WOOD ENERGY IN THE FOREST PRODUCTS INDUSTRY

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Wood is probably the earliest form of fuel used by man. It has had a substantial role as fuel since the dawn of civilization. Fuel is still a major use of wood around the world.. Table 1 shows that in 1976 some 50 percent of the total wood removals was for fuel around the world.(3) In some regions, such as Africa, as much as 89 percent of such removals are made to meet fuel needs. In the tropics, as a whole, 85 percent of wood of wood quantities harvested in 1976 was for fuel, while only 13 percent was utilized for industrial purposes (Table 2).

Table 1. WOOD FUEL - WORLD USE

As Percent of Total Removals - 1976	
LATIN AMERICA	86 %
AFRICA	89 %
ASIA/PACIFIC	80 %
WORLD	50 %

Table 2. WOOD USE IN THE TROPICS - 1976

FUEL	85 %
INDUSTRIAL	11 %
PULP	2 %
OTHER	2 %
TOTAL	100 %

In the early development of the United States, wood was the major fuel. In fact, even in 1800, wood was the primary source of fuel. However, coal began to assume a role as a source of fuel leading to the decline of wood for such purposes (Table 3).(2) The concentrated form of coal proved to be a decided advantage resulting in rapid development of this fuel. Other sources of energy such as oil, gas, and hydro-power gradually assumed their place in providing energy for an industrializing society. Petroleum and gas were heavily relied on after the 1940s continuing to this day as Table 3 and 4 illustrate. (12)

In 1975, nearly 47 percent of the total energy used by the United States came from petroleum. If

Table 3. UNITED STATES PATTERNS OF ENERGY USE

Quads -10^{15} Btu

	Wood	Coal	Oil	Gas	Hydro
1870	2.9	1.0	–	–	–
1900	2.0	6.8	0.2	0.39	–
1920	1.6	15.5	2.6	0.8	0.8
1940	1.4	12.5	7.5	2.7	0.9
1960	0.3	10.1	20.1	12.7	1.7

natural gas contribution is added to that total, some 73 percent of that total came from these two sources. Assuming the energy sources still remain about the same, clearly, the United States has become heavily dependent on petroleum and natural gas to fuel its energy needs.

Although wood began to show a continuous decline as a source of fuel since the 1800s, that decline began a reversal in 1970 as Table 4 illustrates. In

Table 4. SOUCES OF ENERGY USED BY THE UNITED STATES (percent)

	1960	1970	1975
Petroleum	43.5	41.5	46.9
Natural Gas	28.5	33.3	26.4
Coal	22.6	19.2	18.0
Hydroelectric	3.8	4.1	3.9
Nuclear	–	0.3	2.4
Wood	1.6	1.5	2.1
Others	–	–	0.3
Total	100	100	100

1960, only 1.6 percent of the total energy needs of the United States came from wood, decreasing to 1.5 percent in 1970. However, by 1975 that percentage had increased to 2.1 percent and is probably 3 percent or more today.

Wood now ranks as a supplementary fuel providing modest but nevertheless important contributions to the total energy supply in the United States (Figure 1).(12) It is possible and indeed likely that wood may provide as much as 10 percent of the total United States energy needs by the year 2000.

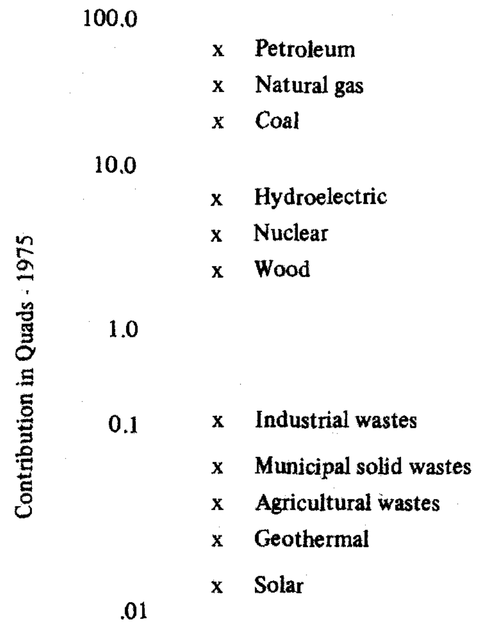

Figure 1. The relative position of wood as fuel in comparison with other sources of fuels.

Wood as Fuel

Wood, as fuel, is not as concentrated (per unit weight) as some of the more popular forms, i.e., petroleum and natural gas. Table 5 shows that petroleum contains some 21,000 Btu per pound contrasting to only 9,000 Btu per dry pound of wood. Coal ranks second with some 13,500 Btu/lb followed by bark, bagasse, and wood. Bulkiness, therefore, can be a distinct drawback. Various processes, such as pelletization, have been used to concentrate more energy into a given volume of wood thereby reducing handling costs. Another problem is the moisture present in wood which could have a substantial influence on its energy yield. Table 6 illustrates this point. It is clear from this table that energy yield can be

Table 5. COMPARISON OF ENERGY CONTENT

Sources	Btu/lb
Petroleum	21,000
Coal	13,500
Douglas fir bark	9,500
Baggase	9,140
Wood	9,000
Raw sewage	7,080
Rice Straw	6,540
Paper mill sludge	5,350

Table 6. WOOD ENERGY/MOISTURE RELATIONSHIP

Moisture Content %	Btu/lb
0	9,000
30	6,000
60	2,600

reduced by as much as 70 percent when moisture content of the wood fuel is 60 percent compared to dry material. In such cases, much of the energy available in wood is utilized to evaporate the moisture, thereby substantially reducing energy yield.

In addition to moisture, energy yield appears to be dependent on the lignin content of the wood. (4, 6, 13) Table 7 indicates that as the lignin content increases from 18.9 percent to 24.0 percent, the energy content of wood species inventoried increases from 8,334 Btu/lb to 8,400 Btu/lb. Carbon content also appears to be directly related to energy yield. In fact, carbon content seems to have a significant influence on energy yield as Table 8 illustrates. (1,4) For example, charcoal with 75.3 percent carbon content contains some 12,094 Btu/lb compared to 8,670

Table 7. RELATIONSHIP BETWEEN LIGNIN AND ENERGY YIELD

Species	Holocellulose-%	Lignin-%	Btu/lb
Red maple	76.0	24.0	8,400
Jack pine	71.4	28.6	8,930
White birch	81.1	18.9	8,334

Table 8. RELATIONSHIP BETWEEN CARBON CARBON CONTENT AND ENERGY YIELD

Species	Carbon Content-%	Btu/lb
Charcoal	75.3	12,094
Douglas fir bark	56.2	9,500
Doublas fir wood	52.3	9,050
Beech	51.6	8,670

Btu/lb for beech wood with 51.6 percent carbon content. This explains a major reason for the widespread use of charcoal production for fuel and a source of industrial carbon around the world.

The major forms of wood energy currently used, in addition to charcoal, include pellets, shavings, sawdust, air-dry hardwoods, hog fuel, bark, and lignin (spent liquor). The pulp and paper industry, by far the greatest user of energy among the forest products industries, utilizes lignin as a major source of fuel. Pellets are basically compressed forms of residue providing a concentrated and fairly uniform source of fuel as earlier noted. Shavings, sawdust, and bark are by-products of sawmilling and other wood processing plants and form an increasingly larger source of fuel. Dry hardwoods, logging residues, foliage, and even portions of the root system are likely to increase their contribution as fuel.

Extent of Energy Used by the Forest Products Industry

The United States produces a greater weight of forest products than any other class of materials with the exception of sand and gravel. Yet, for such volume of production only 5.8 percent of total industrial energy is needed.(4, 5) A major reason is that wood requires relatively little energy per unit of production. Table 9 ranks the various major industries by the amount of energy used. Table 10 shows that to produce a ton of paper or lumber, the energy needs are a fraction of that used by aluminum or plastics. (4).

Table 9. UNITED STATES INDUSTRIAL ENERGY USE*

Industry	Percent Energy Use
Chemical and allied industries	19.7
Primary metals (aluminum, steel, etc.)	21.2
Petroleum and related industries	11.3
Forest products industries	5.8
Food processing	5.3
Stone, clay, glass and concrete	4.9
All other industries	31.8
	100

*Data from various sources and years.

Table 10. ENERGY REQUIREMENTS To Manufacture a Ton of Various Materials

Material	Btu $x10^6$
Aluminum	234
Plastics	150
Steel	52
Paper	21
Lumber	7

As I pointed out earlier, the pulp and paper industry is by far, the major user. Table 11 illustrates this point. In 1976, this industry used nearly 86 percent of the total energy required by the forest products industry. By contrast, the production of lumber required 4.7 percent, plywood and veneer 2.7 percent, etc. Thus, a major energy challenge faces the pulp and paper industry in the decade ahead.

Table 11. UNITED STATES ENERGY USE BY THE FOREST PRODUCTS INDUSTRIES – 1976

Industry	10^{12} Btu	Percent
Pulp and paper	2,193	85.6
Plywood and veneer	70	2.7
Lumber	118	4.7
Logging	77	3.0
Millwork	18	0.7
Other	85	3.3
	2,561	100

Energy Production

A variety of means are available to the forest products industry to produce the steam and electricity it needs from wood biomass. Here, I would like to briefly review the major ones:

Direct Combustion : This technique involves the direct burning of wood biomass to produce steam and/or generate electricity. In this technique burners with either fixed or moving bed varieties are used. Fuel is introduced by either mechanical or pneumatic strokers with wood combustion occurring either in suspension or on grates. One of the more popular types are known as fluidized bed burners which pass gasses, such as air, through a bed of inert particles such as sand. These burners are capable of burning wood fuels of various sizes and moisture levels with high heat transfer characteristics. Some models claim combustion efficiencies of as much as 99 percent with minimal pollution problems. Figure 2 depicts a schematic diagram showing the essential elements of this type of burner (Weyerhaeuser Company). Figure 3 illustrates one possible configuration for steam production with a fluidized bed burner.(9) This figure shows the basic outline of a steam production facility using wood with or without other fuels such as coal, other combustible waste, etc.

Co-generation: Co-generation refers to concurrent production of electricity and process steam. This is a concept of considerable promise as the attempt is made to produce electricity at a competitive cost. Figure 4 illustrates the basic concept. This figure shows that wood biomass with or without association of other fuels is used, in direct combustion, to generate high pressure and temperature steam. The

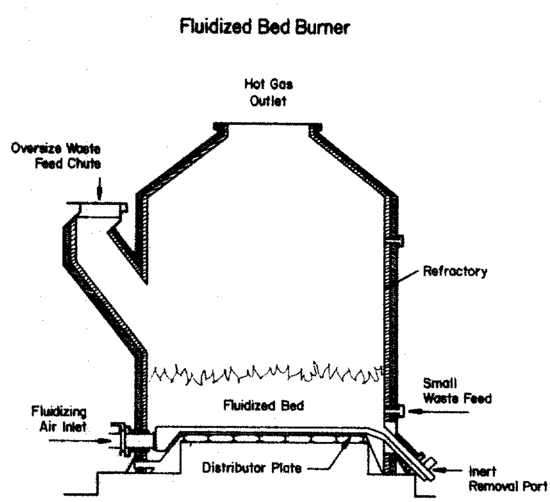

Figure 2. The schematics of a fluidized bed burner.

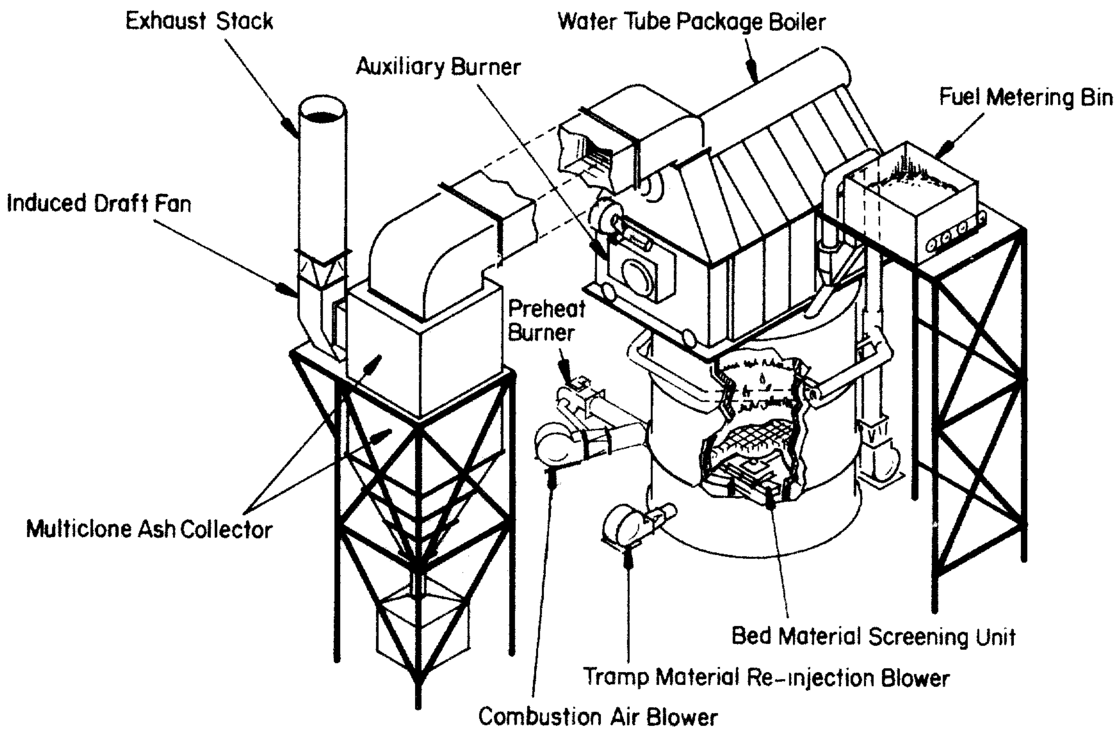

Figure 3. An example of steam production.

steam is routed to a turbine attached to an electrical generator. At the same time, low pressure steam, emerging from the turbine is routed into the mill wherever steam is needed. This concept substantially increases efficiency making energy production from wood economical. Figure 5 illustrates why.

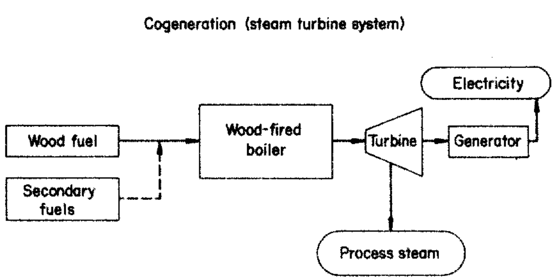

Figure 4. The basic outline of co-generation using wood biomass with or without secondary fuels.

When producing only electrity from wood biomass, the various losses associated with the process leads to an efficiency of only 35 percent.(2) With co-generation, this efficiency is increased to 84 percent since much of the energy is captured in the production of steam. Pulp and paper mills require both steam and electricity in substantial quantities for a variety of production needs. A single power plant complex utilizing co-generation could be used to meet energy needs of an integrated forest products industry located at the same site. Figure 6 illustrates one such concept.(12) Figure 7 presents another general concept of power production using wood biomass.(11)

Pyrolytic Conversion: In pyrolytic conversion, wood biomass is heated to elevated temperatures with minimal presence of oxygen. Below 600℃, greater proportion of gasses (than solid residue) is produced. This is often referred to as gasification. These gasses

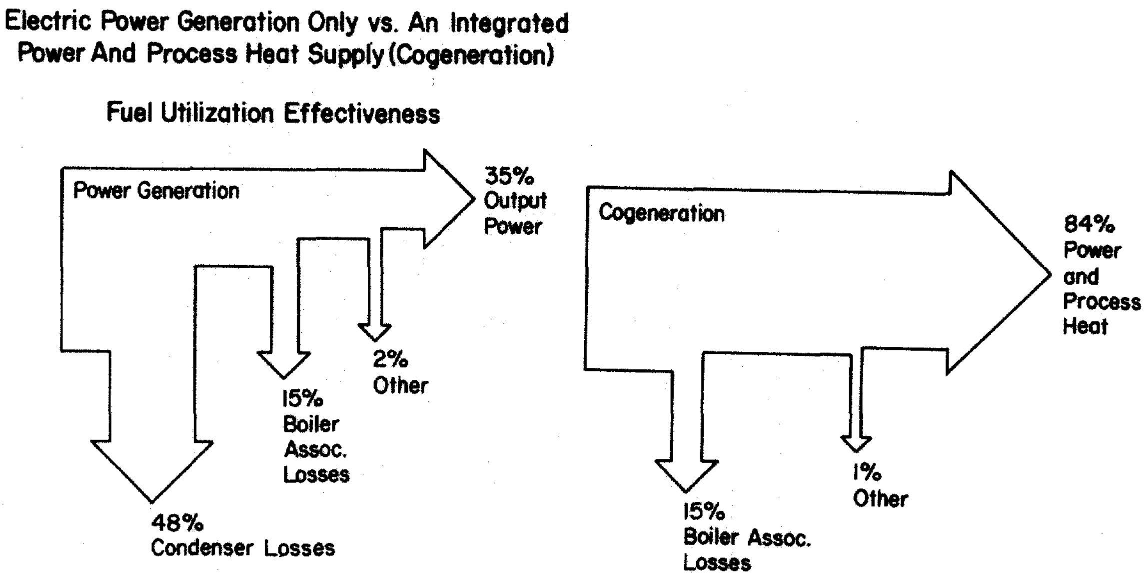

Figure 5. A comparison of efficiencies between cogeneration with electricity production alone.

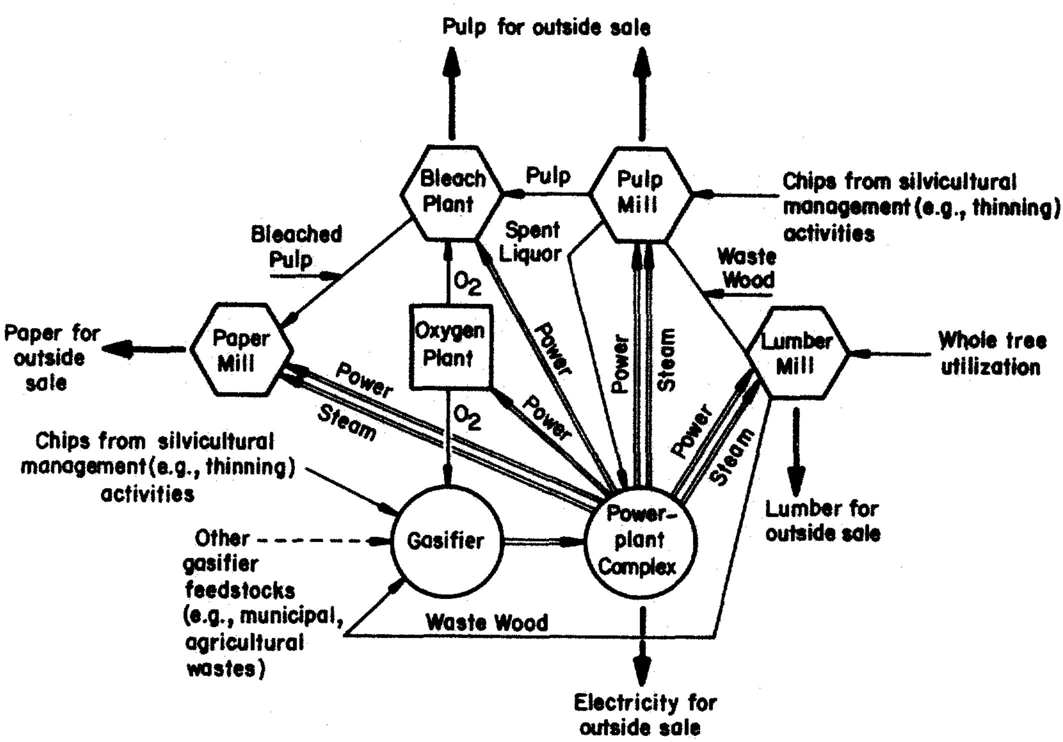

Figure 6. An example of power production in an integrated forest products complex.

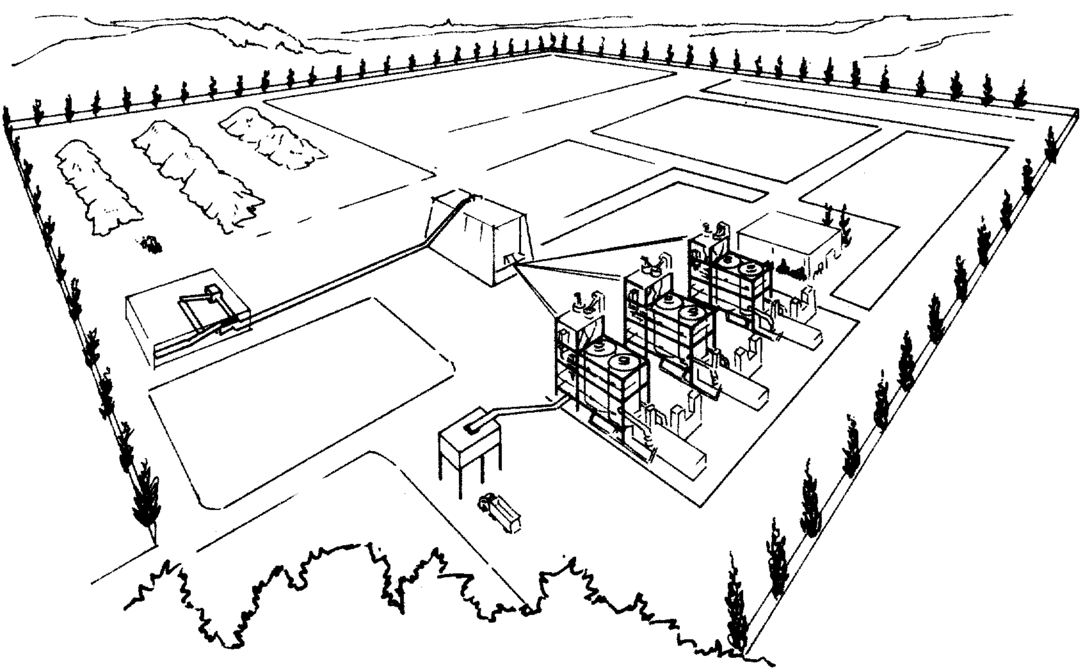

Figure 7. An overview of power generation facility with raw materials storage yard and processing equipment.

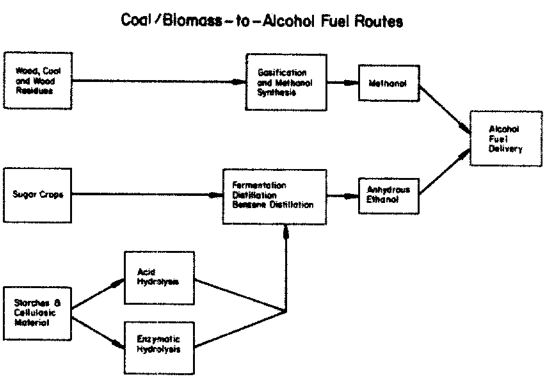

Figure 8. A block diagram showing a variety of routes available for alcohol production.

include CO, CH_4, CO_2, and N_2. They are referred to as low Btu gas because they contain 150-300 Btu/ft^3 compared with 1,000 Btu/ft^3 for natural gas. The gasses so produced can be used as fuel or as the feedstock for methanol (CH_3OH), formaldehyde (HCHO), ammonia and furfural. Methanol can be mixed with gasolin to be used in internal combustion engines without modification. General mixture involves 10-20 percent methanol with 80-90 percent gasoline and referred to as gasahol. Ethanol (C_2H_5OH) produced by fermentation of agricultural by-products and wastes can also be used.(8) Figure 8 illustrates the basic outline of alcohol fuel production using both methanol and ethanol routes.

The Decade Ahead

The decade of the nineteen eighties will be the energy decade. This decade will witness an increased use of wood fuel. The dependance on wood fuel will, in part, result in increased utilization of the total

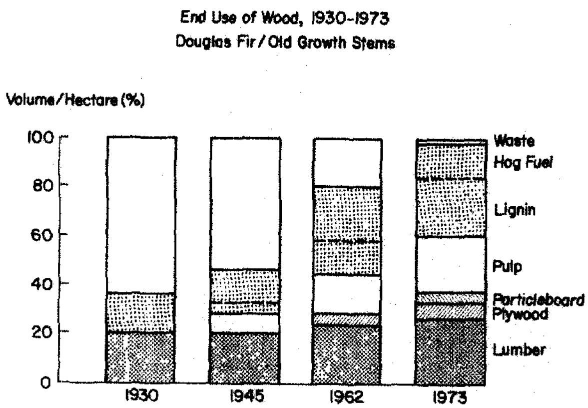

Figure 9. The changing pattern of use for Douglas fir logs over the 1930-1973 period.

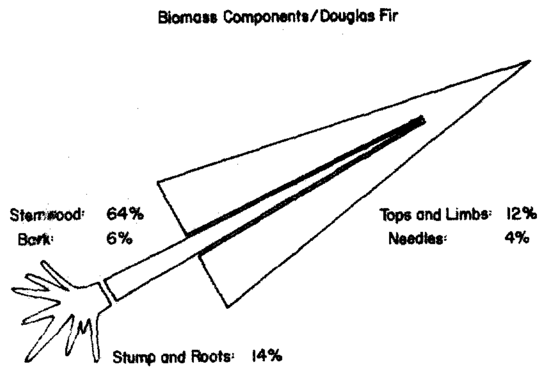

Figure 10. The proportion of the total biomass available in Douglas fir.

tree. Traditionally, only 40 percent of trees have been harvested essentially as stemwood. Additional wastes were generated during the production process. Figure 9 shows an example of the changing pattern for the stems of Douglas fir over the 1930-1973 period in the United States.(10) It is noted that over 60 percent of the stem was wasted in 1930 with that percentage reduced to a small fraction in 1973. The production of other products such as plywood, particleboard, pulp, and energy have accounted for the increased utilization.

Now the situation is changing rapidly. Not only the stemwood but the entire tree including the stump and roots, tops and limbs, and the foliage are being considered for use. Figure 10 illustrates the new approach and indicates the amount of biomass material available for each component of Douglas fir.(10) It is noted that, for Douglas fir, biomass yield can be increased by some 36 percent once these components are considered. Energy production is expected to form a viable use for such portions as bark, tops and limbs, and foliage. The term "energy fiber" has already become prevalent in the industry referring to those portions of the tree destined for energy production.

Self-sufficiency in energy for the forest products industries is a viable goal. Increased resource utilization and rising costs of petroleum and natural gas are the driving force behind the desire to become as self-sufficient as possible. Currently, the forest products industry, as a whole, is 48 percent self-sufficient. Greater levels of self-sufficiencies have been achieved in providing process steam, particularly in larger corporations. For example, in 1978, the Weyerhaeuser Company was 67 percent self-sufficient in process steam.(10) Such self-sufficiencies are not yet matched for electricity (Table 12).

Table 12. WOOD AS ENERGY/Weyerhaeuser Use

Current Use	
○ Self-Sufficiency in Process Steam :	67%
○ Self-Sufficiency in Electricity :	30%
1990 Goals	
○ Maximize Co-Generation	
○ Eliminate Use of Oil and Gas	

However, such large corporations are in the midst of expanding energy production with ambitious goals established for the remaining two decades of this century. Table 13, based on one source,(12) shows that the industry as a whole will be providing the bulk of its energy needs by the year 2 000.

Table 13. ENERGY SELF-SUFFICIENCY OF UNITED STATES FOREST PRODUCTS INDUSTRY (As percent of total energy use)

Industry	1976	2000
Pulp and paper	45	80
Plywood and board	50	80
Lumber	30	60

A limiting factor will involve supply of wood biomass available. Figure 11 estimates the supply-demand picture for the next twenty years(12) indicating no major problems for the United States as a whole.

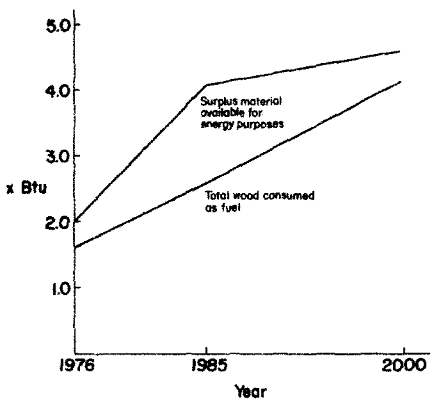

Figure 11. A projection of supply of wood biomass available for fuel in the United States over the 1976-2000 period.

However, localized shortages of wood biomass for energy may develop over the period. In addition, increasing demand for forest products will probably make wood fiber too valuable as raw material for pulp, particleboard, fiberboard and the like. This will make it difficult to justify the use of such raw material for energy purposes. Thus, the forest products industry may begin to look to coal for the primary source of its fuel as we approach the end of this century.

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