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RECOVERING WOOD FOR REUSE AND RECYCLING: A UNITED STATES PERSPECTIVE

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ABSTRACT

The United States is a country with a vast forest resource, comprising about one-third of its total land area (or about 3 million square kilometers). As a result, wood is an important renewable resource and is widely used in many applications, including building construction, furniture, fuelwood, textile fabrics, organic chemicals, and paper manufacture. This wide usage generates a large volume of wood waste. Currently, nearly 63 million metric tons of this material is generated in the manufacture, use, and disposal of solid wood products each year. This paper describes the types and amounts of waste wood generated in 2002, recycling efforts in the United States, and the reuse of lumber salvaged from building removal.

Keywords: *municipal solid wood waste, construction and demolition wood waste, solid wood recycling, lumber reuse and recycling, deconstruction*

INTRODUCTION

The recycling and reuse of recovered solid wood is of growing importance in the United States. While the timber industry has been using wood residues from primary wood processing mills for decades for fuel, pulpwood, and feedstock for products such as particleboard, the recovery and reuse of wood from two other major waste streams, municipal solid waste and construction and demolition waste, is only now being seriously considered. Large quantities of re-

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coverable solid wood end up in America's waste stream. This paper quantifies this solid wood resource and describes developing markets for recycling wood waste materials as well as efforts to reuse lumber and timber from the waste stream.

USE OF WOOD IN THE UNITED STATES

The United States is a nation with a large timber resource. When early settlers arrived in America, roughly one-half of the land mass was forested. Today, about one-third of our land remains tree-covered[1]. However, the character of these forests has changed. Gone are the once expansive virgin forests with large diameter old-growth trees. What remain are largely pine plantations in the southern United States, second- and third-growth softwood forests in the West, and uneven-aged hardwood forests in the North.

In 2002, 520 million m^3, roundwood equivalent*, of timber products were consumed in the United States for industrial products[2]. Included in this total are industrial roundwood used for lumber, plywood and veneer, pulpwood products, other industrial products, imported logs, and pulpwood chips. Solid wood timber products accounted for about 70% (367 million m^3) of the industrial roundwood consumed in 2002 and pulpwood products about 30%. Large amounts of residue are generated in the production of solid wood products annually, exceeding 84 million metric tons in 2002[1]. Just 2% of this residue was not used to produce other products. Most residue was used in the production of pulp and paper, and was equivalent to 10% to 20% of total industrial roundwood consumption. Thus, about half the industrial roundwood consumed in the United States was for solid wood products and the other half for pulp and paper products.

Lumber is by far the single largest use for industrial roundwood in the United States. Of the 367 million m^3 consumed for solid wood products in 2002, 78% or nearly 286 million m^3 was for lumber. Panel products (softwood and hardwood plywood, oriented strandboard, particleboard, and fiberboard) consumption accounted for 19% and other industrial products for the remaining 3%. Solid wood products are primarily made from softwood species. Overall, 78% of all solid wood products are softwood. Southern pines and Douglas-fir are the predominate species used for lumber and structural panel production.

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* Roundwood equivalent is defined as the volume of logs or other round products required to produce given quantities of lumber, plywood, wood pulp, paper, or similar products. Roundwood includes all wood waste produced during manufacture.

In 2002, U.S. softwood lumber production was 62 million m^3, with another 50 million m^3 being imported, largely from Canada (90%)[2]. With just over 2 million m^3 being exported, U.S. consumption of softwood lumber was just over 109 million m^3, nearly 57 million metric tons. New housing and residential upkeep and improvements are the largest end-uses for softwood lumber[3]. Hardwood lumber consumption was nearly 27 million m^3 (about 17 million metric tons). Packaging and shipping (wood pallets, containers, and crating) and furniture are the largest markets for hardwood lumber. Overall, more than 135 million m^3 of softwood and hardwood lumber (about 74 million metric tons) was consumed in 2002.

Industrial roundwood consumption for panel products in 2002 totaled nearly 70 million m^3, about one-fourth that of lumber. Roundwood includes structural panels (softwood plywood and oriented strandboard) used primarily for construction and nonstructural panels (hardwood plywood, particleboard, and fiberboard) used primarily in the manufacture of furniture, cabinets, and other consumer goods, and, to a lesser extent, in construction.

WOOD WASTE RESOURCE

This broad use of wood generates a large amount of waste. In 2002, nearly 63 million metric tons of solid wood waste was generated in the manufacture, use, and disposal of solid wood products in the United States[4]. This waste wood comes from a variety of sources and in a variety of forms. Its principal sources are two waste streams: municipal solid waste (MSW) and construction and demolition (C&D) waste. Each generates distinctly different types of wood waste, with differing degrees and levels of recyclability.

Municipal Solid Waste

Municipal solid waste (MSW) is waste from residential, commercial, institutional, and industrial sources. It includes durable and nondurable goods, containers and packaging, food scraps, yard trimmings, storm debris, and miscellaneous inorganic waste[5]. MSW does not include waste from other sources, such as construction and demolition activities (with the exception of waste from remodeling activities on existing residential structures), automobile bodies, municipal sludge, combustion ash, and industrial process wastes that may or may not be discarded in municipal waste landfills or incinerators. A wide variety of products is included in MSW. Two components of MSW, “wood” and “yard trimmings,” contain solid wood. The “wood” component includes items such as wooden furniture and cabinets, pallets and containers, scrap lumber and wooden panels, and wood from manufacturing facilities. It does not in-

clude roundwood or unprocessed wood and repaired or recycled pallets. Yard trimmings include leaves and grass clippings, brush, and tree trimmings and removals. Although the woody component of yard trimmings is not specifically within the scope of the COST Action E31, it is included here to present a more complete picture of MSW in the United States and because it is often co-mingled with other components of MSW.

Total MSW

In 2002, 288 million Americans generated nearly 209 million metric tons of waste in the MSW stream (Fig. 1). This represents about 724 kg per person per year. Paper and paperboard was the single largest component of MSW, constituting 75 million metric tons or about 36% of all MSW. Yard trimmings was the second largest component (25 million metric tons, 12%), followed closely by food waste and plastics (24 million and 23 million metric tons, respectively. These four components accounted for 70% of total MSW. Overall, about 62 million metric tons (30%) of this material was recovered for recycling or composting; 147 million metric tons (70%) was discarded in landfills or sent to combustion facilities. Paper and paperboard and yard trimmings accounted for about three-fourths of all recovery.

Wood Component of MSW

Just over 12.0 million metric tons of solid wood waste was generated in the wood component of MSW in 2002 (Table 1), about 6% of all MSW generated. Less than 10% (1.1 million metric tons) of this wood was recovered for recycling or composting, and 22% (2.7 million metric tons) was combusted (nearly all of which for energy recovery). The remaining 8.2 million metric tons was discarded. Of the discarded wood, about one-third (2.7 million metric tons) was estimated to be unacceptable for recovery for other uses because of excessive contamination, commingling with other waste, size and distribution of material, or other reasons. The remaining 5.5 million metric tons of waste wood was considered to be available for further recovery.

Yard Trimmings Component of MSW

A total of 25.4 million metric tons of yard trimmings was generated in the United States in 2002 (Fig. 1). This includes all woody and herbaceous vegetative material such as grass, leaves, and tree and brush trimmings from residential, institutional, and commercial sources. Yard trimmings was the second largest single component of MSW, about 12% of total generation. Detailed information on the composition of this material is not readily available from the U.S. Environmental Protection Agency (EPA)[5] who tracks such data, but

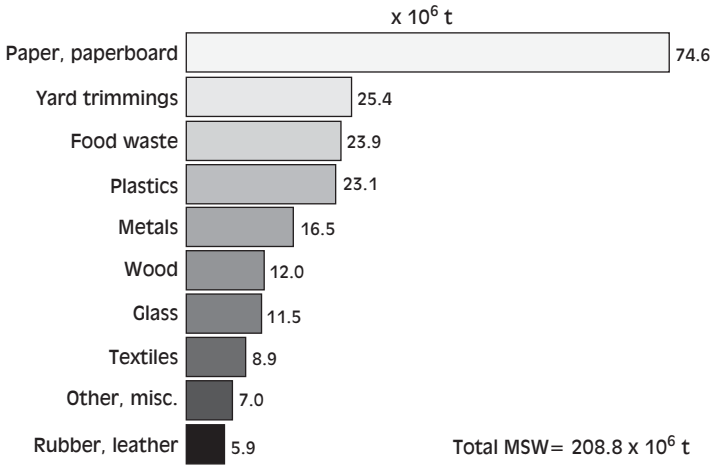

Figure 1. *Components of municipal solid waste, 2002.*

based on a 1994 analysis of the woody component of yard trimmings[6], approximately 14.8 million metric tons of wood chips, logs, stumps, tree tops, and brush was generated as part of MSW in 2002 (Table 1). Of this, about 8.5 million metric tons was recovered, primarily for use as compost and mulch. Of the remaining 6.3 million metric tons, 1.5 million metric tons was sent to combustion facilities and 1.6 million metric tons was deemed unusable. The remaining 3.2 million metric tons of woody yard trimmings was available for further recovery. Note that the volume of woody yard trimmings generated in this component of MSW exceeded the volume of timber harvested from U.S. National Forests in 2002[7].

Total Wood in MSW

In 2002, a total of 26.8 million metric tons of solid wood was generated as part of MSW. Included was 12.0 million metric tons from the wood component and 14.8 million metric tons from the woody yard trimmings component of MSW. This 26.8 million metric tons accounts for about 13% of all MSW generated. About 9.7 million metric tons of this wood was recovered for recycling or composting; the remainder was discarded. Of the discarded waste wood, 4.2 million metric tons was combusted and 13 million metric tons was sent to landfills. About one-third (4.3 million metric tons) of the landfilled material was considered to be of little or no value for further recovery. The remaining 8.7 million metric tons was deemed available for recovery for recycling. Although this waste was deemed available for recovery, many factors affect its re-

coverability and usability, such as the size and condition of the material, extent of commingling with other types of waste, contamination and physical location of the material, and costs associated with acquiring, transporting, and processing the material into a useable raw material. Overall economic conditions and changing recycling rates also affect supplies.

Construction and Demolition Waste

Construction and demolition (C&D) waste is often thought of as a single form of waste because both are typically discarded together in landfills. But since construction and demolition wastes originate from distinct types of activities, have different characteristics, and differ in their ease of separation, recovery, and recyclability, they are in fact different. Construction waste originates from the construction, repair, and remodeling of residential and nonresidential structures. It consists of fairly clean, contemporary building materials, which can be readily separated at the job site. Demolition waste originates when buildings or other structures are demolished. Demolition waste is often contaminated with paints, fasteners, adhesives, wall covering materials, insulation, and dirt, and typically contains a diverse mix of building materials. Some of these materials may no longer be in use or may presently be considered hazardous, making recovery more difficult. On-site separation of demolition waste is time-consuming and costly.

Construction Waste

Nearly all new single-family and low-rise multifamily residential structures in the United States use traditional 2 by 4 wood-frame building technology. Information on this type of construction was the basis for estimates of wood waste generated and recoverable for new construction. Published waste generation rates from case studies were used to develop weighted average waste generation rates for residential construction[8,9]. These rates were then adjusted for residential repair and remodeling, nonresidential construction, and nonresidential repair and remodeling.

In 2002, 1.3 million new single-family houses with an average 216 m^2 of floor area and 0.3 million multifamily living units with an average 104 m^2 of floor area were built in the United States[10]. Applying weighted average waste generation and recoverability rates results in an estimated 3.7 million metric tons of wood waste generated and 3.3 million metric tons recoverable for all new residential construction. Overall, an estimated 34.5 million metric tons of wood products was used for new residential construction. Wood waste was therefore about 11% of all wood used to build residential structures. Conventional wisdom is that about 5% to 15% waste can be expected in new U.S.

house construction. These waste estimates confirm this expectation.

The repair and remodeling of residential structures tends to generate more waste than does new residential construction because many repair and remodeling projects involve both demolition and construction activities, both of which generate waste. In 2002, an estimated 5.6 million metric tons of wood waste was generated from all residential repair and remodeling activities; about 3.8 million metric tons was recoverable.

The construction of smaller, low-rise nonresidential buildings and structures, and their repair and remodeling generated 0.9 million metric tons of wood waste. Nearly 0.8 million metric tons was considered available for recovery. Since wood is not the primary building material for most large or high-rise nonresidential projects, waste wood estimates developed here should not be greatly affected by their exclusion.

Wood waste generation for all new construction was estimated to be 10.5 million metric tons, with 7.8 million metric tons available for recovery (Table 1). About 2.7 million metric tons of the generated waste wood was already being recovered or was not usable.

Table 1. Urban Waste Wood Generated, Recovered, Combusted or Not Usable, and Available for Recovery in the United States, 2002

						Available for recovery		
Source	**Generated (10^6 t)**	**Recovered (10^6 t)**	**Combusted (10^6 t)**	**Unusable (10^6 t)**	**Total (10^6 t)**	**Amount (10^6 t)**	**(%)**	**% of total available**
Municipal solid waste (MSW)								
Wood component	12.0	1.1	2.7	2.7	6.5	5.5	63	20
Woody yard trimmings	14.8	8.5	1.5	1.6	11.6	3.2	37	12
Total	26.8	9.7	4.2	4.3	18.2	8.7	100	32
Construction & demolition waste (C&D)								
Construction	10.5	–	–	–	2.7	7.8	43	29
Demolition	25.2	–	–	–	14.6	10.6	57	39
Total	35.7	–	–	–	17.3	18.4	100	68
Total								
MSW	26.8	–	–	–	18.2	8.7	32	32
C&D	35.7	–	–	–	17.3	18.4	68	68
Total	62.5	–	–	–	35.5	27.1	100	100

Demolition Waste

Demolition waste is a heterogeneous mixture of building materials generated when a building or other structure is demolished. Demolition waste typically contains aggregate, concrete, wood, paper, metal, insulation, glass, and other building materials. Depending on the age and type of structure, asbestos, lead-based finishes, mercury, polychlorinated biphenyl compounds (PCBs), and other contaminates or hazardous materials may be present. As with new construction, waste generation rates for demolition activities are limited to a few case studies[9,11]. These case studies indicate that, on average, about 0.6 kg of demolition waste was generated per person per day in the United States in 1996, and that about 40 % of this material was wood. Based on these rates, an estimated 62.9 million metric tons of demolition waste was generated in 2002; 25.2 million metric tons was wood (Table 1).

Demolition waste wood recovery is difficult to determine. The characteristics of demolition waste and different demolition practices make this material more difficult to recover and recycle than construction waste. Existing demolition waste recycling operations are very sensitive to contamination. If contaminated, entire loads of demolition waste are typically rejected at recycling facilities. Differences in types of technology used, products manufactured, and sources of demolition waste all affect utilization rates. Based on limited case studies[12], an initial overall 30% recovery rate was assumed for 1990 with steady improvement over time. Based on these assumptions, an estimated 10.6 million metric tons of demolition waste wood was recoverable in 2002.

Total C&D Waste

Overall, about 35.7 million metric tons of C&D waste was generated in 2002, with 29.2 million metric tons available for recovery.

Other Sources of Waste

Other sources of waste wood include chemically treated wood from railroad ties, telephone and utility poles, and pier and dock timbers, untreated wood from logging and silvicultural operations, chipped brush and limbs from utility right-of-way maintenance, and industrial waste wood outside the MSW stream. Some of this material is reused, burned, or discarded in hazardous waste landfills but much is left on site. Chemical treatments and costs of collection make much of this material difficult to recover. The amounts of wood available from these other sources (with the exception of logging and silvicultural residues) are fairly small compared to MSW and C&D waste. For example, in 1996,

approximately 13.6 million railroad ties were replaced[13]. These ties weighed approximately 0.7 million metric tons. If half this wood were sound, less than 0.4 million metric tons of wood would be recoverable.

Waste Wood Summary

An estimated 62.5 million metric tons of waste wood was generated in the United States in 2002 in the MSW stream and from C&D activities. Much of this waste was used to produce new products or fuel, or was not suitable for recovery. Of the total amount generated, about 27.1 million metric tons (43%) was deemed suitable for further recovery for recycling or reuse. In comparison, an estimated 230 million metric tons of roundwood timber was produced in the United States in 2002 (excluding fuelwood)[2]. Recoverable waste wood was therefore about 12% of roundwood timber production. Overall, about 32% of the recoverable waste wood was MSW, 29% construction waste, and 39% demolition waste.

CURRENT WOOD WASTE RECYCLING ACTIVITIES

Prior to 1990, recycling of wood waste from the MSW and C&D waste streams in the United States was limited. Today, the EPA estimates that more than 500 wood processing facilities exist across the country[9]. The markets for recovered wood are greatly influenced by local supply and demand; however, they are dominated by production of landscaping mulch and waste wood for fuel. Chipped or shredded wood is also used as a composting bulk agent, sewage sludge bulking medium, and animal bedding. No quantified information is available on the size and distribution of these markets at the national level; however average market price for these materials is generally between $12 and $24 USD (10–20) per ton for processed wood.

Recovered wood can be used to manufacturer value-added products such as medium density fiberboard and particleboard. However, these industries demand clean and consistent feedstocks, which can be difficult to achieve with wood from the waste stream.

Wooden pallets are perhaps one of the best successes in solid wood recycling in the United States. In 1999, the most recent year for which detailed data are available, an estimated 299 million pallets were recovered for recycling[14]. These recovered pallets were recycled into new pallets or related products, or were ground for fuel or mulch. Less than 1% of recovered pallet material was returned to the landfill. Thus, nearly 7 million metric tons of pallet material was diverted from the MSW stream.

CURRENT LUMBER REUSE ACTIVITIES

Additional efforts to recover wood focus on the reuse and remanufacture of recoverable lumber from building removal. Wood-framed building deconstruction is a specific approach to remove materials to reuse them in such a way to preserve their integrity and value to the greatest extent possible and as economically as possible. Deconstruction is generally perceived as manual disassembly of a building, although various combinations of manual and mechanical methods are being studied to improve cost and time performance. Solid wood recovery rates of 50% to 90% are not uncommon.

Deconstruction emphasizes a hierarchy of material use; reuse first, then recycle. For example, it is deemed more preferable to *reuse* a recovered timber beam in its whole form rather than grind it up and *recycle* it into mulch or boiler fuel.

The EPA estimates that the equivalent of 250,000 single-family homes are disposed of each year in the United States[9,15]. This represents nearly 1.8 million m^3 of salvageable structural lumber available per year, equivalent to about 3% of the U.S. softwood harvest. Much of the lumber available for salvage through deconstruction is from decades of old-growth harvest and represents a resource largely unavailable from any other source. As a result, much of this wood is of high structural and aesthetic quality (e.g., higher density, slower grown, fewer defects) than is the lumber produced today. Both reuse (as lumber or timbers) and remanufacture are options for recovered wood. Larger timbers are often used in "timber frame" construction (a traditional type of construction where exposed heavy timber framing forms the building structure). If quality is high enough, adding value through remanufacture can be economical. Remilling of old timbers into flooring is the most common end-use, although paneling, millwork, and siding have all been investigated.

Preservative-Treated Wood

Certainly, one of the foremost challenges in wood recycling is dealing with preservative-treated wood. The volume of material treated with chromated copper arsenate (CCA) (typically southern yellow pine) in the MSW and C&D waste streams is immense. The Southern Forest Products Association estimates that more than 10 million m^3 of CCA-treated southern pine has been produced each year since 1997 and a total volume of more than 102 million m^3 since 1970[16]. Furthermore, the Forest Service estimates that 1.7 million m^3 of CCA-treated wood is removed each year from residential outdoor decks[17]. With the recent decision by the EPA to phase out the use of CCA-treated products in re-

sidential applications, including play structures, decks, picnic tables, landscaping timbers, residential fencing, patios, and boardwalks, it is likely that discarded CCA-treated lumber will be a significant long-term disposal problem.

CONCLUSIONS

The United States uses a large amount of wood. Accordingly, the amount of wood waste produced is also large. In the last decade, interest has been growing in utilizing this resource and millions of tons of solid wood waste are available for recycling into a myriad of products. Though the production of landscaping mulch and fuel are the dominant markets for recycled wood waste, reuse of solid lumber for structural uses and for remanufacture into value-added products is also growing.

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