Utilization of Harvested Wood by the North American Forest Products Industry

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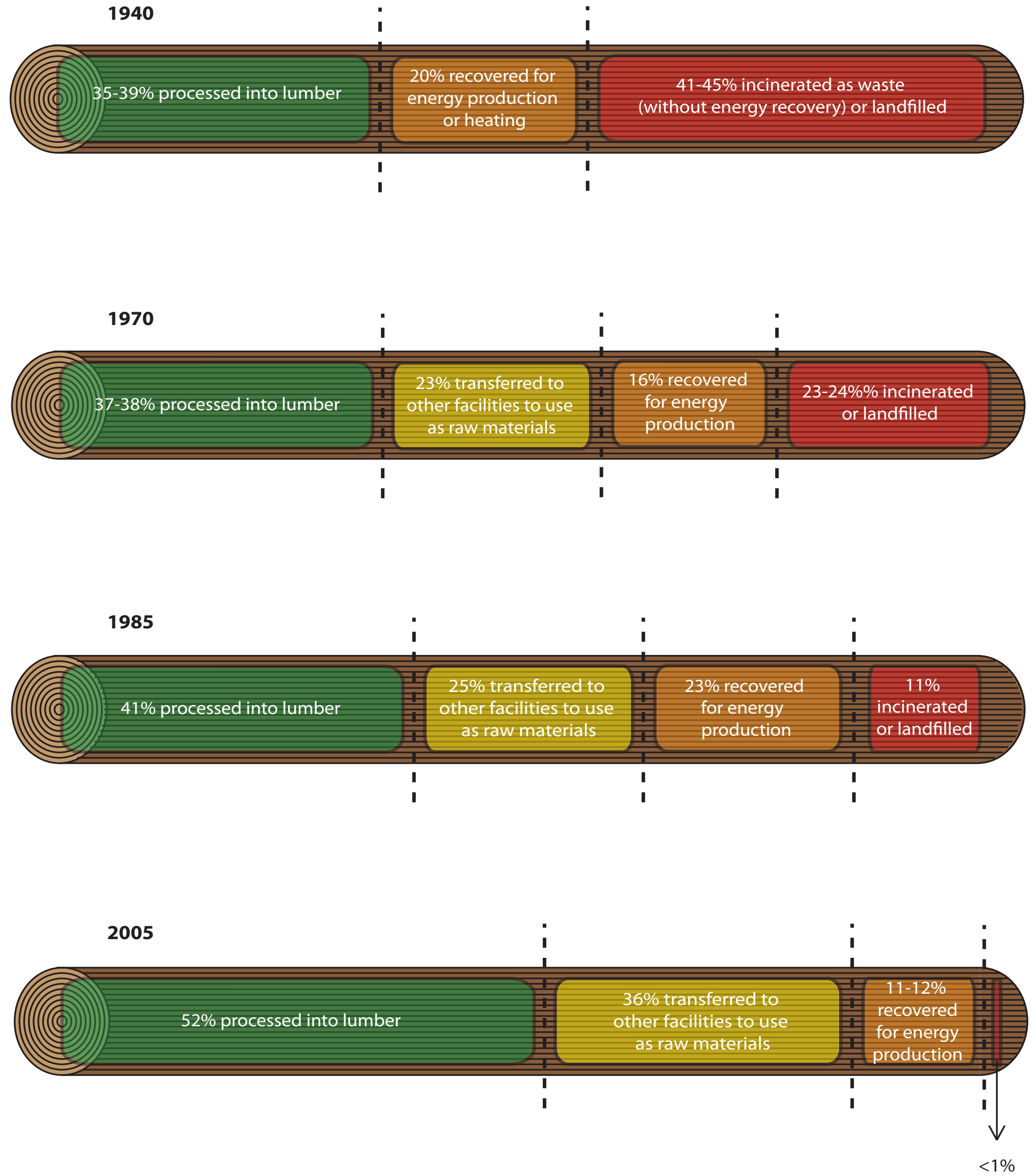
Understanding and Supporting the Benefits of Zero-Waste

The term "waste" is largely obsolete in the context of today's North American forest products industry. Logs brought to U.S. and Canadian sawmills and other wood products manufacturing centers are converted almost totally to useful products, leaving little to no waste (Graphic 1). But it hasn't always been this way. The sector has made great strides since the 1930s, and in-terms of wood use, it has become a zero-waste industry. This is a remarkable achievement and the result of investments in technology, new product development, and increased attention to reducing the environmental impacts of manufacturing. The next challenge for the industry will be to find ways to increase wood re-use and recovery for recycling at the end of use.

Graphic 1.
Utilization of Harvested Wood by the North American Forest Products Industry, 1940 - 2005



Utilization Standards Pre-1960s

In British Columbia, the yield of rough, green softwood lumber from merchantable timber in 1939 was found to be 55.5% (Jenkins 1939), a figure that translates to about 35-39% after processing to a surfaced, dry condition. At about the same time, a statewide survey of sawmill waste in Oregon (Voorhies 1942) showed similar green lumber yield numbers (51 to 54 percent). The volume of waste in 1939 was, as a result, on the order of 50-60% of the log volume entering sawmills. While Voorhies noted that about 30% of this waste was recovered and used for mill fuel, home heating, or other miscellaneous uses, he reported that virtually all of the remaining volume was incinerated or landfilled. As explained by Voorhies: "Although there is a potential market for many of the known by-products that can be made from sawmill waste, the cost of manufacturing and marketing these products by the usual techniques and methods has generally been more than the selling price." Contributing to the high waste factor was the reality that most of the products that are today commonly made from sawmill residues had not yet been invented; production of particleboard, for instance, did not begin in North America until the early 1950s, and sawmill residues were not used as raw materials in papermaking until the 1960s.

Efficiency in the forest products industry increased substantially following World War II (see sidebar). The growing post-war economy and commercialization of technologies developed during the war years soon led to marked acceleration of the rate of innovation and adoption of new technologies.

The Emergence of Markets for Co-Products

By the late 1960s, there had been little change in lumber yield. Kerbes and McIntosh reported in 1969 that the yield from sawtimber of dry, surfaced western spruce lumber in western Canada was still only about 37%. In that same year, the dry-surfaced lumber yield from southern yellow pine sawlogs was reported as

Milestones on the Pathway to Zero-Wood-Waste

1930s: Wood waste at 50-60%

1940's – 1950's: Technology improvements associated with innovations following WWII.

1955: Particleboard commercially produced in the United States

Mid-1960s: Development of retractable chuck lathe for veneer peeling.

1968: Patent issued for laminated veneer lumber (LVL).

1970: Wood waste at 38%.

1970s: Energy embargo of 1973 and oil supply disruption in 1979.

1971: Best Opening Face Technology introduced.

1971: Patent issued for wood structural I-beams.

1973: Start of USDA Forest Products Laboratory's Sawmill Improvement Program (SIP).

Mid-1970s: Centerless lathe technology for veneer production introduced.

1978: Oriented strandboad (OSB) manufactured commercially.

1981: Wood waste at 17%.

Early-1990s: Parallel Strand Lumber (PSL) developed in Canada.

Mid to late 1990s: Finger-jointed lumber accepted for structural uses by all major building codes in the U.S. and Canada

2000s: Growth in bioenergy technologies and energy efficiencies.

2005: Wood utilization reaches 90%, and productivity has grown 29% since 1965 and 14% since 1985.

2012: Wood waste at 0.14% - 1.5%.

38% (Williams and Hopkins 1969). What had changed, however, is that much of what had formerly been waste, now had value. At this point, sawmills commonly chipped slabs and edgings for use in papermaking and found shavings increasingly in demand as a raw material for particleboard manufacture. Shavings were also used as animal bedding, although often provided free of charge as a means of disposal. New markets were also emerging, with rapid growth of hardboard production and establishment, in 1965, of the medium density fiberboard industry in North America (Ince 2000). Nonetheless, only 25 percent of all wood products mill residuals generated in the U.S. in 1970 were used in the originating plants (mostly for fuel), with another 37 percent transferred to other manufacturing facilities for use as raw materials. The remaining 38 percent went unused and either landfilled or burned with no energy recovery (Meil et al. (2007). A very similar situation existed in Canada (Beke et al. 1997).

A Focus on Improving Lumber Yield

In 1973 the US Forest Products Laboratory began a sawmill improvement program (SIP), with a goal of significantly increasing lumber yield. Mills throughout the country were studied to determine yields obtained, and each phase in manufacturing was systematically examined for the purpose of identifying potential for yield improvement. Near-term results were impressive. By 1982 there had been a 15% reduction in log requirements to produce a given amount of lumber (Lundstrum 1982), translating to production of 640 million board feet of additional lumber without any increase in log volume harvested. The SIP program was subsequently replicated in Canada, with similar near-term results.

Technological Development Spurs Productivity Gains, Markets for Residues

Parallel development of technology set the stage for even greater gains in the near future. For example, Best Opening Face technology, which increased lumber yield from logs through computerized evaluation of log positioning prior to sawing, was introduced in 1971. This technology, in conjunction with development of systems for electronic scanning of logs, precise positioning of logs during cutting, optimization of trimming operations, and related technologies would eventually dominate North American production and markedly impact lumber yield. The introduction of log merchandisers, that allowed systematic bucking of long logs and sorting of resulting segments into various use categories for optimum utilization, also contributed to improved utilization. In addition, the concept of composite lumber products was born during this period, with patents issued (in 1968 and 1971, respectively) for wood structural I-beams, and for laminated veneer lumber (LVL). These technologies allowed the production of large-size, high strength "lumber" from small diameter trees of species having relatively low inherent strength.

Technological advancements were not limited to production of lumber. Structural plywood manufacturing was similarly the focus of technological innovation. Development of the retractable chuck lathe made it possible to economically peel small diameter logs to veneer. Introduced in the mid-1960s, this development led to the birth and rapid expansion of the southern pine plywood industry. A decade or so later centerless lathe technology for producing veneer was introduced. This technology allowed the use of logs that previously could not be used in making veneer; this also allowed the peeling of a log down to the center, thus increasing the volume of veneer that could be gleaned from a log.

Driving advancements in structural plywood technology was the emergence of an entirely new family of wood products –structural composite panels. Waferboard, the precurser to oriented strandboard (OSB), was first commercially manufactured in 1955, and accounted for only 0.05 percent of the U.S. structural panel market in 1973. Ongoing development soon led to the emergence of OSB, and rapid displacement of plywood in construction. Again the effect was to allow the economical use of small trees of relatively low inherent strength in production of high-strength products that previously required large diameter logs of high-strength species as raw material.

Cumulatively, these developments led to economic uses for an ever greater portion of each log harvested. Overall, in the 17-year-period between 1965 and 1982 industrial wood output per unit of roundwood input increased by 12 percent (Howard 2007).

Despite productivity gains and a focus on lumber yield improvement, gains came slowly. Based on SIP program data, Koch (1985) reported the yield of rough green softwood lumber at 53%, and of dry planed softwood lumber at 41% as national averages – a gain of about 14 percent from the late 1930s. The productivity gain is a bit more impressive when viewed in the context of lower average log diameter.

Finger-jointing allows the use of end-trimmings or other short sections of wood to produce reconstituted lumber, a relatively high value product; the technique results in bonds that as strong as the wood itself. Similarly, edge-gluing of narrow strips of edge trim from lumber production can be used to create furniture panels or blanks for a wide range of applications. Edge and end trimmings would otherwise be chipped or shredded for use in making paper, fiberboard, particleboard, or bioenergy.

Finger-jointing

Edge gluing

But development and adoption of technology continued to accelerate. By the early 1990s a new type of composite lumber, parallel strand lumber (PSL) had been developed in Canada and was being sold commercially. Oriented strand lumber (OSL), a related product, was also on the commercial market. Moreover, the earlier developed forms of composite lumber – LVL and wood I-beams had by this point achieved wide acceptance in homebuilding applications such as garage door headers and beams, and in commercial/industrial applications as a substitute for steel.

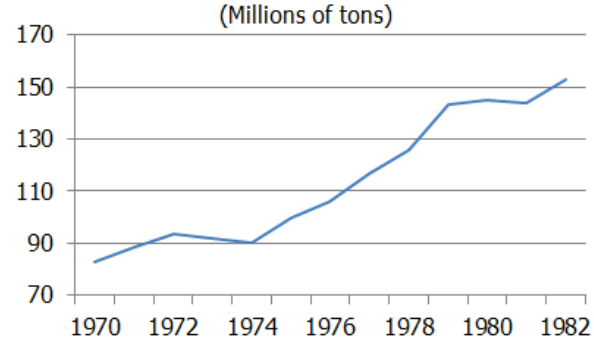
In the solid-sawn lumber arena, the Best Opening Face (BOF) technology, which had been developed in 1971, was by the early 1990s used in conjunction with automated scanners and computer-interfaced production equipment in half of U.S. softwood sawmills, accounting for at least 75 percent of production. Moreover, the use of fingerjointing to produce softwood studs from small pieces of wood that had been previously wasted or burned for power was common practice (see sidebar).

<u>Wood as a Source of Power for the Wood Products Industry</u>

As noted previously, energy was recovered from only a quarter of available wood wastes by generating mills in 1970. At that point, many U.S. sawmills used low-cost fossil fuel rather than wood to meet their energy needs, and most operated teepee-shaped burners in which non-marketable and energy-containing wood residues were incinerated. A number of mills also landfilled unmarketable wastes. This began to change with passage of the National Environmental Policy Act of 1969, which created air quality standards too stringent for continued open-air incineration of waste wood (Zerbe 1988). Environmental legislation also discouraged disposal in landfills, and the combined effect of these legislative initiatives was to increase interest in industrial use of wood wastes and their potential conversion to energy. But it was the energy embargo of 1973, and accompanying supply disruption and oil price increases, that most stimulated a boom in wood energy research and use (Zerbe 1988, Hazel and Bardon 2008). Many sawmills responded by installing heat recovery boilers and cogeneration equipment using what had previously been wastes as fuel. Other segments of the industry made similar moves. Changes were rapid, and dramatic (Figure 1); the use of wood for energy production increased by almost 70 percent in just 8 years (1974 to 1982), with over two-thirds of that increase attributable to the forest products industry. By 1981 the percentage of all sawmill residues landfilled or otherwise disposed of had dropped to 17 percent (from 38 percent in 1970) (Meil et al. 2007), and wood fuel provided about 73 percent of the solid wood industry's energy needs (OTA 1983).

Momentum created by the early '70s oil embargo was reinforced by a second oil supply disruption in 1979. As a result, actions to increase forest industry self-sufficiency continued even as the nation as a whole appeared to become more complacent about energy sources. Zerbe and Skog (2008) reported that all forms of wood residue – sawdust, slabs, edgings, chips, bark, and veneer clippings – were commonly used for energy generation in 2003. This is consistent with the observation of Murray et al. that mills that might have previously sold or given away excess were by 2002 firing all the bark in their boilers; from all sources, the lumber and wood products industry generated around 200 trillion Btu from biomass in 2002 (Murray et al. 2006).

Figure 1
Growth in Wood Use for Energy Consumption in the United States
(Millions of tons)



Source: Zerbe (1988)

In addition to shifting more to wood as a source of energy, the industry also took steps to improve energy efficiency. Energy consumption per unit of output to harvest, transport and manufacture lumber and plywood decreased by 5 and 17%, respectively, between 1970 and 2000 (Meil et al. 2007). The net effect of increased energy generation and energy efficiency was increased energy self-sufficiency on the part of wood products manufacturers. By 2005 the portion of manufacturing process energy derived from residual wood was estimated at 76% for lumber, 90% for plywood and 81% for OSB (Meil et al. 2007).

<u>Industrial Wood Productivity Approaches 100 Percent</u>

2005

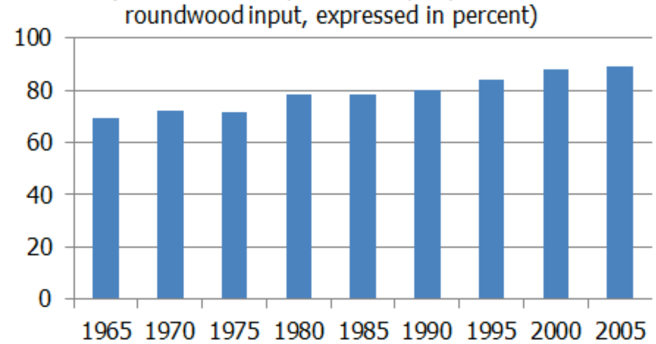
By 2005, the effects of technology development and yield improvement efforts had become more evident. Studies of lumber and total product yield in sawmills of the Pacific Northwest (PNW) and Southeast (SE) regions of the United States found planed dry lumber yields of 55.2 and 48.5% for the PNW and SE, respectively (Johnson et al. 2005). The total marketable product yield in the PNW was 91.1% when expressed as a percentage of debarked log volume, and 83.0% as a percentage of the mass of undebarked logs. Products included pulp chips (26.1% and 28.6% of log mass) and sawdust (6.6

and 7.3%). Another study found a 28% increase in lumber yield in Oregon sawmills in the period 1968-2005 (Gale et al. 2011).

In contrast, the total marketable product yield in the SE region was 95.1% when expressed as a percentage of debarked log volume, and 82.8% as a percentage of the mass of undebarked logs. Products included pulp chips (31.5% and 36.2% of log mass), planer shavings (7.4 and 8.5%) and sawdust (1.7 and 1.9%).

The total utilization percentages determined by Johnson et. al. correspond closely to the U.S. national average industrial wood productivity figure reported by Howard (2007) (Figure 2). This shows that for every 1.0 ton of roundwood input, the output of useful products is 0.892 tons. A nearly identical output number (0.9 tons per 1.0 tons of roundwood input) is reported by the Forest Products Association of Canada. For the U.S. industry as a whole, industrial wood productivity was 29% higher in 2005 than in 1965, and 14% higher than in 1985. Additional data regarding forest products input and outputs by mill category is included in Appendix A.

Figure 2
U.S. Industrial Wood Productivity, 1965 – 2005
(Industrial wood product output per unit of roundwood input, expressed in percent)



Source: Howard, J. 2007. USDA-Forest Service, Research Paper FPL-RP-637, Table 10.

2012

Industrial wood productivity in 2012 is undoubtedly higher than in 2005, if for no other reason than that the utilization of biomass energy has expanded rapidly in North America over the past 5-7 years. An example of this expansion is provided by fuel pellets, produced by an industry that increased its exports of wood pellets by almost 300% in a period of just four years (2008-2011) (Ekstrom 2012). The current situation is summarized in a recent update to what is commonly known as the "Billion Ton Report" (US Department of Energy 2011). Primary processing mills (sawmills, plywood mills, and paper mills) are reported to have produced about 87 million dry tons of residues in the form of bark, sawmill slabs and edgings, sawdust, and peeler log cores in 2002, with very little of this resource going unused at that point in time. Residue use has only increased since then. The report indicates that only 1.5% of primary mill residue is currently unused. An extensive study of unused material in Oregon, the nation's largest lumber producing state, suggests that the unused fraction may be even less than that. A 2008 examination of production and disposition of wood residues from Oregon sawmills and plywood/veneer plants (Gale et al.) found that only 0.14% of residues went unutilized, with almost all of that in the form of bark. A similar study of the residue situation in Canada (Lama 2011) found much the same thing: that generation of wood residues barely meets current regional demand, and that what residues do still remain at mill locations is primarily bark. The appendix of this report (Appendix A) provides detailed input and output data for a full range of mill categories and regions of North America.

Unused residues at secondary manufacturing facilities in the U.S. were reported in the Billion-Ton update as about 6 million dry tons annually; this estimate, however, is based on a 1999 study conducted well before the marked increase in wood energy markets. Current availability of residue from secondary mills is likely similar to that from primary mills – near zero.

The Bottom Line

The portion of harvested wood volume entering primary processing mills in North America that is converted to marketable products, or converted to useful energy, is near 100%. In other words, the wood waste at these mills is near 0%; therefore, in terms of wood use, these are zero-waste facilities. Secondary processing plants are similarly diligent in utilization of raw materials. Mill residues, that for much of the past century represented both an environmental problem and unrealized economic opportunity, are today being fully utilized and provide important benefits.

The industry is now turning its attention to possibilities for re-use and recovery for recycling of a greater portion of wood at the end of use. The paper side of the industry mounted a similar effort in the early 1970s, at a time when recovery of waste paper for recycling stood at 23 percent. By 2011, the percent of paper recovered was 66.8 percent, a near tripling of the proportion of paper recovered in a period of just 40 years. Given the record of success in eliminating wastes in wood products manufacturing processes, tracking progress in the recovery/recycling arena for lumber and other wood products should provide for interesting reading in the decades ahead.

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APPENDIX A.

Forest Products Input/Output Data by Mill Category

Lumber

Softwood Lumber – Pacific Northwest						
In 2000 3.05 m^3 (107.713 ft^3) of logs (PNW) produced:						
Product	kg	% of mass (incl. bark)	% of mass (not incl. bark)	Sold	Used as Fuel	Discarded
Planed dry lumber	774.0	50.3	55.2	774.0		
Rough green lumber	0.0	0	0			
Pulp chips	401.0	26.1	28.6	401.0		
Sawdust (sold)	102.1	6.6	7.3	102.1		
Sawdust (to boiler)	8.2	0.5	0.6		8.2	
Planer shavings	59.2	3.8	4.2	59.2		
Dry sawdust	11.4	0.7	0.8	11.4		
Dry chips	46.5	3.0	3.3	46.5		
Subtotal	1402.4	91.1	100.0	1394.2	8.2	0.0
Bark (sold)	0.0	0				
Bark (to boiler)	116.6	7.6			116.6	
Hog fuel to boiler	19.1	1.2			19.1	
Total	1538.1	100.0		1394.2	143.9	0.0
Summary	Salable products as a % of raw material input (mass basis): 90.6% w bark; 99.4% w/o bark Combusted to generate energy: 9.4% w bark; 0.6% w/o bark Waste incinerated or landfilled: 0					

Source: Milota, M., West, C., and Hartley, I. 2005. Gate-to-Gate Life Cycle Inventory of Softwood Lumber Production. Wood & Fiber Science, 37 (CORRIM Special Edition), pp. 47-57.

Softwood Lumber - Southeast						
In 2000 3.92 m^3 (138.43 ft^3) of logs (SE) produced:						
Product	kg	% of mass (incl. bark)	% of mass (not incl. bark)	Sold	Used as Fuel	Discarded
Planed dry lumber	883.0	42.2	48.5	883.0		
Rough green lumber	1.6	0.1	0.1	1.6		
Pulp chips	659.0	31.5	36.2	659.0		
Sawdust (sold)	34.6	1.7	1.9	34.6		
Sawdust (to boiler)	88.6	4.2	4.9		88.6	
Planer shavings	155.5	7.4	8.5	155.5		
Dry sawdust	0.0	0.0	0.0			
Dry chips	0.0	0.0	0.0			
Subtotal	1822.3	87.0	100.1	1733.7	88.6	
Bark (sold)	82.7	4.0		82.7		
Bark (to boiler)	188.2	9.0			188.2	
Hog fuel to boiler	0.0	0.0				
Total	2093.2	100.0		1816.4	276.8	0.0
Summary	Salable products as a % of raw material input (mass basis): 86.8% w bark; 95.1% w/o bark Combusted to generate energy: 13.2% w bark; 4.9% w/o bark Waste incinerated or landfilled: 0					

Source: Milota, M., West, C., and Hartley, I. 2005. Gate-to-Gate Life Cycle Inventory of Softwood Lumber Production. Wood & Fiber Science, 37 (CORRIM Special Edition), pp. 47-57.

Softwood Lumber – Inland Northwest						
In 2006/2007 836 kg of logs (Inland NW) produced:						
Product	kg	% of mass (incl. bark)	% of mass (not incl. bark)	Sold	Used as Fuel	Discarded
Planed dry lumber	436	52.2	56.0	436		
Pulp chips, green (sold)	216	25.8	27.8	216		
Pulp chips, dry (sold)	4	0.5	0.5	4		
Sawdust, green (sold)	52	6.2	6.7	52		
Planer shavings, dry (sold)	37	4.4	4.8	37		
Wood fiber, green (sold)	3	0.4	0.4	3		
Wood fuel	30	3.6	3.9		30	
Subtotal	778	93.1	100.1	748	30	
Bark (sold)	29	3.5		29		
Bark (to boiler)	29	3.5			29	
Total	836	100.1		777	59	0
Summary	Salable products as a % of raw material input (mass basis): 92.9% w bark; 96.1% w/o bark Combusted to generate energy: 7.1% w bark; 3.9% w/o bark Waste incinerated or landfilled: 0					

Source: Puettmann, M., Wagner, F., and Johnson, L. 2010. Life cycle inventory of softwood lumber from the Inland Northwest U.S. Wood & Fiber Science, 42 (CORRIM Special Edition), pp. 52-66.

Softwood Lumber – Northeast and North Central						
In 2006/2007 931 kg of logs (Inland NW) produced:						
Product	kg	% of mass (incl. bark)	% of mass (not incl. bark)	Sold	Used as Fuel	Discarded
Planed dry lumber	392	37.1	42.1	392		
Pulp chips, green	348	32.9	37.4	348		
Hog fuel, green	3	0.2	0.3		3	
Sawdust, green	84	7.9	9.0	42	42	
Planer shavings, dry	94	8.9	10.1	81	13	
Mixings, dry	10	0.9	1.1		10	
Subtotal	931	87.9	100.0	863	68	
Bark	127	12.0		127		
Total	1058	99.9		990	68	0
Summary	Salable products as a % of raw material input (mass basis): 93.6% w bark; 92.7% w/o bark Combusted to generate energy: 6.4% w bark; 7.3% w/o bark Waste incinerated or landfilled: 0					

Source: Bergmann, R. and Bowe, S. 2010. Environmental Impact of Manufacturing Softwood Lumber in Northeastern and North Central United States. Wood & Fiber Science, 42 (CORRIM Special Edition), pp. 67-78.

Hardwood Lumber – Northeastern U.S.						
In 2005 1170 kg of green logs (1170 is dry weight), and 131kg of bark yielded:						
	kg	% of mass (incl. bark)	% of mass (not incl. bark)	Sold	Used as Fuel	Discarded
Input						
Logs	1,170					
Bark	131					
Total	1,301					
Product						
Green chips	227	17.3	19.4	197.0	30.3	
Green sawdust	189	14.4	16.2	49.0	140.0	
Green bark	139	10.6		138.5	0.5	
Green hog fuel	45	3.4	3.8	26.6	18.4	
Planed dry lumber	535	40.8	45.6	535.0		
Dry shavings	86	6.6	7.4	86.0		
Dry sawdust	46	3.5	3.9	18.6	27.4	
Dry mixings	44	3.4	3.8	44.0		
Total	1,311	100.0	100.1	1,094.7	216.6	0.0
Summary	Salable products as a % of raw material input (mass basis): 84.1% w bark; 81.7% w/o bark Combusted to generate energy: 16.5% w bark; 18.5% w/o bark Waste incinerated or landfilled: 0					

Source: Bergman, R. and Bowe, S. 2008. Environmental Impact of Producing Hardwood Lumber Using Life-Cycle Inventory. Wood & Fiber Science 40(3): 448-458.

Composite Lumber

Laminated Veneer Lumber – Pacific Northwest (2000)						
Inputs	$Kg/10^3m^3$	$\#/10^3\ ft^3$				
Dry Veneer	111,000	6,950				
PLV (wood only)	392,000	24,500				
Total	503,000	31,450				
Outputs			%	Sold	Used as Fuel	Discarded
LVL (wood only)	521,000	32,500	95.6	521,000		
Veneer waste	7,540	471	1.4	7,540		
Layup scrap	6,020	376	1.1	6,020		
Tested LVL	1,360	85	0.2	1,360		
Panel trim	673	42	0.1	673		
Sawdust	8,230	514	1.5	8,230		
Total	544,823	33,988	100.0	544,823	0	0
Summary	Salable products as a % of raw material input (mass basis): 100% Combusted to generate energy: 0% onsite, 4.4% offsite Waste incinerated or landfilled: 0					

Source: Wilson, J. and Dancer, E. 2005. Gate-to-Gate Life Science Inventory of Laminated Veneer Lumber Production. Wood & Fiber Science, 37 (CORRIM Special Edition), pp. 114-127.

Laminated Veneer Lumber – Southeast (2000)						
Inputs	$Kg/10^3m^3$	$\#/10^3\ ft^3$				
Dry Veneer	614,000	38,400				
PLV (wood only)	0	0				
Total	614,000	38,400				
Outputs			%	Sold	Used as Fuel	Discarded
LVL (wood only)	593,000	37,000	91.3	593,000		
Veneer waste	10,900	683	1.7	10,900		
Layup scrap	22,500	1,401	3.5	22,500		
Tested LVL	1,740	109	0.3	1,740		
Panel trim	16,600	1,040	2.6	16,600		
Sawdust	4,520	282	0.7	4,520		
Total	649,000	40,515	100.0	649,000	0	0
Summary	Salable products as a % of raw material input (mass basis): 100% Combusted to generate energy: 0% onsite, 8.6% offsite Waste incinerated or landfilled: 0					

Source: Wilson, J. and Dancer, E. 2005. Gate-to-Gate Life Science Inventory of Laminated Veneer Lumber Production. Wood & Fiber Science, 37 (CORRIM Special Edition), pp. 114-127.

I-Joists – Pacific Northwest (2000)						
Inputs	$Kg/10^3m^3$	$\#/10^3\ ft^3$				
LVL	1,680	1,130				
OSB	1,640	1,100				
Resins	18	12				
Total	3,338	2,242				
Outputs			%	Sold	Used as Fuel	Discarded
Composite I-Joists	3,010	2,020	89.8	3,010		
Sawdust	342	230	10.2	342		
Total	3,352	2,250	100.0	3,352	0	0
Summary	Salable products as a % of raw material input (mass basis): 100% Combusted to generate energy: 0% Waste incinerated or landfilled: 0					

Source: Wilson, J. and Dancer, E. 2005. Gate-to-Gate Life Science Inventory of I-Joist Production. Wood & Fiber Science, 37 (CORRIM Special Edition), pp. 85-98.

I-Joists – Southeast (2000)						
Inputs	$Kg/10^3m^3$	$\#/10^3\ ft^3$				
LVL	2,400	1,610				
OSB	1,770	1,190				
Resins	12	8				
Total	4,182	2,808				
Outputs			%	Sold	Used as Fuel	Discarded
Composite I-Joists	3,870	2,600	93.0	3,870		
Sawdust	292	196	7.0	292		
Total	4,162	2,796	100.0	4,162	0	0
Summary	Salable products as a % of raw material input (mass basis): 100% Combusted to generate energy: 0% Waste incinerated or landfilled: 0					

Source: Wilson, J. and Dancer, E. 2005. Gate-to-Gate Life Science Inventory of I-Joist Production. Wood & Fiber Science, 37 (CORRIM Special Edition), pp. 85-98.

Glued-Laminated Timbers

Glulam – Pacific Northwest (2000)						
Inputs	Kg/10^3m^3	#/10^3 ft^3				
Lumber	537	33,498				
Unaccounted for wood	55	3,434				
Total	592	36,922				
Outputs			%	Sold	Used as Fuel	Discarded
Glulam beams (wood only)	483	30,162	82	483		
Shavings/trimmings	89	5,535	15	89		
Wood waste	20	1,233	3			20
Total	592	36,929	100	572	0	20
Summary	Salable products as a % of raw material input (mass basis): 96.6% Combusted to generate energy: 0% Waste incinerated or landfilled: 3.2%					

Source: Puettmann, M. and Wilson, J. 2005. Gate-to-Gate Life-Cycle Inventory of Glued-Laminated Timber Production. Wood & Fiber Science 37 (CORRIM Special Issue), pp. 99-113.

Glulam – Southeast (2000)						
Inputs	Kg/10^3m^3	#/10^3 ft^3				
Lumber	670	41,800				
Unaccounted for wood	6	362				
Total	676	42,162				
Outputs			%	Sold	Used as Fuel	Discarded
Glulam beams (wood only)	551	34,400	82	551		
Shavings/trimmings	119	7,140	17	119		
Wood waste	6	381	1			6
Total	676	42,191	100	670	0	6
Summary	Salable products as a % of raw material input (mass basis): 99.1% Combusted to generate energy: 0% Waste incinerated or landfilled: 0.9%					

Source: Puettmann, M. and Wilson, J. 2005. Gate-to-Gate Life-Cycle Inventory of Glued-Laminated Timber Production. Wood & Fiber Science 37 (CORRIM Special Issue), pp. 99-113.

Structural Panels

Softwood Plywood – Pacific Northwest (2000)						
Inputs	Kg/10^3m^3	#/10^3 ft^3				
Logs w/o bark	917.0	1,788				
Purchased dry veneer	3.1	6				
Purchased green veneer	7.2	14				
Total	927.3	1,809				
Outputs			%	Sold	Used as Fuel	Discarded
Plywood (wood only)	470	916	50.7	470		
Wood chips	218	425	23.5	218		
Peeler core	49	95	5.3	49		
Green clippings	16	31	1.7		16	
Veneer downfall	1.7	3.4	0.2		1.7	
Panel trim	55	107	5.9		55	
Sawdust	4.9	9.6	0.5		4.9	
Wood waste to boiler	0.13	0.25	0.0		0.13	
Sold wood waste	11	21	1.1	11		
Sold dry veneer	32	63	3.5			
Unaccounted for wood	70	137	7.6	32	48	22
Total	927	1,809	100.0	780	125.7	22
Summary	Salable products as a % of raw material input (mass basis): 84.1% w/o bark Combusted to generate energy: 13.6% Waste incinerated or landfilled: 2.3%					

Source: Wilson, J. and Sakimoto, E. 2005. Gate-to-Gate Life-Cycle Inventory of Softwood Plywood Production. Wood & Fiber Science 37 (CORRIM Special Issue), pp. 58-73.

Softwood Plywood – Southeast (2000)						
Inputs	$Kg/10^3 m^3$	$\#/10^3 ft^3$				
Logs w/o bark	1,066	2,080				
Purchased dry veneer	4.2	8.1				
Purchased green veneer	5.3	10.4				
Total	1,075	2,098				
Outputs			%	Sold	Used as Fuel	Discarded
Plywood (wood only)	541	1,055	50.3	541		
Wood chips	331	645	30.8	331		
Peeler core	57	112	5.3	57		
Green clippings	89	173	8.3		89	
Veneer downfall	0	0	0		0	
Panel trim	31	61	2.9		31	
Sawdust	2.2	4.2	0.2		2.2	
Wood waste to boiler	16	30	1.5		16	
Sold wood waste	11	21	1.0	11		
Sold dry veneer	0	0	0	0		
Unaccounted for wood	-1.4	-2.6	100.3	-1.4		
Total	1,075	2,098	100.3	940	138.2	0
Summary	Salable products as a % of raw material input (mass basis): 87.4% Combusted to generate energy: 12.6% Waste incinerated or landfilled: 0					

Source: Wilson, J. and Sakimoto, E. 2005. Gate-to-Gate Life-Cycle Inventory of Softwood Plywood Production. Wood & Fiber Science 37 (CORRIM Special Issue), pp. 58-73.

Oriented Strandboard (OSB) (2000)						
Roundwood input per 1,000 ft^3 3/8" basis: 1.4 m^3; 49.5 ft^3						
Inputs	Kg	lb.				
Wood	710.3	1,566				
Bark	61.2	135				
Total	771.6	1,701				
Outputs			%	Sold	Used as Fuel	Discarded
OSB	545.7	1,266	70.7	545.7		
Bark mulch	20.3	44.7	2.6	20.3		
Fines	8.3	18.2	1.1	8.3		
Dust/scrap	4.3	9.53	0.6	4.3		
Wood waste	0.05	0.11	0.0			0.05
Wood ash	1.91	4.22	0.2			1.91
Wood fuel	176.4	389	22.9		176.4	
Unaccounted for wood	14.6	32	1.9			
Total	771.6	1701	100.0	578.6	176.4	1.96
Summary	Salable products as a % of raw material input (mass basis): 75.0% Combusted to generate energy: 22.9% Waste incinerated or landfilled: 2.2%					

Source: Kline, D.E. 2005. Gate-to-Gate Life-Cycle Inventory of Oriented Strandboard Production. Wood & Fiber Science 37 (CORRIM Special Issue), pp. 74-84.

Non-Structural Panels

Particleboard (2004)					
Inputs	Kg				
Green hog chips	60				
Dry hog chips	49				
Green shavings	32				
Dry shavings	405				
Green sawdust	92				
Plywood trim	30				
OSB fines	3.1				
Subtotal	672				
UF Resin	68				
Wax	2.5				
Ammonium sulfate catal.	0.72				
Urea scavenger	2.9				
Total	746				
Outputs		%	Sold	Used as Fuel	Discarded
Particleboard (before sanding)	746				
Particleboard (after sanding)			713		
Wood boiler fuel (sold)	5.2		5.2		
Wood boiler fuel	27.1			27.1	
Wood waste	0.4				0.4
Boiler fly ash	0.1				0.1
Total			718.2	27.1	0.5
Summary	Salable products as a % of raw material input (mass basis): 96.3% Combusted to generate energy: 3.6% Waste incinerated or landfilled: 0.1%				

Source: Wilson, J. 2010. Life-Cycle Inventory of Particleboard in Terms of Resources, Emissions, Energy, and Carbon. Wood & Fiber Science 42 (CORRIM Special Issue), pp. 90-106.

<u>Particleboard recycled content in accordance with provisions of:</u>
LEED – 45%
ANSI/ASHRAE/USGBC/IES 189.1 – 45%
IGCC – 90% (Qualifies as recycled material (≥ 50% recycled content))
CALGREEN – 45%
National Green Building Standard (ICC 700) – 45%

Medium Density Fiberboard (2004)					
Inputs	Kg				
Green chips	427				
Green shavings	62				
Dry shavings	125				
Green sawdust	151				
Plywood trim	28				
Subtotal	793				
Urea formaldehyde resin	83				
Wax	5				
Urea scavenger	1				
Total	882				
Outputs		%	Sold	Used as Fuel	Discarded
MDF	741	84.0	741		
Bark mulch (sold)	12.9	1.5	12.9		
Wood boiler fuel (sold)	0.06	0.0	0.06		
Sander dust (fuel)	70	7.9		70	
Woodwaste (fuel)	54	6.1		54	
Woodwaste to landfill	2.21	0.3			2.21
Boiler fly ash to landfill	1.94	0.2			1.94
Total	882	100.0	754	124	4.15
Summary	Salable products as a % of raw material input (mass basis): 85.5% Combusted to generate energy: 14.0% Waste incinerated or landfilled: 0.5%				

Source: Wilson, J. 2010. Life-Cycle Inventory of Medium Density Fiberboard in Terms of Resources, Emissions, Energy, and Carbon. Wood & Fiber Science 42 (CORRIM Special Issue), pp. 107-124.

<u>MDF recycled content in accordance with provisions of:</u>
LEED – 44.5%
ANSI/ASHRAE/USGBC/IES 189.1 – 44.5%
IGCC – 89.1% (Qualifies as recycled material (≥ 50% recycled content))
CALGREEN – 44.5%
National Green Building Standard (ICC 700) – 44.5%

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