Forest Harvesting, Wood Utilization, and Products of the Future

H. M. Montrey, *deputy director, Forest Products Laboratory, and* John I. Zerbe, *manager, Energy from Wood Program, Forest Products Laboratory, Forest Service, Madison, WI*

In the United States, wood is still a major construction and industrial material. Wood housing has been the mainstay of the American family from the time of the first European settlers, and it remains important to our way of life. Today most of our housing is predominantly wood framed. Even single-family houses and low-rise apartment buildings with masonry walls often have wood framing behind the masonry veneer and framing in floors, partitions, and roofs. Results of today's research in improving the use of wood from foundation to rooftop will ensure an adequate supply of comfortable housing at a reasonable cost of construction in the future.

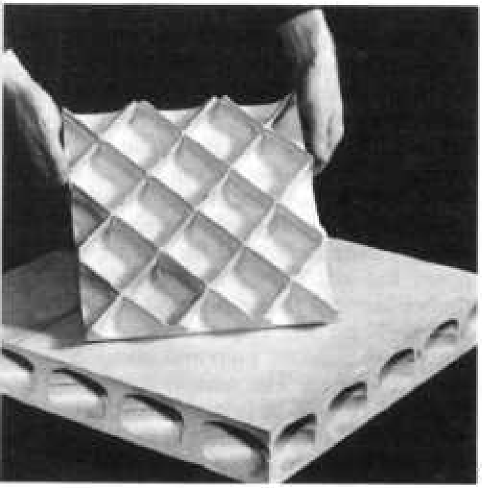
The United States is fortunate that it also has adequate wood supplies. Improvements in harvesting methods and forest-management practices are helping hold costs of timber to affordable levels. Production of this versatile, renewable, and abundant material now exceeds harvest, and available supply is increasing by 1 percent a year. Today much of the excess is in lower grade hardwoods (broad-leaved trees), but research also is leading to ways of making these trees attractive for use in products of tomorrow. More efficient use also is contributing to an effective extension of timber supplies.

Future research will be focused on more closely matching product end-use requirements with raw material quality and processing technology. In 1952, only 60 percent of the residues generated at forest-products manufacturing plants were used for other purposes, but in 1976 all but 4 percent of timber brought to the mill was used. Nearly 60 percent of processing residues were used for pulp and about 20 percent for fuel. The remainder was exported or used in particleboard and a variety of other products.

In the future, more of the residues are expected to go into composite panel products that may be used in structural applications which previously required boards or plywood. Research over the past decade has accelerated the manufacture of nonveneered structural panels such as oriented strandboard and waferboard. As for other particleboard and fiberboard products, manufacturing of these nonveneered structural panels does not require large or straight-growing trees. Composite panel also can be made from a large variety of species, including hardwoods, which are often produced in excess.

Growth and use of forest products may be managed to enhance the environment through resisting erosion by water and damage by wind. Well-managed forests also may help in soil conservation by maintaining a desirable soil nutrient balance. Harvest revenues may pay for better forestry practices as well as other forest uses such as recreation. Research and development efforts can lead to improved harvesting methods, higher levels of forest land management, and increased benefits.

Just as housing construction has been based on wood, U.S. industry has long depended on wood as an important raw material. In 1972 the Na-



Spaceboard—a molded structural sandwich product made from paper—will be used for a variety of applications, including wall and ceiling panels and decking.

tional Commission on Materials Policy found that, of the 21 tons of material per capita required annually in industrial operations, 9 tons were for fossil fuels, ⅔ ton for metals, and 1⅓ tons for forest products. Comparing dollar values for these materials is difficult, but the value of primary forest products is clearly comparable to that of metal products.

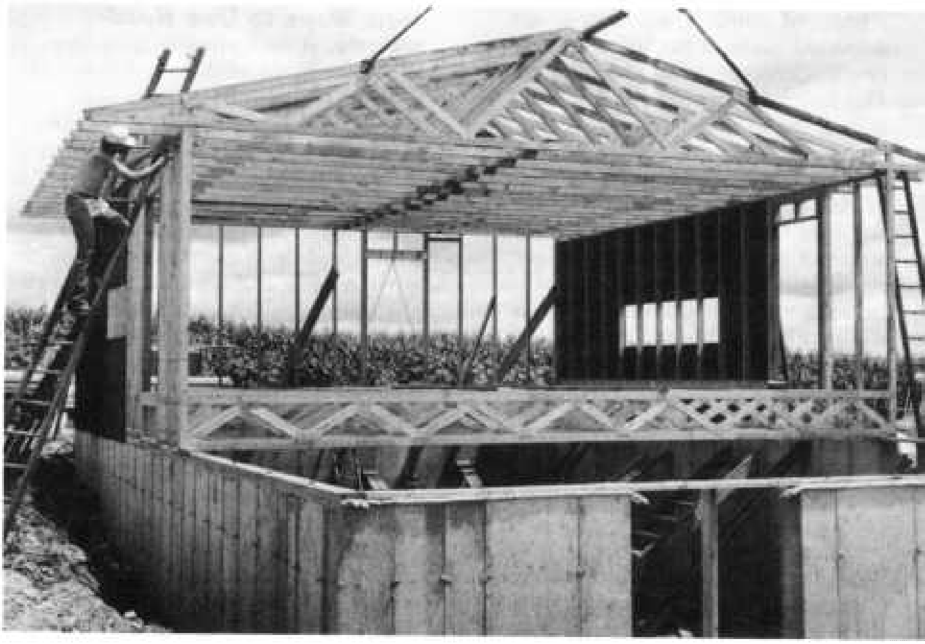
Besides its obvious uses in industrial and consumer products, wood has several intriguing applications in national security and emergency preparedness. Wood is not comparable to metals in importance for armaments and ammunition, but it can replace scarce metals in other applications and has some unique uses for which metals cannot compete. Last year marked the first time since World War II that the Department of Defense awarded a contract for minesweepers, and these ships will be made entirely of wood. Successful large wind electrical generators, which have been designed since the energy crises of 1973 and 1979, generally use blades made of wood.

Wood Use in Housing

One of the most innovative uses of wood in housing construction and one likely to grow significantly in the future is wood foundations. Historically, builders have contended that durable foundations have to be built of masonry. But research has shown that suitably treated wood and plywood foundations with proper drainage of water away from the foundation wall can provide some economic, structural, and esthetic design advantages. Wood foundations should prove to be particularly beneficial in colder climates where they may be erected during most of the year and easily fitted with insulation.

Wood Floor Framing. Wood floor framing has been improved recently with the acceptance of a construction method in which floor surfacing, such as plywood, is glued to load-carrying floor joists to provide composite structural action. The result is more stiffness and strength with less material. Increased use is being made of parallel chord trusses and I-beams, particularly for long spans, as availability of wide lumber decreases. In the future, floor joists may be molded into structural shapes, such as I-beams, from available particulate material as is used in the manufacture of oriented strandboard. Already, the first plant is being built to construct framing members with an inner core weaker material and an outer web of stronger material. The plant will manufacture Com-Ply®, which forms a rectangular cross section like conventional lumber studs and joists but has a particleboard core and veneer surface layers.

Wall Framing. Future wall framing for houses will likely see more appli-



The Truss-Framed System uses less lumber and requires fewer supports than conventional framing.

cations of composites and other improved structural shapes that may be fabricated from more abundant lower-value materials such as strands from hardwoods. A new product type from pulp fiber being studied at the Forest Products Laboratory shows promise for building modules as well as improved paperboard containers. This product—Spaceboard—is a molded structural sandwich that has superior strength-to-weight characteristics and is not as limited in orientation to load application as conventional framing materials. Engineered paperboard structures could become a reality and make better use of our wood resources if adverse effects of moisture and humidity can be overcome.

Oriented strandboard is a new product that fulfills a need for a composite panel board with mechanical properties equivalent to those of structural plywood. Oriented strandboard is composed of three layers of aligned strands bonded together with a liquid phenolic resin. The wood strands in the top and bottom layer lay parallel to panel direction; those in the core lay perpendicular to the panel direction.

In 1980, there was only one structural flakeboard plant in the United States. Today, there are over 15, and construction of other facilities has been announced. Future research will lead to molded oriented strand products tailored for specific end-use application.

Prebuilt Frames. A new development gaining acceptance for floor, wall, and roof framing is the Truss-Framed System developed by Forest Products Laboratory engineers. The system incorporates an open-webbed floor truss, an open-webbed roof truss, and conventional wall studs in a unitized frame. These frames are delivered prebuilt to the construction site and erected on the foundation. The frame is constructed primarily from 2 by 4 lumber instead of the more expensive and less available 2 by 8 and 2 by 10 lumber common in conventionally designed homes. Because the trusses can span the width of most homes, supports are not needed in the basement and load-bearing walls are not necessary on the first floor. This will provide for more flexibility in using space to best advantage. Future construction practice will incorporate increased use of this and other innovative modular systems.

As pressures build within the wood-products industry to penetrate new markets, innovative building systems will be developed to allow wood to substitute for steel in nonresidential construction.

Exterior House Materials. Although the use of wood for exterior house siding has decreased, exterior forest-products finish materials will continue to be used extensively in house construction and their characteristics will be improved. Since some type of finish is generally preferred for protection, performance, and appearance of the wood itself whenever wood is used outdoors, research efforts are aimed at developing more reliable pretreatments and finishes to increase wood's longevity. Better paints, stains, water repellants, and other preservative treatments will be developed as well as better wood and wood composite substrates on which to apply these products.

Processing Improvements

Increased benefits should come from improvements in processing wood raw materials to make the products better and more economically.

New Ways to Use Hardwoods. A new process, Saw-Dry-Rip, uses medium-density hardwoods to make structural-grade lumber, which is normally made from scarcer and more expensive softwoods. Currently, little or no structural lumber is made from hardwoods, in part because it warps and twists when it is sawed and dried conventionally. With Saw-Dry-Rip and with additional benefit from high-temperature drying, stresses in the wood are relieved and warp is reduced. This means the wood is cut straight and stays straight.

Press drying of paper will also permit the use of hardwoods for more conventional purposes. Traditionally, papermakers prefer softwoods because their fibers bond more easily than high-density hardwood fibers, which are short and stiff. By applying heat and pressure to a wet web of wood fibers simultaneously rather than separately, press drying produces strong paper from 100-percent hardwood pulp.

Steam Injection Pressing. In the manufacture of waferboard, particleboard, and medium-density fiberboard, a new steam injection pressing process will reduce press time up to 90 percent on thick boards. With this new process, resin-coated flakes are formed into a mat and loaded into a press as in conventional processes. Then, under computer control, saturated steam is injected into the mat. This permits the center of the board to quickly attain high temperatures as the board is compacted, and the high temperature accelerates the resin cure. Besides reducing the press time significantly, the process also permits use of smaller equipment. The end result is large savings in energy and capital costs. Steam injection pressing also can incorporate additives for greater durability and fire resistance.

Automation of Lumber Production. Perhaps the greatest improvement in wood processing will be full automation of lumber production, since lumber is the most important manufactured solid wood product. Wood processing centers will depend less on human decisionmaking and physical labor. Skilled technicians will monitor the automated operations using advanced computerized devices. These techniques, coupled with state-of-the-art processing techniques such as laser cutting and use of advanced cutting materials, show much promise for the future.

Advanced Drying Technology. For wood to perform satisfactorily in many applications, it must be dried to a moisture content in harmony with the environment where it is used. Otherwise, splitting, twisting, shrinking, swelling, and warping in place will cause problems. Advanced drying technology should result in improved quality and shorter drying times. Savings will then result from elimination of drying defects. conservation of energy, and reduction of storing and handling costs.

Design Improvements

Because of past utilization practices, much of the hardwood forest is composed of low-quality trees. So it is becoming increasingly important to use this lower value material more effectively. Harvesting removes only about half of the woody material, and each subsequent step in the processing chain generates additional residues. Even the best grades of wood are not used to maximum efficiency because we do not know enough about wood's material properties.

For the future, reconstituted panel and fiber products provide an opportunity to produce engineered materials that optimize particle or fiber properties to meet specific end-use requirements and reduce overdesign. Modern engineering design practices require a more precise estimation of lumber properties than can be achieved with current procedures. Today, strength properties are usually assigned by visual grading and correlating appearance with recorded values from tests of specimens that did not have apparent strength-reducing characteristics. In the future, we will see more improved systems for automated lumber grading in which structural pieces are nondestructively evaluated and assigned strength values. As characteristics of the softwood resource change because of increasing volumes of plantation-grown trees, automated lumber grading will become pervasive.

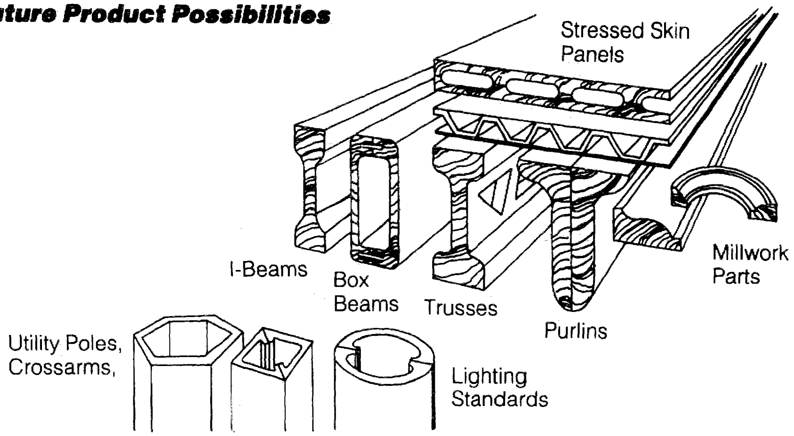
Industrial Chemical Products and Biotechnology

The promise for industrial chemical and biotechnology products from wood is bright. Industrial chemical products from wood have a long history and form the basis for the large pulp and paper industry and other significant segments of our economy. Research is building on this foundation to provide successful new products to replace those made from petroleum and other materials. Products from biotechnology are just beginning to leave the laboratory, but success in areas such as waste treatments is an indication that this technology will have a strong impact on our future progress.

Some industrial chemical products from wood are such diverse, long-established commodities as charcoal, rayon, and natural rubber. An example of a product from biotechnology that has penetrated the market is mushrooms grown on wood.

The potential for increased use of wood for industrial chemicals and products from biotechnology is closely tied to the productive potential of

Future Product Possibilities



wood biomass systems. Approximately 20 billion dry tons of standing lignocellulosic biomass in the United States could be doubled or tripled with intensive forestry. Each year about 6 million dry tons of wood are generated and recycled to the soil without further use. Shrubs, small trees, bark, foliage, and harvesting residues occur in large quantities in many localities. Much of this woody biomass is suited for use in industrial chemical or biological products.

Among the products that will be derived increasingly from wood are fuels, pharmaceuticals, adhesives, plastics, and resins. New chemical and biological modification of wood and paper will produce materials that are more moisture-,fire-, and decay-resistant.

Fuels. Fuels are an obvious outlet for some of the presently unused wood that can be chemically or biologically processed but is unsuited for lumber, veneer, paper, or other conventional products. Alcohol fuels for blending with gasoline are derived from wood in insignificant quantities (4 to 5 million gallons a year) but in the future this output is likely to increase many times.

Both chemical and biological processes are being improved to make this feasible. Extracting ethyl alcohol from wood is based on a hydrolysis process known for 150 years, but improvements in the common chemical reaction with water in the presence of acid catalysts are making the end product more competitive with ethyl alcohol from other sources and with other fuels.

A significant new development is the proven feasibility of biological enzyme hydrolysis of cellulose, which comprises about 50 percent of wood, to glucose. Glucose is a sugar that can be fermented readily to ethyl alcohol. Biological enzyme hydrolysis can convert 80 percent of the cellulose, while acid hydrolysis, in its present state of development, converts only about 50 percent.

Perhaps of even more significance, biotechnology research at the Forest Products Laboratory and elsewhere has shown how to ferment another sugar, xylose, to ethyl alcohol. Xylose is a common derivative of hemicellulose from hardwoods. (Hemicellulose makes up about half of the noncellulosic portion of wood; the other main constituent of wood is lignin.)

Other alcohols that are used increasingly as octane enhancers with gasoline are methyl alcohol and butyl alcohol. Another name for methyl alcohol is wood alcohol, as it was originally made from wood. Now it is manufactured more economically from natural gas, and it also may be made from coal. Nonetheless, methyl alcohol from wood is a potential fuel of the future, either for use in blending with gasoline or without mixing with other fuels. Even today, racing cars run on methyl alcohol or methanol, terms that are used interchangeably. It is now possible to ferment butyl alcohol from wood, and this product will likely become more competitive in the future.

Gases and Oils. In the future, gases and oils will be derived from forest products. Gases are obtained mainly through pyrolysis processes in which wood is heated in the absence of sufficient oxygen for combustion. Other products such as charcoal also may be produced, or the wood is converted almost wholly to gas. The gas is most commonly generated as a low or medium heat-value gas. A high heat-value gas comparable to natural gas could be obtained only through an additional enrichment process.

Hydrocarbon oils can be obtained through naturally occurring chemicals contained in some trees. One example is the seed of the Chinese tallow tree, introduced to the United States by Ben Franklin in 1763. It has become naturalized throughout most of the coastal South and in moist parts of southern California.

Pharmaceuticals and Cosmetics. Among the possible medicinal chemicals to be derived from wood in the future are steroids for such uses as contraceptives, corticosteroids, and geriatric drugs. Steroids are obtained from tall oil, an important extractive compound found in pines and some other softwood species. Tall oils contain phytosterol for steroid production, which can replace a similar chemical from more expensive soybeans, freeing up the soybeans for food and animal feed. Other related sterol compounds may be used as emulsifiers, emulsion stabilizers, viscosity modifiers, and emollients in cosmetics. The chemical L-dopa, for treating Parkinson's disease, also can be derived from trees.

It is impossible to tell how many diseases may be treated with pharmaceuticals derived from the forest, but species diversity in our forests must be maintained so that the potentially beneficial chemicals contained in different trees will not be lost through their extinction. Many of our medicines have originated from plants, including trees, and this pattern is likely to continue.

Adhesives and Other Products from Lignin. The lignin fraction of wood has long been a tempting, but mostly unproductive, subject of research in our quest for valuable chemicals. Today some 20 million dry tons of lignin from pulping operations go unused each year. The lignin byproduct of kraft pulping operations is used for fuel.

Waste pulping liquors are processed on a small scale to produce commercial vanillin, dimethylsulfoxide, and lignosulfonates, but in the future other products are likely to lead to more intensive utilization. Vanillin is important for flavoring, but it is used in such small quantities that it does not constitute a major market. Dimethylsulfoxides and lignosulfonates have greater established and potential markets as oil field chemicals, surfactants, dispersants, binders, concrete admixtures, and sequestering agents.

Among the most promising products from lignin are adhesives, phenolic compounds, toluene, and benzene. Adhesives derived from wood lignin are likely to be substituted for the durable phenolic adhesives now used in the manufacture of plywood.

Other adhesives may be produced from the tannins and carbohydrates in wood.

The study of biotechnical approaches to converting byproduct lignins to more useful products has only begun. In the future, lignin will be biodegraded to produce many diverse low-molecular-weight products. On the other hand, retaining the high-molecular-weight character of lignin without breaking it down while speeding other chemical interactions to provide useful compounds similar to plastics might turn out to be more advantageous.

Plastic and Plastic Fiber Products. Although wood is a magnificent competitor for many plastics in its own right, it is likely to be used more as a feedstock for synthetic plastics in competition with plastics made from petroleum. Today, polyethylene made from petroleum is the fundamental building unit for many plastic products, but wood is becoming more nearly competitive for this market. When oil prices were approaching $40 per barrel, it might have been practical to make ethylene and polyethylene from wood through an intermediate ethyl alcohol hydrolysis. As the technology for making ethyl alcohol from wood is improved, the feasibility of deriving polyethylene plastics from wood is enhanced.

Other plastic and plastic fiber products normally made from wood are cellophane, cellulose acetate, and rayon. Wood was originally used in the manufacture of nylon fiber and is likely to be used more in the future, if a precipitating agent such as furfural can be made economically from wood. Presently, wood hemicellulose can be used to produce this agent.

Rubber. Synthetic rubber also may be produced from wood. Normally this product is made from butadiene, which can be derived from ethyl alcohol. In another approach, butane-2, 3-diol is derived from wood through biological fermentation and used as a precursor for synthetic rubber.

Oleoresins. Oleoresins from tall oil and other wood extractive fractions are another reservoir of chemicals for the future. Among the products that can be derived from them in addition to the medicinals and cosmetics mentioned previously are adhesives, special plastics, and high-value fuels.

Food. The concept of feeding animals and people from wood is another area in its infancy. Today, the field is limited to yeast from some pulp mill wastes and molasses from hemicellulose obtained as a byproduct of hardboard manufacture. Mushrooms are raised on wood substrates to a limited degree in the United States. Only now has the shiitake mushroom industry established a foothold, but there is a good opportunity for this industry to benefit from new technology, grow, and displace shiitake imports.

Special sugars and related chemicals from wood have advantages over more conventional products. Xylitol and sorbitol can displace sucrose and help in preventing tooth decay. Glucose also has special dietetic applications.

Other Chemical Products. Among other potential growth chemicals from wood are glycerol for explosives, tannins for curing leather, ammonia and urea for fertilizer, and high-quality wax for special applications. Organic acids such as formic, acetic, propionic, saccharinic, succinic, and many others are likely to be derived from wood and to substitute for organic acids from other sources. These acids may be used in the manufacture of many other products. As an example, acetic acid may be processed to such consumer commodities as vinyl and cellulose acetate.

Biotechnology Applications. Many other biotechnology applications can add to the quality of life in the future. Trees of the future will be superior to those of today, partly because biotechnology promises to decrease the time required for identifying and propagating selected better trees, and plant tissue culture will provide alternative means to clone superior trees. Traits such as growth efficiency, photosynthetic efficiency, stress tolerance, and resistance to diseases, frost, drought, salinity, herbicides, and heavy metals and other chemicals may be screened in tissue culture.

Biological fixation of atmospheric nitrogen has the potential to offset the need for commercial nitrogen fertilizers. It should be possible to develop nitrogen-fixing clones of the best tree species that already absorb nitrogen from the air and fix it in the ground. It may be possible to create hybrids between species that fix nitrogen and other trees that are desirable for different purposes. Better strains of bacteria that fix nitrogen can be developed.

Growth of forest trees may be improved in the future by inoculating the soil with mycorrhizae, or root–fungus structures formed by special types of fungi. Experiments on inoculation of southern pines with selected strains of the fungus *Pitholithus tinctorius* have dramatically increased survival and growth on adverse sites.

Spraying chemicals on forests to control insects or disease has met with only limited success, is environmentally questionable, and is often not cost-effective. Biotechnology can play an important role in developing pest-resistant varieties of trees and biological control agents, particularly for insect pests and, possibly, for forest diseases. Italian researchers have demonstrated that a virus can kill the fungus that causes chestnut blight.

In the processing of wood, biotechnology will affect how pulp and paper are made. For instance, pines engineered to overproduce turpentine or pulpwood with a lowered lignin content will have to be pulped differently from the way today's wood is pulped. Because certain micro-organisms can partially break down the cell walls of wood, biological (nonchemical) pulping may be possible in the future.

Pulp and paper mills also produce much more waste than the lignin mentioned previously. Based on the sizes of U.S. industries and the characteristics of the waste streams, 1.2 million metric tons of sugar could be available annually from sulfite pulp mills in North America, and about 1.5 million metric tons of cellulosic material could be recovered from primary sludges in kraft pulp mills. Hardboard and insulation board plants produce about 150,000 metric tons of nonutilized sugar annually. Each of these byproduct streams could be used for the production of numerous fermentation chemicals or microbial protein with the application of biotechnological processing. Because lignins do not serve as growth substrates for microbes, their use as substrates for conversion to protein or other fermentation products is apparently not possible without extensive pretreatment.

The pulp and paper industry already depends on microbial technology to treat its manufacturing wastes, and microbes are being improved to degrade specific industrial wastes or recalcitrant products. The Forest Products Laboratory, in cooperation with North Carolina State University, has recently investigated the use of white-rot fungi, which degrade lignin, to decolorize the highly colored first extraction-stage effluent of pulp mills. This process holds much promise for successful commercial use in the future.