC)) came largely from roundwood from forests. Less than a quarter of residential use comes from the main stem of growing stock trees.†[11] The remaining 99·6 M Mg is wood waste from making other wood products. Continued growth in wood energy use will require use of more roundwood from forests and/or untapped sources of wood waste. Data[12] suggest 'waste' sources could provide 544 M ovendry Mg (628 M Mg at 15% MC) per year without diminishing timber for other products. Amounts physically available include (among others):

*A cubic meter of stacked wood is also known as a stere. One cord = 128 ft^3 = 3·625 m^3.

†The main stem of growing stock trees is the volume in trees of sufficient quality and vigor (excludcs cull trees) that is between the stump and a 101·6-mm (4-in) top, outside bark, or the point where the central stem breaks into branches.

TABLE 3

Wood Costs Equivalent to Projected Cost for Selected Nonwood Fuels [a]

Sector and fuel	*Equivalent costs*				
	1973	*1984*	*1995*[b]		
			Base case	*High oil imports*	*Low oil imports*
	1985 $/m³ stacked wood (cord)[c]				
Commercial					
Natural gas	5·24 (19)	15·45 (56)	18·76 (68)	19·32 (70)	18·21 (66)
Heating oil	7·73 (28)	18·21 (66)	18·21 (66)	15·73 (57)	21·80 (79)
Coal for steam	2·48 (9)	5·24 (19)	5·79 (21)	5·79 (21)	5·79 (21)
Industrial					
Natural gas	2·76 (10)	11·86 (43)	16·00 (58)	16·28 (59)	15·73 (57)
Residual fuel oil	4·42 (16)	12·69 (46)	13·24 (48)	11·86 (43)	15·18 (55)
Coal for steam	2·48 (9)	4·47 (18)	5·52 (20)	5·52 (20)	6·62 (24)

[a] Prices for selected nonwood fuels from DOE [10] are converted to cordwood cost assuming a cord of green wood contains 20 MM Btu; 10 MM must be used to convert water in wood to steam and the remaining 10 MM Btu are converted to energy at the same efficiency as the fuel that wood replaces. These assumptions imply a cord of green wood (containing 10 MM usable Btu) would have a value 10 times the price charged for 1 MM Btu of nonwood fuel. For example, if natural gas costs $ 10/MM Btu, we could afford to pay up to $ 100/green cord to replace natural gas.

[b] *For* three assumptions regarding rate of oil imports to the United States. The base case, high import, and low import cases assume the following world oil prices per barrel, respectively, in 1995 : $ 30, $ 25. and $ 37. World oil price in 1984 was $ 30.

[c] *To* convert to dollars per cord basis multiply $ /m³ x 3·625.

	Million megagrams (15% MC)
Forest	
Harvest sites	
Logging residues from growing stock and nongrowing stock	167
Standing live and dead trees	21
Timberland	
Excess growing stock	224
Mortality	99

Urban	
Tree removals and wood wastes	75
Other	
Forest products industrial waste	21
Waste wood from land clearing	21
Total, other	*42*
Total. all sources	*628*

However, roughly one-half of the wood physically available is available only at prohibitively high costs. As use of wood for fuel grows, market forces may not lead us directly to use these dispersed waste materials, particularly where wood fuel markets are not well organized.

If fuelwood needs were satisfied by conventional logging practices, we could face several ecologically or economically unsound situations:

(1) Overthinning of high-quality trees for fuel with loss of future high-value large timber
(2) Loss or change of some wildlife
(3) Negative impact on recreation

AN OPPORTUNITY

If this potential problem is properly addressed within the next 10 years, through research and adoption of appropriate technology, we have the opportunity to reap considerable benefits from wood energy.

Already, wood energy use has reduced US dependence on imported oil. Replacement of oil with wood and energy conservation efforts in the pulp and paper industry alone have reduced fuel oil use from $5{\cdot}28 \times 10^8$ MJ (500 trillion Btu) in 1972 to $2{\cdot}43 \times 10^8$ MJ (230 trillion Btu) in 1984, a drop of more than *50 %.* At the same time, production of paper has increased.

Over 55·9 M Mg (15 % MC) of wood were used for residential fuel in 1983, greatly relieving economic hardships caused by higher oil prices. In the process, this use of wood has created thousands of jobs and helped stem the hemorrhage of US dollars in our balance of payments. (Unfortunately, the home use of wood is not without its problems — such as air pollution; thus, industrial or residential use with proper air pollution

As fuelwood use grows, harvest of large quantities of wood can be used to improve forest management. A substantial portion of this wood can come from less intensively managed nonindustrial private forest land. Fifty-eight percent of US timberland is in nonindustrial private ownership. Twenty percent of this land is in parcels of less than 40"5 ha (100 acres).[8] Given these factors, the problem becomes one of how to fill the need for wood fuel from many private ownerships.

The challenge is to supply wood fuel from known, existing, untapped sources. as demand increases.

A SOLUTION

One solution is removal of low-quality wood using small equipment — called 'low-grading' -– from private woodland through farm or farmlike cooperatives.

An independent farmer/landowner could chip undesirable species and multiple-stemmed, improperly spaced, or poorly formed trees up to 128 to 179 mm (5 to 7 in) in diameter using a tractor-mounted or independently powered chipper. The whole-tree chips would be trucked to a concentration yard run by a local farm coop, or wood coop patterned after the farm coop, for consolidation, storage, and shipment, or they would be trucked directly to an industrial or commercial customer. If trucked directly to the customer, the coop would act as the broker.

The coop would have at least two marketing options:

(a) screen and clean the chips to upgrade them for pulp, or
(b) sell the mixed material as fuel

Companies could buy chips from the coop and ship them in bulk by rail or truck.

The idea helps meet the challenge both to supply fuelwood and improve forest productivity. This approach satisfies the need for small regional fuelwood markets to meet the demands of small businesses that could not support large-scale chipping contractors. A conscious decision to encourage low-grading by owners of small woodlands recognizes that ownership of the majority of commercial timber land is private, and that stands are typically unmanaged and include large quantities of small-diameter hardwood trees and some large potentially commercially valuable trees.

The cooperative provides a new means for collecting, concentrating, and transporting scattered wood material. The use of existing coops reduces overhead costs. Because they are member-owned, the operation and management are generally accepted by the farmer. Because existing farm coop facilities can be used, the need for investment in new facilities is reduced. The addition of chips strengthens the coop by broadening its product line.

The use of a tractor-mounted or independently powered chipper — rather than a large whole-tree chipping system — minimizes landowner capital investment. Coops can buy small-scale chipping equipment and rent it to members or as suggested by Brusila[14] hire a crew and do chipping for landowners. The use of small-size chipping equipment encourages the removal of the small low-quality trees rather than the well-formed larger trees. It results in less damage to the remaining trees and ecosystem and frees desirable trees for maximum growth. Poor-quality large trees can be cut for firewood or reduced in size and chipped.

The accumulation of chips from a number of small landowners at a coop helps reduce the high fixed costs per ton for a single small landowner to arrange sale and transport of a small quantity of chips to a buyer. Consolidation of small quantities of chips would allow bulk shipment by rail or truck, and many coops are located at railheads. The coop can upgrade the whole-tree chips to pulp chips or particleboard chips, or can sell unprocessed chips as fuel, depending on market conditions.

Centralized marketing facilitates the acquisition of wood chips by a pulp and paper company, fuel supplier, or fuel buyer by allowing them to deal with a single organization rather than a multitude of landowners. Centralized marketing will also help stabilize the supply of wood chips for buyers.

An additional benefit of the cooperative idea is that the rights of the landowner are given protection from. interference in land management because buyers are dealing with the landowner’s coop rather than the owner directly.

Increased demand for wood for energy is a reality. That we can meet the demand with an as-yet-untapped resource is a possibility. Current means of timber harvesting have economic and ecological problems when used to supply small regional markets. The alternative of low-grading with the aid of cooperatives can serve as a silvicultural treatment that will yield multiple forestry benefits and return a profit to the landowner. Committing ourselves to innovative ideas can assure tomorrow’s bounty — in this case, turning the threat of fuelwood shortages into an exciting challenge.

REFERENCES

1. US Department of Agriculture, Forest Service. (1984). US timber production trade, consumption, and price statistic: 1950–83. *USDA Forest Serv. Misc. Publ. (1442),* Washington, DC, 83 pp.
2. American Paper Institute. (1984) How long will good times last? *Paperboard Packaging,* **69** *(8), 18-46.*
3. American Paper Institute (1984). *US pulp, paper und paperboard industiy estimated fuel and energy use. New* York, NY, Am. Paper Inst., 24 pp.
4. US Department of Energy, Energy Information Administration. (1984) Estimates of US wood energy consumption 1980-1983. DOE/EIA-0341 (83). Washington, DC, 61 pp.
5. Goetzl, A. & Tatum, S. (1983). Wood energy use in the lumber and wood products industry. *Forest Prod. J.,* **33** (3), 44-8.
6. US Department of Energy, Energy Information Administration. (1982). Estimates of US wood energy consumption from 1949 to 1981. DOE/EIA-0341. Washington, DC, 149 pp.
7. Wahlgren, H. G. & Ellis, T. H. (1978). Potential resources availability with whole tree utilization. *Tappi,* **61** *(11),* 37-9.
8. US Department of Agriculture, Forest Service. (1981). Tree biomass — a state-of-the-art compilation. *Gen. Tech. Rep.* WO-33, Washington, DC, 34 pp.
9. Haynes, R. W. & Adams, D. M. (1985). *Simulations of the effects of alternative assumptions on demand-supply determinants on the timber situation in the United States.* Report to USDA Forest Serv., Forest Resource Economics Research, Washington, DC. 113 pp.
l0. US Department of Energy, Energy Information Administration. (1986). Annual energy outlook, 1985. DOE/EIA-0383(85). Washington, DC, 99 pp.
11. Skog, K. E. & Watterson, I. A. (1986). Residential fuelwood use in the United States: 1980-81. *USDA Forest Serv. Resour. Bull. WO-3,* Washington, DC. 42 pp.
12. US Department of Agriculture, Forest Service. (1980). A national energy program for forestry. *USDA Forest Serv. Misc. Publ. (1394),* Washington, DC; 16 pp.
13. Birch, T. W., Lewis, D. G. & Kaiser, H. F. (1982), The private forest-land owner in the United States. *USDA Forest Serv. Resour. Bull.* WO-1, Washington, DC, 61 pp.
14. Brusila, B. (1982). Forest management and marketing cooperatives: are they a viable alternative? In: *Prom Fuelwoo(i management utilization seminar,* 9–1 1 November, 1982, 110–114. East Lansing, Ml, Michigan State University.