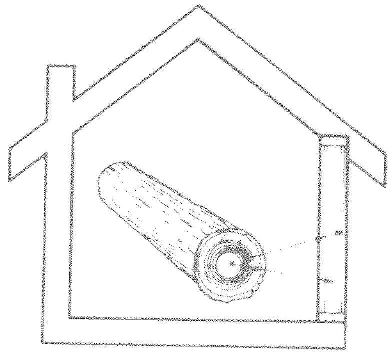
U.S. Department of Agriculture
Forest Service Research Paper SE-197



COM-PLY® REPORT 15

ECONOMIC FEASIBILITY OF MANUFACTURING COM-PLY STUDS IN THE SOUTH

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

NATIONAL FOREST SYSTEM · COOPERATIVE FORESTRY · FORESTRY RESEARCH · FOREST SERVICE · U S · DEPARTMENT OF AGRICULTURE

COOPERATIVE RESEARCH

COM-PLY® is a registered trademark of the American Plywood Association.

November 1978

Southeastern Forest Experiment Station
Asheville, North Carolina

ECONOMIC FEASIBILITY OF MANUFACTURING COM-PLY STUDS IN THE SOUTH

by

Gerald A. Koenigshof, Principal Wood Scientist

Forestry Sciences Laboratory

Athens, Georgia

Cooperative Research by

U.S. Department of Agriculture, Forest Service

Southeastern Forest Experiment Station

and

U.S. Department of Housing and Urban Development

Division of Energy, Building Technology

and Standards

PREFACE

This report is one of a series on the possibilities of producing house framing and structural panels with particleboard cores and veneer facings. These COM-PLY or composite materials were designed to be used interchangeably with conventional lumber and plywood in homes. Research on structural framing was initially limited to COM-PLY studs but has now been extended to include larger members such as floor joists.

In 1973, the home-building industry faced a shortage of lumber and plywood and consequent rising prices. Both industry and government recognized that this situation was not a temporary problem, and that long-range plans for better using the Nation's available forest resources would be necessary.

The Forest Service of the U.S. Department of Agriculture and the U.S. Department of Housing and Urban Development accelerated cooperative research on ways to utilize the whole tree. They concentrated on composite wood products made with particleboard and veneer as a way of using not only more of the tree stem, but also using less desirable trees and a greater variety of tree species than would conventional wood products. The particleboard which comprises a large portion of COM-PLY studs and joists is made from chipped-up wood that comes from forest residues, mill residues, or low-quality timber. Thus, such composites could greatly increase the amount of lumber and plywood available for residential construction, our major use of wood, without eroding the Nation's timber supply.

Research on composite wall and floor framing was performed by the Wood Products Research Unit, Southeastern Forest Experiment Station, Athens, Georgia. The American Plywood Association cooperated in these studies by designing and testing composite panel products that are interchangeable with plywood. Both types of products have been incorporated in demonstration houses.

Included in this series will be reports on structural properties, durability, dimensional stability, strength, and stiffness of composite studs and joists. Other reports will describe the overall project, compare the strength of composite and solid wood lumber, suggest performance standards for composite lumber and provide construction details on houses incorporating such lumber. Still others will explore the economic feasibility of manufacturing composite lumber and panels and estimate the amount and quality of veneer available from southern pines. These reports, called the COM-PLY series, will be available from the Southeastern Forest Experiment Station and the U.S. Department of Housing and Urban Development.

CONTENTS

Page

FINANCIAL FEASIBILITY ANALYSIS.......... 2

PROCESS USED FOR MANUFACTURE.......... 2

INVESTMENT REQUIREMENTS.......... 2

Land.......... 2

Buildings.......... 3

Facilities.......... 3

Machinery.......... 3

Cash.......... 3

Inventory.......... 5

Accounts Receivable.......... 5

Contingency.......... 5

FLOW OF MATERIALS.......... 5

OPERATING COSTS.......... 8

Unit Materials Cost.......... 9

Wood.......... 9

Particleboard Resin.......... 12

Resin Catalyst.......... 13

Particleboard Wax.......... 13

Laminating Adhesive.......... 13

Total Materials Cost.......... 13

Labor Cost.......... 13

Energy Cost.......... 14

Other Production Costs.......... 17

Depreciation Costs.......... 17

ANNUAL SALES, OPERATING CASH FLOWS, AND TOTAL MANUFACTURING COST.......... 17

NET CASH FLOWS AND INTERNAL RATE OF RETURN.......... 22

DISCUSSION AND CONCLUSIONS.......... 25

LITERATURE CITED.......... 26

ACKNOWLEDGMENT

The Forestry Sciences Laboratory, Wood Products Research Unit, acknowledges the valuable assistance and guidance of:

Harold Evans
Consultant for Plywood and
Panel Products

ECONOMIC FEASIBILITY OF MANUFACTURING COM-PLY STUDS IN THE SOUTH

Abstract.--The investment and production cost required to manufacture COM-PLY studs in the South are presented. It is possible to obtain a 20 percent or greater internal rate of return on an investment in manufacturing COM-PLY studs.

KEYWORDS: Manufacturing costs, stud cost, economics of stud manufacture, cost analysis, COM-PLY factory, rate of return.

Cooperative research by the Forest Service, U.S. Department of Agriculture, and the U.S. Department of Housing and Urban Development has led to development of a new composite lumber product. The new product, called COM-PLY, has potential for significantly increasing our supply of lumber for building homes. COM-PLY lumber is a structural sandwich construction with a particleboard core between layers of solid wood veneer.

The first composite lumber product developed was a 2 x 4 wall stud typically used to frame exterior walls in houses (fig. 1). COM-PLY studs are intended to be used as direct substitutes for conventional studs of sawn lumber and must be priced competitively.

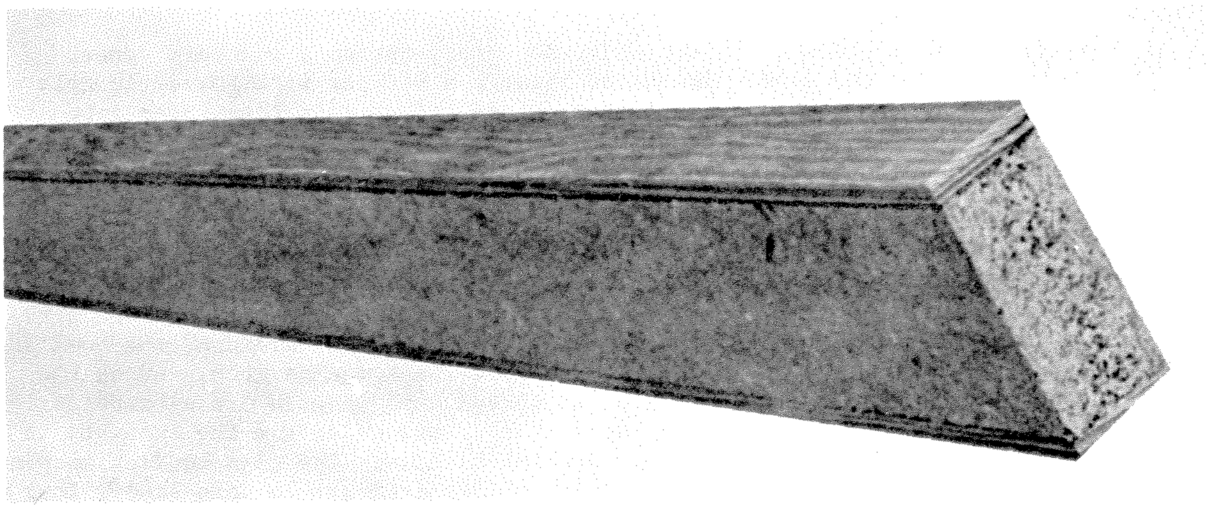


Figure 1.--COM-PLY stud used for framing exterior walls of houses.

Potential manufacturers of COM-PLY studs want to know how much it will cost to make them. They also want to know if a COM-PLY stud factory would be a profitable investment, one that would give a greater return on the investment than a sawmill. This report presents estimates on the amount of investment required to build a COM-PLY stud factory; the cost of manufacturing COM-PLY studs; the annual sales and operating cash flows; and the annual net cash flows and internal rate of return.

A study of financial feasibility is only as good as the validity of the assumptions upon which it is based. In this study, we assume that the factory is located in Arkansas and uses both hardwood and southern pine for its wood supply. The assumptions concerning costs are based on industry averages and therefore do not reflect values for any specific company.

Results presented in this report are no guarantee that any firm can profitably manufacture COM-PLY studs--profitability depends on competent managerial skills, market demand, production efficiency, and other business factors. However, the results strongly indicate that it is economically feasible to manufacture COM-PLY studs. Although a specific firm's assumptions about price, cost, and quantity may vary from those in this report, minor variances would not greatly affect the overall conclusions reported.

FINANCIAL FEASIBILITY ANALYSIS

PROCESS USED FOR MANUFACTURE

The results of any analysis of financial feasibility are greatly affected by the process used for manufacture. A brief explanation of the process used will therefore help the reader. In this analysis, 1-1/2-inch-thick particleboard is made on a 4-foot-wide by 24-foot-long multiplaten hot-press with 20 openings. The press completes five cycles each hour, and each cycle consists of 10 minutes' curing time and 2 minutes for loading and unloading. The particleboard has a specific gravity of 0.6. Six percent uncatalyzed phenolic resin (based on ovendry weight of wood in the particleboard) is used in the face layers (each face is 1/4 inch thick), and 6 percent catalyzed phenolic resin is used in the core layer (1 inch thick). Wax is used at a rate of 0.5 percent throughout the particleboard. The particleboard is cut into strips 1-1/2 inches thick by 2-1/2 inches wide and 8 feet long to serve as cores for COM-PLY studs.

Veneer, 1/4 inch thick by 8 feet wide, is rotary-cut on a standard veneer lathe. After drying, the veneer is passed through a clipper with knives equally spaced 1-1/2 inches apart around a cylinder; these knives clip the veneer into strips 1/4 inch thick, 1-1/2 inches wide, and 8 feet long. Then the veneer strips are graded, sorted, and automatically stacked vertically in feeder bins.

The last step in the process is laminating the veneer strips to the edges of the particleboard cores with a phenol-resorcinol laminating adhesive. The veneer strips and particleboard cores are automatically fed from bins into a glue spreader. Glue is spread on one surface of the veneer and sprayed on each edge of the particleboard core at a minimum rate of 40 lb/Mft^2 of glueline. Therefore, the bondline between the veneer and the particleboard core contains twice as much glue as the bondline between veneers. After the glue is spread, the veneers are automatically turned on edge in their final position against the core edges and the assembly is transferred laterally into a lumber edge-bonding machine. The edge-bonding machine could utilize heated platens or radio frequency (RF) curing. In this study, four RF-curing edge-bonding machines were required to balance the production rate of the particleboard press. After the veneers are laminated to the particleboard cores, the studs are hot-stacked for final curing. Later, studs are run through one machine to ease the edges and a second machine to label the edges according to use designation. Then the studs are banded together in packages and stored in the warehouse until shipped to customers.

INVESTMENT REQUIREMENTS

Land

The total land required was assumed to be 30 acres and cost $8,950 per acre; thus, total land cost would be $268,500. Thirty acres of land is a generous estimate; a 15-acre site would be adequate when a company can maintain a low inventory of logs. In this study, the log inventory was assumed to be a 2-month supply, which would require the larger site. Land-developing costs such as engineering, overhead, and contingencies were assumed to be $13,410. Thus, the total cost of land and development was $281,910.

Buildings

A main building with 150,000 square feet, constructed at a cost of $8.40 per square foot, and miscellaneous small buildings with 7,000 square feet, constructed at a cost of $10.98 per square foot, resulted in costs of $1,260,000 and $76,900 for the structures. Engineering design, construction overhead, and contingencies added $500,000 to the basic building cost, for a total of $1,836,900 for buildings.

Facilities

Cost of facilities to be added to the buildings and grounds in order to make the plant operational are:

	Cost (dollars)
Site preparation	30,000
Roads, parking, and paving	30,000
Outside fire protection	48,000
Outside lighting	3,600
Outside piping (water supply and sewer)	12,000
Waste disposal	6,000
Fuel storage (gas and diesel tanks and pumps)	6,000
Inside electrical equipment (installed)	528,000
Inside piping (air, water, sewer)	43,200
Engineering, construction overhead, and contingencies	651,250
Total	1,358,050

Machinery

In this study, it was assumed that new machinery was purchased. Table 1 is a list of machinery and machinery costs for the COM-PLY stud factory. The number and size of machines required depend on the flow of materials through the factory, a topic discussed later in this report. The total cost for machinery in this analysis is $8,136,075.

Cash

In this analysis we assume that cash in the amount of 2 months' payroll is sufficient to meet the payroll, provide petty cash, and otherwise meet the cash needs of the business. In a later section, we shall show that the annual labor costs in 1975 would be $2,268,024 if the plant were operating at 100 percent capacity. Thus, cash required was assumed to be $378,004.

Table 1.--Machinery and machinery cost for a COM-PLY stud factory

Machinery or associated item	Cost
	Dollars
Log storage and handling equipment (unloaders, storage skids, sprinkling, and facilities)	182,250
Log barking equipment	445,000
Machinery foundations and supports (installed)	187,000
Block handling equipment and steam vault	238,000
Boiler	189,000
Log conveyors to lathe and foundation (installed)	41,850
Lathe and charger (installed)	261,900
Trays and tripples (installed)	75,600
Green clipper (installed)	96,000
Green veneer sorting line (installed)	92,000
Green veneer conveyor	7,400
Green veneer chipper and conveyor (installed)	71,550
Core chipper (installed)	52,650
Bark conveyor (installed)	48,600
Chip handling facility	48,600
Dryer (installed)	545,000
Dryer feeder	58,320
Dryer unloader	34,630
Moisture meter	6,750
Dry sorting chain	13,500
Dry veneer strip clipper	33,750
Dryer emission control equipment	36,450
Flaker	67,500
Fiber dryer	472,500
Fiber dryer emission control equipment	20,250
Fiber screen	8,100
Glue mixing, pumping, and metering equipment	22,950
Two blenders (installed)	83,700
Forming felter and caul line	893,025
Particleboard press (4 ft. x 24 ft.--20 openings)	2,059,425
Board stacker and conveyor	218,700
Core-cutting saw with feeder and bins	96,600
Laminating glue spreader	81,000
Stud-laminating machines (installed) (4 RF curing or 6 lumber edge-bonding machines)	575,000
Eased edge machine	56,700
Inspection line	2,700
Labeling and marking machine	1,350
Packaging and strapping machine	6,075
Forklifts and carts	87,750
Air compressor (installed)	44,550
Maintenance equipment and small tools	67,500
Spare parts and quality control equipment	70,200
Sweeper and yard truck	25,650
Storage tanks	81,000
Storage bins	54,000
Air conveyers (blowers, cyclones, piping)	113,400
Freight in for machinery	160,650
Total	8,136,075

Inventory

Investment is required to buy raw materials and cover cost of materials being processed and in finished products awaiting shipment. In this study, it was assumed that one-sixth of the annual cost of raw materials for a factory operating at full capacity would be sufficient to cover all requirements for inventory investment. It will be shown in other parts of this report that the total annual cost of raw materials for this study is $13,232,010. Therefore, the investment required for inventory would be $2,205,335.

Accounts Receivable

A considerable investment is required to cover sales to customers who do not pay immediately for the products purchased. Such customer accounts--accounts receivable--may typically be paid in 10 to 60 days. The average collection period from customer sales was assumed to be 30 days. Investment to cover accounts receivable was considered to be 1 month (30 days) of sales. Sales will vary with the unit price received for products and the quantity produced each year. Three unit prices were used in this study; but at an average first-year sales price of $130/M board feet, there would be sales of $24,710,400 per year. For this study, the investment required for accounts receivable would be $2,059,200.

Contingency

The investment for any individual item such as land or buildings may vary from the amounts assumed or there could be investments for items that might not be evident until factory construction and operation begins. Therefore, to be on the safe side, a contingency investment amounting to 5 percent of all other investments has been used in this analysis. The total of all investments up to this point is $16,255,424. Five percent of $16,255,424 is $812,771, which is the contingency investment for this study. The time when an investment is made is important in an economic analysis. Cash invested in a factory could also have been invested in securities and thus be earning interest. In this study, we assume that the major capital investments would be made during the first 3 years of factory operation. Table 2 shows the amounts and timing of investments made for this study when an average unit price of $130/M board feet is received for COM-PLY studs in 1975. The total investment for a new COM-PLY stud factory is $17,068,195.

FLOW OF MATERIALS

Forest products manufacturers with whom we worked in making this study said that creditability of the results would only be as good as the assumptions made about manufacturing cost. They said if detailed information is provided in this study, then they could use the information to make similar studies of their own by adjusting our assumptions to fit their own manufacturing operations. This section on flow of materials contains much of the detailed information upon which operating costs are based and may be skipped by readers more interested in results of the study.

Once the size and operating speed of the particleboard press has been selected, it is possible to calculate the flow of materials through the factory. Table 3 provides some of the specific assumptions made with regard to particleboard manufacture. Maloney (1973) has shown that 1-1/2-inch-thick particleboard could be cured in a minimum of 10 minutes with catalyzed phenolic resin and a platen temperature of 400° F. The catalyzed resin is needed only in the core of the particleboard because the face layers will reach curing temperatures in less than 10 minutes with uncatalyzed resin. About 1-1/2 minutes are typically required for press loading, unloading, and closing. Therefore, 11-1/2 minutes would be the minimum cycle time for making 1-1/2-inch-thick particleboard. To be on the safe side, cycle time was rounded to 12 minutes or five cycles per hour.

Table 2.--Net investment required for the first 3 years of factory operation

Investment	Beginning of first year	End of first year	End of second year	End of third year	Total
	- - - - - - -	- - - - - - -	-Dollars-	- - - - - - -	- - - - - - -
Land	281,900	0	0	0	281,900
Buildings	0	612,300	1,224,600	0	1,836,900
Facilities	0	1,086,400	271,600	0	1,358,000
Machinery	0	2,712,000	5,424,100	0	8,136,100
Cash	0	126,000	252,000	0	378,000
Inventory	0	735,100	735,100	735,100	2,205,300
Accounts receivable	0	686,400	686,400	686,400	2,059,200
Contingency	62,800	150,000	250,000	350,000	812,800
Net investment	344,700	6,108,200	1/ 8,843,700	1,771,500	17,068,200

1/ This total differs from the values in the column above because of rounding.

Table 3.--Values assumed for production variables in order to calculate flow of materials through the particleboard section of the COM-PLY stud factory

Variable	Value			
	Feet	Number	Amount	Percent
Net width of press	4			
Net length of press	24			
Press openings		20		
Press cycles per hour		5		
Allowance for width trim	.35			
Allowance for length trim	.35			
Specific gravity of particleboard			.6	
Resin solids in face layer of board				6
Resin solids in core layer of board				6
Catalyst in face layer of board (liquid basis)				0
Catalyst in core layer of board (liquid basis)				6
Wax solids in face layer of board				.5
Wax solids in core layer of board				.5
Other solids in resin used in face layer (percent of resin solids)				29.3
Other solids in resin used in core layer (percent of resin solids)				29.3
Solids in catalyst used in face layer				66.0
Solids in catalyst used in core layer				66.0
Average specific gravity of wood supply			.59	
Ratio of wood weight in core to wood weight in face			2	

On the basis of the assumptions in table 3, we used a computer to calculate the hourly flow of materials through the particleboard section of the factory (table 4). In making the calculations, we used Koch's (1972) value of 1.15 for the ratio of green wood volume to dry wood volume.

Table 4.--Flow of materials through particleboard section of COM-PLY stud factory at 100 percent efficiency

Material	Flow		
	Cubic feet per cycle	Cubic feet per hour	Pounds per hour
Particleboard pressed	264.8	1,324	
Ovendried wood in face layer			14,699
Ovendried wood in core layer			29,398
Solid ovendried wood in face layer		399	
Solid ovendried wood in core layer		798	
Green wood from peeling residue to be chipped			87,742
Green wood from top logs too small to peel into veneer			7,066
Resin solids in face layer			882
Resin solids in core layer			1,764
Liquid catalyst in face layer			0
Liquid catalyst in core layer			105.8
Wax liquid emulsion in face layer			153
Wax liquid emulsion in core layer			306
Other solids from resin and catalyst in face and core layers			775.2
Water in particleboard after pressing			1,763.9

At the factory, the particleboard is cut into stud cores with a gang ripsaw having a kerf of 0.125 inch. Computations show there would be 5,400 cores produced per hour. Net requirements for veneer are 4 square feet per stud, but 5 percent waste must be added to obtain the gross requirements for veneer. Table 5 shows the computed hourly quantities of stud cores, veneer, veneer logs, and peeling residues processed at the factory by converting tree-length southern pine into veneer.

These quantities are based on a study by McAlister and Taras (1978), who provided information on the dry-volume yields of veneer per acre from southern pine timber. For their study, representative loblolly and slash pines in natural stands were cut into veneer blocks and peeled into veneer at a commercial plywood plant. The grade and dry volume of veneer produced from the peeler blocks were tallied. Table 6 shows the yields of products produced from an acre of typical southern pine timber.

Table 6 is important in demonstrating total-tree utilization and computing the flow of materials in a factory. Veneer of grade C or better has sufficient strength to be used in COM-PLY studs. Notice that the dry volume of C and better veneer (412.6 ft^3) is 30.5 percent of the total dry tree volume (1351.6 ft^3) in that acre. A COM-PLY stud with 1/4-inch-thick veneer contains 30 percent veneer (assuming 5 percent waste veneer) by volume. Thus, a COM-PLY stud factory could utilize all of the C grade and better veneer in a typical stand and convert the rest of the wood to particleboard, thereby providing total-tree utilization.

Table 5.--Hourly flow of materials through veneer and chip-preparation sections of a COM-PLY stud factory at 100 percent efficiency

Material	Amount per hour				
	Number	Square feet	Cubic feet	Linear feet	Pounds
Stud cores produced	5,400				
Dry veneer required for above stud cores including 5 percent waste		22,680			
Dry veneer required			473		
Green veneer logs required			1,507		
Green logs to be barked				2,728	
8-foot peeler blocks to be peeled	341				
Peeling residues produced from cores, round-up, and spur trim			964		
Green wood required in addition to peeling residues to supply wood particles for particleboard cores (assumed to come from tops of trees above height where peeler blocks occur)			414		
Small logs from upper tree stems to be barked for wood particles				1,737	
12-foot-long small logs to be barked	145				
Water removed from green veneer during drying					20,005
Water removed from green wood chips during drying					50,711

One of the most important uses of table 6 is to compute ratios for the flow of veneer, veneer residues, and linear feet of logs through the factory. Some of the more important ratios are shown in table 7. For example, table 7 shows that there will be 2.04 cubic feet of green peeling residues, D veneer, and fishtail produced for each dry cubic foot of dry C and better veneer produced. The ratios shown in table 7 were used in the computer analysis to obtain hourly flow of wood products shown in table 5.

For production of 5,400 studs per hour and spread rates of 40 lb/Mft^3 of glueline between veneers and 80 lb/Mft^3 between veneers and the core, the hourly quantities of phenol-resorcinol adhesive including catalyst can be computed. Four hundred thirty-two pounds of mixed adhesive would be required per hour on veneer-to-veneer gluelines and 864 pounds per hour on veneer-to-particleboard gluelines.

OPERATING COSTS

Operating costs are needed to determine annual net earnings or cash proceeds that will result from the investment. Operating costs provide insight on how the cost of producing COM-PLY studs compares with the cost of producing sawn lumber studs. The following discussion is concerned with operating costs to produce COM-PLY studs at 1975 price levels. In this study, it is assumed that the factory operates 6 days per week and 50 weeks per year. Out of each 24-hour day, it is assumed that there are 22 hours of useful work. Efficiency is thus about 92 percent or 6,600 hours of production per year. Such high efficiency is possible because only a single item is being made and the setup and startup times will be small. Normally, plants that make a variety of particleboards have efficiencies of about 85 percent.

Table 6.--Average dry volume of veneer and residues per acre in a typical, natural stand of southern pine[1/]

Item	Yield per acre	Proportion of total stand volume per acre
	Cubic feet	Percent
A & B veneer	121.5	9.0
C veneer	291.1	21.5
D veneer	182.1	13.5
Total full-length veneer	594.7	44.0
Fishtail	43.6	3.2
Total veneer	638.3	47.2
Peeling residue	507.5	37.6
Total block volume	1,145.8	84.8
Top log residue	205.8	15.2
Total tree volume	1,351.6	100.0

[1/] From McAlister and Taras (1978). Based on per-acre values for number of trees, block volume, and tree volume in a typical, natural stand of southern pine.

Unit Materials Cost

Wood

Potential manufacturers of COM-PLY studs have several sources of wood for their factory. One method of purchasing wood is to buy stud-grade veneer and the lowest-cost mill residue for the wood particles in the particleboard. Another method is to purchase full tree-length timber and process it. If the second method is used, veneer of the needed quality must be pulled from that portion of the tree with a nominal diameter of 8 inches or larger; then the peeling residues and portions of the tree too small to peel must be converted to wood particles for the particleboard. We have used the second method in this study. Of the many methods possible for purchasing wood for COM-PLY studs, the one that results in the highest internal rate of return on the investment should be used. Purchasing full-tree-length timber has distinct advantages which offset its disadvantages.

One advantage of using full-tree-length timber is that the parts of the tree too small to peel, as well as the peeling residues from the veneer operation (cores, roundup, spur-trim), are cleaner and of higher quality than mill residues typically used to make particleboard. Practically no wood waste is generated from such a wood supply. In this study, we assumed that 5 percent waste and scrap would be lost during veneer peeling and particle chipping. In a plywood plant, wood losses are usually higher because of waste generated by trimming veneer into widths for 4-foot-wide panels, trimming the panels, and sanding.

Table 7.--Ratios used for computing the flow of veneer, veneer residues, and linear feet of logs through a COM-PLY stud factory[1/]

Ratio	Value
Volume of green peeling residue, D veneer, and fishtail to volume of dry C and better veneer	2.04
Linear feet of green peeler log per cubic foot of green peeler log	[2/] 1.44
Linear feet of small green logs from upper part of tree to cubic foot of green peeler log	[2/] 4.20
Volume of green peeler log to volume of dry C and better veneer	3.19

1/ From McAlister and Taras (1978). The values in their study are for dry volumes. The dry volumes of peeling residue and block volumes were increased by 15 percent to obtain the green volumes used in computing the ratios in this table.

2/ From unpublished studies by G. A. Koenigshof on file at the Forestry Sciences Laboratory, Athens, Georgia.

The most important advantage of using full-length trees is that an optimum size and shape of wood particle can be made from peeling residues and those parts of the tree too small to peel. Particles made by flaking roundwood and then milling the wide flakes into narrow ones are ideal for COM-PLY studs (fig. 2). Much less resin is required to coat flakes up to 2 inches long than to coat particles made from sawmill residues, which typically contain a large percentage of fine material. Although more energy is required to dry flakes and splinters made from green wood than to dry sawmill residues, this higher energy cost is more than offset by the reduced amounts of waste, scrap wood, and resin.

In 1975, southern pine saw logs cost about $117.25/M board feet (Doyle scale) delivered to the mill, and oak and gum saw logs cost $76.50 and $79.93/M board feet (U.S. Dep. Agric. 1977). When converted to cost per green cubic foot, these prices are approximately $0.53 for southern pine, $0.34 for oak, and $0.36 for gum. Full-tree-length logs could probably be obtained for less cost per cubic foot because harvesting and hauling costs would be somewhat less than for saw logs. Assuming COM-PLY studs would be made from half hardwood and half southern pine, the 1975 cost per cubic foot for green saw logs delivered to the mill is about $0.44. For full-tree-length logs, green mixed pine and hardwood could probably be obtained for about $0.40 per cubic foot in 1975. Since wood shrinks about 15 percent when dried and we assumed that 5 percent is wasted in the factory, the cost of dry wood in the stud is about $0.483 per cubic foot. For the 10-year investment period in this study, costs of green wood were assumed to increase at a compound rate of 7 percent per year, as tabulated below:

Yearly period	Cost of green wood (dollars/cubic foot)
1	0.400
2	.428
3	.458
4	.490
5	.524
6	.561
7	.600
8	.642
9	.687
10	.735

Typically, prices of softwood timber fluctuate with prices of softwood lumber. However, when prices of pine sawtimber are rising rapidly because of strong demand, the price of hardwood usually remains relatively constant. Therefore, the cost per cubic foot of a mixture of hardwoods and softwoods would probably not escalate as rapidly in a period of strong demand as the cost of softwoods only.

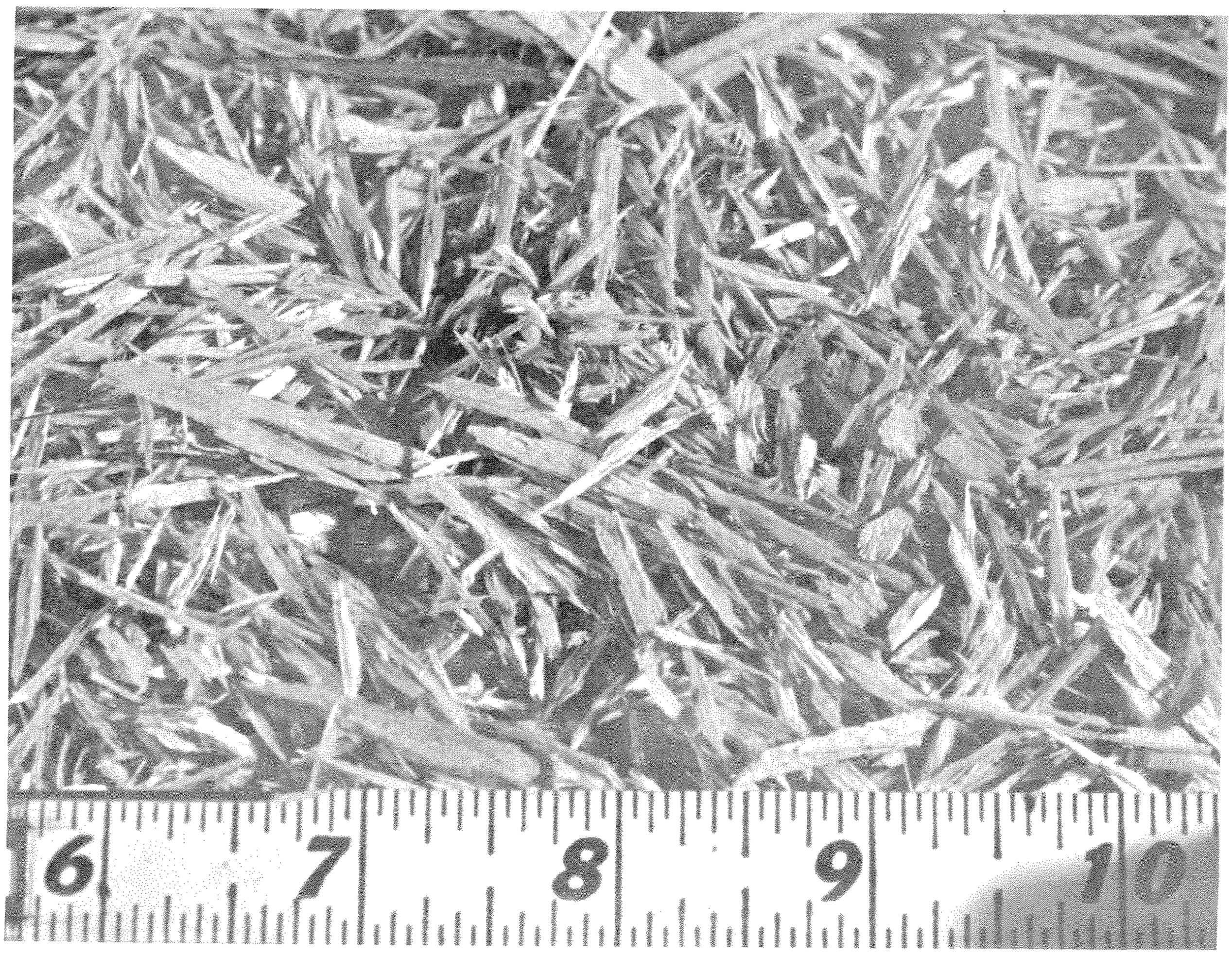


Figure 2.--Flake-type particles made from peeler cores; they can be coated satisfactorily with 6 percent resin.

The volume of veneer in a stud is about 20 to 30 percent of the stud volume, whereas the volume of C and better veneer in an average mixture of southern pine trees is slightly over 30 percent. In other words, there is a slight surplus of veneer generated in making COM-PLY studs when full-length southern pine timber is used. Thus, there are opportunities to reduce wood cost by supplementing the factory's raw wood supply with low-cost, high-quality residues, such as waste from a plywood mill.

Veneer for COM-PLY studs does not require high-quality timber. This study is based on veneer grades and yields of southern pine from timber of No. 2 sawlog quality.

Potential manufacturers of COM-PLY studs must consider all the factors discussed and select the right combination from the wood supply at their disposal when making their own analysis of economic feasibility. However, the quantity of resin required to make a stud that will meet the quality standards for the product is greatly influenced by the type of wood used to make the particles.

Particleboard Resin

Figure 3 shows industrial average prices for the phenolic resin used in particleboard on a 100 percent solids basis. From 1955 to 1973, the price of phenolic resins steadily declined. Then in 1974 the price rose drastically as a result of shortages of petrochemicals and plant capacity. This study is based on the 1975 price of $0.31 per pound for phenolic resin and an estimated price increase at a compound rate of 5 percent per year.

Figure 3.--Price of phenolic resin per dry pound on a 100 percent solids basis.

Resin Catalyst

Research performed for the Forest Service at Washington State University showed that phenolic resin binders for particleboard can be cured in 10 minutes at a platen temperature of 400° F if a catalyst is used to accelerate curing. Assuming that the time for press loading, closing, opening, and unloading does not exceed 2 minutes, it is possible to have a 12-minute press cycle (the time assumed in this study) when a catalyzed resin binder is used. The 1975 price for the catalyst was $0.48 per liquid pound. The amount of liquid catalyst required is 6 percent of the dry resin binder used. Catalyst prices are also estimated to increase at a compound rate of 5 percent per year.

Particleboard Wax

Liquid wax emulsions are added to particleboard in order to reduce thickness swelling when the particleboard is soaked in water for short periods. These emulsions, roughly half wax solids, were priced at $0.09 per liquid pound in 1975. In this study, we used this 1975 price for wax emulsion and assumed it would increase at a compound rate of 5 percent per year.

Laminating Adhesive

Phenol-resorcinol adhesives that cure at room temperature are widely used for laminating large structural timbers. Such adhesives are a mixture of five parts liquid phenol-resorcinol resin and one part paraformaldehyde hardener by weight. Cost of these adhesives when mixed was about $0.50 per liquid pound in 1975. The adhesives contain a large percentage of resorcinol in order to allow curing at room temperature in a few hours, but the adhesive can be cured with high-frequency heating equipment in just a few minutes. By reducing the amount of resorcinol resin and increasing the amount of phenolic resin, the cost could be reduced to about $0.25 per liquid pound. Two major manufacturers said that they would supply a laminating resorcinol-modified phenol adhesive that could be cured with high-frequency heat at a cost of only $0.25 per mixed liquid pound in 1975. We adopted this price for the present study and assumed that prices would increase at a compound rate of 5 percent per year.

Total Materials Cost

Total annual cost for materials is found by multiplying the quantity of materials flowing per hour times 6,600 hours per year times the unit price of the materials (table 8). This cost was calculated to be $13,232,010.

Labor Cost

Labor costs vary with the levels of skill demanded of workers, fringe benefits paid, and geographic location. Labor wages have been rising rapidly since 1961. Table 9 was developed from industry reviews to show the wage assumptions used in this study for various levels of skill from 1975 through 1985. We assumed that the factory would be built in Arkansas and pay wages including fringe benefits at the prevailing rates in that State. Table 10 lists all of the job descriptions, number of workers, number of shifts worked, wage rate paid, hours worked per day, and daily labor cost for each operation. Total daily labor cost was calculated to be $7,560.08. This sum multiplied by the 300 days worked per year is the total annual labor cost. At full production capacity, the annual labor cost at the 1975 rate is $2,268,024.

The annual cost for labor will escalate exponentially from year to year, as indicated by the growth rate in table 9. Of course, the amount of labor required during the beginning years will be less than when the plant reaches full production. In fact, during the first-year construction period (1975), there will be no direct labor cost.

Table 8.--Annual cost of materials for a COM-PLY stud factory

Item	Flow of materials per hour		Time worked per year		Unit price		Total annual cost
			Hours		Dollars		Dollars
Wood (green-tree length)	1,921 ft^3	X	6,600	X	0.40/ft^3	=	5,071,440
Particleboard resin	2,646 lb(dry)	X	6,600	X	.31/lb	=	5,413,716
Particleboard catalyst	106 lb(liquid)	X	6,600	X	.48/lb	=	335,808
Particleboard wax	459 lb(liquid)	X	6,600	X	.09/lb	=	272,646
Laminating adhesive	1,296 lb(liquid)	X	6,600	X	.25/lb	=	2,138,400
Total							13,232,010

Table 9.--Estimated labor costs (including fringe benefits) of operating a COM-PLY stud factory in Arkansas from 1975 through 1985[1/]

Year	Skill level of workers		
	Skilled	Semi-skilled	Unskilled
	Dollars per hour		
1975	4.96	4.54	4.02
1976	5.23	4.78	4.24
1977	5.51	5.05	4.47
1978	5.81	5.32	4.71
1979	6.13	5.61	4.97
1980	6.46	5.92	5.24
1981	6.82	6.24	5.52
1982	7.19	6.58	5.82
1983	7.58	6.94	6.14
1984	7.99	7.31	6.47
1985	8.42	7.71	6.83

[1/] Wages escalate by the amount $10^{0.023(n-1)}$ where n is 1 to 11 for years 1975 through 1985.

Energy Cost

A COM-PLY stud factory requires two types of energy for its operation--electrical and thermal. Some operations require both electrical and thermal energy, while others require only one. Actual energy costs depend on the volume of materials being processed, efficiency of the machinery, fuel type, and fuel costs.

Table 11 lists the important energy-using operations in a COM-PLY stud factory and shows the estimated quantities of electrical and thermal energy for a given production unit per hour. For example, table 11 shows that drying chips requires

Table 10.--Labor requirements for COM-PLY stud factory

Operations or job	Workers	Shifts	Hourly wage rate1/	Time worked per day	Daily cost for labor
	- - - No.	- -	Dollars	Hours	Dollars
Log scaler	1	1	4.96	8	39.68
Log lift driver	2	1	4.54	16	72.64
Barker operator	1	1	4.54	8	36.32
Conveyor chaser	1	1	4.02	8	32.16
Fireman	1	3	4.54	24	108.96
Cut-off sawyer	1	1	4.54	8	36,32
Helper	1	1	4.02	8	32.16
Log sorter	1	1	4.96	8	39.68
Jitney driver (veneer)	1	1	4.54	8	36.32
Grinding room man	1	1	4.96	8	39.68
Lathe operator	1	3	4.96	24	119.04
Clipperman (green)	1	3	4.54	24	108.96
Offbearer	3	3	4.02	72	289.44
Jitney driver (veneer)	1	3	4.54	24	108.96
Dryer tender	1	3	4.54	24	108.96
Veneer grader	4	3	4.54	96	435.84
Dryer feeder & offbearer	3	3	4.02	72	289.44
Strip clipperman	3	3	4.54	72	326.88
Stacker	8	3	4.02	192	771.84
Glue mixer	1	3	4.54	24	108.96
Lam machine & saw operator	4	3	4.54	96	435.84
Feeders-Laminator	8	3	4.54	192	871.68
Eased edger	1	3	4.96	24	119.04
Inspector	2	3	4.96	48	238.08
Jitney driver (general)	1	3	4.54	24	108.96
Jitney driver (warehouse)	1	1	4.54	8	36.32
Car loader	3	1	4.54	24	108.96
Splitter & slasher	1	1	4.54	8	36.32
Chipper operator	1	1	4.54	8	36.32
Clean up (screen)	1	1	4.02	8	32.16
Flaker operator	1	3	4.54	24	108.96
Hammermill operator	1	3	4.54	24	108.96
Dryer & screen operator	1	3	4.54	24	108.96
Resin mixer	1	3	4.54	24	108.96
Former operator	1	3	4.96	24	119.04
Press operator	1	3	4.96	24	119.04
Trimmer & cooler	1	3	4.54	24	108.96
Core cutter & stacker	4	3	4.54	96	435.84
Jitney driver (particleboard)	1	3	4.54	24	108.96
Millwright	1	3	4.96	24	119.04
Millwright helper	1	3	4.54	24	108.96
Electrician	1	3	4.96	24	119.04
Cleanup	1	3	4.02	24	96.48
Foreman	1	3	8.25	24	198.00
Superintendent	1	1	10.00	8	80.00
Machinist	1	1	4.96	8	39.68
Pipefitter	1	1	4.96	8	39.68
Storeroom man	1	1	4.54	8	36.32
Watchman	1	3	4.02	24	96.48
Strapper operator	1	3	4.02	24	96.48
Shipping clerk	1	1	4.54	8	36.32
Total				1,664	7,560.08

1/ Hourly rate includes 25 percent for taxes and fringe benefits.

Table 11.--Energy required to make COM-PLY studs

Production operations	Production units per hour	Electrical energy per unit	Thermal energy per unit
		kWh	Btu
Barking logs	Linear feet of logs	0.004 to 0.012	-
Hogging waste wood and bark	Green tons	20 to 40	-
Conveying chips, logs, etc.	Green tons	35	-
Steaming peeler blocks	Green tons	-	110,000
Log cut-off and slasher saws	Linear feet of logs	0.002	-
Log-sorting deck equipment	Linear feet of logs	0.003	-
Peeling veneer blocks on rotary lathe	Square feet of veneer	0.006	-
Veneer drying			
a. electrical	Square feet of veneer	0.007	-
b. thermal	Pounds of water removed	-	1,500
Conveying veneer	Square feet of veneer	0.003	-
Chipping round and waste wood into chips	Green tons of wood	17 to 40	-
Hammermilling chips into particles	Green tons of chips	15 to 25	-
Drying chips			
a. electrical	Green tons	18	-
b. thermal	Pounds of water removed	-	1,800
Screening chips	Dry tons of chips	0.3 to 0.5	-
Blending particles with resin and resin mixing	Dry tons of particles	8	-
Forming particleboard matt	Dry tons of matt	5	-
Prepress matt	Square feet of matt	0.004	-
Press matt into particleboard			
a. electrical	Dry tons of matt	6	-
b. thermal			
(1) heat matt	Dry tons of matt	-	120,000 to 160,000
(2) heat cauls (if used)	Dry tons of matt	-	80,000 to 160,000
(3) heat losses			
(a) water evaporation	Dry tons of matt	-	80,000 to 160,000
(b) radiation	Dry tons of matt	-	6,000 to 12,000
(c) convection	Dry tons of matt	-	4,000 to 12,000
Finish studs	Number of studs	0.001	-
Laminate studs	Number of studs	0.003	150

18 kilowatt hours of electrical energy for every green ton of chips processed and 1,800 Btu of thermal energy for every pound of water removed from the chips. The values for energy shown in table 11 are estimates; actual values in a factory could vary widely, depending on machine efficiency.

Table 12 shows the energy computations. For example, the amount of green wood to be chipped and dried (from table 4) is 87,742 pounds per hour of peeling residues and 7,066 pounds per hour of small top logs. The total is 94,808 pounds per hour or 47.4 tons per hour. The estimated electrical energy required for drying chips is 18 kilowatt hours per green ton (from table 11) times 47.4 green tons per hour or 853.2 kilowatt hours per hour. Table 5 shows that the amount of water removed from green chips is 50,711 pounds per hour. The estimated thermal energy required to dry the green chips is obtained by multiplying 50,711 pounds of water per hour times 1,800 Btu per pound of water removed or 91,279,800 Btu per hour. The values for electrical energy are based on full-rated horsepower of motor-driven equipment and must be reduced to 70 percent of the values shown in order to be more realistic about actual loads on the motors. For electricity costing $0.014 per kilowatt hour, the cost per year for electricity is $415,000; for thermal energy costing $0.07 per therm, the cost per year is $649,000. The total energy cost per year for this analysis is $1,064,000 in 1975. In this study the price of fuel increases at a compound rate of 5 percent per year.

Other Production Costs

There are various other costs associated with manufacture that need to be accounted for in operating a factory. These costs are best obtained from accounting records of an actual factory; the amounts shown in table 13 are rough estimates.

Sales promotion expenses were arbitrarily assumed to be 6 percent of the 1975 sales if the plant had been operating at full capacity and were distributed over the first 3 years of operation in declining amounts of 3 percent, 2 percent, and 1 percent of sales.

Depreciation Costs

Depreciation expense must be computed in order to determine the manufacturing costs for studs and taxable income and to determine return on investment. In determining manufacturing costs, the straight-line method of depreciation was used; in determining return on investment, the sum-of-the-years digit method was used. In this study, buildings, facilities, and machinery were depreciated over the 10-year investment period.

ANNUAL SALES, OPERATING CASH FLOWS, AND TOTAL MANUFACTURING COST

The purpose of this section is to determine the cash proceeds or net earnings that accrue to the business as a result of manufacturing operations. In computing net earnings, it is necessary first to compute revenue from sales and then to subtract manufacturing costs and taxes.

Some price has to be assumed for the product. In this analysis, therefore, the prices of COM-PLY studs are assumed to compete with those of sawn kiln-dried studs.

It is extremely difficult to make accurate predictions of stud prices because they fluctuate widely with various economic conditions. The average f.o.b. mill price of kiln-dried Hem-fir studs was $61.83/M board feet in 1966 and rose to $157.17/M board feet in 1976 (Evans 1976). This rise in price is about 10 percent compound growth for a 10-year period. In 1975, the average f.o.b. mill price for kiln-dried Hem-fir studs was $126.33/M board feet. The year 1975 was a period of recession, low home-building activity, and low lumber prices. We therefore estimated that stud prices would increase at a lower compound growth rate of 7 percent during the investment period from 1975 to 1985--about 3 percent less growth than during the previous 10-year period. Three price levels for COM-PLY studs in 1975 were used in the study; the first was assumed to be $123.50/M board feet, the second was assumed to be $130.00/M board feet, and the third was assumed to be $136.50/M board feet. Since 1975 was a period of relatively low lumber prices, the second price level probably most closely represents the base for the long-term price trend for studs. Table 14 shows f.o.b. mill prices for COM-PLY studs at the three levels during the investment period.

Table 12.--Estimated energy required per hour to produce COM-PLY studs[1/]

Operation	Energy unit		Materials unit		Energy/hour	
					Electrical	Thermal
					kWh	Btu
Barking logs	0.006	X	4,465.0	=	26.79	
Hogging fuel	30.000	X	7.0	=	210.00	
Conveying chips	35.000	X	63.2	=	2,212.00	
Steaming blocks	110,000.000	X	59.7	=		6,567,000
Log cut-off	.002	X	4,465.0	=	8.93	
Log sorting	.003	X	4,465.0	=	13.40	
Peeling veneer	.008	X	22,680.0	=	181.44	
Veneer drying	.004	X	22,680.0	=	90.72	
Veneer drying	1,800.000	X	20,004.09	=		36,007,362
Conveying veneer	.003	X	22,680.0	=	68.04	
Flaking wood	28.000	X	47.4	=	1,327.20	
Hammermilling	20.000	X	47.4	=	948.00	
Drying chips	18.000	X	47.4	=	853.20	
Drying chips	1,800.000	X	50,711.0	=		91,279,800
Screening chips	.400	X	22.1	=	8.84	
Blending	8.000	X	22.1	=	176.80	
Forming matt	5.000	X	24.8	=	124.00	
Prepress matt	.004	X	96.0	=	.38	
Pressing matt	6.000	X	24.8	=	148.80	
Heating matt	140,000.000	X	24.8	=		3,472,000
Heating cauls	100,000.000	X	.0	=		0
Water loss	80,000.000	X	24.8	=		1,984,000
Radiation loss	9,000.000	X	24.8	=		223,200
Convection loss	8,000.000	X	24.8	=		198,400
Finish stud	.001	X	5,400.0	=	5.40	
Laminate stud	.003	X	5,400.0	=	16.20	
Laminate stud	150.000	X	5,400.0	=		810,000
Total					6,420.14	140,541,762
					X .70[2/]	
					4,494.10	

[1/] Factory is assumed to work 6,600 hours per year. Hourly totals for kWh and Btu must be multiplied by this value to obtain yearly totals.

[2/] Electrical energy is 70 percent of total in order to account for motors not running at full rated horsepower.

Table 13.--Miscellaneous production costs in operating a COM-PLY stud factory

Cost	Amount		
	Percent of sales	Percent of land, building, and facilities cost	Salary (in 1975)
			Dollars
Production supplies	2.0		
Maintenance supplies	1.0		
Utilities	.1		
General manager			25,000
Office manager			18,000
Office clerks (three at $6,000 each)			18,000
Grade-certification fees	1.0		
Other office administrative expenses	.5		
Sales promotion	6.0		
Facilities maintenance		2.0	
Facilities taxes		.5	
Facilities insurance		.5	
Sales expense	5.0		
Contingency expense	2.0		

Table 14.--Estimated f.o.b. mill prices for COM-PLY studs during the investment period from 1975 to 1985

Year	Price level		
	(1)	(2)	(3)
	- - - - -Dollars per M board feet- - - - -		
1975	123.50	130.00	136.50
1976	132.15	139.10	146.06
1977	141.40	148.84	156.28
1978	151.29	159.26	167.22
1979	161.88	170.40	178.92
1980	173.22	182.33	191.45
1981	185.34	195.09	204.85
1982	198.31	208.75	219.19
1983	212.20	223.36	234.53
1984	227.05	239.00	250.95
1985	242.94	255.73	268.52

Given a choice between COM-PLY and conventional sawn studs at the same price, the builder probably would choose COM-PLY because they do not warp. Builders often recut 10 to 25 percent of their conventional studs into shorter lengths for use as blocking or short members because of excessive warpage. Thus, builders might even pay a premium price for COM-PLY studs, although we have not made that assumption in this study.

Table 15 shows the annual cash flows from operating a COM-PLY stud factory over the 10-year period. In this study, it is assumed that the production level of studs will be zero during the first year, 20 percent the second year, 80 percent the third year, and 100 percent the fourth year. When the factory reaches the 100 percent level, it will be operating at an efficiency of 92 percent.

The cash flows from sales in table 15 were computed by multiplying the f.o.b. mill price times the board footage of studs produced per year. There were 5,400 studs produced per hour for 6,600 hours per year, and each stud contains 5-1/3 board feet. Thus, annual production would be 190,080,000 board feet annually by the fourth year of operation.

There is some terminal salvage value for buildings, facilities, and machinery at the end of the 10-year investment period. Because this terminal salvage is revenue from a sale and is taxable, it is treated as a sales item during the last year of the investment period.

Computing the cash flows for operating costs in table 15 is similar to computing the cash flows for sales. The inflation rate was 7 percent for logs and items that were computed as a percentage of sales. Otherwise, the inflation rate used was 5 percent except for wage rates, which escalated at the rate shown in table 9. The general manager, office manager, and clerks were assumed to be hired on a full-time basis at the beginning of the second year. Sales promotion occurred only during the first 3 years, declining from $741,300 the first year to $247,100 by the third year. Only 50 percent of the facilities expense was assumed to occur the first year, but full facilities expenses occurred in subsequent years and escalated at a rate of 5 percent.

Total operating costs for purposes of computing taxable income were found by totaling the cost for raw materials, production expenses, administrative expenses, sales promotion, facilities expense, contingency expense, sales expense, and depreciation. For example, the operating cost for the fourth year, when full production had been reached, is shown as $24,901,200. Depreciation is included with the operating cost because the Internal Revenue Service allows depreciation to be deducted as an expense for tax computations. Depreciation began in the second year, when most of the investment for machinery and facilities had been made.

The taxable income is the difference between sales and total operating cost including depreciation. For the fourth year, the taxable income is $5,370,100. For this study, we assumed that the Federal tax rate is 48 percent and that there would be 4 percent additional state and local tax charges, for a total tax rate of 52 percent. Tax on income for the fourth year is $2,792,500 and after-tax profit is $2,577,600.

To obtain the net annual earnings for the fourth year, the depreciation (which was subtracted as a production cost for computing taxes) is added back to the after-tax profit. The net earnings for the fourth year are $4,225,800.

Notice that a negative income tax is shown for the first and second years. The Federal government does not make tax refunds to companies that have a loss from operating. However, for a large company, these losses could be charged off against other parts of the business that were operating profitably; therefore, they have been left in this analysis. For a company that could not write off the losses that occur during the first 2 years, there would be zero income tax and negative net earnings for both years.

Operating costs shown in table 15 can be used to compute the 1975 manufacturing cost of a stud. This cost is computed by projecting the amounts for each item during the fourth year back to the 1975 cost. For most items, the 1975 price

Table 15.--Ten-year cash flow from operations of a COM-PLY stud factory[1/]

Item	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	-Thousands of dollars-									
A. Sales										
COM-PLY studs	0	5,288.0	22,632.7	30,271.3	32,390.3	34,657.6	37,083.6	39,679.5	42,457.1	45,429.1
Terminal salvage	0	0	0	0	0	0	0	0	0	206.0
Total	0	5,288.0	22,632.7	30,271.3	32,390.3	34,657.6	37,083.6	39,679.5	42,457.1	45,635.1
B. Raw materials										
Logs	0	1,085.3	4,645.0	6,212.7	6,647.6	7,112.9	7,610.8	8,143.6	8,713.6	9,323.6
Particleboard resin	0	1,136.9	4,774.9	6,267.0	6,580.4	6,909.4	7,254.9	7,617.6	7,998.5	8,398.4
Particleboard catalyst	0	70.5	296.2	388.7	408.2	428.6	450.0	472.5	496.1	520.9
Particleboard wax	0	57.2	240.4	315.6	331.3	347.9	365.3	383.6	402.8	422.9
Laminating adhesive	0	449.1	1,886.1	2,475.5	2,599.2	2,729.2	2,865.7	3,008.9	3,159.4	3,317.4
Total	0	2,799.0	11,842.6	15,659.5	16,566.7	17,528.0	18,546.7	19,626.2	20,770.4	21,983.2
C. Production expenses										
Direct labor	0	1,195.7	2,521.4	2,658.6	2,803.2	2,955.6	3,116.4	3,285.8	3,464.6	3,653.0
Power and fuel	0	223.5	938.8	1,232.2	1,293.8	1,358.5	1,426.4	1,497.7	1,572.6	1,651.2
Production supplies	0	105.8	452.7	605.4	647.8	693.2	741.7	793.6	849.1	908.6
Maintenance supplies	0	52.9	226.3	302.7	323.9	346.6	370.8	396.8	424.6	454.3
Utilities	0	5.3	22.6	30.3	32.4	34.7	37.1	39.7	42.5	45.4
Total	0	1,583.1	4,161.8	4,829.1	5,101.0	5,388.5	5,692.3	6,013.6	6,353.3	6,712.5
D. Administrative expenses										
General manager	0	26.2	27.6	28.9	30.4	31.9	33.5	35.2	36.9	38.8
Office manager	0	18.9	19.8	20.8	21.9	23.0	24.1	25.3	26.6	27.9
Clerks (3)	0	18.9	19.8	20.8	21.9	23.0	24.1	25.3	26.6	27.9
Grade-certification fees	0	52.9	226.3	302.7	323.9	346.6	370.8	396.8	424.6	454.3
Other	0	26.4	113.2	151.4	162.0	173.3	185.4	198.4	212.3	227.1
Total	0	143.4	406.7	524.7	560.0	597.7	638.0	681.0	727.0	776.1
E. Sales promotion	741.3	494.2	247.1	0	0	0	0	0	0	0
F. Facility expenses										
Maintenance	34.8	73.0	76.7	80.5	84.5	88.7	93.2	97.8	102.7	107.9
Taxes	8.7	18.3	19.2	20.1	21.1	22.2	23.3	24.5	25.7	27.0
Insurance	8.7	18.3	19.2	20.1	21.1	22.2	23.3	24.5	25.7	27.0
Total	52.2	109.5	115.0	120.7	126.8	133.1	139.8	146.8	154.1	161.8
G. Contingency expenses	0	105.8	452.7	605.4	647.8	693.2	741.7	793.6	849.1	908.6
H. Sales expense	0	264.4	1,131.6	1,513.6	1,619.5	1,732.9	1,854.2	1,984.0	2,122.9	2,271.5
I. Cost of operations (B+C+D+E+F+G+H+L)	793.5	7,559.6	20,211.7	24,901.2	26,064.0	27,309.4	28,642.7	30,069.3	31,594.8	33,225.6
J. Taxable income (A-I)	-793.5	-2,271.5	2,421.0	5,370.1	6,326.3	7,348.2	8,440.9	9,610.2	10,862.2	12,409.4
K. Income tax (52% X J)	-412.6	-1,181.2	1,258.9	2,792.5	3,289.7	3,821.0	4,389.3	4,997.3	5,648.4	6,452.9
L. Depreciation										
Machinery	0	1,479.3	1,331.4	1,183.4	1,035.5	887.6	739.6	591.7	443.8	295.9
Facilities	0	580.9	522.8	464.7	406.6	348.5	290.4	232.4	174.3	116.2
Total	0	2,060.2	1,854.2	1,648.1	1,442.1	1,236.1	1,030.1	824.1	618.1	412.0
M. After-tax profit (J-K)	-380.9	-1,090.3	1,162.1	2,577.6	3,036.6	3,527.1	4,051.6	4,612.9	5,213.9	5,956.5
N. Net earnings (M+L)	-389.9	969.8	3,016.3	4,225.8	4,478.8	4,763.2	5,081.7	5,437.0	5,831.9	6,368.6

[1/] Data may not equal totals because of rounding and truncating.

is either 0.8638 or 0.8163 times the 1978 values in order to account for a 5 or 7 percent annual compound increase in prices. However, labor cost changed at a different annual rate, and the adjustment for labor is 0.8531 times the 1978 cost. Total expense for sales promotion was averaged for the 10 years to give an average yearly cost for 1975. Straight-line depreciation for a 10-year period was used for computing depreciation cost for 1975. After making these adjustments, the 1975 values were divided by 35,640,000 (the number of studs produced per year) to obtain the cost per stud and by 190,080,000 (the number of board feet produced per year) to obtain the cost per M board feet. Table 16 shows the 1975 estimated manufacturing cost for COM-PLY studs made in Arkansas and selling at $130/M board feet.

Computing the operating cost shown in table 15 is difficult and requires much time for collecting accurate data. Potential manufacturers of COM-PLY studs probably have a good source of data in their own company records. By using their own data and making computations similar to those shown in this section, manufacturers can more accurately estimate the factory cost for their own company.

Table 16.--Estimated manufacturing cost in 1975 for COM-PLY studs made in Arkansas and selling at $130/M board feet f.o.b. at the mill

Item	Cost per stud	Cost per M board feet
	- - - -Dollars- - - - - -	
Raw material		
Logs	0.142	26.70
Particleboard resin	.152	28.50
Resin catalyst	.010	1.80
Wax	.008	1.40
Veneer adhesive	.060	11.20
Labor	.063	11.90
Power and fuel	.030	5.60
Other production expenses	.021	4.00
Administrative expenses	.012	2.30
Sales promotion	.004	.80
Facilities expense	.003	.50
Contingency expense	.014	2.60
Sales expense	.035	6.50
Depreciation	.032	6.00
Total	.586	109.80

NET CASH FLOWS AND INTERNAL RATE OF RETURN

The previous sections dealt with the estimated investment to build a COM-PLY stud factory and the net annual earnings that might be expected from its operation. In one section, we were considering cash outlays for an investment and in the other section we were considering cash proceeds that accrue from profitable operation. Potential manufacturers of COM-PLY studs want to know what return on their investment they can expect from the cash proceeds or net earnings.

The return on investment is found by determining interest rates on the basis of the present-value concept. In simple terms, if we invest $100 today at 6 percent interest, the value 1 year from today is $106. The $106 is called the future sum. The future sum includes the original amount (present value) plus interest accumulated (return on investment). The $100 is analogous to investments or cash outlays to build a factory, while the $106 is analogous to cash proceeds resulting from profitable operation. If we did not know the interest rate for the present value of $100 and future sum of $106 for a period of 1 year, we could find it by using trial interest rates until we found one that yielded $6 per year on a $100 investment.

The process of computing the present value of future sums at a given interest rate is referred to as discounting. In this study, the annual cash outlays (such as for investments) are considered as negative future sums and annual cash proceeds (such as net earnings from profitable operation) are considered as positive future sums. The object of the analysis is to find the compound interest or discount rate for 10 annual periods when the present value (at the beginning of the investment period or time zero) of the cash outlays is just equal to the present value of the cash proceeds. This procedure is widely used for evaluating the economic feasibility of investments and is often referred to as a discounted cash flow analysis. Finding the appropriate compound interest or discount rate is a trial-and-error process.

In finding the appropriate discount rate, a low interest rate is selected and the net annual cash flows (outlays and proceeds) or future sums are converted to their present value on the basis of the rate selected. If the cumulated net annual cash flow is positive, then the present value of the cash proceeds is greater than the present value of the cash outlays for the 10 years of operation. In that case, a higher trial interest rate is selected and the procedure is repeated until a rate is found at which the positive present values of cash proceeds just equal the negative present values of cash outlays. This interest or discount rate is called the internal rate of return. Table 17 shows a discounted cash flow analysis if COM-PLY studs are sold for $130/M board feet.

Table 17.--Discounted cash flows at a 15 percent rate of return for a COM-PLY stud factory during a 10-year investment period[1/]

Year	Outlay (investment)		Proceeds (net earnings)		Net annual cash flow		At 15%		Present value Annual return	Cumulative
	- - - - -		- - - - -		-Thousands of dollars-				- - - - -	
0	-344.7	+	0	=	-344.7	X	1.0000	=	-344.7	-344.7
1	-6,108.2	+	-380.9	=	-6,489.1	X	.8696	=	-5,642.7	-5,987.4
2	-8,843.7	+	969.8	=	-7,873.9	X	.7561	=	-5,953.8	-11,941.2
3	-1,771.5	+	3,016.3	=	1,244.7	X	.6575	=	818.4	-11,122.7
4	0	+	4,225.8	=	4,225.8	X	.5718	=	2,416.1	-8,706.6
5	0	+	4,478.8	=	4,478.8	X	.4972	=	2,226.7	-6,479.9
6	0	+	4,763.2	=	4,763.2	X	.4323	=	2,059.3	-4,420.6
7	0	+	5,081.7	=	5,081.7	X	.3759	=	1,910.4	-2,510.2
8	0	+	5,437.0	=	5,437.0	X	.3269	=	1,777.4	-732.8
9	0	+	5,831.9	=	5,831.9	X	.2843	=	1,657.8	925.0
10	4,642.5	+	6,368.6	=	11,011.1	X	.2472	=	2,721.8	3,646.7

1/ Data may not equal totals because of rounding and truncating.

The first column in table 17 shows the year or period of investment. Year 0 represents the beginning of year 1, but the other numbers--1 through 10--represent year-end times. The next column shows cash outlays for investment and is taken from table 2. The values are negative because they represent cash outlays, except for the value at year 10. This value represents working capital (cash, inventory, accounts receivable) that is recovered at the end of the investment period. The recovered working capital is treated as a positive nontaxable cash flow.

Column 3 is taken from the net earnings (table 15). If production operations are unprofitable, the net earnings will be negative. However, if the production operation is profitable, the net earnings are positive and represent cash proceeds.

Column 4 is the sum of columns 2 and 3 and represents net annual cash flows.

Column 5 lists the present-value factor for a 15 percent interest rate. This interest rate was selected because it represents a minimum rate of return on an investment. At rates of return less than 15 percent, a company might be better off to invest elsewhere. The values in column 4 represent future sums at the end of the year indicated. By multiplying the values in column 4 by the present-value factor in column 5, the amount in column 4 is discounted (moved backward through time) to its present value (shown in column 6). For example, at the end of year 5, the net annual cash flow was $4,478,800 and the present value of annual return was $2,226,700. In other words, if we had invested $2,226,700 at time zero at a compound interest rate of 15 percent, we would have a future sum of $4,478,800 at the end of 5 years.

Column 7 shows the cumulative present values of annual cash flows in column 6. At a discount rate of 15 percent, the $17,068,200 investment would be paid back in 8.44 years. Thus, the internal rate of return is 21.09 percent. In other words, if we had used present-value factors for a discount rate of 21.09 percent, the investment would have been paid back at the end of the tenth year. For a discount rate of 21.09 percent, the negative present values of the cash outlays would just equal the positive present values of the cash proceeds over a 10-year period.

Internal rates of return were calculated for the three price levels of studs, but the operating cash flows and discounted cash flow analysis are shown only for studs priced at $130/M board feet at the mill. Rates of return and related factors for the three price levels are summarized in table 18.

Table 18.--Payback periods, internal rates of return, and break-even points for a COM-PLY factory selling studs at three price levels (f.o.b. mill)

Sales price for studs (Dollars/M board feet)	Payback period at 15 percent discount rate	Internal rate of return for 10-year investment period	Break-even point
	Years	Percent	M board feet
123.50	9.50	17.16	97,086
130.00	8.44	21.09	81,891
136.50	7.44	24.75	71,019

DISCUSSION AND CONCLUSIONS

Under average conditions, a manufacturer should be able to obtain an internal rate of return of 20 percent or more on an investment in a new COM-PLY stud factory. However, much greater profit potential exists if existing facilities for manufacturing particleboard and veneer are converted to the manufacture of COM-PLY studs. For such a conversion, investment would be less and positive annual cash flows would occur sooner than if a new plant were built. For a small investment in a stud-laminating operation, the return on the total investment would be much larger than shown in this study.

Conversion of existing facilities to the manufacture of COM-PLY studs would also help alleviate this country's current excess capacity to produce particleboard. Because so many particleboard plants have been built, many of them are providing a low internal rate of return. A 100 percent conversion from particleboard to COM-PLY studs would not be necessary. Even converting one-third of a factory's particleboard production to COM-PLY studs should greatly improve its earning capacity.

Consumer demand for particleboard often peaks a year or two after the peak demand for lumber and plywood, primarily because demand for lumber and plywood is greatest during a housing boom. After a housing boom subsides, the need for lumber and plywood drops off, as it did late in 1973. Subsequently, construction of shopping centers and manufacture of furniture increase, both of which create a strong demand for particleboard.

There are other financial benefits for a manufacturer who can produce COM-PLY lumber and particleboard in one factory. He can shift production to the product in greatest demand. As a result, a facility that can produce both products has the potential for larger positive cash flows over a longer period of time than one that produces particleboard alone. Under present practice, many particleboard plants suffer heavy losses or are forced out of business during recessions.

Potential manufacturers should carefully compare the manufacturing costs for COM-PLY studs (table 16) with those for sawn lumber studs, especially from the standpoint of fluctuating costs of raw materials. One of the greatest expenses in making conventional studs is the cost of wood. During periods of peak demand for lumber, the prices for stumpage increase, more so for softwoods than hardwoods. Because COM-PLY studs can be made from a mixture of hardwoods and softwoods, they have a distinct cost advantage in raw materials. Furthermore, wood represents a smaller percentage of the total cost of a COM-PLY stud than of a conventional stud. In COM-PLY studs, the cost for resin binder, catalyst, wax, and laminating adhesive is greater than for wood. These nonwood costs do not fluctuate greatly in unison with wood prices.

In the future, we will undoubtedly face the problem of getting 2 x 6's, 2 x 8's, and 2 x 10's for lumber-framing from smaller logs than have been available in the past. This study shows that it is economically feasible to manufacture COM-PLY 2 x 4's now. Therefore, the economic potential for making even larger COM-PLY lumber framing is highly favorable.

This study was made for the investment period from 1975 to 1985. As time passes, manufacturing costs will tend to favor COM-PLY studs over sawn lumber studs. Analysis of financial feasibility for some later period--say 1980 to 1990--should show even greater internal rates of return than those we found for the period from 1975 to 1985.

LITERATURE CITED

Evans, David S., ed.
1976. Random lengths 1976 yearbook. Random Lengths Publications, Inc., Eugene, Oregon. 181 p.

Koch, Peter
1972. Utilization of the southern pines. U.S. Dep. Agric., Agric. Handb. 420, p. 291. U.S. Gov. Print. Off., Wash., D.C.

McAlister, Robert H., and Michael A. Taras
1978. Yield of southern pine veneer suitable for composite lumber and panels. U.S. Dep. Agric., For. Serv., Res. Pap. SE-179, COM-PLY Rep. 9, 15 p. U.S. Dep. Agric., For. Serv., Southeast. For. Exp. Stn., Asheville, N.C.

Maloney, T. M.
1973. Particleboard for composite studs. Wash. State Univ., Coll. Eng. Res. Pap. 73/57-101, 18 p. Pullman, Wash.

U.S. Department of Agriculture, Forest Service
1977. The demand and price situation for forest products, 1976-77. U.S. Dep. Agric., For. Serv., Misc. Publ. 1357, p. 53. U.S. Gov. Print. Off., Wash., D.C.

Koenigshof, Gerald A.
1978. Economic feasibility of manufacturing COM-PLY studs in the South. U.S. Dep. Agric. For. Serv., Res. Pap. SE-197, COM-PLY Rep. 15, 26 p. Southeast. For. Exp. Stn., Asheville, N.C., and U.S. Dep. Housing and Urban Develop., Washington, D.C.

The investment and production cost required to manufacture COM-PLY studs in the South are presented. It is possible to obtain a 20 percent or greater internal rate of return on an investment in manufacturing COM-PLY studs.

KEYWORDS: Manufacturing costs, stud cost, economics of stud manufacture, cost analysis, COM-PLY factory, rate of return.

Koenigshof, Gerald A.
1978. Economic feasibility of manufacturing COM-PLY studs in the South. U.S. Dep. Agric. For. Serv., Res. Pap. SE-197, COM-PLY Rep. 15, 26 p. Southeast. For. Exp. Stn., Asheville, N.C., and U.S. Dep. Housing and Urban Develop., Washington, D.C.

The investment and production cost required to manufacture COM-PLY studs in the South are presented. It is possible to obtain a 20 percent or greater internal rate of return on an investment in manufacturing COM-PLY studs.

KEYWORDS: Manufacturing costs, stud cost, economics of stud manufacture, cost analysis, COM-PLY factory, rate of return.

The Forest Service, U.S. Department of Agriculture,is dedicated to the principle of multiple management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forest and Grasslands, it strives - as directed by Congress - to provide increasingly greater service to a growing Nation.