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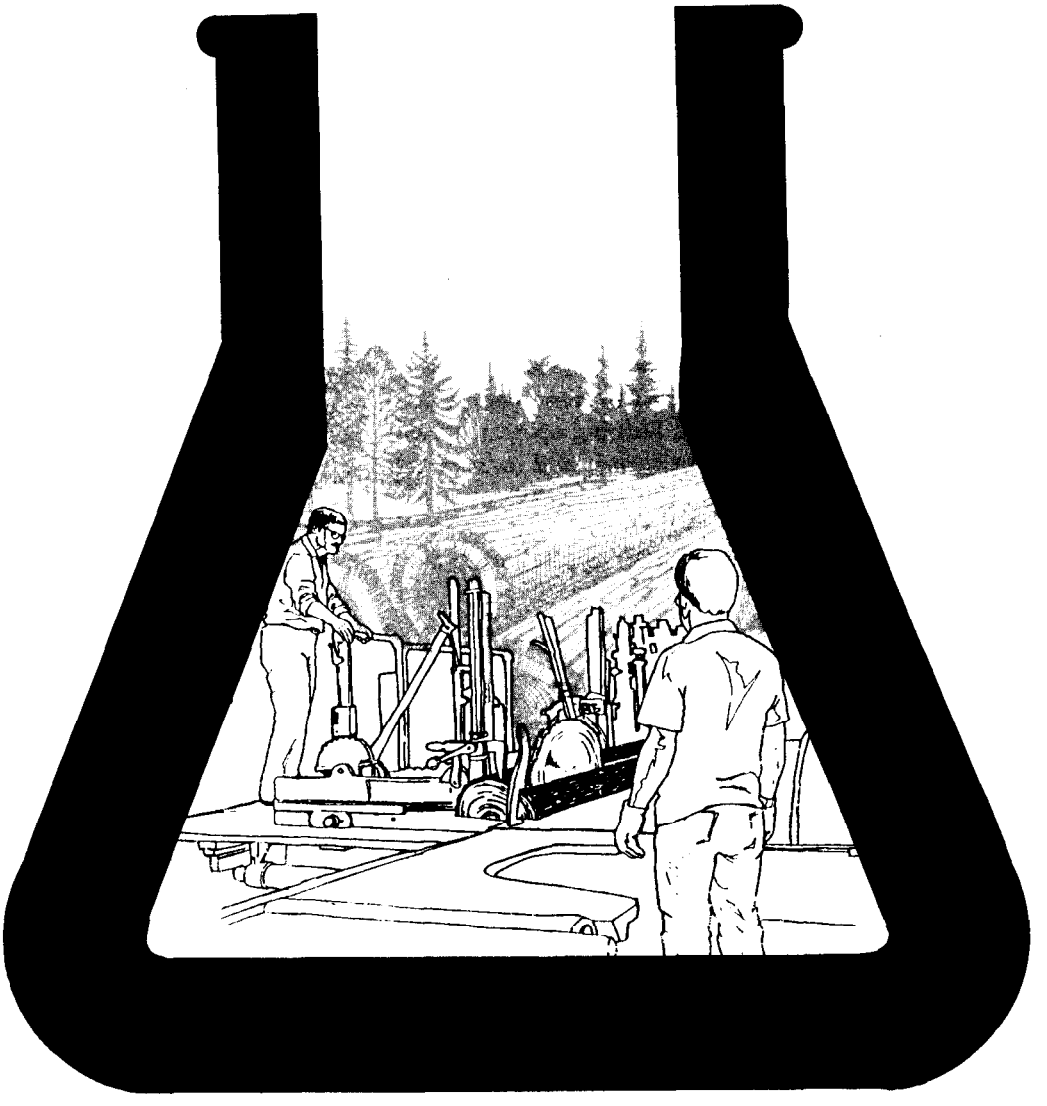
Supporting Rural Wood Industry Through Timber Utilization Research

Kenneth Skog



Abstract

This report evaluates the potential impact of USDA Forest Service wood utilization and wood energy research on rural employment and income. Recent projections suggest employment will decrease in many forest products industries, such as softwood sawmilling, but will eventually increase in softwood plywood and reconstituted panel mills. Forest products industries expected to provide wages exceeding the average manufacturing production wage include logging, softwood sawmills, millwork, softwood plywood-veneer, structural wood members, particleboard, wood partitions, pulp mills, paper mills, and paperboard mills. Industries expected to pay 90 percent of the average manufacturing production wage include wood kitchen cabinets, mobile homes, prefabricated wood buildings, and wood preservatives. Projected employment increases are virtually all in timber-oriented industries or industries oriented to both timber and end-use markets. Location of forest products mills in rural areas will be influenced by the need to minimize transportation costs. Research on design and performance of wood structures may lead to the greatest increase in employment by 2020. Research on pulp, paper, and paperboard recycling may also increase employment as less paper is imported and more paper with recycled paper content is produced in the United States. Research could lead to wood energy cost savings. If these cost savings were the same as a 3- to 5-percent increase in fossil fuel prices nationwide by 2010, this would produce a net increase of about 5,200 jobs/year and $87 million/par in net income nationwide. These potential job and income changes related to wood energy use include direct job gains in wood burning operations, indirect job gains in the consumer sector, and indirect job losses in fossil fuel supply and end use.

Keywords: Forest products research, research evaluation. rural development

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Clarification

Page 2, Table 1

Data for establishments and employment in columns 3 through 6 are from 1987.

Errata

Page 1, paragraph 3

The last sentence of the paragraph ("Data on indirect jobs...") does not apply to this section.

Page 17, Table 12

The letter p in the fourth entry of the last column should be deleted.

Supporting Rural Wood Industry Through Timber Utilization Research

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Introduction

The purpose of this study was to assess how research, development, and adoption of selected changes in timber utilization may provide economic benefits to rural areas in the United States. The study was part of the Forest Service initiative to identify opportunities for rural development through economic diversification, using the forest resource as a base. A USDA background report (USDA 1989) stressed that rural areas need not only economic growth (more jobs and income) but also economic development (higher per capita income).

This report evaluates the potential impact of Forest Service research in two areas: wood utilization and wood energy.

Wood Utilization Research

The objectives of the study on wood utilization research were to determine what current or potential research areas could lead to the greatest increases in rural employment and income and how many new jobs would have higher salaries than those of existing jobs. The study of current and potential USDA Forest Service research related to wood utilization was conducted in three steps. First, we examined current and projected employment and income by type of forest products industry, geographic region, and location (urban or rural). Second, we identified major areas of current or potential Forest Service research. Third, we estimated the potential timing and level (increase or decrease) of change in employment and income that would result from research. Only direct employment and income from forest products industries were estimated. Data on indirect jobs and income were also generated, but no estimates were made.

Current and Projected Employment and Income

Current Employment and Income

Between 1970 and 1987, total U.S. employment increased 30 percent and manufacturing employment remained relatively stable. Employment in standard industrial classification (SIC) industries for lumber and wood products (SIC 24) and paper and allied products (SIC 26) increased by 15 percent and decreased by 4 percent, respectively (U.S. Bureau of the Census 1988). In 1987, 102.3 million employees were in nonagricultural industries, 18.6 million employees in manufacturing industries (18.6 percent), and 1.2 million employees (1.2 percent) in 25 primary and secondary forest products industries (Table 1). The 25 forest products industries provided a payroll of $24.6 billion ($10^9$ 1987 US$) in 1987, an increase from $16.1 billion ($10^9$ 1982 US$) in 1982. (Note: Dollar figures in this report are expressed in terms of 1982, 1985, or 1987 U.S. dollars, as noted.) The 12 largest of these industries provided 80 percent of the 1.2 million jobs in 1987 (Table 2).

According to 1982 statistics, the 25 industries provided the most employment and income in the South, followed by the North, Pacific Coast, and Rocky Mountain regions (Table 3). Solid wood products employment (SIC 24) was highest in the South, followed by the Pacific Coast and North, but the Pacific Coast income was equal to that in the South as a result of higher wages on the Pacific Coast. Income was lower in the North as a result of greater employment in secondary forest products industries. Employment and income in selected furniture and fixture industries (SIC 25) was highest in the South, followed by lower levels in the North and Pacific Coast. Pulp, paper, and paperboard employment and income were highest in the North.

Table 1—Forest products industry employment and income[a]

SIC[b]	Industry	Establishments: Total	Establishments: 20+ employees	Employment (x 10^3): Total	Employment (x 10^3): Production workers	Employment growth rate (percent/year): 1972-87	Employment growth rate (percent/year): 1982-87	Total income ($\times 10^6$\$) (1987\$)	Average production wage (\$/h): 1982 (1982\$)	Average production wage (\$/h): 1987 (1987%)
2411	Logging camps and contractors	11,952	821	87.4	73.6	0.6	1.6	1,550	8.27	9.15
2421	Sawmills and planing mills	5,724	1,682	146.8	127.9	-0.8	2.2	2,792	7.66	8.30
2426	Hardwood dimension and flooring	737	343	29.9	26.2	-0.3	5.5	441	5.27	6.49
2429	Special product sawmills, n.e.c.	235	32	2.2	1.9	-6.9	-6.0	33	6.53	8.06
2431	Millwork	2,782	855	89.0	71.6	1.6	9.4	1,810	7.73	9.27
2434	Wood kitchen cabinets	3,714	668	67.6	54.2	3.8	9.2	1,197	6.59	7.72
2435	Hardwood veneer and plywood	310	213	20.5	17.4	-1.3	2.9	340	6.21	7.00
2436	Softwood veneer and plywood	231	190	38.9	35.1	-0.8	2.2	888	8.93	9.97
2439	Structural wood members, n.e.c.	893	396	24.6	18.5	4.6	15.1	435	7.08	7.76
2441	Wood boxes	308	95	5.9	4.9	-3.9	-1.6	85	5.96	6.31
2448	Wood pallets and skids	1,700	420	25.8	21.7	4.0	3.1	326	5.05	6.13
2449	Wood containers, n.e.c.	208	51	5.4	4.7	-5.1	-6.1	70	5.27	5.86
2451	Mobile homes	395	315	39.9	32.2	-3.8	-1.4	734	6.73	8.07
2452	Prefab wood buildings	682	256	24.9	18.0	-0.1	8.2	466	6.88	7.98
2491	Wood preserving	539	203	11.8	9.1	0.3	1.6	208	6.56	7.71
2493	Reconstituted wood products	257	158	22.2	17.8	—	—	510	—	9.95
2499	Wood products, n.e.c.	3,315	670	56.0	46.3	—	—	822	—	6.67
(SIC 24 total/average)		33,991	7,377	708.8	591.1	0.2	3.7	12,716	7.31	7.45
2511	Nonupholstered wood furniture	2,946	862	135.4	118.6	0.1	1.5	2,014	5.43	6.69
2512	Upholstered wood furniture	1,146	572	82.1	69.5	-0.8	3.1	1,292	6.03	7.41
2517	Wood cabinets (TV, radio, etc.)	80	36	5.8	5.0	-7.6	-3.7	90	6.15	6.90
2521	Wood office furniture	647	232	31.0	24.3	6.8	8.1	561	6.06	7.83
2541	Wood partitions, etc.[c]	1,865	557	40.5	30.2	1.8	5.0	861	8.09	9.29
(SIC 25 (partial) total/average)		6,684	2,259	294.8	247.6	0.2	2.9	4,818	5.98	7.33
2611	Pulp mills	39	38	14.2	11.1	2.0	-3.2	537	13.88	16.49
2621	Paper mills, excl. building papers	281	269	129.3	99.3	-0.0	0.0	4,589	12.30	16.10
2631	Paperboard mills	199	203	53.6	41.1	-1.6	-9.7	1,896	12.63	15.50
(SIC 26 (partial) total/average)		519	510	197.1	151.5	-0.4	-0.4	7,022	12.51	15.96
(SIC 24/25/26 (partial) total/average)		41,194	10,146	1,200.7	990.2	0.1	2.7	24,556	8.07	8.75

[a] U.S. Bureau of the Census, 1982 and 1987 Census of Manufactures.

[b] SIC definitions changed between 1982 and 1987. Consequently, employment growth rate is overstated for SIC 2411, 2431, and 2611; it is understated for SIC 2421, 2499, and 2631. SIC 2621 gained and lost, so the net effect of this industry is not clear.

[c] SIC 2541 includes wood office and store fixtures, partitions, shelving, and lockers.

Table 2—Employment in large forest products industries in 1987

SIC	Industry	Employment ($\times 10^3$)
2421	Sawmills and planing mills	146.8
2511	Nonupholstered wood furniture	135.4
2621	Paper mills, excl. building papers	129.3
2431	Millwork	89.0
2411	Logging camps and contractors	87.4
2512	Upholstered wood furniture	82.1
2434	Wood kitchen cabinets	67.6
2499	Wood products, n.e.c.	56.0
2631	Paperboard mills	53.6
2541	Wood partitions, etc.	40.5
2451	Mobile homes	39.9
2436	Softwood veneer and plywood	38.9

Between 1972 and 1987, employment increased in 11 of 23 forest products industries.[1] Employment increased in 16 of 23 industries between 1982 and 1987 (Table 1). Growth was slow for SIC 24 and 25 between 1972 and 1987, but picked up between 1982 and 1987. Employment declined overall in pulp, paper, and paperboard production (SIC 26) (-0.4 percent/year) over both periods.

Between 1972 and 1987, the largest primary industries with an increase in employment were sawmills, paper mills, logging, millwork, and softwood veneer-plywood. Employment in the oriented strandboard (OSB)-waferboard industry also increased. Production increased from $<50\times10^6$ ft^2 ($<4.6\times10^6$ m^2) (3/8-in. (9.5-mm) basis) in 1970 to 3.6×10^9 ft^2 (3.3×10^8 m^2) in 1986 (USDA Forest Service 1990). The largest secondary industries with increasing employment were wood kitchen cabinets and wood partitions (Table 1).

Projected Employment and Income

For the purposes of this report, employment projections were collected or developed for selected forest products industries through the year 2020 (Table 4). Projections were made for industries identified as likely to be directly affected by selected current wood utilization research.

Projections of employment for softwood lumber and softwood plywood industries were available from a recent Forest Service study (Lange and others 1990). For other industries, rough projections of employment were based on projections of production and, where available, on trends in employee productivity. These projections roughly indicate future employment in various industries for our base case, where we assumed wood utilization research is not conducted. Analysis of the impact of completion and adoption of selected research indicates how much production of selected products may change and thereby alter future employment and income.

Employment in the softwood lumber industry is projected to increase by 0.3 percent/year between 1986 and 2000, and by less than 0.1 percent through 2020. Softwood plywood employment is projected to decrease 2.4 percent/year between 1986 and 2000, as it is partially replaced by OSB-waferboard, then to increase by 0.6 percent/year through 2020. We assumed these rates of employment growth apply to SIC 2421, sawmills and planing mills, and SIC 2436, softwood veneer and plywood mills, respectively. Employment will increase substantially in OSB-waferboard production. Employment increased 7.8 percent/year between 1981 and 1987; it is projected to increase by 2.8 percent/year between 1987 and 2000, then by 1.1 percent through 2020.

On the basis of projected harvest and trends in worker productivity, employment in logging is projected to decline from 87,400 in 1987 to 53,100 in 2020, for an average decline of 1.5 percent/year. Employment in hardwood dimension lumber, millwork, and hardwood veneer and plywood are all projected to increase; the greatest increase will occur in hardwood veneer and plywood industries (Table 4). For the seven solid wood products industries studied, total employment is projected to increase slightly from 434,700 in 1987 to 461,900 in 2020.

For the pulp, paper, and paperboard industries, total employment is projected to decline from 197,100 to 148,800 between 1987 and 2020. These projections do not consider a potential shift in newsprint production from Canada to the United States with increased demand for newsprint with recycled content.

Employment and Income by Industry Orientation

The likelihood that a forest products industry will locate in a rural area is influenced by many factors. Two key factors are the cost of purchasing and transporting raw materials and the cost of transporting products to market. Certain forest products industries are more likely to locate near timber resources (timber oriented), others to locate near population centers (market oriented). Some industries try to locate near both timber and markets.

[1] Data for 1972 and 1982 were not available for new SIC groups 2493 (reconstituted wood products) and 2499 (wood products, n.e.c.). However, production of oriented strandboard-waferboard, part of SIC 2493, has increased substantially in recent years.

Table 3—Forest products industry employment and income by SIC group and region, 1982[a]

SIC	Industry	Employment (× 10^3) North	South	Rocky Mountains	Pacific Coast	Not disclosed	U.S. total	Income (× 10^3 1982$) North	South	Rocky Mountains	Pacific Coast	Not disclosed	U.S. total
	Total manufacturing employment	10,607	5,803	883	2,702	0	19,995	222,171	97,906	16,855	57,264	-0	394,196
2411	Logging camps and contractors	11	34	5	29	2	81	145	369	85	587	23	1,208
2421	Sawmills and planing mills	23	51	6	42	10	132	284	630	103	858	146	2,020
2426	Hardwood dimension and flooring	3	10	—	2	8	23	32	112	—	16	93	253
2429	Special product sawmills, n.e.c.	0	—	—	1	1	3	3	—	—	17	14	33
(SIC 242 total)		27	61	6	45	20	158	319	742	103	890	252	2,306
2431	Millwork	25	15	4	12	1	57	413	198	49	210	25	895
2434	Wood kitchen cabinets	18	14	3	7	2	44	260	176	44	106	22	607
2435	Hardwood veneer and plywood	5	8	—	3	2	18	69	95	—	51	27	241
2436	Softwood veneer and plywood	—	13	1	17	4	35	—	218	19	358	72	667
2439	Structural wood members, n.e.c.	1	3	1	2	5	12	20	40	9	42	73	186
(SIC 243 total)		49	54	8	40	14	165	762	726	122	767	219	2,596
2441	Wood boxes	1	1	2	2	6	16	13	—	29	19	77	
2448	Wood pallets and skids	10	8	—	2	2	22	107	74	—	25	25	230
2449	Wood containers, n.e.c.	1	3	—	0	4	7	8	35	—	4	37	84
(SIC 244 total)		12	12	0	4	8	36	130	121	0	58	81	391
2451	Mobile homes	6	24	3	5	4	43	98	337	43	83	62	622
2452	Prefab wood buildings	5	7	1	1	3	17	9	89	11	21	58	258
(SIC 245 total)		11	31	4	7	8	60	178	425	54	103	120	880
2491	Wood preserving	1	4	—	1	4	11	13	54	—	27	66	159
2493	Reconstituted wood products	0	2	—	1	0	3	7	29	—	25	-0	60
2499	Wood products, n.e.c.	19	16	—	10	11	56	261	210	—	148	203	822
(SIC 249 total)		20	22	0	13	15	70	281	293	0	200	269	1,042
(SIC 24 total)		130	214	23	137	65	569	1,815	2,676	363	2,605	964	8,423
2511	Nonupholstered wood furniture	27	77	1	13	7	126	341	820	13	159	69	1,403
2512	Upholstered wood furniture	9	49	1	8	5	71	129	543	14	104	59	850
2517	Wood cabinets					0						0	
2521	Wood office furniture	6	6	—	5	5	21	81	71	—	72	72	296
2541	Wood partitions, etc.	15	7	1	5	5	32	261	91	10	102	79	543
(SIC 25 (partial) total)		56	138	3	30	21	249	813	1,526	37	437	279	3,092
2611	Pulp mills	—	3	—	2	12	17	—	82	—	61	325	468
2621	Paper mills, excl. building papers	74	23	—	10	22	129	1,887	645	—	304	595	3,431
2631	Paperboard mills	9	23	—	4	19	56	214	663	—	118	507	1,502
(SIC 26 (partial) total)		83	49	0	17	52	201	2,101	1,389	0	484	1,427	5,400
(SIC 24/25/26 (partial) total)		270	401	26	184	139	1,020	4,728	5,591	401	3,526	2,669	16,914

[a]U.S. Bureau of the Census, 1982 Census of Manufactures. Dashes indicate information withheld by the Bureau of Census.

Table 4—Forest products industry employment growth rates, 1987-2020[a]

SIC	Industry	Total employment 1987	Projected employment ($\times 10^3$) 2000	2010	2020	Employment growth rate (percent) 1987-2000	2000-2010	2010-2020	Projection basis[b]
2411	Logging camps and contractors	87.4	64.5	58.8	53.1	−2.3	−0.9	−1.0	Prod./eff.
2421	Sawmills and planing mills	146.8	153.8	155.1	155.1	0.4	0.1	0.0	Lange and others (1990)
2426	Hardwood dimension and flooring	29.9	32.4	34.7	34.3	0.6	0.7	−0.1	Prod./eff.
2429	Special product sawmills, n.e.c.	2.2	—	—	—	—	—	—	—
2431	Millwork	89.0	93.3	94.0	94.0	0.4	0.1	0.0	Prod.
2434	Wood kitchen cabinets	67.6	—	—	—	—	—	—	—
2435	Hardwood veneer and plywood	20.5	35.4	42.9	54.0	4.3	1.9	2.3	Prod.
2436	Softwood veneer and plywood	38.9	28.3	29.4	31.8	−2.4	0.4	0.8	Lange and others (1990)
2439	Structural wood members, n.e.c.	24.6	—	—	—	—	—	—	—
2441	Wood boxes	5.9	—	—	—	—	—	—	—
2448	Wood pallets and skids	25.8	—	—	—	—	—	—	—
2449	Wood containers, n.e.c.	5.4	—	—	—	—	—	—	—
2451	Mobile homes	39.9	—	—	—	—	—	—	—
2452	Prefab wood buildings	24.9	—	—	—	—	—	—	—
2491	Wood preserving	11.8	—	—	—	—	—	—	—
2493	Reconstituted wood products	22.2	32.0	35.9	39.6	2.8	1.2	1.0	Prod.
2499	Wood products, n.e.c.	56.0	—	—	—	—	—	—	—
2511	Nonupholstered wood furniture	135.4	—	—	—	—	—	—	—
2512	Upholstered wood furniture	82.1	—	—	—	—	—	—	—
2517	Wood cabinets	5.8	—	—	—	—	—	—	—
2521	Wood office furniture	31.0	—	—	—	—	—	—	—
2541	Wood partitions, etc.	40.5	—	—	—	—	—	—	—
2611	Pulp mills	14.2	12.5	11.4	10.1	−1.0	−0.9	−1.2	Prod./eff.
2621	Paper mills, excl. building papers	129.3	124.1	125.3	115.8	−0.3	0.1	−0.8	Prod./eff.
2631	Paperboard mills	53.6	38.8	29.6	22.9	−2.5	−2.7	−2.5	Prod./eff.

[a]Historical data: U.S. Bureau of the Census, 1987 Census of Manufactures. Projections: SIC 2421, 2436—Lange and others (1990); other-estimates based on Bureau of Census trends in production and, if available, trends in production per employee (efficiency).

[b]Prod. is production trend; eff. is trend in production per employee.

Table 5—Forest products industry employment and income by orientation and region, 1982[a]

SIC	Industry	Employment (× 10^3) North	South	Rocky Mountains	Pacific Coast	Not disclosed	U.S. total	Income (× 10^3 1982$) North	South	Rocky Mountains	Pacific Coast	Not disclosed	U.S. total
	Timber oriented												
2411	Logging camps and contractors	11	34	5	29	2	81	145	369	85	587	23	1,208
2429	Special product sawmills, n.e.c.	0	—	—	1	1	3	3	—	—	17	14	33
2435	Hardwood veneer and plywood	5	8	—	3	2	18	69	95	—	51	27	241
2436	Softwood veneer and plywood	—	13	1	17	4	35	—	218	19	358	72	667
(Subtotal)		17	55	6	49	9	137	217	681	105	1,012	135	2,149
	Timber and market oriented												
2421	Sawmills and planing mills	23	51	6	42	10	132	284	630	103	858	146	2,020
2426	Hardwood dimension and flooring	3	10	—	2	8	23	32	112	—	16	93	253
2431	Millwork	25	15	4	12	1	57	413	198	49	210	25	895
2439	Structural wood members, n.e.c.	1	3	1	2	5	12	20	40	9	42	73	186
2491	Wood preserving	1	4	—	1	4	11	13	54	—	27	66	159
2493	Reconstituted wood products	0	2	—	1	0	3	7	29	—	25	0	60
(Subtotal)		54	85	10	60	29	238	770	1,062	161	1,178	403	3,573
	Market oriented												
2434	Wood kitchen cabinets	18	14	3	7	2	44	260	176	44	106	22	607
2441	Wood boxes	1	1	—	2	2	6	16	13	—	29	19	77
2448	Wood pallets and skids	10	8	—	2	2	22	107	74	—	25	25	230
2449	Wood containers, n.e.c.	1	3	0	4	7	8	35	—	4	37	84	
2451	Mobile homes	6	24	3	5	4	43	98	337	43	83	62	622
2452	Prefab wood buildings	5	7	1	1	3	17	79	89	11	21	58	258
2499	Wood products, n.e.c.	19	16	—	10	11	56	261	210	148	203	822	
2511	Nonupholstered wood furniture	27	77	1	13	7	126	341	820	13	159	69	1,403
2512	Upholstered wood furniture	9	49	1	8	5	71	129	543	14	104	59	850
2517	Wood cabinets	—	—	—	—	0	—	—	—	—	—	0	—
2521	Wood office furniture	6	6	—	5	5	21	81	71	—	72	72	296
2541	Wood partitions, etc.	15	7	1	5	5	32	261	91	10	102	79	543
(Subtotal)		116	211	10	58	49	444	1,641	2,458	135	853	705	5,792
	Pulp, paper, and paperboard												
2611	Pulp mills	—	3	—	2	12	17	—	82	—	61	325	468
2621	Paper mills, excl. building papers	74	23	—	10	22	129	1,887	645	—	304	595	3,431
2631	Paperboard mills	9	23	—	4	19	56	214	663	—	118	507	1,502
(Subtotal)		83	49	0	17	52	201	2,101	1,389	0	484	1,427	5,400
(Total)		270	401	26	184	139	1,020	4,728	5,591	401	3,526	2,669	16,914

[a] U.S. Bureau of the Census, 1982 Census of Manufactures. Blank entries indicate information withheld to prevent disclosure by the Bureau of Census.

In a recent study on the orientation of 22 solid wood product industries, 4 solid wood products industries were identified as timber oriented, 6 as both timber and market oriented, and 12 as market oriented (Table 5) (Polzin 1990). The seven solid wood products industries that are expected to be most influenced by current wood utilization research are either timber oriented or oriented to both timber and markets (Table 4). Orientation to timber favors location in rural areas.

Wages in Rural Areas

If employment in forest products industries is increased in rural areas, to what extent will such employment increase the average income of workers?

To answer this question, we looked at the replacement or augmentation of various manufacturing jobs with jobs in forest products industries and the consequent increase in average income. For each major region, we compared the average production wage for 25 forest products industries to the average manufacturing wage for non-SMSAs (standard metropolitan statistical areas) in the region (Table 6). We used manufacturing wages for non-SMSAs as a proxy for manufacturing wages in rural areas. The non-SMSAs are counties that do not contain large central cities. Data from 1982 (Table 7) were used for the comparison because 1987 data on wages by SMSA-non-SMSA were not available from the Bureau of the Census when we conducted our analysis.

Wages in the reconstituted wood products industry will probably exceed the average non-SMSA manufacturing wage in most regions, based on the high national wage of this industry as indicated by the 1987 Census of Manufactures. This industry group was formed after the 1982 Census of Manufactures.

If the forest products industry wage does not exceed the non-SMSA manufacturing wage in a region, it may still exceed the average wage for jobs in other sectors. However, the national wage of most nonmanufacturing sectors is higher than the aggregate national average wage of the 25 forest products industry SIC groups. One nonmanufacturing sector with a consistently lower wage is retail trade.

Summary

Ten solid wood products industries are expected to be most influenced by wood utilization research. Average production wages will exceed the average non-SMSA manufacturing wage in seven industries:

2411 Logging camps and contractors

2421 Sawmills and planing mills

2436 Softwood veneer and plywood

2493 Reconstituted wood products

2611 Pulp mills

2621 Paper mills (excluding building papers)

2631 Paperboard mills

The remaining three industries likely to be most influenced by research are

2431 Millwork (wages >90 percent of non-SMSA wage, North and South)

2426 Hardwood dimension and flooring

2435 Hardwood veneer and plywood (wages >90 percent of non-SMSA wage, South and Pacific Coast)

These 10 industries are timber oriented or oriented to both timber and markets, and therefore they are likely to locate near timber resources. (The orientation of pulp, paper, and paperboard industries was not determined.) The 10 industries employed 631,800 persons in 1987 (53 percent of employees in the 25 forest products industries studied). The following sections describe selected areas of wood utilization research and their influence on employment and income of these industries.

Evaluation of Research Areas

Seven areas of Forest Service wood utilization research were evaluated:

1. harvesting,
2. lumber, plywood, and veneer processing,
3. expanded use of timber bridges,
4. development of new or improved composite products,
5. design and performance of wood structures,
6. development of improved adhesives from renewable resources, and
7. pulp, paper, and paperboard processing.

Scientists at the Forest Products Laboratory (FPL) and other Forest Service research stations identified how successful completion of current research-development-adoption efforts may alter timber processing or demand for timber products. For many research areas, the scientists assumed complementary research and development would be done by universities and/or industry. For each research area (other than pulp, paper, and paperboard), the scientists described how research would alter such technical factors as product recovery factors, processing costs, or rate of wood use in various end-products, as well as the timing of such changes.

Table 6—Average forest products industry production wages compared to average non-SMSA manufacturing wage by region[a]

SIC	Industry	United States	North	South	Rocky Mountains	Pacific Coast
	Non-SMSA (1982 US$)	$7.35	$8.30	$6.41	$8.03	$9.89
2411	Logging camps and contractors	A	C	B	A	A
2421	Sawmills and planing mills	A	C	B	A	A
2426	Hardwood dimension and flooring	C	C	C	—	C
2429	Special product sawmills, n.e.c.	C	C	—	—	C
2431	Millwork	A	B	B	C	C
2434	Wood kitchen cabinets	C	C	B	C	C
2435	Hardwood veneer and plywood	C	C	B	C	A
2436	Softwood veneer and plywood	A	—	A	A	A
2439	Structural wood members, n.e.c.	B	C	B	A	B
2441	Wood boxes	C	C	C	—	C
2448	Wood pallets and skids	C	C	C	—	C
2449	Wood containers, n.e.c.	C	C	C	—	C
2451	Mobile homes	B	B	B	B	C
2452	Prefab wood buildings	B	B	B	B	C
2491	Wood preserving	B	C	C	B	B
2493	Reconstituted wood products	D	D	D	D	D
2499	Wood products, n.e.c.	C	C	B	C	C
2511	Nonupholstered wood furniture	C	C	C	C	C
2512	Upholstered wood furniture	C	C	C	B	C
2517	Wood cabinets	C	C	—	—	—
2521	Wood office furniture	C	C	C	C	C
2541	Wood partitions, etc.	A	A	A	A	A
2611	Pulp mills	A	A	A	A	A
2621	Paper mills, excl. building papers	A	A	A	A	A
2631	Paperboard mills	A	A	A	A	A

[a]SMSA is standard metropolitan statistical area.
A, forest products industry wage higher than non-SMSA wage.
B, forest products industry wage >90 percent of non-SMSA wage.
C, forest products industry wage <90 percent of non-SMSA wage.
D, forest products industry wage probably higher than non-SMSA wage.
Dash, no production wage data available from the Bureau of Census; disclosure of confidential information prohibited by small number of establishments in these industries.

Table 7—Forest products industry production wage by region, 1982[a]

SIC	Industry	Wage (1982$/h) North	South	Rocky Mountains	Pacific Coast	U.S. average
	Non-SMSA (average production wage)	8.30	6.41	8.03	9.89	7.35
2411	Logging camps and contractors	7.12	6.23	9.35	10.81	8.32
2421	Sawmills and planing mills	6.13	5.85	9.56	10.70	7.69
2426	Hardwood dimension and flooring	4.76	5.29	–	5.24	5.18
2429	Special product sawmills, n.e.c.	4.50	–	–	7.71	6.87
(SIC 242 average)		5.94	5.76	9.56	10.44	7.41
2431	Millwork	8.15	6.33	6.7	8.80	7.71
2434	Wood kitchen cabinets	6.83	5.83	6.2	7.85	6.60
2435	Hardwood veneer and plywood	6.07	5.05	–	10.28	6.18
2436	Softwood veneer and plywood	–	7.06	10.8	10.57	9.00
2439	Structural wood members, n.e.c.	7.33	6.02	8.25	8.91	7.33
(SIC 243 average)		7.40	6.2	7.1	9.55	7.53
2441	Wood boxes	6.22	4.94	–	7.45	6.42
2448	Wood pallets and skids	5.07	4.73	–	6.14	5.05
2449	Wood containers, n.e.c.	7.25	5.51	–	5.33	5.70
(SIC 244 average)		5.29	4.98	–	6.66	5.36
2451	Mobile homes	7.99	6.37	6.44	7.47	6.75
2452	Prefab wood buildings	7.93	6.04	6.80	7.38	6.86
(SIC 245 average)		7.96	6.31	6.51	7.45	6.77
2491	Wood preserving	6.42	5.94	9.33	6.74	
2493	Reconstituted wood products	–	–	–	–	9.22
2499	Wood products, n.e.c.	6.48	6.04	–	6.87	6.41
(SIC 249 average)		6.54	6.13	–	7.62	6.62
(SIC 24 average)		6.77	6.01	8.14	9.77	7.33
2511	Nonupholstered wood furniture	6.03	5.27	4.5	5.48	5.46
2512	Upholstered wood furniture	6.73	5.73	7	6.77	6.01
2517	Wood cabinets	–	–	–	–	–
2521	Wood office furniture	6.06	5.68	–	6.06	5.93
2541	Wood partitions	8.44	6.73	8.22	9.99	8.31
(SIC 25 (partial) average)		6.75	5.51	6.06	6.57	5.97
2611	Pulp mills	–	13.90	–	15.34	14.49
2621	Paper mills, excl. building papers	11.63	12.72	–	15.65	12.20
2631	Paperboard mills	10.66	13.24	–	14.97	12.74
(SIC 26 (partial) average)		11.52	13.02	–	15.44	12.4
(SIC 24/25/26 (partial) total/average		8.33	6.73	7.89	9.71	7.87

[a]U.S. Bureau of the Census, 1982 Census of Manufactures.
Blank entries indicate information withheld by the Bureau of Census.

Forest Service econometric models were used to determine the impact of the technology changes on production of various forest products. Information about changes in production was used to estimate changes in employment and income.

Two econometric models-the Timber Assessment Market Model (TAMM) and the Hardwood Assessment Market Model (USDA Forest Service 1990)—were used to translate expected technology changes into sets of changes (one set for each research area) to the base case assumptions used to make timber market projections to 2040. We use TAMM to refer to both models. The sets of changes were used to make separate simulation runs to project timber market conditions that reflect successful completion, development, and adoption of research in each area. The TAMM projections of timber and wood product consumption and prices were compared between the base case and the altered cases. For one research area-pulp, paper, and paperboard-the FPL Pulpwood Model was used to make market projections (Howard and others 1988). Scientists estimated technical characteristics (pulp yield and cost) of new ways to make various grades of paper and the timing of their commercial introduction. These new processes were inserted in the FPL Pulpwood Model to alter projections of pulpwood and paper-paperboard production and prices. Altered projections of pulpwood and paper-paperboard price and production were compared to the base case. Altered projections of pulpwood consumption were then inserted in the TAMM model, and the resulting sawtimber and solid product projections were compared to the TAMM base case.

The following sections describe the work being conducted in each research area and the anticipated technology changes as implemented in TAMM or the FPL Pulpwood Model. The section on general findings explains the potential impact of the research areas on timber and wood products prices, harvest-consumption levels, and total annual product value.

Harvesting

Two kinds of research were evaluated for their potential impact on softwood sawtimber-veneer log harvesting: (1) research on transferring analyses and ideas about the best types of existing equipment for various situations and (2) research on improving the efficiency of equipment and systems with new types of hardware or new designs. The effect of these changes on harvest costs was estimated using a harvest technology projection model developed by Bradley (1989, 1990). To implement the effect of the first type of research activity, we increased the pace of change in the mix of harvesting systems used. The change was small; we assumed the base case system mix for the year 2001 would be achieved by 2000. For the second type of research activity, we estimated how cost efficiency could be improved in various equipment systems by 2040 with continued research by the Forest Service, universities, and industry. We assumed the Forest Service would produce about one-third of the efficiency gains (in rough proportion to total harvesting research expenditures). The harvesting model estimated that the combined effect of the two research activities, after accounting for projected changes in tree stand density and stem diameter, would reduce harvesting cost 5 to 7 percent by 2040, depending on the geographic region.

lumber, Plywood, and Veneer

We evaluated three activities that could improve lumber, plywood, and veneer processing: (1) the IMPROVE program, (2) research on using Best-Opening-Face (BOF) concepts for hardwood lumber production, and (3) research on developing the Automated Lumber Processing System (ALPS) for hardwood lumber (McMillin and others 1984).

The IMPROVE[2] program, a technology transfer program for sawmill, veneer, and plywood industries, would expedite improvement in softwood lumber and plywood recovery and reductions in processing costs. The program would also help increase hardwood lumber recovery. As a result, we assumed improvements formerly estimated to occur by 2001 would occur by 2000. We estimated the effect of these changes on lumber and plywood recovery and costs by using softwood lumber and plywood technology projection models developed by Skog (1989) and Spelter (USDA Forest Service 1990). By 2000, softwood lumber and plywood recoveries would increase an extra 0.3 and 0.5 percent, respectively, and softwood lumber and plywood processing costs would decrease an extra 0.5 and 0.1 percent, respectively.

As a result of the IMPROVE program and successful completion and adoption of BOF concepts for hardwood lumber production, overall hardwood lumber recovery would increase at a rate of approximately 1.6 percent/decade between 1985 and 2000 and approximately 1.5 percent/decade between 2000 and 2040. In the base case, hardwood lumber recovery increases 1.0 percent/decade.

Implementation of ALPS would increase recovery of higher hardwood lumber grades by using tomography to scan for internal defects of logs and computers to aid in log breakdown. We estimated 10 percent of the lumber formerly graded as less-than-l-common would

[2] Integrated Mill Production and Recovery Options for Value and Efficiency, a program cooperatively developed by FPL and State and Private Forestry.

be upgraded to 1-common, and 10 percent of the lumber formerly graded as 1-common would be upgraded to other grades. We assumed this technology would be first used in 1995, and its use would increase gradually to 25 percent of lumber production by 2040. The slow pace of adoption is due to the expected high capital investment required and relatively small size of most hardwood mills. Implementation of ALPS would also decrease by 10 to 15 percent the amount of lumber needed to produce a given quantity of furniture parts by using computer vision and computer-controlled conventional or laser cutting. By 2040, we assumed this technology would be used for 50 percent of furniture-part production.

Timber Bridges

The Forest Service has undertaken a program for promoting the use of timber to replace thousands of small bridges in the United States each year. Roughly one-quarter million bridges are in need of eventual repair or replacement. Currently, <1,000 timber bridges are built each year. With improved, economical designs, we assumed that the annual construction of timber bridges would increase to 7,500 bridges by 1995 and continue at that level through 2040. An average bridge would use 1,300 ft^3 (36.8 m^3) of wood, for a total of 9.75 × 10^6 ft^3 (0.276 ×10^6 m^3) or 120 × 10^6 board feet per year. We assumed 75 percent softwoods and 25 hardwoods would be used. This extra production would be 0.19 and 0.33 percent of 1986 softwood and hardwood lumber production, respectively.

Composite Products

Research on composite products includes development of steam injection pressing for products like oriented strandboard (OSB), chemical treatments to improve dimensional stability and water resistance of composite panels, and composites of wood and nonwood materials (such as plastics) for many applications.

We assumed that by 2040, chemically treated OSB would substitute for (1) much plywood in foundations and concrete forms, (2) some plywood in single-family housing, slightly expanding the market for such housing, and (3) about half the lumber millwork in exterior applications. These changes amount to a relatively small shift from plywood and lumber to OSB-type products compared to the base case projections.

Research on wood-nonwood composites is providing products that pair wood with nonwood biomass, metal, plastics, glass, or synthetic fibers. Much current research is devoted to wood-plastic composites. These composites could substitute for existing wood products such as packaging (containers, cartons, pallets). Even though overall material use may increase with greater demand for a cheaper product, the wood input would decrease. Composites could substitute for nonwood products, such as auto and truck components, and thus increase the use of wood. We assumed wood-plastic composites will have the widest use, and overall they will tend to increase wood use. This assumption was based on current trends in composite applications. We used wood-plastic composites in auto or truck components as a proxy to indicate the overall net increase in wood use. Wood use in such composites could be 3.6 ×10^6 ft^3 (0.102 × 10^6 m^3) by 2040, assuming 15-percent wood use in 30 percent of such components.

Design and Performance of Wood Structures

Research that could improve the design and performance of wood structures includes

- development of more reliable engineered wood structural components such as wood I-beams,
- improved design criteria for efficient and reliable structural connectors,
- accurate determination of effects of use conditions on structural components,
- improved resistance of wood products and assemblies to fire,
- improved techniques for rehabilitating wood structures,
- advanced design procedures for improving the competitiveness of designs that use wood (relative to designs that use steel or concrete),
- improved adhesive-connected structural components,
- accurate assessment of structural lumber properties (aids in using advanced design concepts),
- flexible and precise nondestructive evaluation techniques to aid grading of lumber, and
- development of stress-class and species-independent grading to enhance use of diverse species.

Success in these research activities could (1) increase lumber and panel use for nonresidential structures and (2) decrease lumber use and increase panel use per unit of residential construction. For nonresidential structures, we assumed that by 2010 and thereafter, research will increase lumber, plywood, and OSB-waferboard use by 15 percent over levels in the base case by increasing the number of nonresidential buildings where wood is used. This increase accounts for the fact that advanced design procedures will reduce the wood used per square foot (0.09 m^2) of floor area. For single- and multifamily homes, we assumed this research will accelerate technology changes projected to occur at a slower pace in the base case. For single-family homes, lumber use will decrease 15 percent because of more

efficient design (by 2010 rather than 2040); by 2010, structural panel thickness will increase (to provide needed strength with wider stud spacing) in floors, wall sheathing, and siding by an average of 7.5 to 12 percent. For multifamily homes, lumber use in floors will decrease slightly and average floor panel thickness will increase. Lumber use in roofs and walls is already quite efficient. The aggregate effect of the research will be to increase both lumber and structural panel consumption above levels in the base case projections.

Adhesives From Renewable Resources

Adhesives developed from renewable resources, particularly tree components, may be cheaper than petroleum-based phenolic adhesives if oil prices increase substantially. If adhesives from renewable resources are not available and if oil prices increase to $50 (1982 US$) per barrel (U.S. Department of Energy 1988) by 2020, we estimated increases in phenolic adhesive prices would increase plywood prices by 5 to 16 percent and OSB prices by 46 percent by 2020. Availability of economical adhesives from renewable resources would hold down such panel price increases.

Pulp, Paper, and Paperboard

Research on pulp, paper, and paperboard was evaluated for the following areas: mechanical pulping, peroxymonosulfate pulping, wastepaper recycling, newsprint production, and development of FPL Spaceboard.

Mechanical Pulping-Research on mechanical pulping for hardwoods in linerboard could lead to use of pulp with 85- to 95-percent yields compared to 50- to 55-percent yields for conventional unbleached kraft pulp. With chemithermomechanical pulping (CTMP) and press drying, linerboard could be made from loo-percent hardwoods with 80-percent yield by the year 2015. Mechanical pulping could also increase the use of hardwoods for printing and writing papers.

Peroxymonosulfate Pulping—By 2010, research on peroxymonosulfate pulping may facilitate the increased use of hardwood in newsprint, unbleached kraft paperboard, solid bleached paperboard, printing and writing papers, packaging and industrial papers, and tissue. Peroxymonosulfate pulping may be able to produce a relatively high-yield pulp from loo-percent hardwoods that has improved bonding strength and higher brightness relative to other hardwood pulps. Peroxymonosulfate pulp could be used in combination with other pulps to make many grades of paper.

Wastepaper Recycling—By 2010 to 2015, research on wastepaper recycling may facilitate additional increases in use, or altered use, of recycled paper for newsprint, unbleached kraft paperboard, solid bleached paperboard, recycled paperboard, printing and writing papers, packaging and industrial papers, and tissue. To increase recycling, research projects include developing a disk separation process to separate contaminants from recycled fiber, improving the means to remove ink from printing and writing papers, and developing chemical and biological treatments to restore bonding strength to recycled fibers.

Newsprint Production—Chemithermomechanical pulping and biomechanical pulping (BMP) may be successfully combined with press drying to make newsprint from loo-percent hardwoods. Mills may be able to combine CTMP or BMP with press drying as early as 2015 and 2025, respectively. Combining CTMP with press drying may achieve higher sheet strength, previously attainable only with softwoods. (Bleaching may be needed when using certain hardwood species.) Combining BMP with press drying may increase strength and also retain optical properties for low- and medium-density hardwood species.

FPL Spaceboard l-Through research, a product developed at FPL, FPL Spaceboard I, could replace some corrugated fiberboard for boxes (Setterholm 1985). Spaceboard is a sandwich of two or more pulp-molded structures. We assumed that manufacturing plants will be built near large cities by 2000; the plants will use loo-percent recycled corrugated containers as raw material. We estimated Spaceboard I may replace 25 percent of corrugated container board by 2040.

General Findings

In terms of the magnitude of impact, the research areas fall into three categories: (1) harvesting, lumber and plywood-veneer, timber bridges, and composite products, (2) wood structures and adhesives, and (3) pulp, paper, and paperboard. In the first category, research will cause <5 percent increase or decrease in price, harvest-consumption volume, and value through 2040 (Tables 8 and 9). Research on design and performance of wood structures and development of adhesives from renewable resources may increase or decrease the price or consumption of some products by 5 to 20 percent by 2040 (Table 10). Finally, research on pulp, paper, and paperboard may decrease softwood pulpwood consumption 33 percent and increase softwood sawtimber harvest 17 percent by 2040 (Table 11). A key difference between pulp and paper research and the first two categories is that the full effect of research in these categories is expected well before 2010, whereas the effect of pulp and paper research will not begin until 2010 to 2020. Except for pulp, paper, and paperboard, the research areas are expected in the long run to lead to higher softwood sawtimber prices, and, with the exception of adhesives and pulp, paper, and paperboard research, to higher softwood sawtimber harvest.

Table &--Potential impact of harvesting, lumber, and plywood-veneer research on price, production level, and value of various types of lumber and wood products in the future[a]

Market characteristic and product[b]	Harvesting					Lumber, plywood-veneer				
	2000	2010	2020	2030	2040	2000	2010	2020	2030	2040
	Difference from base case projection (percent)									
Price[c]										
SW sawtimber	*	0.6	2.5	4.2	3.5	−0.8	0.9	1.2	2.2	1.3
HW sawtimber	NA	NA	NA	NA	NA	−0.2	−0.4	−0.6	−0.8	−1.0
SW lumber	0.2	−0.2	*	−0.2	−0.8	−0.3	0.2	0.2	*	−0.3
HW lumber	*	*	*	*	*	−0.2	−0.7	−1.1	−1.4	−1.7
SW plywood,	*	−0.1	1.3	−0.6	0.5	−0.2	−0.6	1.9	−1.0	3.1
OSB-waferboard	*	0.1	*	−0.5	−1.9	0.3	0.2	−0.7	−1.0	−2.2
Harvest-consumption[d]										
SW sawtimber	0.1	0.2	0.2	0.4	0.2	−0.2	0.2	*	0.1	*
HW sawtimber	NA	NA	NA	NA	NA	−0.2	−0.5	−0.8	−0.9	−1.0
SW lumber	*	*	0.1	*	*	0.1	*	*	−0.1	−0.1
HW lumber	*	*	*	*	*	−0.2	−0.4	−0.7	−0.9	−1.0
SW plywood	*	*	−0.1	*	−0.2	0.1	0.2	−0.1	0.1	−0.4
OSB-waferboard	*	*	*	*	*	−0.1	−0.1	−0.5	*	*
	Value difference ($\times 10^6$ 1982 US$)									
Value										
SW sawtimber	3	59	231	413	357	−57	82	104	209	127
HW sawtimber	NA	NA	NA	NA	NA	−11	−35	−72	−116	−163
SW lumber	37	−39	3	−53	−201	−43	44	53	−5	−100
HW lumber	*	*	*	*	−1	−17	−59	−115	−177	−235
SW plywood	−1	−6	56	−30	18	−5	−18	82	−45	144
OSB-waferboard	1	1	1	−12	−49	3	2	−25	−24	−56

[a]Asterisk indicates a value between -0.05 and 0.05. A positive value indicates the altered case is greater than the base case. NA, effect of reduced hardwood harvesting costs was not estimated.

[b]SW is softwood, HW hardwood, OSB oriented strandboard.

[c]Sawtimber prices are for stumpage, other prices for delivered products.

[d]Sawtimber volume is for U.S. harvest. Other volumes are for amounts consumed in the United States. Net imports from Canada may change and are included.

Table 9—Potential impact of timber bridge and composites research on price, production level, and value of various types of timber and wood products in the future[a]

Market characteristic and product	Timber bridge technology transfer					Composites				
	2000	2010	2020	2030	2040	2000	2010	2020	2030	2040
	Difference from base case projection (percent)									
Price										
SW sawtimber	1.1	*	1.0	1.3	0.7	0.5	0.7	-0.1	0.8	0.2
HW sawtimber	1.4	1.1	1.3	1.2	1.2	*	*	*	*	*
SW lumber	0.6	-0.6	0.3	-0.2	-0.8	0.2	-0.4	-0.4	-0.6	-1.0
HW lumber	1.8	3.3	3.2	3.0	3.0	*	*	*	*	*
SW plywood	0.2	-0.1	1.3	0.4	3.9	-0.2	-0.5	2.3	-1.6	-0.3
OSB-waferboard	0.2	0.3	-0.7	-1.3	-4.0	0.5	0.8	-0.4	0.4	-2.2
Harvest-consumption										
SW sawtimber	0.1	-0.2	0.1	0.2	0.1	*	0.1	0.1	0.1	-0.1
HW sawtimber	2.5	2.0	1.8	1.6	1.5	*	*	*	*	*
SW lumber	0.2	0.4	0.2	0.3	0.4	-0.1	-0.1	-0.2	-0.2	*
HW lumber	2.5	2.0	1.8	1.6	1.5	*	*	*	*	*
SW plywood	*	*	*	*	-0.5	-0.1	-0.4	-1.0	-0.9	-1.6
OSB-waferboard	*	*	*	*	*	0.8	1.5	2.2	2.4	2.4
	Value difference ($\times 10^6$ 1982 US$)									
Value										
SW sawtimber	65	-12	91	91	84	0.5	0.8	*	0.9	0.2
HW sawtimber	121	131	168	194	218	*	*	*	*	*
SW lumber	143	-50	124	4	83	0.1	-0.5	-0.6	-0.8	-1.0
HW lumber	185	290	324	361	388	*	*	*	*	*
SW plywood	9	-3	58	19	179	-0.3	-0.9	1.2	-2.5	-1.9
OSB-waferboard	1	4	-15	-30	-102	1.2	2.3	1.7	2.8	0.1

[a]See footnotes to Table 8.

Table 10—Potential impact of research on design and performance of wood structures and adhesives on price, production level, and value of various types of timber and wood products in the futurea

Market characteristic and product	Design and performance of wood structures					Adhesives from renewable resources				
	2000	2010	2020	2030	2040	2000	2010	2020	2030	2040
	Difference from base case projection (percent)									
Price										
SW sawtimber	3.1	5.6	6.0	7.4	6.8	0.2	0.9	*	1.5	1.2
HW sawtimber	*	-0.1	*	0.1	0.1	*	0.1	0.2	0.4	0.6
SW lumber	0.9	1.1	1.3	1.9	1.4	0.2	0.5	-0.2	-0.3	0.1
HW lumber	*	*	*	0.1	0.1	*	0.1	0.2	0.3	0.4
SW plywood	1.0	2.1	3.5	0.9	6.0	-1.8	-3.4	-3.5	-3.8	-3.9
OSB-waferboard	0.2	-0.8	0.5	-0.2	-0.1	-10.0	-15.0	-20.0	-19.0	-19.0
Harvest-consumption										
SW sawtimber	0.3	0.5	0.1	0.3	0.1	*	-0.1	-0.2	-0.4	-0.6
HW sawtimber	*	*	*	-0.1	*	*	*	-0.1	-0.1	-0.2
SW lumber	0.7	1.4	1.5	1.6	1.7	-0.1	-0.2	-0.1	*	0.1
HW lumber	*	*	*	*	*	*	-0.1	-0.1	-0.1	-0.2
SW plywood	0.7	1.0	0.9	1.0	0.2	-0.6	-1.2	-1.4	-0.9	-0.5
OSB-waferboard	2.3	4.5	4.7	4.8	5.0	1.3	2.0	1.6	1.1	0.8
	Value difference ($\times 10^6$ 1982 US$)									
Value										
SW sawtimber	183	461	539	701	664	-13	-54	13	-100	-59
HW sawtimber	-1	-6	0	0	6	0	-3	-8	-18	-29
SW lumber	278	520	654	817	740	-27	-68	64	73	-32
HW lumber	0	3	2	4	3	0	0	7	13	21
SW plywood	67	137	204	93	331	-94	-211	-238	-249	-246
OSB-waferboard	37	71	110	104	127	-134	-304	-473	-513	-585

[a] See footnotes to Table 8.

Table 11—Potential impact of research on pulp, paper, and paperboard on price, production level, and value of various types of pulpwood, timber, and wood products in the future[a]

Market characteristic and product	Pulp, paper, and paperboard				
	2000	2010	2020	2030	2040
	Difference from base case projection (percent)				
Price					
SW pulpwood	1.3	-0.6	-13.1	-7.2	-8.7
SW sawtimber	-6.1	2.5	-5.6	-29.0	-43.0
HW sawtimber	*	-0.1	-0.1	-0.2	-2.0
SW lumber	-1.2	*	-4.1	-14.1	-37.9
HW lumber	*a*	-0.1	*	-0.1	-0.3
SW plywood	-2.3	0.8	-0.1	-10.7	-10.4
OSB-waferboard	0.3	*	0.4	-2.0	-5.2
Harvest-consumption					
SW pulpwood	-0.3	-1.0	-13.7	-20.1	-32.7
H W pulpwood	-0.5	0.4	-0.8	-1.9	-0.8
SW sawtimber	0.5	0.7	3.0	11.7	16.8
HW sawtimber	*	*	*	*	-0.1
SW lumber	0.5	0.5	1.0	3.0	4.7
HW lumber	*	0.1	*	0.1	0.1
SW plywood	0.7	0.2	0.2	01.7	01.8
OSB-waferboard	-0.4	-0.2	*	-0.1	-0.1
	Value difference ($\times 10^6$ 1982 US$)				
Value					
SW pulpwood	39	-74	-1,304	-1,530	-2,459
HW pulpwood	-11	14	-30	-74	-353
SW sawtimber	-307	240	-241	-1,873	-3,189
HW sawtimber	2	-3	-2	-8	-170
SW lumber	-133	108	-729	-2,690	-8,243
HW lumber	1	-1	-2	-5	-18
SW plywood	-62	44	4	-460	-474
OSB-waferboard	-1	-5	-10	-47	-135

[a] See footnotes to Table 8.

Impact of Research on Employment and Income

The impact of research on forest products industry employment and income was estimated by using the percentage changes in pulpwood, sawtimber, lumber, and panel production (Tables 8 to 11) to calculate change in employment and income in selected industries. The percentage change in production of one or more products was multiplied by projected employment. Total employment change for a research area is the sum of the changes in various industries whose production is changed by the research. The change in income caused by research was calculated by multiplying the projected change in number of employees in one or more industries by the 1987 income per employee. This approach is intended to roughly indicate the relative impact of the research. It does not account for the degree to which income per employee may increase faster in one industry as opposed to another, nor does it account for the degree to which income per employee may increase faster than inflation.

Potential changes in employment and income were calculated for 2000, 2010, and 2020 for each research area (Table 12). Estimated changes in income are in 1987 dollars. The estimated employment and income increases do not include indirect jobs that would develop based on expenditures of forest industry employees.

Based on our analysis of the seven research areas, research on design and performance of wood structures is likely to lead to the greatest increase in employment and income by 2020 (4,000-6,000 jobs and $80-$120 million income). The next highest impact may be from widespread successful response to timber bridge technology transfer (500-1,000 jobs and $4-$10 million income) and by composites research (200-500 jobs and $4-$10 million income). The other research areas may provide a net increase of <200 jobs and <$4 million income. Increases are projected to be low for many research areas because research may increase employment in one industry but decrease it in others. For example, lumber, plywood, and veneer research is expected to increase sawmill and logging employment, but decrease plywood and reconstituted panel employment. The net possible increase is small. Potential accelerated research on paper and paperboard recycling (not included in the seven selected **research areas) could also** lead to substantial employment and income increases in pulp, paper, and paperboard industries.

The impact of harvesting research, which is to increase logging employment and income by <200 jobs and <$4 million, is low for two reasons. First, research will improve labor productivity as well as reduce logging costs. Improved labor productivity will hold down the number of jobs. Second, our analysis estimated the contribution of only Forest Service research to an increase in production and jobs. If we include the effect of university and industry research, the increase could be 200-500 jobs and $4-$10 million income by 2020.

The impact of lumber, plywood, and veneer research would be a slight increase in employment in logging and softwood sawmills, but a decrease in employment in hardwood sawmills, plywood mills, and reconstituted panel mills. Because of the uncertainty of our estimates, overall employment and income could increase or decrease.

Table 12—Potential employment and income increase in the future resulting from current wood utilization research

Research area	Employees			Income ($\times 10^6$ 1987 US$)		
	2000	2010	2020	2000	2010	2020
Harvesting	<200	<200	<200	<4	<4	<4
Lumber-plywood	<200	<200	<200	<4	<4	<4
Timber bridges	500-1,000	500-1,000	500-1,000	10-20	10-20	4-10
Composites	1,000-2,000	1,000-2,000	1,000-2,000	4-10	4-10	4-10p
Design-performance of wood structures	2,000-4,000	2,000-4,000	4,000-6,000	40-80	80-120	80-120
Adhesives	<200	<200	<200	<4	<4	<4
Pulp, paper, and paperboard[a]	<200	<200	<200	<4	<4	4-10

[a] Excludes potential employment increases in pulp, paper, and paperboard plants.

Timber bridge technology transfer could increase employment and income in logging and hardwood and softwood sawmilling by 500-1,000 employees and $4-$10 million, respectively. In making these estimates, we assumed a fairly high level of timber bridge construction—7,500 bridges per year.

Composites research would increase employment and income substantially in the production of reconstituted wood products (500-1,000 jobs and $10-$20 million by 2020) but it would decrease employment and income in sawmills and plywood mills. The overall increase may be 200-500 jobs and $4-$10 million income.

Research on design and performance of wood structures stands out in that it may increase employment and income substantially over a wide range of industries: logging, sawmills, plywood mills, reconstituted panels, and prefabricated buildings. The estimated increase in employment is 2,000-4,000 jobs by 2010 and 4,000-6,000 jobs by 2020. Income may increase $80-$120 million by 2010.

The effect of adhesives research is unusual in that such research will help retain forest products industry jobs if costs of fossil-fuel-based adhesives increase to high levels. Adhesives research could retain 500-1,000 jobs ($4-$10 million income) in the reconstituted panel industry, but, at the same time, jobs would be lost in sawmills and plywood mills. The overall increase or decrease in jobs may be slight. The shift in jobs may provide greater overall income—in 1987, reconstituted panel jobs nationwide provided a higher average wage than did sawmill jobs and about the same wage as that of softwood plywood jobs.

The three basic effects of pulp, paper, and paperboard research will be (1) to increase the pulp yield from wood material, (2) to generate a shift to greater use of hardwoods rather than softwoods, and (3) to increase the use of recycled paper and paperboard. Current pulp and paper research (included in the seven selected research areas) is long term, and its effects would be felt after 2010. By 2020, the main employment effects would be to reduce logging jobs overall (greater sawlog harvest, but much lower pulpwood harvest) and to increase sawmill jobs. Logging jobs may decrease overall by 1,000-2,000 ($20-$40 million income). Sawmill jobs may increase 1,000-2,000 ($20-$40 million income) by 2020 as a result of the higher demand for cheaper lumber. There may be a slight overall gain in jobs. Potential accelerated research on paper and paperboard recycling (not included in the seven research areas) could accelerate the development of production processes that would increase domestic production and reduce imports, thereby increasing employment. One recent analysis indicated that current industry recycling initiatives will increase U.S. paper and paperboard production by 5 percent, 8 percent, and 11 percent by 2000, 2010, and 2020, respectively, over Forest Service base case projections (Ince 1991). Accelerated Forest Service recycling research could help achieve these increased production levels sooner and result in greater near-term employment increases. A l-percent increase in pulp, paper, and paperboard employment in 2010 would represent about 2,500 jobs and $89 million in income.

Summary of Wood Utilization Research

In the near term (before 2010), research in the design and performance of wood structures could lead to the largest and most widespread increase in forest products employment and income. Timber bridge and harvesting research could also increase employment and income, but in lower figures and fewer product areas. The effect of lumber, plywood, and veneer research is less certain; such research may increase or decrease employment and income. Adhesives and composites research would tend

to increase employment in the OSB-waferboard industry and decrease employment in the manufacture of other products if there are price increases for fossil-fuel-based adhesives. In the long run (after 2010), current pulp and paper research could substantially increase employment in sawtimber logging, sawmills, and softwood plywood mills, but it could decrease employment in pulpwood logging and OSB-waferboard production. In the near term, potential accelerated research on paper and paperboard recycling could notably increase employment in pulp, paper, and paperboard production based on new recycling technology if paper imports are decreased and more U.S. paper is made from recycled paper.

Wood Energy Research

The objective of the study on wood energy research was to determine to what extent research might lead to increases in rural employment and income. The available data did not permit us to estimate how many new jobs would have higher salaries than those of existing jobs.

Unlike the evaluation of wood utilization research, we do not attempt to specify how various wood energy research activities might increase wood energy production. Instead, we examine the economic effect of research (to decrease the cost of wood energy compared to fossil fuel energy) and estimate how a certain cost decrease may increase jobs and income as a result. We then describe an array of Forest Service energy-related research programs that could decrease wood energy costs relative to fossil fuel energy costs. We do not attempt to judge how much the research activities may actually reduce energy costs. Our analysis includes the use of wood for heat or steam generation in homes, industry, commercial buildings, and utilities. It does not include the use of wood to make alcohol.

Reduced Wood Energy Costs

Forest Service wood energy projections (High and Skog 1990) were used to estimate the effect of reduced wood energy costs on wood energy production. The industrial-commercial wood energy projections assumed that prices for oil and natural gas would increase an average of 4 to 5 percent per year between 1986 and 2010. The residential wood energy projections assumed oil, natural gas, and liquid petroleum gas prices would increase an average 3 to 4 percent per year between 1986 and 2010. The models projected that these fuel price increases would increase U.S. wood fuel use at the rate of about 4,300,000 green tons per year (excluding black liquor) between 1986 and 2010 (Table 13).

A link can now be made between reduction in wood energy costs and increases in wood energy production. The annual fossil fuel cost increases translate into an increase in relative cost savings for using wood fuels. Between 1990 and 2010, each yearly increase in cost savings is projected to increase wood energy use by an average of 4,345,000 green tons (Table 13). If wood energy research could also increase relative cost savings by the same amount by decreasing the cost of wood energy relative to fossil fuel energy, then research could be said to have increased wood energy production by 4,345,000 green tons (a one-time continuing savings equivalent to 4 to 5 percent of fossil fuel costs for all industrial wood energy use, and 3 to 4 percent cost savings for all residential heating).

Employment and Income Related to Wood Energy

Recent studies in the eastern United States (SERBEP 1989, Council of Great Lakes Governors 1985) evaluated how the increased use of wood energy might increase jobs and income. Input-output models were used to calculate direct and indirect job gains and losses resulting from increased wood energy use.

Direct job-income gains arise from jobs in harvest, transport, and end use of wood for energy. Indirect job-income gains arise from (1) construction of plants and equipment, (2) the creation of consumer sector jobs from expenditures of wood energy enterprises, (3) expenditures of wood energy sector employees, and (4) savings in energy and landfill costs. Indirect job-income losses would result from decreased jobs related to the supply, conversion, and use of fossil fuels.

A study of the Great Lakes States (Council of Great Lakes Governors 1985) indicated that each 1,000 green tons of wood used for residential, industrial, and commercial energy production would result in 1.6 direct jobs, 1.3 net jobs, and $20,500 in net income (Table 14). A study of the Southeastern states (SERBEP 1989) indicated that each 1,000 green tons of wood used for industrial energy production would result in 1.1 to 1.38 net jobs and $17,000 to $24,000 net income, depending on how much wood was purchased rather than generated on site (Table 14). If all wood was purchased, 1.38 net jobs and $24,000 net income would be generated.

To estimate the potential effect of wood energy research on employment and income, we assumed that 1,000 green tons/year of wood for energy would generate 1.2 net jobs/year and $20,000/year income. Then, a one-time additional increase of 4,300,000 green tons nationwide, which would be sustained in future years,

Table 13—Projections of wood used for energy in the United States, 1986-2020

Year	Region			
	North	South	West	United States
	Wood used for energy ($\times 10^9$ ft^3)[a]			
1986	2.0	1.9	1.2	5.2
1990	2.1	2.3	1.1	5.5
2000	2.8	2.9	1.3	7.0
2010	3.5	3.4	1.6	8.5
2020	3.5	3.6	1.7	8.8
	Wood used for energy ($\times 10^6$ green tons)			
1986	59.3	55.1	36.1	150.4
1990	61.6	66.3	32.7	160.6
2000	81.4	84.1	38.1	203.6
2010	102.1	99.2	46.2	247.5
2020	103.2	103.7	49.1	256.0
	Increase in wood energy use ($\times 10^3$ green tons)			
1990	2,300	11,200	-3,400	10,200
2000	22,100	29,000	2,000	53,200
2010	42,800	44,000	10,200	97,100
2020	43,900	48,600	13,000	105,600
	Average increase rate ($\times 10^3$ green tons/year)			
1986-1990	575	2,800	850	2,550
1990-2000	1,980	1,780	540	4,300
2000-2010	2,070	1,510	810	4,390
2010-2020	110	450	290	850
1990-2010 (average)	2,025	1,645	675	4,345

[a] 1 ft^3 = 0.028 m^3.

Table 14—Effect of increase in wood energy use on employment and income by region[a]

Region and wood energy sector	Jobs		Net income
	Net	Direct	
Great Lakes states			
Residential, commercial, industrial	1.27	1.58	$20,500
Southeastern states, industrial			
All wood	1.10	—	$17,000
Purchased wood only	1.38	—	$24,000

[a] Jobs and income per 1,000 green tons of wood.

would provide 5,214 net jobs (1.2 x 4,345) and $87 million/year income (1985 US$) (20,000 × 4,345). Most jobs and income would be in the North and South—about 2,430 net jobs/$41 million income and 1,974 net jobs/$33 million income, respectively.

Job Locations

Most direct job gains from wood energy production will be in rural areas, where wood energy systems are more cost effective compared to such systems in urban areas. Job losses in fossil fuel supply, conversion, and use sectors may tend to be greater in urban areas. As a result, the number of jobs gained in rural areas may actually exceed the estimated 1.2 net jobs gained per 1,000 green tons of wood used.

Research Activities

The Forest Service research activities that would increase jobs and income are those that decrease the cost of producing wood energy relative to the cost of producing fossil-fuel-based energy. Current research activities that may reduce costs include the following:

- Research on intensive culture of fast-growing trees—to the extent that such culture would provide fuelwood more cheaply than do traditional wood sources
- Research on small log and residue harvesting systems-to the extent that they reduce costs of supplying wood fuel
- Research on a wood-fired gas turbine engine-to the extent that it would provide a cheaper way to generate electricity using wood
- Analysis of exhaust gas from burning contaminated wood-to the extent that it would permit use of cheaper wood sources

Conclusions

A wide range of Forest Service research activities may contribute to reducing costs of producing wood energy and thereby increase income and employment. These include growing wood at lower cost (relative to current cost); harvesting, transport, and storing wood at lower cost; and converting wood to energy at lower cost. If wood energy cost reductions that result in the same increase in wood cost savings as a 3 to 5 percent increase in fossil fuel prices could be achieved nationwide by 2010, then wood energy research may produce 5,214 net jobs/year and $87 million/year in net income nationwide.

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