Wood and Bark Residues in Oregon

Trends in Their Use

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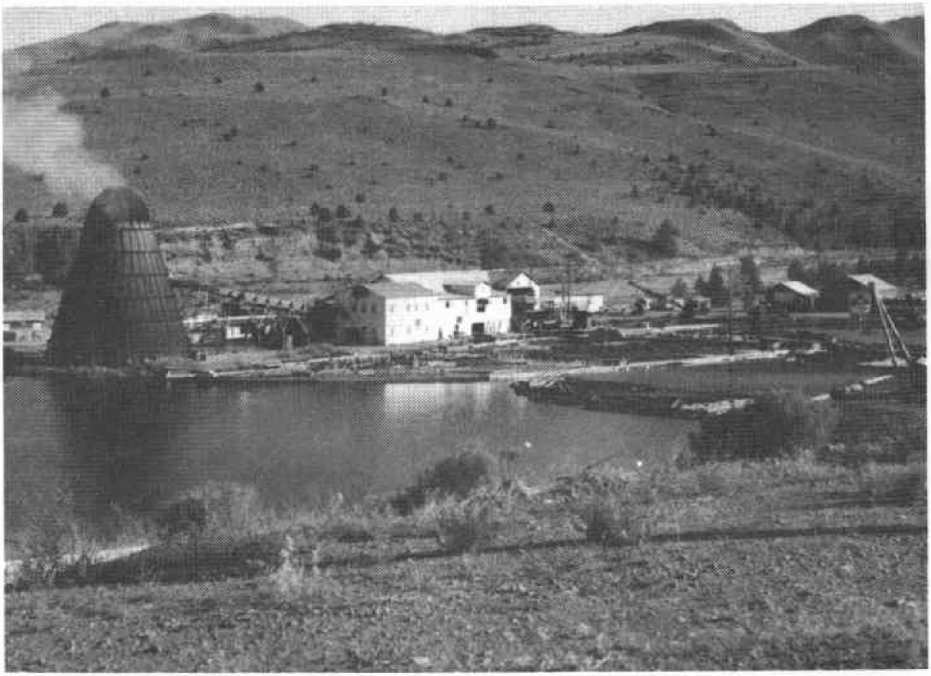
Research Paper 11

March 1972



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WOOD AND BARK RESIDUES IN OREGON
TRENDS IN THEIR USE

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Research Paper 11
March 1972

Paper 827
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COVER PHOTOGRAPH

A typical sawmill in Eastern Oregon

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PREFACE

Obtaining maximum use of Oregon's forest resource is a goal of our Forest Research Laboratory. This report points out advances that have been made in using a valuable forest resource, residues from primary manufacture. In addition, the report indicates amounts, locations, and types of residue remaining unused so that efforts can be made to effect even more complete utilization.

A summary of the findings from this study was presented previously in reference 3. This report gives more complete information from the study.

Grateful acknowledgment is made of the cooperation and information supplied by many mill operators, which was necessary for this report. Industrial associations and representatives from the Oregon Department of Forestry were most helpful in supplying information. Their assistance is appreciated greatly.

WOOD AND BARK RESIDUES IN OREGON: TRENDS IN THEIR USE

INTRODUCTION

The forest-products industries are most important to the state of Oregon. Oregon leads the nation in the production of plywood, lumber, and particle board. More than half of softwood plywood production in the United States came from Oregon at the time of this survey, and more than a fifth of the lumber and about a third of the particle board were produced in Oregon.

Over 90 percent of the logs harvested in the state at the time of this survey were destined for sawmills and plywood plants. In producing lumber and plywood from logs, less than half of the entering log volume emerges as the finished primary product. That portion of the log remaining consists of such items as bark, sawdust, shavings, slabs, veneer trim, plywood trim, cores, and sander dust. This portion that remains after primary manufacture frequently is called residue. Much of this residue formerly was considered waste and usually was disposed of by burning. But now a large portion of this residue material is recovered for other uses—primarily as raw material for paper and wood-composition board manufacture. If residue is not used, it presents a problem of disposal within allowable limits of pollution.

Because these residue materials are a valuable raw material, we conducted a survey of virtually all sawmills and plywood plants in the state to determine how these residues were being used; to point out what quantities might be available for future use; and to note the changes that had occurred in residue usage since previous surveys.

An additional objective was to obtain information on a material balance[1] for sawmill and plywood plants, so that conversion factors could be developed for estimating average quantities of different types of residue generated from a given production of lumber or plywood. From these conversion factors, the average amount of a given type of residue that might be expected in producing a given board footage of lumber or a given square footage of plywood can be estimated.

RESIDUE FACTORS

Sawmills

When logs are converted to lumber, residue produced in the conversion process can be classified as coarse residue, fine residue, and bark. Coarse residue consists essentially of slabs, edgings, and lumber trim. If the bark is removed from the log before sawing, the coarse wood residue can be converted into chips and used as raw material for paper and wood-composition board[2]. Fine residue consists of sawdust produced from the sawing operations and shavings that come from planing or surfacing the lumber. Bark is, of course, attached to the log and usually is removed by a mechanical debarker as the first step in processing.

[1] A material balance of an industrial process is an accounting of the materials that enter, leave, accumulate, or are depleted during a given time interval of operation.

[2] Wood-composition board is a term for all manufacured board products using wood fiber or wood particles. Such products include particleboard, hardboard, fiber board, and insulation board.

A material balance illustrating proportions of primary product and different types of residue from the log breakdown in lumber manufacture is shown in Figure 1. Table 1 gives average quantities of residue produced in sawing a thousand board feet of lumber.

The proportions and factors given in Table 1 and Figure 1 are only intended to be averages. The factors from a particular mill at a particular time might be quite different from the averages. The conversion factors will depend on such variables as type or kind of debarking and sawing equipment, quality control at the mill, kind and size of product being produced, and quality and size of the logs being processed.

The factors given in Table 1 are based in part on a previous study (2), which was modified by information obtained from operating mills contacted in this survey. A comparison with related past studies (10, 11, 12, 14, 16, 18) indicated that recent residue factors are not greatly different from those found up to 25 years ago. A more recent and extensive study (8) showed proportions of residues and product recovery similar to those listed in Table 1. Recent studies tend to indicate a higher proportion of coarse residue. More coarse residue might be explained by a trend toward using small-diameter logs and also by a tendency for mills to bring in low-quality logs. In recent years, expanding markets for wood chips have resulted in incentives to bring in logs with low lumber yields.

Table 1. Average Conversion Factors for Estimating Residues from the Manufacture of a Thousand Board Feet of Lumber in Oregon.

Item	Solid volume[1]	Proportion by volume	Dry weight	
			Western Oregon	Eastern Oregon
	Cu Ft	*Percent*	*Tons*	*Tons*
Coarse wood residue[2]	43	26.0	0.580	0.516
Sawdust	22	13.4	0.297	0.264
Planer shavings	16	9.7	0.216	0.192
Total wood residue	81	49.1	1.093	0.972
Bark residue	19	11.5	0.285	0.228
Lumber	65	39.4	0.878	0.780
Total log	165	100.0	2.256	1.980

[1]Equivalent undried solid volume.
[2]Includes slabs, edgings, and lumber trim.

Factors in Table 1 are based on lumber tally, although logs usually are marketed in Oregon by the Scribner log rule. To offer a basis of comparison, Figure 2 shows the total wood volume in a thousand board feet, gross Scribner log scale, for different log diameters. The curve was drawn with the assumption that the log had the shape of a frustum of a cone, had a taper of 1 inch in diameter per 10 feet of length, and had a length of 16 feet, 10 inches (nominal 16 feet). The log scale was obtained from the Scribner Decimal C log rule (7). The gross wood volume in a thousand board feet, Scribner net log scale, will be greater than shown on the curve. If the deductions for defects from the gross log scale are about equal to the overrun of lumber from net log scale, then the gross log-volume input would be about the same for a thousand board feet of lumber production as for a thousand board feet, gross log scale.

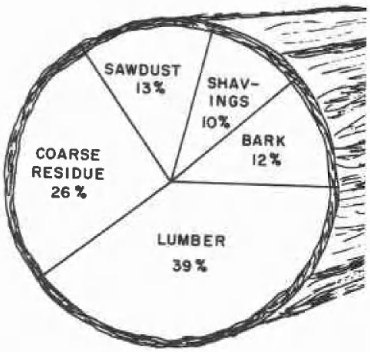

Figure 1. Average proportions of products and residues from lumber manufacture in Oregon.

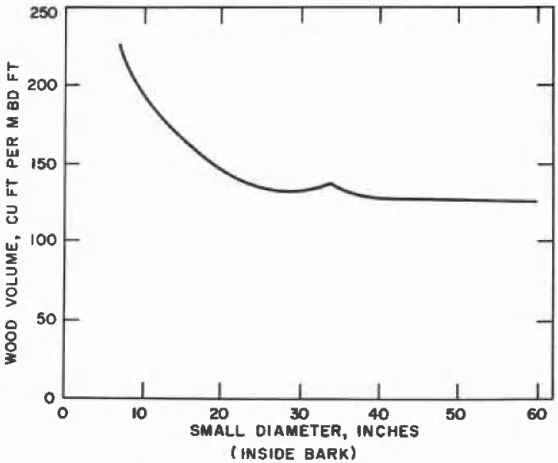

Figure 2. Log diameter related to wood volume per M fbm gross log scale (Scribner, Decimal C) based on a log taper of 1-inch diameter in 10 feet of length, a 10-inch trim allowance, and a nominal 16-foot-long log.

The average conversion factors in Table 1 are given in both equivalent undried solid volume and in dry weight. Water is present in various amounts in the wood and bark. The dry weight is the weight of a given quantity of wood or bark if all the water were removed. The wood densities used to calculate dry weights were obtained by taking densities of different species given in the Wood Handbook (15) and then weighting the values according to the proportion of each species cut. Weighted wood densities were 27 pounds, dry weight, per cubic foot of green volume for Western Oregon and 24 pounds for Eastern Oregon. Bark densities were obtained in a similar manner from density values in unpublished information. Bark density used for Western Oregon was 30 pounds, dry weight, per cubic foot of solid volume, and a value of 24 pounds was used for Eastern Oregon. Residues usually are marketed by either bulk volume or dry (moisture-free) weight. When marketed by dry weight, the weight unit is usually either the oven-dry ton (2,000 pounds moisture-free)or the "bone-dry unit," which is defined as 2,400 pounds of oven-dry (moisture-free) material.

The moisture-free weight contained in a bulk-volume unit (200 cubic feet) of residue will vary with such factors as type of residue, particle size and size distribution, species, moisture content, and means of loading. An indication of the average moisture-free weight of a 200 cubic-foot unit of different kinds of residue when shipped by truck is given in Table 2. Average values were obtained from trucking companies and from companies purchasing these residues. To obtain total weight for a volume unit of residues, variable moisture associated with the residue would need to be added to the dry weights in Table 2.

Plywood and Veneer Plants

Conversion of logs to plywood results in residue from several sources. One general classification of residues from plywood manufacture is: log trim, bark, green-end residues, and dry-end residues. A plant producing only veneer would have the first three of the above residue classes, but a plant that only "laid up" plywood would have just the last class of residue.

Table 2. Average Oven-dry Weight of Selected Residues Contained in a Unit (200 cubic feet), when Shipped by Truck.

Species	Dry Weight
	Pounds
PLANER SHAVINGS	
Green[1]	1,200
Kiln dried[1]	1,600
SAWDUST	
Douglas fir	1,900
Western hemlock	1,700
PULP CHIPS	
Douglas fir	1,900
Western hemlock	1,700
HOGGED BARK	
Douglas fir	2,600
Western hemlock	2,200

[1]Averages from mixtures of Douglas fir and western hemlock.

Figure 3. Log trim, or pond lilies, at a plywood plant.

Log trim and bark usually are produced before the log enters the mill. Log trim or "pond lilies" are short lengths of log that occur when the log is sawed into peeler blocks from 8½ to 9 feet long (Figure 3). Bark usually is removed mechanically from either the log or the peeler block.

Green-end residues include all residues produced from the time the peeler block is put into the lathe until the veneer enters the dryer. Main items of green-end residue are veneer trim, spur trim, roundup, and cores.

Dry-end residues are those that occur from the veneer drying operation until the finished plywood is produced. Major items of dry-end residue are reclip-veneer reject, veneer breakage, jointer shavings, veneer reject at the glue spreader, plywood panel trim, and sander dust.

A material balance illustrating the average proportions of the log that end up as primary product and residue in the manufacture of plywood is shown in Figure 4. Average conversion factors for estimating amounts of different types of residue produced from the manufacture of a thousand square feet (3/8-inch, rough basis) of plywood is given in Table 3. As explained previously, there are many variables that influence conversion factors, and those listed are intended only to represent averages. Caution should be exercised in applying these factors to a particular plant. The conversion factors in Table 3 are based on previous mill studies (2, 9), which were modified by information obtained from the American Plywood Association and from operating plants in this survey. Comparisons of the above factors with other studies (4, 5, 8) show reasonable agreement.

All volumes listed in Table 3 are based on equivalent green volume. The equivalent green volume of the finished plywood is about 1.15 times the actual dry compressed volume, to account for a volumetric shrinkage of 9.4 percent (15) from green condition to 6 percent

Table 3. Average Conversion Factors for Estimating Residues Developed from the Manufacture of a Thousand Square Feet of Equivalent 3/8-Inch Plywood (Rough Basis) in Oregon.

Item	Solid volume[1]	Proportion by volume	Dry weight
	Cu ft	*Percent*	*Tons*
Log trim	3.4	4.4	0.046
Cores	3.7	4.8	0.050
Undried veneer[2]	18.5	24.1	0.250
Dried veneer[3]	6.5	8.5	0.088
Sander dust	1.6	2.1	0.021
Total wood residue	33.7	43.9	0.455
Bark residue	8.8	11.5	0.132
Plywood	34.3	44.6	0.463
Total log	76.8	100.0	1.050

[1]Volumes are based on equivalent undried solid volume.
[2]Undried veneer residue includes veneer clippings, roundup, and spur trim.
[3]Dried veneer residue includes dry veneer loss and panel trim.

moisture and to account for compression during pressing of about 4 percent (6). Because about half of the plywood produced in Oregon in 1967 was sanded and the other half unsanded (1), average residue factors reflect this distribution. A mill producing only unsanded plywood would, of course, have no sander dust, but a mill producing only sanded plywood might expect twice the amount of sander dust given in Table 3. Plywood quantities would vary accordingly. Sander dust was calculated for an average sanding allowance of 0.06 inch (6) and an average panel thickness of 5/8 inch for those panels that are sanded. Densities used to determine dry weights were the same as those previously given for Western Oregon lumber factors. Slight differences in densities were discounted in rounding values.

SURVEY PROCEDURE

Virtually all sawmills, planing mills, veneer plants, and plywood plants were visted during the summer of 1968, and information was obtained from the mill manager or plant representative on their production in 1967 and on actual or proportionate usage and disposition of different types of residue material. The appropriate residue factors from Tables 1 and 3 were applied to each mill's production to arrive at an estimate of the amount of residue generated. Information supplied by the mill representative on actual or proportionate residue usage was applied to amounts of residues generated to arrive at quantities of residue for each use or disposal category.

The state was divided into districts along county boundaries (Figure 5, Table 4). These districts were chosen as convenient geographical units for which results could be compared to previous surveys (2). Counties shown with "no timber" (Figure 5) also had no forest-industry plants.

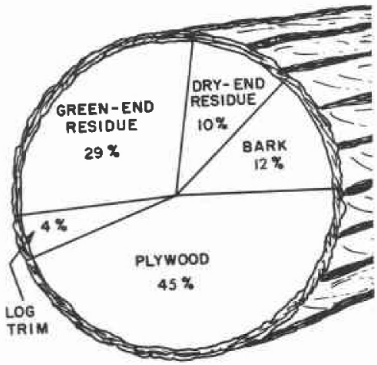

Figure 4. Average proportions of products and residues from plywood manufacture in Oregon.

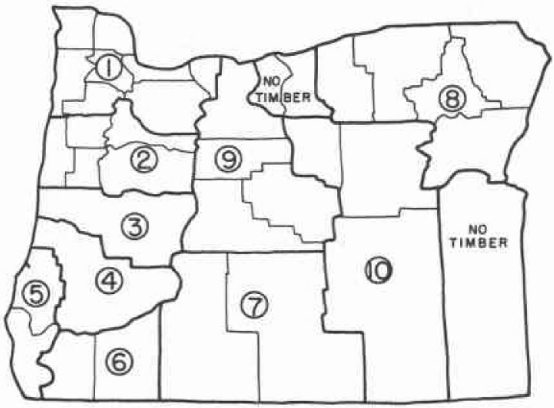

Figure 5. District boundaries for Oregon residue survey.

Table 4. Counties Included in Given Districts for the Survey of Oregon Mill Residues.

District	Counties included
	WESTERN OREGON
1	Clatsop, Columbia, Tillamook, Washington, Yamhill, Multnomah, Clackamas, Hood River
2	Polk, Lincoln, Benton, Linn, Marion
3	Lane
4	Douglas
5	Coos, Curry
6	Josephine, Jackson
	EASTERN OREGON
7	Lake, Klamath
8	Morrow, Umatilla, Union, Baker, Wallowa
9	Crook, Wasco, Jefferson, Deschutes
10	Harney, Grant, Wheeler

RESULTS OF SURVEY

Plants producing lumber, veneer, and plywood as determined by the survey are enumerated in Table 5. Production of lumber and plywood reported by sawmills and plywood plants is given in Table 6. About 77 percent of the state's reported lumber production was from Western Oregon, and 23 percent from Eastern Oregon. About 94 percent of the reported plywood production came from Western Oregon. Oregon lumber production reported by the Western Wood Products Association (17) was about 3 percent greater than found in our survey, and plywood production reported by American Plywood Association (1) was about 10 percent less than our survey indicated.

A comparison of production at the time of the last state-wide survey in 1953 (2) shows lumber production decreased about 13 percent but plywood production increased over 4 times between 1953 and 1967.

Nearly 12 million dry tons of wood residue were produced from lumber and plywood manufacture in 1967, and all but 11 percent was utilized. About 3 million dry tons of bark residue were produced, and 43 percent was not used. A discussion of residue use and disposition is given in following sections.

Residues from Lumber Production

Production and disposition of residues from Oregon's lumber production in 1967 are tabulated in Table 7. Proportionate disposition of different types of sawmill residue is shown graphically in Figure 6. Total wood residues produced amounted to 7.77 million dry tons, of which 64 percent was used in pulp and wood-composition board manufacture, 20 percent was used for fuel, and 4 percent went to other uses, leaving 12 percent that was not used.

Table 5. Plants Producing Lumber, Veneer, and Plywood in Oregon in 1968.

District	Sawmills	Planing mills	Veneer only	Plywood layup only	Both veneer, layup
		WESTERN OREGON			
1	103	7	4	3	10
2	51	3	11	6	11
3	48	2	16	5	16
4	31	0	10	1	7
5	33	1	10	1	8
6	26	3	4	8	6
	292	16	55	24	58
		EASTERN OREGON			
7	13	0	2	0	1
8	29	1	0	0	2
9	9	1	0	0	1
10	11	1	2	0	1
	62	3	4	0	5
All	354	19	59	24	63

Table 6. Production of Lumber and Plywood Reported for 1967 by Sawmills and Plywood Plants in Oregon.

District	Lumber	Plywood
	Millions fbm	*Millions sq ft*[1]
	WESTERN OREGON	
1	1,412	848
2	1,013	1,875
3	1,213	1,722
4	634	826
5	723	1,012
6	698	1,486
	5,693	7,769
	EASTERN OREGON	
7	516	--[2]
8	487	--[2]
9	377	--[2]
10	281	--[2]
	1,661	468
All	7,354	8,237

[1]Square feet of equivalent 3/8-inch thickness (rough basis).
[2]All districts combined to avoid disclosure for individual mill.

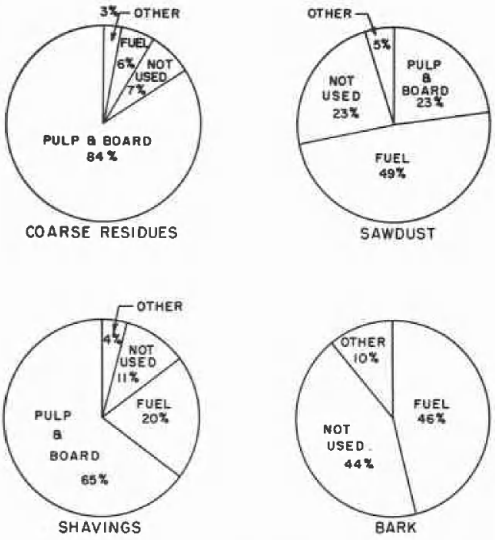

Figure 6. Disposition of different types of residue from Oregon sawmills and planing mills in 1967.

There were 183 sawmills with debarking equipment at the time of our survey. Because most large and medium-size sawmills had debarkers, a high proportion of the lumber production came from sawmills with debarkers. A previous study (2) indicated that only 15 Oregon sawmills had debarkers in 1956, so about 12 times as many sawmills had debarkers in 1968 than in 1956. Installation of debarkers allows production of bark-free coarse residue that can be converted to "pulp chips."

Course residue. Total production of coarse sawmill residue was about 4.2 million dry tons, of which 84 percent was used in the manufacture of pulp and wood-composition board, 6 percent as fuel, 3 percent for other uses, and 7 percent was not used (Figure 7). There was a somewhat higher proportion of coarse residues used for pulp and wood-composition board in Western Oregon (87 percent) then in Eastern Oregon (75 percent). Closer proximity of mills in Western Oregon to pulp and wood-composition board plants probably accounts for this difference.

A very marked change in disposition of coarse residue occurred between 1953 and 1967 (Figure 7). There was a large increase in usage for pulp and board manufacture, with decreasing quantities in other categories (Figures 8-9). In 1967, coarse sawmill residue used for pulp and board manufacture was nine times the amount used in 1953. The explanation of the increase in total coarse residues from 1953 to 1967, when lumber production had decreased, was that there were larger values for coarse residue conversion factors in 1967.

Table 7. Production and Disposition of Wood and Bark Residues by Sawmills and Planing Mills in Oregon for 1967, in Thousands of Tons, Dry Weight.

District	Bark				Coarse[1]				Sawdust				Shavings			
	Total	Fuel	Other	Not used	Total	Fuel	Pulp, board	Other	Not used	Total	Fuel	Pulp, board	Other	Not used	Total	Fuel	Pulp, board	Other	Not used
								WESTERN OREGON											
1	394	135	108	151	816	27	690	72	27	420	70	212	63	75	289	75	142	28	44
2	274	115	23	136	589	6	562	3	18	301	125	120	19	37	206	31	164	3	8
3	343	195	44	104	704	28	607	22	47	360	262	22	5	71	262	31	204	1	26
4	176	104	0	72	368	37	310	0	21	188	99	35	0	54	135	18	107	0	10
5	200	105	1	94	418	7	378	3	30	215	122	22	2	69	152	7	133	11	1
6	190	41	2	147	405	37	310	1	57	207	68	27	6	106	147	17	122	1	7
	1,577	695	178	704	3,300	142	2,857	101	200	1,691	746	438	95	412	1,191	179	872	44	96
								EASTERN OREGON											
7	118	79	7	32	266	49	185	0	32	136	110	0	8	18	96	71	0	9	16
8	111	48	1	62	253	13	218	3	19	129	53	40	4	32	80	24	44	5	7
9	86	65	0	21	195	10	170	4	11	99	74	4	1	20	76	2	46	0	28
10	62	16	0	46	145	29	70	5	41	74	56	2	0	16	39	28	0	0	11
	377	208	8	161	859	101	643	12	103	438	293	46	13	86	291	125	90	14	62
All	1,954	903	186	865	4,159	243	3,500	113	303	2,129	1,039	484	108	498	1,482	304	962	58	158

[1]Coarse residue includes slabs, edgings, log trim, and lumber trim.

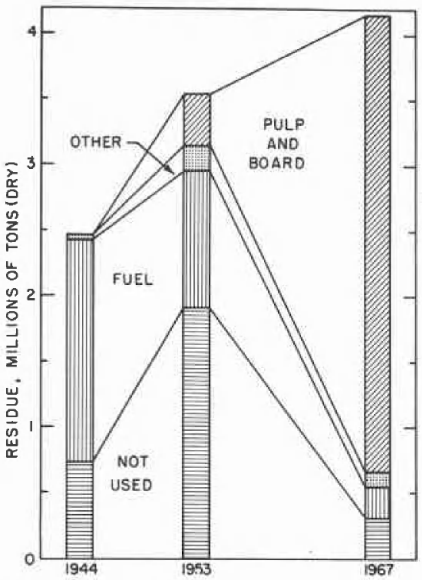

Figure 7. Disposition of coarse residue from sawmills in Oregon.

Figure 8. Rail cars of chips on the way to a pulp mill.

Fine Residue. Fine residue from lumber manufacture, consisting of sawdust and shavings, totaled about 3.6 million dry tons. Of the total fine residues, 40 percent was used for pulp and board manufacture, 37 percent for fuel, 5 percent for other uses, and 18 percent was not used (Figure 10). A higher proportion of shavings (65 percent) was used for pulp and board raw material than of sawdust (23 percent), as illustrated in Figure 6.

Changes in disposition of fine sawmill residues can be seen in Figure 10. As was true for coarse residues, the most striking change in disposal of fine residues has been their increasing use for pulp and wood-composition boards. In 1953, no sawdust and shavings were used in pulp and board manufacture (2). But in 1967, 40 percent of this fine residue was so used. Indeed, the rapid expansion of Oregon's particleboard industry has been based largely on the use of shavings.

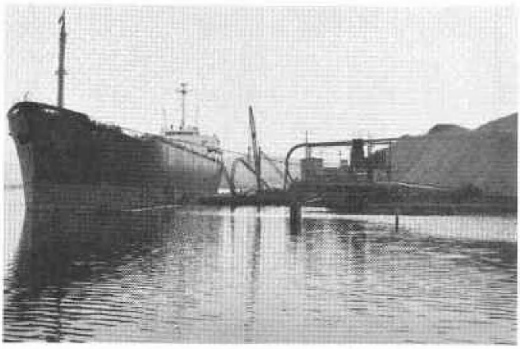

Figure 9. Loading pulp chips at Coos Bay for export.

Bark. Bark generated from lumber production totalled about 2.0 million dry tons. Nearly half (46 percent) of the bark produced was used for fuel, 10 percent for other purposes—mainly for application on the soil, and 44 percent was not used. Bark was utilized least of all types of residue.

Residues from Plywood Production

Production and disposition of residues from plywood manufacture in Oregon for 1967 are given in Table 8. Percentage disposition for selected types of residues is illustrated in Figure 11.

Undried veneer residue, consisting of green veneer clippings, spur trim, and round up, is the major source of "pulp chips" from veneer and plywood plants. Of a total of 2,175 thousand dry tons produced, 94 percent was converted to "pulp chips" for use in making pulp and board products, 3 percent was used for fuel, and 3 percent was not used.

Many cores are sawed into lumber with a nominal size of 2 by 4 inches and 8 feet in length, commonly referred to as "studs." Total production of cores was 436 thousand dry tons, with 81 percent remanufactured mainly into studs, 17 percent used for pulp and boards, and 2 percent for fuel.

The main use of log trim is for fuel, although recent equipment developments allow log trim to be "chipped." Disposition of the 396,000 dry tons of log trim was 59 percent to fuel, 15 percent to "chips" for pulp and board production, 1 percent to other uses, and 25 percent not used.

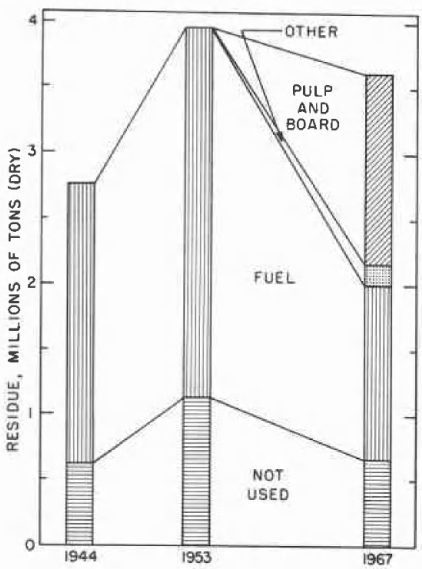

Figure 10. Disposition of fine residues (sawdust and shavings) from sawmills in Oregon.

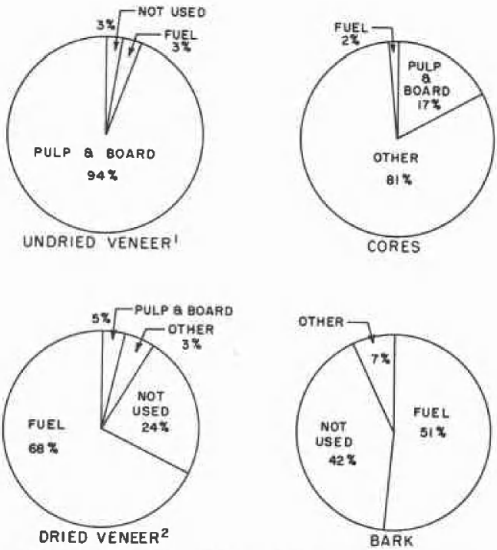

Figure 11. Disposition of selected types of residue from Oregon veneer and plywood plants in 1967.

[1] *Undried veneer includes "green" veneer trim, spur trim, and round-up.*

[2] *Dried veneer includes dry veneer loss and panel trim.*

Table 8. Production and Disposition of Wood and Bark Residues from Veneer and Plywood Plants in Oregon for 1967, in Thousands of Tons, Dry Weight.

District	Total	Fuel	Pulp, board	Other	Not used	Total	Fuel	Pulp, board	Other	Not used
			BARK					CORES		
1	93	58	--	22	13	35	4	1	30	0
2	213	126	--	0[1]	87	81	0	7	73	1
3	297	140	--	39	118	113	0	16	97	0
4	169	81	--	1	87	64	1	7	56	0
5	165	102	--	5	58	63	1	26	36	0
6	137	62	--	11	64	52	0	11	41	0
Western	1,074	569	--	78	427	408	6	68	333	1
Eastern[2]	73	20	--	3	50	28	0	6	21	1
All	1,147	589	--	81	477	436	6	74	354	2
			LOG TRIM					UNDRIED VENEER[3]		
1	32	27	3	0	2	175	12	162	0	1
2	73	56	9	0	8	404	20	378	0	6
3	101	63	21	0	17	563	33	507	0	23
4	59	21	4	0	34	321	0	306	0	15
5	58	20	21	2	15	313	1	309	0	3
6	48	35	2	0	11	260	1	259	0	0
Western	371	222	60	2	87	2,036	67	1,921	0	48
Eastern[2]	25	11	0	1	13	139	0	132	0	7
All	396	233	60	3	100	2,175	67	2,053	0	55
			DRIED VENEER					SANDER DUST		
1	73	56	2	4	11	18	13	--	5	0
2	165	96	2	0	67	36	21	--	0	15
3	152	121	9	2	20	33	20	--	7	6
4	73	54	1	7	11	15	12	--	2	1
5	89	74	4	6	5	21	13	--	3	5
6	131	68	17	3	43	31	11	--	7	13
Western	683	469	35	22	157	154	90	--	24	40
Eastern[2]	41	24	1	2	14	8	6	--	0	2
All	724	493	36	24	171	162	96	--	24	42

[1]Zeros signify less than 500 dry tons.
[2]All districts in Easter Oregon combined.
[3]Undried veneer includes "green" veneer trim, spur trim, and roundup.
[4]Dried veneer includes dry veneer loss and panel trim.

Dried veneer residue consisting of plywood panel trim and miscellaneous dry veneer losses amounted to 724,000 dry tons. Major use was 68 percent for fuel, with 5 percent for pulp and boards, 3 percent other uses, and 24 percent not used.

Sander dust is a residue of very fine particles. Because it is dry and its particles are small, sander dust is a good fuel when used in equipment designed for such fuel. Production of

Figure 12. Bark being applied for highway landscaping.

162,000 dry tons was distributed 59 percent to fuel, 15 percent for other uses (mainly wood flour), and 25 percent not used.

Bark from logs used in plywood manufacture amounted to 1,147,000 dry tons. Fuel accounted for 51 percent of the production, 7 percent went to other uses largely for soil application (Figure 12), and 42 percent remained unused.

CONCLUSIONS

There was a very large increase in the use of wood residues from lumber and plywood manufacture between the years 1953 and 1967. A greatly expanded use of wood residues as a raw material for pulp and wood-composition board accounted for the increased utilization (Figure 13). A small proportion of wood residues at manufacturing sites remained unused, and those residues that were unused occurred mainly at small plants or at locations distant from markets for residues. Some wood residues that are used now for fuel might be diverted to other uses if those uses had greater value, but such an opportunity exists mainly for fine residues. As wood residues from mill sites become more fully utilized, pulp and wood-composition board plants might look to logging residues and forest thinnings as a source of raw material for further expansion.

There were still large quantities of bark residue that were not used and would be available for additional use. Further research should be aimed toward greater use of this raw material.

Results of this study show the same general conclusions as a similar study (13) conducted a year later.

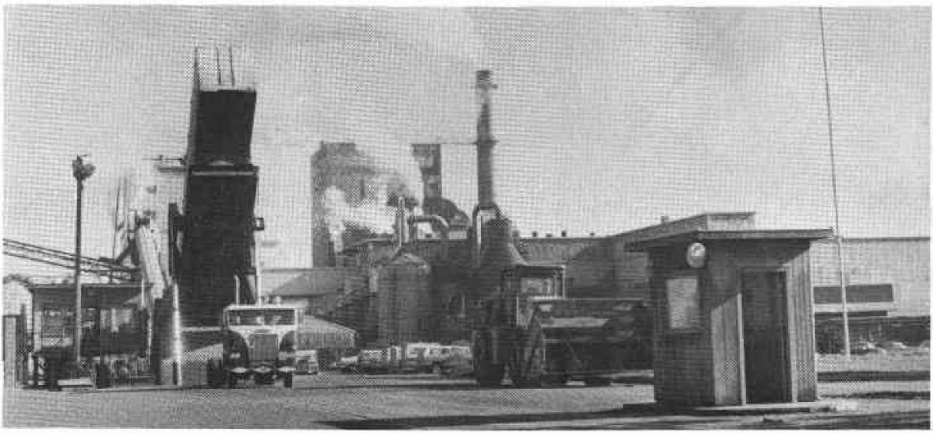

Figure 13. Unloading chips at a pulp mill.

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