*In:* Proceedings of the 1995 International environmental conference;
1995 May 7--10; Atlanta, GA. Atlanta, GA: TAPPI PRESS: 315-325; 1995.

# THE ROLE OF MARKETS AND TECHNOLOGY IN CONSERVATION OF TIMBER RESOURCES

Peter J. Ince
Research Forester
USDA Forest Service
Forest Products Laboratory[1]
Madison, WI 53705-2398

David B. McKeever
Research Forester
USDA Forest Service
Forest Products Laboratory
Madison, WI 53705-2398

Richard W. Haynes
Program Manager
Pacific Northwest Forest and Range Experiment Station
Portland, OR 97208

## ABSTRACT

Technological options exist for timber conservation by using more recycled fiber, new composite or engineered wood products, and substitutes based on alternative materials or technologies. Given these technological options, conservation could occur as an economic response to market conditions. This is supported by historical trends, economic theory, and cost comparisons. In the longrun, market conditions and technology development could lead to timber conservation in much the same way that constraints on energy resources recently led to energy conservation. In any case, markets and technology together play a significant role in timber conservation.

## INTRODUCTION

Timber resource conservation is one strategy for dealing with prospective limitations on timber supply. Recent studies of timber supply and demand in the United States suggest that timber harvests could continue to increase over the next 50 years (1, 2, 3). Total roundwood timber harvest in the United States is projected to grow at an average rate of 0.6 percent per year to 780 million cubic meters by 2040 (current United States timber harvest levels are around 500 million cubic meters per year).

With consumption of all forest products currently at the equivalent of 2.3 cubic meters of timber per person per year in the United States, some have questioned why actions should not be taken to reduce timber consumption. There is concern that focusing on increasing supplies of timber in response to growing demand threatens the integrity of forest ecosystems, both in the United States and in countries that we import forest products from. Apart from policy intervention to reduce timber consumption or intensification of timber management to provide greater timber supply, markets and technology can play a significant role in effectuating timber conservation.

In this paper, we recognize that efficient pathways for evolution of technology in the future will be determined to a great extent by the influence of resource market conditions (i.e. market trends for timber, energy, etc.). Without policy intervention, timber consumption will be determined largely by input requirements of different production technologies and the evolution of those technologies as influenced by comparative economic advantages and market conditions. Changing market conditions can influence timber consumption via economic substitution and technological change. Thus, resource markets and technology of the forest product sector (including pulp and paper) are significantly intertwined with timber resource conservation.

### Consumption Trends and Supply Constraints

The Food and Agriculture Organization of United Nations (FAO) has estimated that world consumption of pulpwood was approximately 635 million cubic meters in 1991, nearly three times higher than the level of world pulpwood consumption in 1960 (4). This significant upward trend shows only limited signs of abating in the near future despite increased paper recycling. Projections by FAO indicate that world pulpwood consumption may be between 970 and 1,150 million cubic meters, depending on projected recycling rates, by the year 2010. In the United States, pulpwood consumption has increased by more than threefold since the 1950s to around 200 million cubic meters (including roundwood and residues). It may increase to more than 240 million cubic meters by 2010 (3).

In anticipation of such trends in demand for wood resources, timber growth has been more intensively managed in recent decades. For example, land area planted to trees annually in the United States increased from roughly 0.2 million hectares per year in the early 1950s to around 1.2 million hectares per year in recent years (5). Also, forest management and fire suppression helped reduce annual acreage of forest land burned by wildfire in the United States from more than 6 million hectares per year in the early 1950s to generally only 1 to 2 million hectares per year in recent years. In terms of timber output, results of increased management intensity have been positive. As harvest levels have increased over the years, so has the net growth of timber. Net annual growth of timber in the United States increased from 219 million cubic meters in 1952 to 339 million cubic meters in 1991 for softwoods, and from 175 million cubic meters in 1952 to 273 million cubic meters in 1991 for hardwoods (5). Net annual growth could be further increased with more intense forest management (more plantations, selected species, chemical application, equipment, etc.).

[1]The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain and not subject to copyright.

Increased management intensity, however, tends to change the character of forest ecosystems, and maintaining the integrity of native forest ecosystems is currently an important public issue. Given this, policy constraints can be placed on forest management intensity, which can in turn put significant constraints on timber supply and future supply growth. Timber supplies can also be constrained by withdrawal of timberland from harvest for reserved uses such as parks or wilderness, or for urban development and a variety of other uses. In general, resource supply constraints are reflected in the market by increases in market value, as occurred in the case of petroleum resources in the 1970s. Supply constraints and increases in market value are likely to engender shortrun impacts of reduced consumption and product substitution and longrun impacts of technological change and innovation aimed at conservation.

**The Role of Markets and Technology**

Economics is the study of the allocation of scarce resources, and competitive markets are recognized as an efficient mechanism for accomplishing much of that allocation. As timber resources become more scarce and expensive, they will be conserved. Conservation may occur as the result of reduced consumption (due to income and substitution effects as added resource expenses are passed on to consumers) and/or input-saving adjustments to production via technological change. This is expected to occur in competitive markets. In addition, research and innovation can expand technological options and improve the efficiency of available technologies.

Thus, markets and technology share an important role in effectuating resource conservation. One basic element of this role is that technology directly determines resource use. Each production process generally requires certain quantities of resource inputs, such as wood or wood fiber. Different technologies usually require different quantities and types of these inputs. Such technologies often compete with one another in the same markets or in the same end use arena. In some cases, one technology may be regarded as a timber-conserving technology relative to another if it requires a smaller amount of timber resource input or otherwise promotes timber conservation. Thus, as technologies differ in their resource input requirements, some having lower requirements of certain resources than others, technologies offer dynamic opportunities to achieve resource conservation as they evolve and compete with one another.

Virgin-bleached kraft or sulphate pulp, for example, is produced commonly with pulp yields in the vicinity of 47 to 50 percent (tons of pulp per ton of wood input), meaning that one ton of pulp requires approximately two tons of pulpwood input. Mechanical pulps, such as groundwood, TMP, or CTMP, are produced commonly with yields in the range of 90 to 95 percent, meaning that each ton of pulp requires only slightly more than one ton of pulpwood input. Virgin-fiber newsprint, which is made conventionally from 75 to 90 percent mechanical pulp blended with bleached kraft, will require roughly 1.3 tons of pulpwood input per ton of output.

Alternatively, newsprint can be made from 100 percent recycled fiber, based on washing and flotation deinking technology. In this case, newsprint production requires no pulpwood input, but requires instead the input of around 1.25 tons of recovered paper (usually old newspapers (ONP) and old magazines (OMG)). This suggests that recycled newsprint is a timber-conserving technology relative to virgin-fiber newsprint. Coupling this with an understanding of economic theory and the recent history of fiber markets provides an explanation for recent increases in recycled newsprint production and related gains in timber conservation.

As early as the 1930s, the economist John R. Hicks had elaborated economic theory by explaining why technological progress would exhibit a bias toward saving a particular production input if the relative market value of that input was increased (6). According to his theory, maximization of product output or minimization of costs leads producers toward employing resource inputs in amounts that equate input price ratios, marginal rates of technical substitution, and marginal product ratios. If certain resource inputs become relatively more expensive and if technology affords resource-conserving options, evolution and expansion of production capacity will be toward conserving resources that have become more expensive. One example of this is the recent trend toward increased recycling in newsprint production in the United States.

From 1989 to 1993, a glut in recovered paper markets developed in the United States due to substantial increases in collection of paper for recycling with depressed market values for commodities like ONP. This glut created a period in which the relative market value of softwood pulpwood went dramatically upward in relation to market value of ONP (Fig. 1) (based on

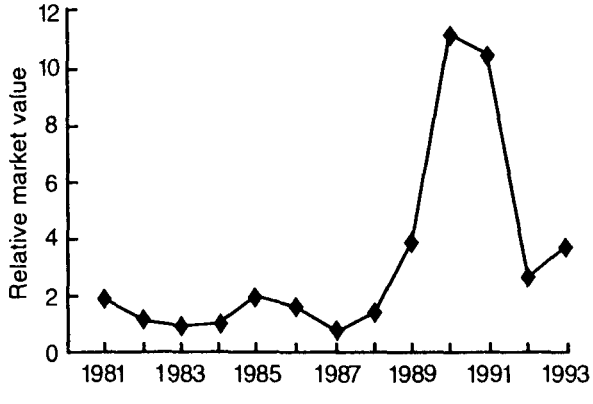


Fig. 1. Market value of softwood pulpwood (US South) relative to ONP (Chicago).

the ratio of reported average values for Southern pine pulpwood to market value of ONP in Chicago; data source: Pulp & Paper North American Factbook, 1981-93, Miller Freeman Publications: San Fransisco).

As a result of a substantially higher relative market value for pulpwood and the glut in recovered paper supply, the United States pulp and paper industry substantially increased its capacity to produce recycled newsprint. Consequently, there was a dramatic increase in the rate of paper recycling for newsprint produced in the United States from 1989 to 1993 (Fig. 2) (ratio of recycled paper consumption in newsprint to production of newsprint; data source: Statistics of Paper, Paperboard, and Wood Pulp, 1993, American Forest & Paper Association, Washington, DC).

Figure 3 shows estimated pulpwood consumption in United States newsprint production per ton of product output, based on assumed ratios of pulpwood input for virgin-fiber newsprint production and historical recycling rates. Significant conservation of timber resources occurred in newsprint production due to recycling when the relative market value of pulpwood increased Figs. 1 and 3).

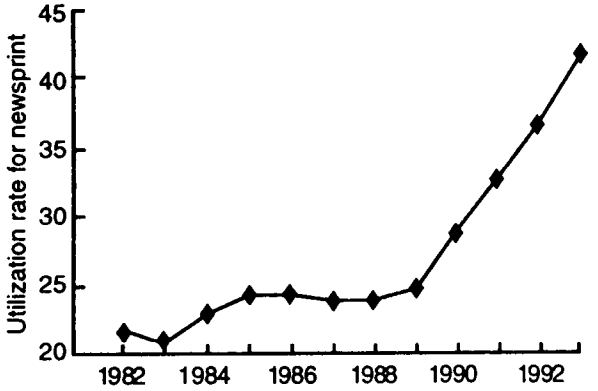


Fig. 2. Recovered paper utilization rate for newsprint produced in the United States.

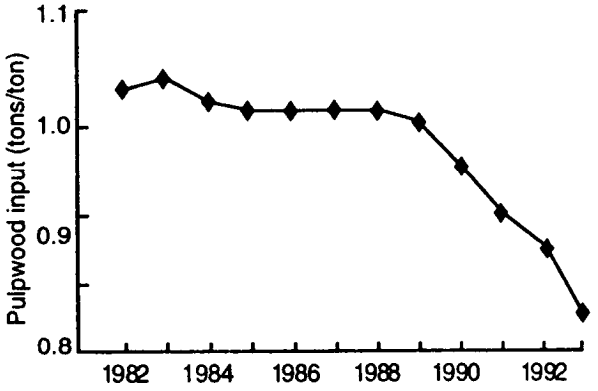


Fig. 3. Pulpwood input requirements per ton of newsprint produced in United States.

The recent trends in the newsprint industry show how economic behavior leads to resource conservation as anticipated by economic theory. The recent timber conserving trend in newsprint (Fig. 3) was the direct result of technological change involving recycling (Fig. 2), which occurred only when the relative market value of timber had increased in the period from 1989 to 1993 (Fig 1). Similar cases could be cited using other examples, such as the extensive development and timber-conserving substitution of oriented strand board (OSB) for softwood plywood, which occurred only after substantial increases in the relative market value of veneer logs in the late 1970s. In general, as anticipated by economic theory, capacity expansion and technological change will lead to timber resource conservation whenever the relative market values of timber resource inputs increase and when technology options allow for adjustment in the marginal product of other inputs relative to wood inputs.

Firms in competitive markets will tend to seek the development and application of technologies that contribute the most to their sales revenues or that minimize their production costs. Generally, technologies that have the lowest overall production costs afford the highest contribution to revenues. Therefore, looking at overall comparative advantages in production costs of timber-conserving technologies helps understand or predict the role of markets and technology in timber conservation.

## EXAMPLES

Cost estimates and wood input requirements were obtained for three significant examples of wood use. For each, we compared total costs for a dominant conventional timber-based technology to an alternative technology that satisfied the same product or end use. In each case, the alternative timber-conserving technology used less timber input or otherwise helped conserve timber resources. The three examples included newsprint production, comparing virgin-fiber and recycled newsprint technologies; housing construction, comparing lumber frame construction and steel frame construction; and structural wood panel production technologies, comparing softwood plywood and OSB. We analyzed how comparative costs are likely to be influenced by variable market conditions and, in turn, how market conditions and technologies are likely to influence timber conservation.

Generally, we observed that cost advantages of timber-conserving technologies would be enhanced by increases in the market values of timber or wood inputs. Changes in market values of other inputs, however, may also be important. Changes in market values of other inputs such as energy or steel can affect comparative advantages of timber-conserving technologies and can influence prospects for timber conservation. Again, the extent to which timber resource conservation is achieved will be determined largely by wood input requirements of different technologies and by the influence of market conditions on the comparative economic advantages of each technology.

Table I summarizes estimates of resource input requirements, recent market values of inputs, and total production costs for these three examples. The estimates are based on approximation of averages for the United States. The data are estimates only and are not actual cost data. We recognize that actual costs may vary from one production facility to another and may also vary according to less tangible factors such as production and management skills and vintage of equipment. Our purpose is not to provide definitive cost data, but simply to provide a basis for understanding how markets and technologies can play a role in timber conservation.

**Example 1-Newsprint**

The pulp and paper sector. of which newsprint is a part, represents the largest industrial consumer of primary and secondary wood fiber in the United States and the world. As mentioned earlier, world pulpwood consumption has increased by nearly three-fold in recent decades and is expected to continue increasing in the future. Product grades vary substantially in terms of wood or fiber input requirements, recyclability, and product performance requirements, but technology options exist for timber conservation in most product grades.

In the United States, around 200 million cubic meters of pulpwood (including roundwood and residues) are consumed annually in the production of pulp, paper, and paperboard products. Just a 5-percent reduction in pulpwood consumption, for example, could conserve roughly 10 million cubic meters of timber, assuming that pulpwood conservation would translate primarily into reduced roundwood harvest and that wood residue consumption would remain the same.

Although newsprint production accounts for less than 10 percent of total pulpwood consumption in the United States, recycling in newsprint has already accomplished sizable gains in timber conservation. Newsprint in the United States, for example, increased from 5.5 million metric tons in 1989 to 6.4 million metric tons in 1993, but reductions in timber use per ton of newsprint (Fig. 3) meant that pulpwood consumption in the United States newsprint production actually declined by a small fraction over the same period, saving the equivalent of roughly 2 million cubic meters of pulpwood.

In this example, we compared virgin-fiber newsprint production to recycled newsprint production. Input requirements and costs were estimated on the basis of 1 metric ton (t) of newsprint. As mentioned previously, virgin-fiber newsprint is produced in the United States mainly from mechanical pulp (TMP or groundwood) with usually a small fraction of bleached chemical pulp input (10 to 25 percent). Recycled newsprint can be produced from 100 percent recycled fiber, primarily ONP, with small fractions of OMG (e.g. 30 percent OMG in a flotation deinking process). Recycled newsprint has become competitive with virgin-fiber newsprint in the United States markets. Relative to virgin-fiber newsprint, recycled newsprint is a timber-conserving technology.

Table I. Approximate Input Requirements, Input Market Values, Costs, and Total Production Costs for Conventional Timber-Based Technologies and Alternative Timber-Conserving Technologies

| Input requirements or cost | Newsprint | | Housing construction | | Structural panels | |
|---|---|---|---|---|---|---|
| | Virgin | Recycled | Wood | Steel | Plywood | OSB |
| Wood/fiber input requirement | 1.3 tons pulpwood/t newsprint | 1.25 ton recov.paper/ t newsprint | 0.132 $m^3$ lumber/$m^2$ housing | 0.099 $m^3$ lumber/$m^2$ housing | 1.97 $m^3$ veneer logs/ $m^3$ plywood | 1.82 $m^3$ pulpwood/ $m^3$ OSB |
| Market values of wood! fiber inputs per unit of input | $65/ton pulpwood | $75/ton ONP, OMG | $280/$m^3$ lumber | $263/$m^3$ lumber | $47.7/$m^3$ veneer logs | $26.5/$m^3$ pulpwood |
| Cost of wood or fiber inputs per unit of product output | $85/ton newsprint | $94/ton newsprint | $36.90/$m^2$ housing | $26/$m^2$ housing | $84/$m^3$ plywood (net wood) | $47/$m^3$ OSB |
| Other production inputs | 2 MWh/t | 1 MWh/t | — | 0.014 ton steel framing/$m^2$ housing | — | — |
| Market values of other inputs | $50/MWh | $50/MWh | — | $990/ton steel framing | — | — |
| Costs of other inputs | $100/ton newsprint | $50/ton newsprint | — | $13.90/$m^2$ housing | — | — |
| Total production costs | $490/ton newsprint | $430/ton newsprint | $106.1$m^2$ housing | $107.9 $m^2$ housing | $170/$m^3$ plywood | $126/$m^3$ OSB |

It is estimated that virgin-fiber newsprint technology requires about 1.3 tons of pulpwood input per ton of newsprint produced, while 100-percent recycled newsprint technology requires about 1.25 tons of recovered paper inputs (Table I). Based on recent market data, we set market values at $65 per ton of pulpwood and $75 per ton of recovered paper delivered to newsprint mills (representing weighted averages for ONP and OMG). Whereas the reported market value of pulpwood has been relatively stable in the United States in recent decades, the market value of recovered paper turned upward over the past year from the depressed market values of the early 1990s.

In addition to wood fiber inputs, we considered electrical energy inputs to newsprint production, estimated to be approximately 2 MWh per ton for virgin-fiber newsprint production and 1 MWh per ton for recycled newsprint production (with approximate values for electricity of $50/MWh). Under these assumptions, virgin-fiber newsprint production costs were estimated to be approximately $490 per metric ton, while recycled fiber newsprint production costs were estimated to be approximately $430 per metric ton (at new facilities). The costs and energy inputs for newsprint were based on recently published estimates (7, 8, 9). Again, these are only estimates, not actual mill data. Newsprint mills in the United States commonly use a combination of recycled and virgin-fiber processes, often at the same location. Also, mill operating costs vary substantially due to location and variation in equipment.

**Example 2–Housing Construction Technology**

Future changes in housing construction technology could significantly affect timber resource requirements of the United States. New single-family residential construction is the largest single market for solid wood products in the United States. In 1992, an estimated 41.3 million cubic meters of lumber, 9.0 million cubic meters of structural panels, and 3.0 million cubic meters of nonstructural panels were consumed in the construction of just over 1 million houses (10). A 5-percent reduction in wood use in housing construction, for example, would save 2.1 million cubic meters of lumber and 0.6 million cubic meters of panels annually.

New technologies can reduce the amount of wood products required through improved wood products manufacturing, by substituting more efficient wood products for existing wood products, or by substituting nonwood products for wood products. By reducing the amount of wood needed to build a house, these technologies conserve the timber resource. The level of conservation is directly related to the extent of the improvement or substitution.

The single-family house in the United States has undergone many changes in the past 100 years. One hundred years ago, wood-framed houses were built almost entirely from lumber, Walls were framed with full-sized studs, floors and roofs used larger dimension lumber, floor, walls and roofs were sheathed with lumber, and wooden shakes, shingles, and siding were commonly used for the exterior covering. Many houses were also heated entirely with wood. Large amounts of wood were required both to build and maintain a house.

Over the years, a variety of improved building products have been developed. Examples include fiberboard wall sheathing, softwood plywood wall, floor and roof sheathing, a variety of nonwood exterior wall siding products, and reduced dimensions for standard framing members. These products conserve the timber resource since new homes that use these technologies require less wood per square foot of floor area than homes that were built several years ago. The different construction techniques and products used to build houses can be viewed as different construction technologies for housing. Recent increases in the market value of softwood framing lumber have generated interest in alternative construction technologies. Steel framing technology for residential construction is currently receiving considerable attention as an alternative to lumber.

In this example, we compared two alternative housing construclion technologies, one based exclusively on lumber framing and the other based, in part, on steel framing. Input requirements and costs were estimated on the basis of one square meter of finished floor area. In the United States, wood framing is the dominant technology in light frame construction. It has been refined and improved in recent decades through the development of engineered wood trusses and other significant architectural improvements. Lumber framing is based on softwood dimension lumber, the production of which requires timber resource inputs. Steel framing technology exists as a commercially available alternative. Generally, steel framing also relies on wood to some extent. Thus, both wood and steel framing construction systems are estimated to have timber resource inputs, but the steel framing system is regarded as a timber-conserving technology relative to wood framing.

According to the American Iron and Steel Institute (11), steel studs arc superior to wood because they do not warp or twist, are termite and fire resistant, can be erected faster and with a smaller construction crew, are made from a high percentage of recycled material, and are themselves recyclable. Their goal is to make steel framing a part of 25 percent of all new house construction within the next 5 years (12).

The American Forest & Paper Association, however, claims that wood is currently the material of choice in 94 percent of all new residential house framing and that wood is the best environmental choice for framing (13). They assert that steel is over 400 times more conductive of heat than wood, that it is one of the most energy-intensive industrial materials, that it generates pollution and waste from all stages of manufacturing, and that claimed levels of recycled material in steel framing are often exaggerated. In either case, proponents of steel framing are

prepared to change the way houses are built in the United States. Ultimately. the consumers will make the final decision, a decision based largely on the cost and design of a new house as constrained by such things as technology and building codes

Reliable cost data for comparing steel and wood framing technologies are sketchy. Some information, however, suggests that market values for dimension lumber have recently been at or near the point where steel framing may become more cost effective. A preliminary comparison of construction costs to frame and enclose a typical 165 square meter house (square meters of floor area) with lumber framing and OSB sheathing, and with steel framing and OSB was done by Spelter (14). Included in construction estimates were costs for floor, exterior and interior wall, and roof framing; floor decking and exterior wall and roof sheathing; exterior siding; insulation; garages and decks: and other miscellaneous items. The lumber framing technology used wood floor trusses, conventional wood framed walls, wood roof trusses, and OSB decking, sheathing, and siding. The steel framing technology used steel framed floors and walls, wood roof trusses, and OSB decking, sheathing, and siding. All exterior amenities (garages, decks, etc.) were built entirely from wood. For each technology, market values and costs for all inputs (building materials and labor), except energy, were quantified, as were the amounts of each required to build the house.

The lumber framing technology required an estimated 0.132 cubic meters of lumber per square meter of finished floor area, while the steel framing technology required an estimated 0.099 cubic meters of lumber and 0.014 metric tons of steel for framing per square meter of finished floor area. Using recent market data, the value of framing lumber was set at $212, board lumber at $267, and stress-rated lumber for truss framing at $538 per cubic meter. Steel framing was set at $990 per metric ton. All other costs were held constant. The lumber framing technology required more of the higher value stress-rated lumber (for trusses) than the steel framing technology. Thus, the weighted average costs of lumber inputs were estimated to be $280 per cubic meter for the lumber framing technology and $263 per cubic meter for the steel framing technology. At the assumed lumber and steel input values, the housing construction costs were estimated to be $106.1 per square meter using the lumber framing technology and $107.9 per square meter using the steel framing technology (Table I).

**Example &Structural Panels**

We compared Southern Pine softwood plywood to OSB production technology. Input requirements and costs were estimated conventionally on the basis of one cubic meter of structural panels (plywood or OSB). Softwood plywood is produced from veneers obtained by rotary peeling of softwood logs. Veneer log cores and rejects are a residue byproduct in plywood production. Therefore, softwood plywood technology generally has a wood input requirement that substantially exceeds the volume of wood in product output. However, these residue byproducts are not wasted. They are often used to produce framing lumber, woodpulp, or particleboard furnish. Softwood plywood wood costs used here reflect net wood costs to the mill (total wood cost less value of residues). The wood input requirements vary substantially by region, log size, and technology used in individual mills. Input and cost estimates represent approximations of average requirements and costs for softwood plywood produced in the Southern United States. Again, estimates are only approximations and are not based on actual mill data.

The OSB technology produces a product that competes with softwood plywood in structural sheathing applications. OSB generally uses the entire log with little or no residue output (except bark). Generally, OSB can use smaller logs (comparable to pulpwood logs), more defective logs, and a wider variety of species, including hardwoods, than can softwood plywood production. Estimates of wood input requirements and total costs for OSB technology are presented in Table I.

Since it was introduced commercially in the United States 15 years ago, OSB technology has gained an increasing share of total structural panel production. According to APA-The Engineered Wood Association (APA), total softwood plywood production fell from 18.1 to 17.4 million cubic meters between 1985 and 1993 (15). During the same period OSB production grew from 2.4 to 6.3 million cubic meters. The APA expects this trend to continue through 1998, with production expected to be 15.0 million cubic meters of softwood plywood and 10.2 million cubic meters of OSB. We would attribute the general shift in technology to OSB's competitive cost advantage, which stems largely from advantages in wood costs. Softwood plywood is expected to maintain or increase its share of the market only for the higher quality sanded panels where OSB is a less viable substitute for plywood.

Shifting the mix of structural panels produced in the United States from softwood plywood to OSB affords a certain degree of timber resource conservation. Plywood production tends to use more expensive softwood sawlogs or veneer logs; OSB production tends to use more lower value pulpwood, hardwood species, and lower quality sawlogs. OSB also has a slightly smaller net wood input requirement than plywood (Table I). With the advent of OSB technology, previously underutilized timber resources have become more usable, and OSB has served as a benefit to timber management. Timber stands that previously had little or no value can now be managed more profitably, and management of a wider variety of tree species and forest types has become commercially viable. Also, the rotation age for OSB-sized timber is shorter than that for plywood veneer logs, permitting more frequent harvesting intervals and more varied approaches to timber management. Thus, not only

does increased OSB production conserve higher quality logs, it also contributes to greater flexibility in forest management and conservation of forest resources in general. Thus, OSB technology may be regarded as a timber-conserving technology because it permits the use of smaller-diameter and less desirable trees of species not typically used for sawlog or veneer log production.

## ANALYSIS

For each example, we prepared charts illustrating comparative costs and advantages of timber-conserving technologies under varying market conditions for timber, wood, energy, and other inputs. The charts were developed on the basis of the approximate cost and input estimates shown in Table I. The estimates are only approximations and are not based on actual costs at any existing production facility.

Figures 4 and 5 show comparative costs of recycled versus virgin-fiber newsprint production under varying timber and fiber market conditions. Although the cost of recycled newsprint production is not directly affected by changes in pulpwood markets, increases in market values for pulpwood would enhance the comparative advantage of recycled newsprint, while lower pulpwood market values would reduce the comparative advantage of recycled newsprint (Fig. 4).

Conversely, although virgin newsprint production is not directly affected by changes in recovered paper markets, higher market values for recovered paper will decrease the comparative advantage of recycled newsprint relative to virgin newsprint (Fig. 5). This observation is particularly relevant given recent volatility in recovered paper markets.

Changes in the market value of energy inputs would also affect comparative cost advantages of recycled newsprint production (Fig. 6). Because of the lower electrical energy input associated with production of recycled newsprint, increases in the market value of electrical energy input would enhance the comparative advantage of recycling technology.

To examine the role of markets and technology in housing construction, we looked at how variation in market values for softwood dimension lumber and steel would affect housing construction costs for the lumber and steel framing technologies. If softwood lumber were to increase in market value by about 15 percent, the housing construction costs using either technology would be approximately equal, at just over $110 per square meter (Fig. 7). In other words, lumber framing technology could lose its comparative cost advantage to steel framing with an increase in lumber market values of about 15 percent above the market values assumed in this analysis, all else being equal. Additional lumber increases would favor steel construction over wood.

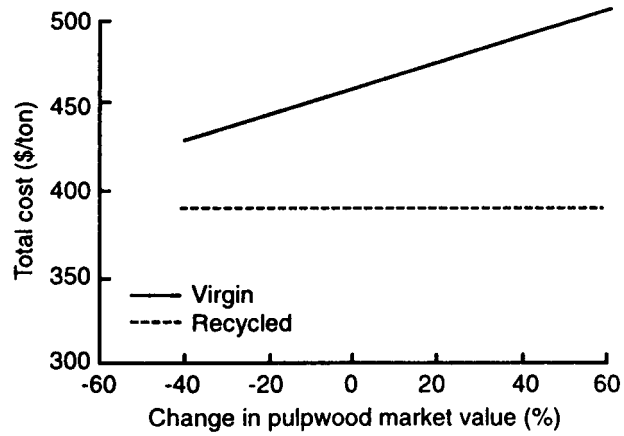


Fig. 4. Comparative costs of virgin and recycled newsprint relative to change in pulpwood market values.

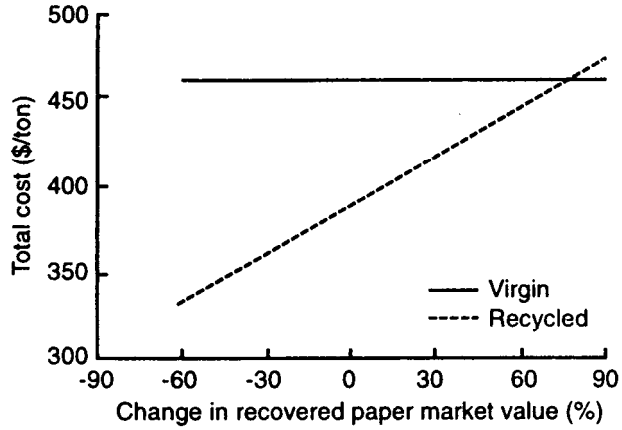


Fig. 5. Comparative costs of virgin and recycled newsprint relative to change in market value of recovered paper.

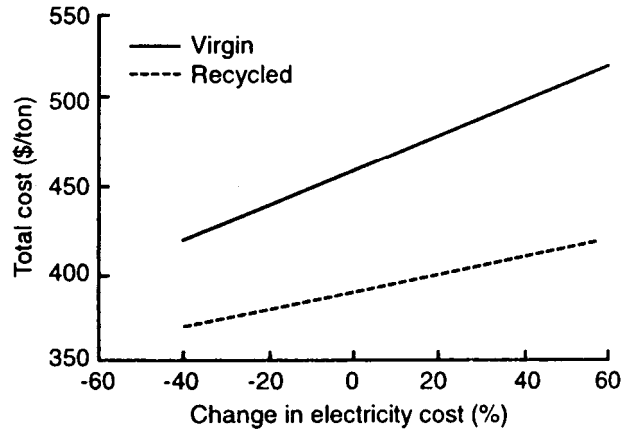


Fig. 6. Comparative costs of virgin and recycled fiber newsprint relative to change in electric energy costs.

Market data for softwood lumber in the United States over the past several years have shown considerable variability and temporary changes in market value well in excess of 15 percent. Thus, potential increases in the market value of lumber in the future may tend to favor conservation of timber resources via conventional lumber and steel framing options.

Likewise, decreases in the market value of steel framing inputs would tend to favor timber conservation (Fig. 8). The volume of lumber in the steel house could be further reduced if the roof and garage were built from steel. On the other hand, modest increases in the market value of steel could substantially enhance competitiveness of lumber framing technology. The amount of lumber saved by changes in housing technology and effects on timber resources will depend on future market conditions and the rate at which technology adjusts to these conditions.

Although we have not predicted the level or rate of substitution and resulting timber resource savings for housing technology, it would appear that future increases in the market value of lumber could potentially provide steel framing with a competitive advantage. In that case, we would expect that the market share for steel framing could increase significantly. Thus, a potential exists for significant conservation of timber resources via changes in residential construction practices from wood framing to steel framing. for example, if such changes are induced to occur by the market.

Finally, to look at the role of markets and technology in structural panel production, we examined how comparative costs are influenced by changes in market values of four major inputs in production of softwood plywood and OSB. Spelter (16) recently quantified estimates of all variable costs associated with production of Southern Pine plywood and OSB. Four major input costs, energy, labor, adhesives, and wood were examined. Each input is used in different amounts depending on the technology. Table II shows estimated input costs per cubic meter and percentage contribution to total production cost for each of the four inputs in 1993 (16).

Changes in the market value of one or more inputs will affect total production cost of plywood and OSB and will determine which panel type has the competitive advantage. The extent of this effect depends on the magnitude of the change and relative significance of the inputs in the production processes. For example, changing energy costs will have little effect on total production costs or relative cost advantage because energy is a fairly small cost component, and it is about the same percentage of total cost for each panel type.

Increases in the cost of wood have a greater effect on total production costs and will result in an increased cost advantage to OSB. Conversely, decreases in the cost of wood should favor plywood over OSB. Changes in cost of adhesives and labor are

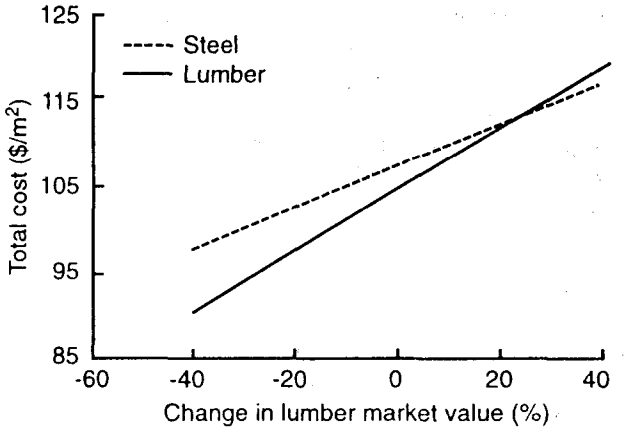


Fig. 7. Costs of housing construction for lumber and steel framing relative to softwood lumber market values.

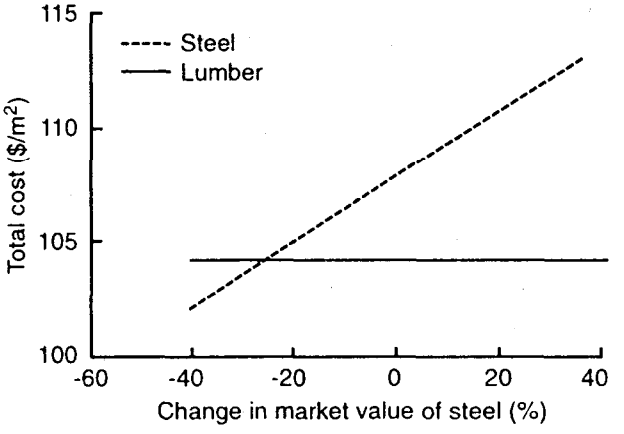


Fig. 8. Costs of housing construction for lumber and steel framing relative to change in market value of steel.

Table II. Production Cost Comparison for Southern Pine Plywood and OSB

| | Estimated cost/cubic meter ($) | | Total production cost (%) | |
|---|---|---|---|---|
| | Southern Pine plywood | OSB | Southern Pine plywood | OSB |
| Energy | 12 | 11 | 7 | 9 |
| Labor | 37 | 20 | 22 | 16 |
| Adhesive | 10 | 20 | 6 | 16 |
| Wood | 84 | 47 | 50 | 37 |

intermediate in effect, with labor cost increases favoring OSB and adhesive cost increases favoring plywood. Figures 9 through 12 show how total production costs change as a result of changes in market values for each of the four major input factors, all others held constant.

In both plywood and OSB, wood is the single most costly input. OSB has a production cost advantage of roughly $44 per cubic meter, much of which is attributable to differences in wood input costs (Table I). A 20-percent overall increase in cost of wood will increases this advantage to nearly $50 per cubic meter (Fig. 9). Increases in the market value of softwood veneer logs and higher quality sawlogs required to produce plywood are thought to be more likely and are expected to be greater in the future than those for the lower quality sawlogs and pulpwood-sized logs used to produce OSB. Such a differential adjustment in wood costs would further increase the competitive advantage of OSB.

Modest increases in total production costs would be expected for both plywood and OSB in the event of increased energy costs (Fig. 10). Neither panel type would benefit substantially from such an increase.

Plywood production tends to be more labor intensive than OSB, while OSB technology is more intensive in the use of adhesives. However, changes in the market values of these inputs will have only modest effects on the competitive advantage of OSB and plywood, respectively (Figs. 11 and 12).

## LIKELY IMPACTS OF MARKETS AND TECHNOLOGY

These examples illustrate how comparative advantages of resource-conserving technologies may be influenced by a change in market conditions. The analysis leads to some general conclusions regarding the likely role of technologies and markets in timber resource conservation.

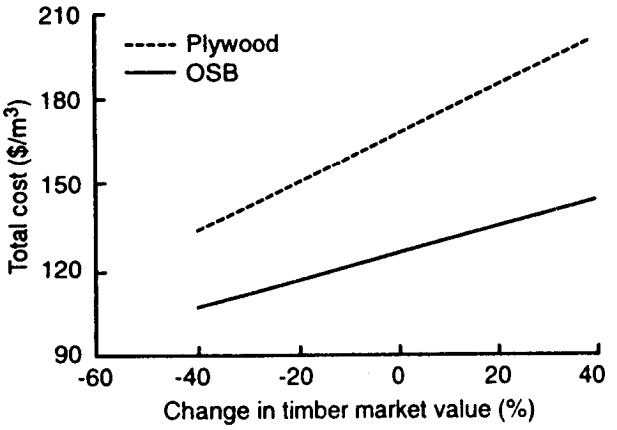


Fig. 9. Costs of Southern Pine plywood and OSB production relative to change in market value of timber.

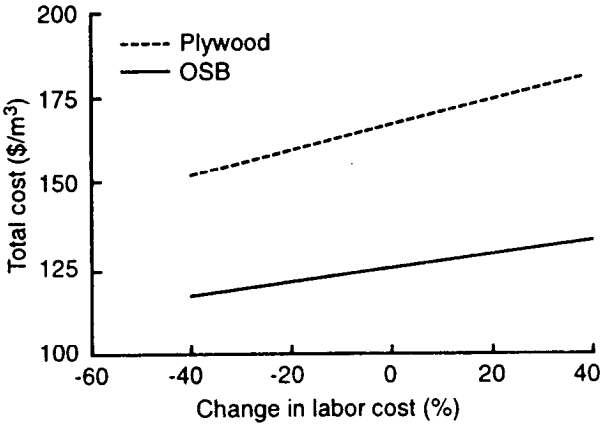


Fig. 11. Costs of Southern Pine plywood and OSB production relative to change in labor costs.

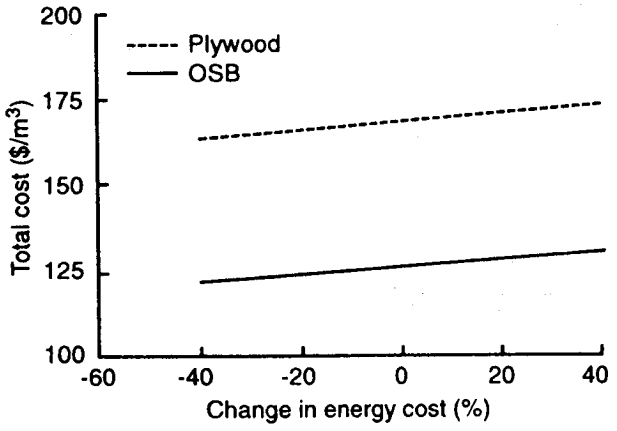


Fig. 10. Costs of Southern Pine plywood and OSB production relative to change in energy costs.

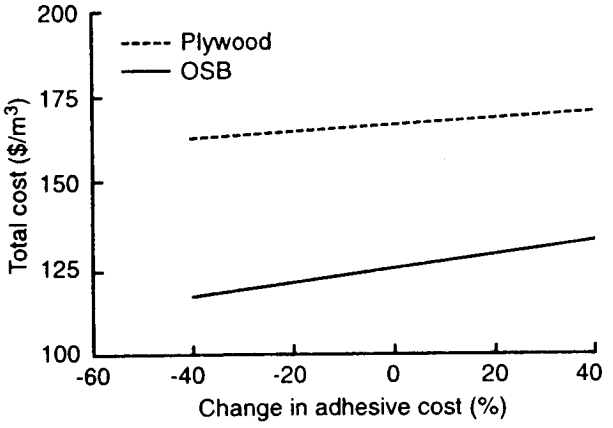


Fig. 12. Costs of Southern Pine plywood and OSB production relative to change in adhesive costs.

For newsprint production, the comparative cost advantage of recycled newsprint technology would appear to be maintained even in the event of substantial changes in market values of pulpwood or energy (Figs. 4 and 6). Thus, continued conservation of timber resources via increased recycling in newsprint production is expected even with significant changes in pulpwood or energy markets, all else being equal. However, substantial increases in the market value of recovered paper could potentially eliminate the comparative advantage of recycled newsprint (Fig. 5). Given that market values of recovered paper have been quite volatile over the last year or so, increases in their value could reduce the comparative advantage of recycled newsprint production. Thus, prospects for sustaining future gains in conservation of timber resources via increased recycling in newsprint appear to hinge most significantly on future trends in recovered paper markets (e.g. for ONP and OMG).

In housing construction, the timber-conserving option of steel framing technology does not appear to have an immediate cost advantage relative to conventional lumber framing technology. Given the recent volatile behavior of softwood lumber markets, however, there may be significant changes in the comparative cost advantage of lumber framing technology relative to the steel framing option if the market value of lumber increases (Fig. 7). Increases in the market value of lumber, or a combination of increases in lumber market values and decreases in steel framing costs (Fig. 8) could provide steel framing technology with a comparative cost advantage over lumber framing.

For structural panels, the timber-conserving option of OSB appears to have significant cost advantages over softwood plywood. These cost advantages, principally in wood raw material costs (Fig. 9), have already resulted in the rapid growth of OSB production at the direct expense of softwood plywood. Further significant inroads are expected in the years ahead, particularly if the market value of higher quality softwood veneer logs or sawlogs increases. Changes in values of energy or labor inputs would not be expected to substantially alter the OSB growth trend relative to plywood.

## SUMMARY

In this report, we have discussed the synergistic role of markets and technology in conservation of timber resources. Different technologies usually require different quantities and types of wood or wood fiber inputs. Such technologies often compete with one another in the same product or end-use arena. In some cases, one competing technology can be regarded as timber-conserving relative to another. Examples include recycled versus virgin-fiber newsprint, steel framing versus wood framing, and OSB versus softwood plywood.

The relative market values of inputs coupled with physical input requirements determine the comparative costs and competitive advantages of each technology. Changes in market values for key inputs can influence relative costs and advantages of timber-conserving technologies. Increases in the market value of timber inputs relative to alternative inputs can result in significant conservation of timber resources, as observed recently in the case of newsprint recycling. Future gains in timber conservation are likely to be influenced significantly by market values of recovered paper used in recycled newsprint production, market values of lumber used in light frame construction, and market values of timber used in OSB and plywood production. Without market intervention, the extent to which timber resource conservation is achieved will ultimately be determined by wood input requirements of different technologies and how the comparative advantages of those technologies are influenced by market conditions. In any case, the important role of markets and technology must be considered whenever the issue of timber resource conservation is being considered.

In addition, an understanding of the role of markets and technology in resource conservation should also be regarded as fundamental in understanding opportunities for research and development in forest products. The evolution of technology will remain intertwined with the evolution of resource markets, and vice versa. Consequently, issues of how to improve forest products technology through technical research, market development, and other means are relevant to resource conservation.

## REFERENCES


1. USDA Forest Service. *The South's Fourth Forest: Alternatives for the Future.* Forest Resource Report No. 24. Washington, DC, 1988, 512 p.

2. Haynes, R.W. *An Analysis of the Timber Situation in the United States: 1989-2040.* Gen. Tech. Rep. RM–199, USDA Forest Service, Rocky Mtn. Forest and Range Experiment Station, Fort Collins, CO, 1990, 286 p.

3. Ince, P.J. *Recycling and Long-Range Timber Outlook.* Gen. Tech. Rep. RM–242, USDA Forest Service. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, 1994, 23 p.

4. Food and Agriculture Organization of the United Nations. *Pulp and Paper Towards 2010.* An executive summary, Forestry Planning and Statistics Branch, Rome, 1994.

5. Smith, W.B, Faulkner, J.L., and Powell, D.S. *Forest Statistics of the United States, 1992 Metric Units*, Gen. Tech. Rep. NC–168, USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN, 1993, 147 p.

6. Hicks, J.R. *The Theory of Wages.* Macmillan & Co. Ltd., London, 1932.

7. Pesonen, K.V. *Proceedings Focus 95*, Recycled vs. virgin—energy and manufacturing cost differentials: four hypthetical case studies, TAPPI Press, Atlanta, GA. 1991, pp. 251–265.

8. Iannazzi, F.D, *Pulp & Paper*, "The economics are right for U.S. mills to recycle old newspapers," pp. 114–116 (March. 1992).

9. Ince P.J. *Recycling and Long-Range Timber Outlook: Background Research Report*. Res. Pap. FPL–RP-534, USDA Forest Service, Forest Products Laboratory: Madison, WI, 1994, 110 p.

10. McKeever, D.B. and Phelps, R.B. *Forest Prod. J.*, "Wood products used in new single-family house construction, 1950–1992," 4(11/12): 66–74 (1994).

11. American Iron and Steel Institute. *1994. Builders' Perspectives*. RG–9403. American Iron and Steel Institute, Church Hill, MD, 1994, 8 p.

12. Building Systems Builder. *Steel houses*. Peterson Bros. Inc. Building Systems Builder, Corry, PA 14(3): 18–22. (1993).

13. American Forest & Paper Association. *AF&PA News*. "Environmental Building News picks wood over steel," American Forest & Paper Association, Washington, DC, Sept. 8, 1994.

14. Spelter, H. Unpublished data on file with USDA Forest Service, Forest Products Laboratory, Madison, WI, 1994.

15. Adair, C. *Regional production and distribution trends for structural panels and engineered wood products*. APA Economics Report E56, American Plywood Association, Tacoma, WA, 1994, 57 p.

16. Spelter, H. *Capacity, production, and manufacturing of wood-based panels in North America*. General Technical Report FPL–GTR–82, USDA Forest Service, Forest Products Laboratory: Madison, WI, 1994, 17 p.

PRINTED WITH SOY INK
on recycled paper