Timber: More Effective Utilization

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Timber is commonly defined as trees or forested lands that are a source of wood. Timber provides the renewable resource base for the forest-based industry, considered by various measurements as the fifth largest in the United States.

The major products from timber are (i) structural wood products and (ii) fiber products. The first category consists of lumber and rigid panels including plywood, particleboard, flakeboard, fiberboard, and insulating board, which serve in primary forms as building materials and from which innumerable secondary products are made. The fiber products are market pulp, dissolving pulp, paper, paperboard, molded pulp goods, hardboards, and the hundreds of products made from them (*1*). Three other groups of products are or may also be derived from trees, namely, extractive materials (naval stores, oils, drugs, tannin, and other products); chemicals from the woody tissue or lignocellulose (sugars, alcohol, phenols, and others); and energy (wood fuel, bark, pulping by-products, and pyrolytically produced methanol, gases, and charcoal). In this article we shall deal mainly with structural wood products and fiber products, which provide by far most of the end-use materials from our forests.

Structure of the Industry

Some 250 million tons (226 million metric tons) of raw wood—approximately equal to the U.S. annual production of all metals, cements, and plastics—are currently annually processed by the nation's forest products industries. Projections of the U.S. Forest Service predict a doubling of this demand between 1970 and 2000. Currently, approximately 35 percent of the raw material from the forests is converted to fiber-based products, and 63 percent is required for primary structural materials. By the year 2000, fiber-based products are expected to account for approximately 46 percent of the 22.3 billion cubic feet (630 $\times 10^6$ cubic meters) predicted then to be required annually, with structural products accounting for about 50 percent.

Structural Products

For limited structural applications, wood enters the market in its simplest form as a segment of a tree trunk. For use as poles, posts, and piling, processing requirements beyond harvesting are largely limited to removal of bark and often impregnation with preservative chemicals toxic to fungi and insects. Over 85 percent of structural wood, however, is first converted into prisms or sheets as primary products which are used in these forms for such purposes as building construction or, alternatively, manufactured into innumerable secondary products reliant in part for their utility on form and structural integrity.

Basic primary products are lumber, which is sawed or shaped from the log, and rigid panels, fabricated by reducing roundwood to veneer, particles, flakes, strands, or fibers, which are, in turn, reconstituted into thin sheets by pressing between heated platens, usually in combination with an adhesive. Sheets thus formed are plywood, fabricated from veneer, and building board consisting of an array of engineered products generically classified as particleboard, flakeboard, hardboard, and insulating board.

In 1970, approximately 62 percent of the structural wood consumed in the United States entered the market as lumber, 14 percent as plywood, and 11 percent as building board. This product mix is continuously changing, with reconstituted products accounting for increasing percentages of the total, as a result of changes in the size and quality of the forest raw material, modifications in techniques of building construction (which consumes over 50 percent of our structural wood products), and improvements in processing technology.

The diminishing supply of large logs suitable for lumber of large dimensions, and for plywood, the necessity of using an increasingly higher percentage of the forest biomass which has previously been considered forest residue, and the economic desirability of complete utilization of all raw material entering processing combine as strong incentives for the development of new reconstituted structural products as alternatives to lumber and plywood. Products important among those which are technically and economically feasible and can be expected to enter the market soon are lumber laminated from veneer and a variety of designs of reconstituted structural wood. The former, fabricated from veneer unsuitable for plywood, can serve the same function as lumber of large dimensions, but can be used more efficiently in engineered structures because of better control of variability. The latter, reconstituted from strands or flakes generated largely from what is now forest residue or from low-grade hardwood logs (which are in oversupply), can be used as alternatives to lumber or plywood, depending on the design. The use of structural flakeboard for sheathing in building construction—a function now served largely by plywood—is particularly promising.

Fiber Products

The data in Table 1 indicate that the U.S. pulp, paper, and paperboard industry is large by any standard and plays an important role in the nation's economy. This industry has experienced rapid, continuous growth, amounting to an increase in production of almost 3½-fold over the past three decades. Per capita consumption was 618 pounds (278 kilograms) in 1974 and 616.6 pounds in 1972 compared to 293.7 pounds in 1942, 368.3 pounds in 1952, and 452.7 pounds in 1962.

At the same time that this growth in production and consumption was taking place, the fiber raw material picture has been improving. This is due in part to better management and utilization of our forests, to greatly increased use of mill and forest residues, to broader use of tree species, and to greater efficiency in processing fiber raw materials.

All forecasts indicate a continued future growth of demand and production of paper and paperboard both in the United States and on a world basis. Projections for the United States compared to values for 1972 are shown in Table 2. World demand for paper and paperboard in 2000 is expected to be 456 million tons compared to 155 million tons in 1972. The projected U.S. demand for 2000 is estimated to be 148 million tons or 32 percent of the world consumption.

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Factors Affecting Technological Change

In response to numerous driving forces, the technology of wood processing is undergoing continuous and often drastic change. In order to meet the nation's increasing needs for wood-based materials, future technological advances must occur at a substantially expanded rate.

Future developments leading to more efficient utilization of renewable resources will grow mainly from recent and present trends. Most new processes and technologies take several years after initial research to reach operational stages, so that much of the short-range future can be anticipated.

Included among the numerous factors affecting technological change are construction and equipment costs, energy considerations, legislation and regulations, economic incentives, and, particularly noteworthy, the changing nature of the raw materials base and environmental considerations.

Cost considerations and the availability of capital are most important in the pulp and paper industry which is capital-intensive and each year faces higher capital and operating costs relative to those of other materials industries, including the plastics industry. This implies an increasing cost for these renewable resource products, which tends to restrict the rate at which industry capacity can grow. Cost considerations are, therefore, vital at all stages of pulp and papermaking operations.

Changing Nature of the Raw Material Base

Perhaps the most important factor affecting technological advances in the structural products industry is the rapidly changing nature of the raw materials base. During the period up to the year 2000, most of the accessible, remaining natural forest designated for production will have been harvested and placed under management for sustained and increasingly productive yield. Accompanying this transition will be substantial changes in the size and quality of forest raw materials available for industry. Conversion from old-growth to managed forests will result in a continuing reduction in the size of logs entering manufacture. The long-established trend of more complete utilization of the forest biomass will continue, with the upper limits determined by site and economic considerations. This will further reduce the size, and in many cases the quality, of industrial forest raw material. The ratio of the less desirable hardwoods to the more desirable softwoods available to industry will increase. Hardwoods have provided an increasing proportion of the industry's supply since World War II.

Table 1. Statistics for 1972 characterizing the U.S. pulp, paper, and paperboard industry (excluding hardboard). Tons, where listed, signify short tons; kwh eq, kilowatt-hour equivalent. [Source (*4*)]

Item	Quantity
Number of establishments	787
Total number of employees	221,100
Total products produced* (tons)	57,491,000
Tons of production per man-hour	0.158
Value added by manufacture (millions)	$ 5,364.2
Total value of shipments (millions)	$11,675.4
Capital expenditures (millions)	$ 893.6
Payroll (millions)	$ 2,455.7
Cost of materials (millions)	$ 5,388.9
Cost of electricity and fuel† (millions)	$ 891.0
Purchased fuel (kwh eq/ton)	5,509
Electric energy purchased (kwh/ton)	470
Generated less sold (kwh/ton)	429
Purchased fuel and electric energy (kwh eq/ton)	5,979
Materials input	
Pulpwood (including harvesting and manufacturing residues) (cords)	71,538,000
Wood pulp (from above pulpwood) (tons)	43,628,000
Waste paper (tons)	11,405,000
Inorganic chemicals, clay, starch, and others (tons)	9,095,000
Nonwood fibers (tons)	1,047,000

*Excluding hardboard (1,908,000 tons). †The figure for contract and resale was $14.9 million.

Forest productivity data indicate that there will be adequate forest biomass, at least until the turn of the century, available to meet the nation's industrial needs. Because of the factors indicated above, technological advances, many of which are now well under way, will be required to utilize this biomass more completely and to adjust to its changing size and quality.

Environmental Concerns

The structural products industries are becoming relatively free from environmental problems because the burning of waste material has nearly ceased except for some small plants. Some problems are encountered by wood preservation plants. Major environmental concerns center around the manufacture of pulp and paper.

Meeting anticipated environmental regulations of the paper industry is expected to be very costly and has resulted in intensive research to mitigate and solve air and water pollution problems. In 1972 the industry spent $339 million in capital expenditures (*2*) for pollution abatement equipment. Other costs relating to this problem amounted to $243 million. Significant progress has been made by the pulp and paper industry in pollution control, but there is concern over the industry's ability to sustain environmental protection expenditures in excess of the $0.5-billion annual level that has been met during the past 3 years. This includes considerable research expenditures necessary for the development of the best pollution control technology.

Such research expenditures decrease the funds that can be budgeted for other technological developments and for needed capacity expansions. However, the stimulus to solve pollution problems is leading to the development of new technologies for processes that are more environmentally acceptable. These include new pulping and bleaching processes that lead to pollution abatement. Important advances are being made in modifying the kraft process and in the development of new pulping and bleaching processes using oxygen, with concomitant reduction in pollution emissions.

Energy Effectiveness

In view of the high probability of increasing costs of liquid and gaseous fuel, at least until the turn of the century, the relatively low energy requirements for processing wood into primary products, and the degree to which wood processing for many products is self-sufficient are particularly important. As can be expected, energy requirements are related to the extent to which the basic raw material must be altered in processing. In general, the fiber-based industry is understandably more energy-intensive than are many segments of the structural products industry. Essentially all forms of wood processing, however, are superior to the processing of alternative materials from the standpoint of national energy self-sufficiency.

Structural Wood Products

Energy requirements for raw material extraction and its processing to a commodity are shown in Table 3 for selected structural wood products and for commodities used as alternatives. Not only are the gross energy requirements for many wood products substantially lower than alternative products based on nonrenewable materials, but the degree of energy self-sufficiency of many wood products is striking. Softwood and hardwood lumber and hardwood plywood, which in combination account for more than 62 percent of currently used structural wood products, are not only completely energy self-sufficient in the manufacturing process but additionally generate a substantial residue of fuel which can be used elsewhere for industrial or domestic energy. Structural flakeboard, which is not now in production but is highly promising as an alternative to

plywood, will similarly be energy self-sufficient. Softwood plywood, which now accounts for about 13 percent of our structural wood requirements, and laminated veneer lumber, which holds much future promise, both generate adequate processing residue for fuel to supply more than half of the demands for energy required in their manufacture.

More than half of the structural wood products consumed in the United States are used in the construction of residential and light industrial buildings. This expanding market is highly attractive for alternative materials based on nonrenewable resources. A recent study by the Committee on Renewable Resources for Industrial Materials (CORRIM), under the auspices of the National Academy of Sciences/National Research Council, comparing residential construction systems for floors, walls, and roofs incorporating wood and nonwood materials, demonstrated a clear superiority of wood over nonwood alternatives in energy efficiency. Taken into consideration are energy requirements for raw material extraction, processing into building materials, and transportation of materials to the building site. This study shows, for example, that steel floor joists require 50 times as much energy as their wood counterparts performing the same function. Aluminum framing for exterior walls is approximately 20 times as energy-intensive as wood framing. Aluminum and steel studs for interior walls require, respectively, 12 and 8 times the energy of wood studs. Steel rafters exceed wood trusses by a factor of 7 in energy requirement, and aluminum siding requires approximately 5 times the energy of its plywood and fiberboard counterparts. Brick siding requires 25 times the energy of wood-based siding materials. Similar conclusions with respect to commercial structures are drawn from a well-documented study by Bingham (*3*).

The CORRIM study also compared labor and capital depreciation requirements for alternative floor, roof, and wall construction systems and revealed no consistent differences in these requirements for systems based on wood and nonwood components. It appears that, when the conservation of energy is of prime importance, wood is the preferable material for residential and light commercial construction. The insulation characteristics of wood are also superior, which means lower energy requirements for heating.

The Paper Industry

The paper industry is a major consumer of energy (320 billion kilowatt-hour equivalents) which is greater than that consumed by the plastics, rolled aluminum, or plate-glass industries. However, the energy consumed per ton is less than for any of these other materials. Also, the energy cost as a fraction of total manufacturing cost (10 to 16 percent) is less than for such nonrenewable materials as plastics or aluminum.

The paper industry now supplies as much as 42 percent of its energy need from its own process wastes. Therefore, as purchased fuel and power costs increase, the effect on the cost of a ton of paper will be less than the increase in cost of a competing product made from a nonrenewable resource. New technology to improve this capability would further increase this advantage and economize on imported fuel.

Research is under way to reduce energy consumption at the various process steps in the manufacturing operations, such as in refining and drying. Other energy-saving research includes recovering low-level heat from process streams (better heat exchange and recycling), improving generation of energy from processing wastes (better recovery furnace operation), producing low energy, high yield products, reducing the fiber weight in the end-use product, and lowering the brightness requirement for paper.

Efficiency of Material Use

The forest products industry is often considered wasteful of raw material in harvesting and processing. Undeniably, under

Table 2. Statistics and forecasts for paper and paperboard for 1972, 1985, and 2000. Data for hardboard are excluded from the table; figures for hardboard for these years are 1,908,000, 2,885,000, and 4,500,000 short tons, respectively. Figures for the real gross national product (GNP) are $792.5 billion for 1972, $1,222.0 billion for 1985, and $2,000.0 billion for 2000. [Data from the American Paper Institute, New York]

Year	Thousands of short tons				Trend‡
	New supply*	Exports	Imports	Production†	
1972	62,278	2,841	7,626	57,491	78.58
1985	95,155	3,935	10,730	88,360	77.87
2000	148,335	5,710	17,185	136,860	74.17

*Real GNP times trend. New supply = production + imports − exports. Assuming no change in inventories, new supply is considered to be apparent consumption (demand). †Production = new supply + exports − imports. ‡Ratio of new supply to real GNP; extrapolations of past ratios for the future.

Table 3. Energy requirements for selected wood-based commodities and commodities not based on wood. In calculations of supplementary requirements, it is assumed that energy from processing residual fuel can be used only in the manufacturing process and not in extraction. Values in parentheses are for energy from processing residual fuel in excess of that required for manufacture which could be available for other uses. [Source (*5*)]

Commodity	Energy (10^6 Btu/oven-dry ton)				
	Extraction	Manufacture	Total	Available from processing residual fuel	Supplementary requirements for manufacture
Wood-based					
Softwood lumber	0.943	4.846	5.789	8.313	0 (3.467)
Oak flooring	1.073	5.691	6.764	11.388	0 (5.697)
Lumber laminated from veneer	0.740	6.587	7.327	3.540	3.047
Softwood sheathing plywood	0.747	6.871	7.618	3.697	3.174
Structural flakeboard	0.956	7.511	8.467	8.616	0 (1.105)
Medium-density fiberboard	0.783	9.303	10.086	2.741	6.562
Insulation board	0.622	10.539	11.161	0.667	9.872
Hardwood plywood	1.041	10.242	11.283	10.629	0 (0.387)
Underlayment particleboard	4.617	8.101	12.718	1.529	6.572
Wet-formed hardboard	0.743	19.662	20.405	0.797	18.865
Not wood-based					
Gypsum board	0.14	2.73	2.87		
Asphalt shingles	0.03	5.70	5.73		
Concrete	0.52	7.60	8.12		
Concrete block	0.52	7.60	8.12		
Clay brick	0.57	7.73	8.30		
Carpet and pad	6.60	28.69	35.29		
Steel wall studs	2.45	46.20	48.65		
Steel floor joists	2.45	46.20	48.65		
Aluminum siding	26.80	172.00	198.80		

past economic conditions closely related to an abundance of inexpensive large logs of desirable species from wild, old-growth forests, only a small percentage of the resource from the forest entered manufacture. Also, a substantial percentage of the raw material entering the plant became unused residue from the primary product. The changing resource base, accompanied by increasing raw material costs, has stimulated ever-increasing industrial integration with an associated increase in efficiency in the use of all available material. Harvesting technology is being directed to obtain maximum economic removal of as much forest material as can be processed. Processing technology is rapidly being developed to make most species and all sizes of trees and tree parts useful. In the future, the volume of forest residues used can be expected to be influenced by requirements for maintaining site quality rather than by harvesting and processing technology.

The Structural Products Industry

In processing, the quantity of raw material entering the plant for manufacture of the primary product varies with the form and quality of the entering raw material. In today's modern, economically viable plants, the residue from the manufacture of the principal product becomes input raw material for an integrated manufacturing process or fuel to provide energy for manufacture. This reduces or eliminates reliance on fossil fuels. As illustrated in Table 4, absolute waste does not occur in such plants. Less efficient plants, lacking in integration, in which substantial quantities of residue remain unused are still to be found, but their numbers are diminishing.

Better Fiber Utilization

In recent years there has been a continuing trend toward more efficient processing and utilization of wood by the paper industry. For example, there has been a decline in the amount of wood used per unit ton of all pulp types from 1.60 cords per short ton in 1960 to 1.51 cords per ton in 1973. This reduction is partly due to the use of greater percentages of hardwood but primarily it is the result of technological changes enabling the use of higher yield pulps in the manufacture of packaging papers and paperboard, as well as for dissolving pulps.

Since 1950 there has been a shift, not only to a greater use of hardwoods (about 25 percent of all wood pulped), but to integrated utilization of sawmill residues. In 1973 about 38 percent of all wood pulped was in the form of wood manufacturing residues (32.5 percent) and logging residues (5.2 percent), compared to only 17 percent in 1960. When we take into account recycled waste paper and other residual fibers (linters, rags, and bagasse), then more than half the fiber supply that the industry draws upon comes from fibers that would otherwise be discarded. This leads to fuller utilization of the forest resource on an integrated operational basis.

Other waste wood from urban forestry, construction, demolition, pallets, and so forth is another potential fiber source. This is only now beginning to be considered significant.

Today about 22 percent of paper fiber is recycled. In recent years the industry has thoroughly assessed the potential for expanded recycling. It is believed that waste paper recycling will peak at some value less than 30 percent. This figure is based on the economics and technology of collection, handling, and transportation and on the assumption that there will be some degree of public encouragement. This appears to be quite reasonable for the U.S. market and quality demands, since research has shown that the primary fiber has lost its strength potential after about the third recycle. It is possible to regenerate some of its lost potential by chemical treatment, but costs and pollution are factors that mitigate against such efforts.

As more and more of our major cities go to the burning of their organic wastes for heat and energy, the waste paper in this solid waste stream will provide a major combustible component. Only the higher quality and readily collectable clean waste will be recycled for more paper.

Of growing importance is the concept of whole tree utilization, or use of the whole tree above the ground: trunk, branches, twigs, leaves, and bark. Since 1970 there has been some usage of whole tree chips for pulping. As further demands are made on wood and costs rise, there will be greater dependence upon the use of the whole tree. This will fully tap the forest resource and, together with the use of wood manufacturing wastes, will greatly enhance our fiber supply. Moreover, it will lead to better forest management practices to achieve optimum growth rates.

Although wood costs themselves will cause a trend toward wider fiber use and higher pulp yields, developing technologies lend themselves to use of lower quality fiber and higher pulp yields. This is fortunate, and will encourage the development and early application of these new processes.

Table 4. Wood-based primary structural commodities. These materials balance summaries are based on 1 oven-dry ton input of forest-based raw material. [Source (5)]

Principal product	Approximate recovery (oven-dry ton)						
	Input raw material	Principal product	Lumber (studs)	Pulp chips	Fuel	Solubles and volatiles	Other
Wet-formed insulation board*	1/2 bark-free chips, 1/2 forest residual chips	1.04			0.05	0.10	
Underlayment particleboard†	Dry mill residue	0.98			0.11		
Wet-formed primary hardboard‡	1/2 bark-free chips, 1/2 forest residual chips	0.87			0.05	0.10	
Medium-density fiberboard§	1/2 roundwood, 1/2 bark-free chips	0.86			0.17	0.06	
Softwood plywood (unsanded)‖	Roundwood	0.45	0.06	0.30	0.12		0.08 Particleboard furnish
Softwood lumber	Roundwood	0.35		0.29	0.21		0.15 Particleboard furnish
Hardwood plywood (sanded)¶	Roundwood	0.30		0.48	0.23		
Hardwood lumber	Roundwood	0.28		0.29	0.23		0.20 Particleboard and medium-density fiberboard furnish

*0.19 ton of starch, wax, and asphalt added to raw materials; mechanical pulping assumed. †0.087 ton of adhesive and wax added. ‡0.02 ton of adhesive and wax added. §0.09 ton of adhesive and wax added. ‖0.01 ton of adhesive added. ¶0.01 ton of adhesive added.

Legislation and Economic Factors

Legislation and regulations that directly affect the forest industry are those dealing with land use, the environment, food and drugs, energy, occupational safety and health, interstate commerce, consumer protection, building codes, and enhancement of recycling. Environmental regulations have had a large impact upon the paper industry in the past few years and are expected to play a major role in the industry's future.

The amount of capital available for the expansion and improvement of cost effectiveness of a business is limited by the cash flow and profits that can be generated by that business. The extent to which this amount of capital is allocated to facilities or operations that are solely designed to meet governmental regulations, such as those pertaining to the environment, without increased production or product improvement, reduces the amount available for capacity expansion, cost reduction, and product improvement. Furthermore, older plants may have to be closed prematurely because they cannot afford to meet new environmental requirements, causing local unemployment. Consequently, productive capacity could be curtailed and fall behind product demand. This and the failure to reduce costs lead to higher prices and inflation.

Economic incentives may take the form of outright grants, investment tax credits, or other special legislation available to the government to encourage the adoption of new technology and concepts to expand and improve the utilization of the renewable wood material resource. If other factors do not interfere, economic incentives can speed up acceptance of new technology and operating concepts by as much as 5 years.

Recommendations

The forest products industries as a whole have needs which apply to all its segments. In addition, the major components of these industries have their own special needs. The recommendations to fulfill these needs are listed accordingly.

The Forest Products Industries

1) Centers of excellence for the education of scientific manpower in wood and fiber science and technology should be maintained with governmental support at leading universities.

2) Substantially increased research directed toward advancing technology in wood and wood-fiber materials must be strongly encouraged with governmental financial support where needed.

3) Because of the decreasing size of available timber and the increasing necessity to utilize a higher percentage of the forest biomass, it is important to develop cost-effective methods of recovering forest residues and other material of small and irregular size.

4) Attention must be directed to reducing power consumption in all phases of logging, manufacture, and transport in the forest products industries.

5) There should be economic incentives to maintain the growth of the forest-based industries and enable them to invest in innovative activities by (i) outright grants; (ii) investment tax credits; (iii) financial assistance for capital costs, for research in environmental control and energy efficiency, and for research and development activity in engineering, production and marketing of new products and processes; and (iv) legislation to encourage the adoption of the technology and concepts to expand and improve the utilization of the renewable wood resource and the protection of the environment.

The Structural Products Industry

1) Inasmuch as the future structural products mix must consist of ever-increasing percentages of reconstituted products, concentrated research must be directed toward improving processes of manufacturing structural materials suitable for exterior and interior use from hardwood and softwood flakes, strands, veneer, fiber, and pieces of small size, alone or in combination. An associated need is the development of inexpensive adhesives, not petroleum-based, for reconstituted products, with particular attention to an exterior adhesive which can serve the function of the currently used phenol-formaldehyde. Lignin from wood could be a potential source for the development of such adhesives.

2) Because a major portion of the energy required for the manufacture of wood structural materials can be provided from processing residue, research should be directed to the development of economical greenwood and bark burners for direct-fired dryers and wood-fired boilers. There should also be research on the development of dryers, heating vats, and hot-presses of high thermal efficiency.

The Pulp, Paper, and Paperboard Industry

1) The renewable wood fiber industries should be encouraged to reduce further the consumption of energy and thereby not only help improve the overall energy situation, but also reduce costs and improve competition with nonrenewable materials. This can be done by (i) reducing energy used in processing by heat exchangers, thermal recycling, and closed loop systems; (ii) improving generation of energy from processing wastes; and (iii) producing lower energy, high yield products.

2) There should be a concentrated research effort by the industry with governmental support. Present funding for research in the pulp and paper area is about $250 million annually, of which about 40 percent goes for maintaining present equipment and technology and the remainder for innovative research. This expenditure is about 0.6 percent of the industry's sales value or about 9 percent of its capital outlays, which is small compared with budgets dealing with other materials and processes. The crises in energy and scarce materials call for immediate steps to permit the renewable fiber industries to improve their products, reduce energy, improve their competitive position with respect to petrochemical and other nonrenewable materials, and improve processing efficiency by increasing yields, reducing wastes, lowering costs, and enhancing the quality of the environment. To achieve most of these goals for the paper industry by 1985 requires that the innovative component of the overall research effort be increased to a figure of around $450 million now and then be kept level with inflation. This figure plus the continued maintenance research cost of $100 million (in 1975 dollars) would bring the total annual research expenditure to about 1.3 percent of the present sales value. These figures are for R & D only. Commercial implementation will require continued large capital investments to meet environmental, energy, and innovative process and product demands over the next decade.

3) Governmental regulations, especially those pertaining to the environment, should be implemented and administered in such a way that (i) their impact upon the consumer and the renewable fiber resource industries is reasonable and (ii) the health of these renewable industries is not endangered, but instead maintained in sound condition.

References and Notes

1. In the United States, 98 percent of the fiber for paper and paperboard is derived from wood.
2. Data from the National Council of the Paper Industry for Air and Stream Improvement, Inc., New York.
3. C. W. Bingham, *For. Prod. J.* **25** (No. 9), 9 (1975).
4. Data from 1972 Census of Manufactures, Washington, D.C., and the American Paper Institute, New York.
5. Data from "Renewable resources for structural and architectural purposes," report of Panel II, Structural Purposes, Committee on Renewable Resources for Industrial Materials, National Academy of Sciences/National Research Council.

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