## GENERATORS AND USERS

# HOW WOODY RESIDUALS ARE RECYCLED IN THE UNITED STATES

*More than 160 million tons of "waste wood" were generated last year. This report from the Forest Products Laboratory analyzes recovery data and methods.*

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SOLID waste wood is typically not considered to be an important recyclable commodity. However, for decades, wood residues from primary timber processing facilities have been made into usable products. Nearly all particleboard produced in the United States, for example, is made from such residues. Wooden pallets, once destined for landfills after only a few trips, are now being repaired and recycled at increasing rates. About one-third of all pallets produced annually are made from recycled wood. Solid waste wood from construction and demolition sites and from the municipal solid waste stream is also gaining importance as a wood resource.

An important step in developing solid waste wood into a viable resource is to quantify the amounts of waste available by source and type of material. Three major sources of wood waste exist in the United States: 1) Municipal solid waste; 2) Construction and demolition waste; and 3) Wood residues from primary timber processing mills. Each source generates distinctly different types of wood waste, with differing degrees of recyclability. To determine quantities of each source, the factors estimated were total amount of waste generated, amount of waste wood generated, and amount of waste wood available for further recovery in 1998. Trends since 1990 were also examined.

Estimates were based on published waste generation rates and recoverability, measures of economic activity, and trends in virgin wood use in specific markets. These estimates provide consistent information for the 1990s and update similar estimates made for 1993, 1994 and 1996 (McKeever 1995, 1996, 1998). Estimates of residues left in the forests from logging or cultural operations, waste wood from other lesser sources, and other nonwood agricultural wastes were not included, nor were estimates of debris from catastrophic natural events, which may be disposed of outside of the three principal waste streams examined here.

### THE WOODY FRACTION OF MUNICIPAL SOLID WASTE

Two categories of MSW – wood and yard trimmings – contain solid wood. Wood includes items such as wooden furniture and cabinets, pallets and containers, scrap lumber and panels from other than new construction or demolition activities, and wood from manufacturing facilities. Not included are roundwood or unprocessed wood and re-

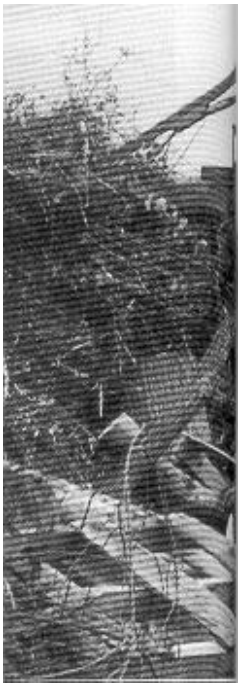
*Table 1. Wood waste generated; recovered, combusted, or not usable; and available for recovery in the United States, 1998.*

| Source | Generated (million tons) | Recovered, Combusted Or Not Usable (million tons) | Available For Recovery – Amount (million tons) | Available For Recovery – Total Waste Wood Available (%) |
|---|---|---|---|---|
| Municipal solid waste | | | | |
| Waste wood | 11.8 | 6.4 | 5.4 | 18 |
| Woody yard trimmings | 25.2 | 18.4 | 6.8 | 23 |
| Total | 37.0 | 24.8 | 12.2 | 41 |
| Construction and demolition waste | | | | |
| Construction | 8.7 | 2.1 | 6.6 | 22 |
| Demolition | 26.4 | 17.4 | 9.0 | 30 |
| Total | 35.1 | 19.5 | 15.5 | 52 |
| Primary timber processing residues | | | | |
| Bark residues | 24.5 | 23.9 | 0.6 | 2 |
| Wood residues | 65.8 | 64.5 | 1.3 | 4 |
| Total | 90.3 | 88.4 | 1.9 | 6 |
| Total waste wood | 162.4 | 132.8 | 29.6 | 100 |

Generation of solid wood waste as part of MSW has remained fairly steady during the 1990s, ranging from a high of 12.3 million tons in 1992 to a low of 10.4 million tons in 1995.

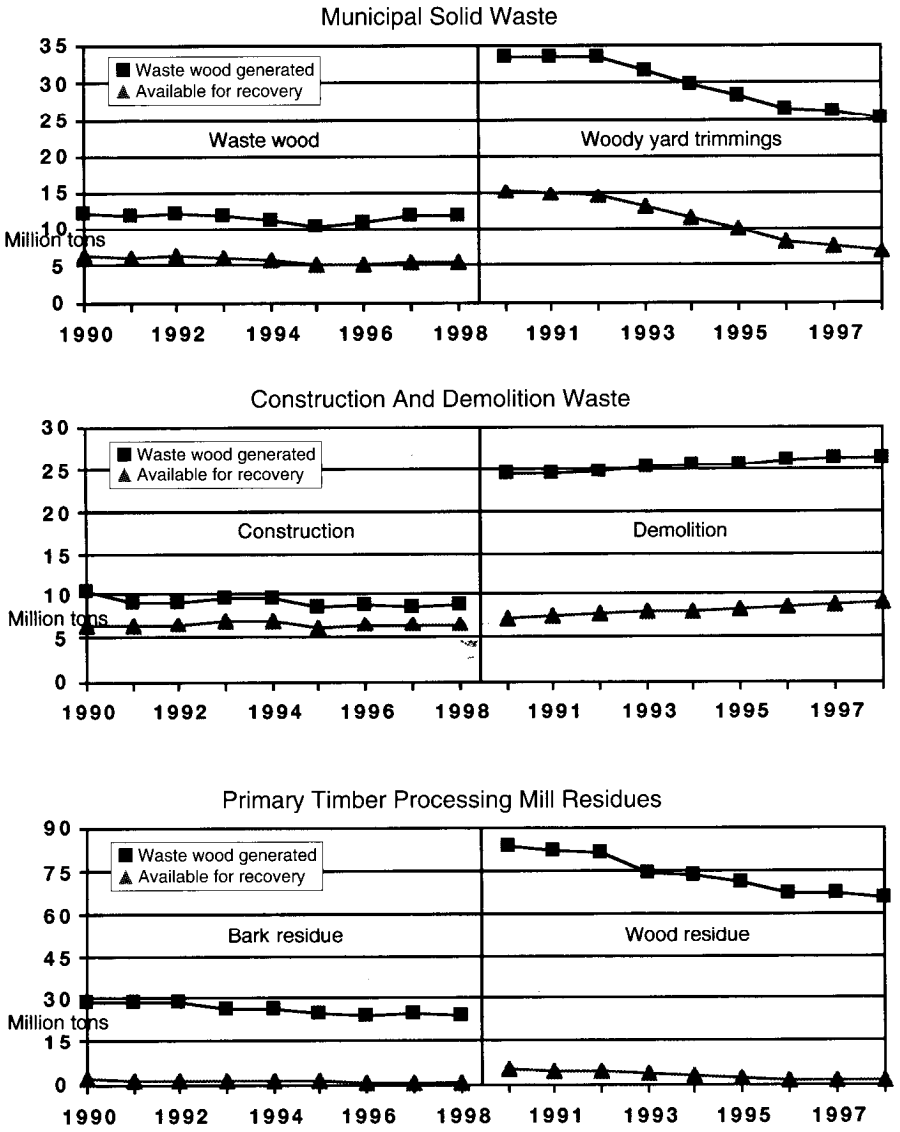
paired or recycled pallets. (In 1995, the most recent year for which detailed data are available, an estimated 206 million pallets were recovered for recycling, 171 million by the pallet industry and 35 million from landfills (Bush 1997). These recovered pallets were recycled into new pallets or related products or were ground for fuel or mulch. Less than one percent of recovered pallet material was returned to the landfill as unusable. This resulted in approximately 5.3 million tons of pallet material being diverted from the MSW stream.) The physical supply of solid wood waste that may be available for recovery from the municipal waste stream is determined by the amounts and types of waste generated, the amounts and types of waste currently recovered for recycling, composting, or combustion, and the amounts and types of waste discarded.

In 1998, 11.8 million tons of solid wood waste were generated in the United States as part of the MSW (Table 1). This was about five percent of all MSW generated. About 600,000 tons were recovered for recycling or composting, and the remainder was discarded. Of the discarded wood waste, an estimated 3.1 million tons were sent to combustion facilities (nearly all of which was for energy recovery), and about 2.7 million tons were considered to be unacceptable for recovery because of excessive contamination, commingling with other waste, or other reasons. The remaining 5.4 million tons of waste wood were considered available for further recovery.



The generation of solid wood waste has remained fairly steady during the 1990s, ranging from a high of 12.3 million tons in 1992 to a low of 10.4 million tons in 1995. With the exception of slight increases in the past two years, amounts available for further recovery have tended downwards since 1990. Much of this is due to increased recovery and combustion rates in recent years.

*Figure 1. Waste wood generated, and available for recovery in the United States, by source, 1990-1998.*




### YARD TRIMMINGS COMPONENT

Yard trimmings were the second largest single component of MSW in 1998 at 12 percent of total generation. Yard trimmings include many types of woody and herbaceous debris including tree limbs and stumps, brush, and leaves and grass clippings. According to a recent study, about 95 percent of all urban tree and landscape residues were woody residues (NEOS Corp. 1995). That study included all urban tree and landscaping residues, not just those in MSW, and may therefore overstate to some extent the portion of woody verses herbaceous residue. Thus, about 25.2 million tons of woody yard trimmings were generated as part of MSW in 1998 (Table 1), with 11.1 million tons being recovered for recycling or composting. Of the remaining 14.2 million tons, 3.9 million tons were combusted and 3.4 million tons were disposed of as unusable. The remaining 6.8 million tons were considered available for further recovery.

Woody yard trimmings totals in MSW have fallen in recent years due largely to the success of source reduction and backyard composting projects. Much of the impetus for these projects came from legislative bans on landfill disposal of yard trimmings. Since 1990, woody yard trimmings in MSW fell steadily from 33.3 million to 25.2 million tons. During this same time, recovery for composting increased and combustion and disposal decreased, resulting in about 18.5 million tons of woody yard trimmings per year being removed from the waste stream. As a consequence, amounts of woody yard trimmings available for fur-

According to latest annual data, an estimated 206 million pallets were recovered for recycling - 35 million from landfills and 171 million by the pallet industry.

ther recovery have fallen by more than half, from 15.2 million tons in 1990 to just 6.8 million tons in 1998. Expectations are for continued increases in source reduction, resulting in further reductions in amounts available for recovery.

Overall, about 12.2 million tons of all solid wood waste in MSW were considered to be available in 1998. This is just a little more than half the amount available in 1990. Much of the decline is directly attributable to reductions in woody yard trimmings. Many factors affect the recoverability and usability of this waste, such as its size and condition, 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 feedstock. Overall economic conditions and changing recycling rates also affect waste supplies.

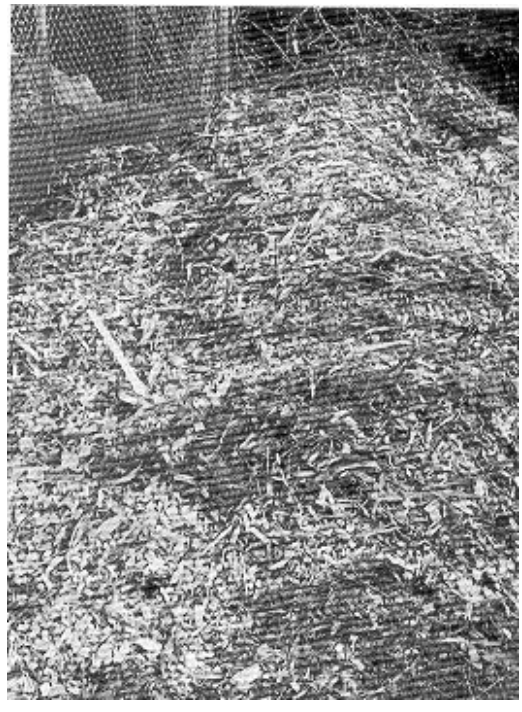
### CONSTRUCTION AND DEMOLITION WASTE

Construction and demolition (C&D) waste are often referred to as a single form of waste. But since they originate from distinctly different types of activities, have different characteristics, and differ in their ease of separation, recovery and recyclability, they should be evaluated separately. 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 coverings, insulation, and dirt, and typically contains a diverse mix of building materials. Some of these materials may no longer be in use or are now considered to be hazardous, making recovery more difficult. On-site separation of demolition waste is time-consuming and costly.

Little consistent information is available nationally on C&D generation and recovery, and even less is available on demolition debris generation and recovery. Available data are limited to anecdotal or case studies at specific points in time, exhibit high degrees of variability within and between studies, and tend to reflect local building practices and building products used (Solid Waste Association of North America 1993). Many factors affect waste generation rates including overall activity levels, types of structures being built or demolished, types of building materials used, age of structure being demolished, and extent to which materials are removed for reuse or recycling prior to demolition. Because of this variability, information that could be linked to national levels of construction activity and population was used to estimate C&D waste generation. The resulting estimates, although not precise, provide a good, overall indication of the C&D waste resource.

### ANALYZING CONSTRUCTION WASTE

The economic well being of the nation directly affects the generation of construction waste. When the economy is prosperous, housing starts and average house size, expenditures for new nonresidential construction, and expenditures for the repair and remodeling of existing buildings and structures are high. High levels of building activity result in high levels of construction waste. The construction of new single family and multifamily houses, and their repair and remodeling, and the construction of new nonresidential buildings and other structures, and their repair and remodeling, were the bases for the construction waste estimates developed here. Nearly all new single family houses and low rise multifamily structures are built using traditional wood



About 25.2 million tons of woody yard trimmings were generated last year as part of the municipal solid waste stream, with 11.1 million tons being recovered for composting and recycling.

Advances in processing equipment for collecting, sorting and sizing recyclable wood from waste streams have greatly helped to increase recovery rates.

About 55.2 million tons of wood products were used for construction in the U.S. in 1998, generating nearly 8.7 million tons of waste wood. Nearly 6.6 million tons were considered to be available for recovery.

frame technology. Much is known about new residential construction, including numbers of units built, their average size, and amounts of wood products used.

For this article, wood products consumption for specific types of construction are Forest Service estimates based on a variety of sources including Phelps and McKeever (1990), Anderson and McKeever (1991), McKeever and Anderson (1993), McKeever and Phelps (1994), Adair (1996), McKeever and Adair (1998), and Wood Products Council (1999). The repair and remodeling of residential structures use the same types of building practices and building products as new residential construction. Waste generation rates per square foot of floor area for new residential construction were developed from case studies conducted throughout the United States in the mid-1990s (McGregor et al. 1993, U.S. EPA 1998). These generation rates were then converted to a per unit of wood used basis and adjusted to reflect greater levels of waste associated with residential repair and remodeling.

New nonresidential buildings, and their repair and remodeling, use wood less often and in lesser amounts than residential buildings. Also, nonresidential buildings exhibit a much higher degree of variability than residential buildings. This variability makes case study data based on building size less reliable in estimating wood waste than waste generation factors based on total wood use. Therefore, waste generation rates per unit of wood used for residential construction were used for nonresidential buildings and were also used for other nonresidential structures after being adjusted to reflect higher waste rates.

In 1998, 1.16 million new single-family houses with an average 2,190 $ft^2$ (203.5 $m^2$) of floor area and 346,000 multifamily living units with an average 1,065 $ft^2$ (99 $m^2$) of floor area were built in the United States (Bureau of the Census 1999a). Applying empirical average solid wood waste generation rates of 2.5 and 1.5 $lb/ft^2$ (12.2 and 7.3 $kg/m^2$) of finished floor area for single family and multifamily structures, respectively, resulted in an estimated 3.4 million tons of wood waste generated for new residential construction. Recoverability was estimated to be about 3.0 million tons, based on empirical recovery rates of about 88 percent of total waste generated. Overall, about 29.7 million tons of wood products were used in 1998 for new residential construction. Wood waste was therefore about 11 percent of all wood used to build residential structures. Conventional wisdom is that about five to 15 percent waste can be expected in new construction. These waste estimates confirm this expectation.

Nearly $121 billion (billion = $10^9$) were spent on residential repair and remodeling in 1998 (Bureau of the Census 1999b). This level of activity required about 18.9 million tons of wood. Based on waste generation rates per unit of wood used for new residential construction adjusted to reflect higher levels of waste associated with repair and remodeling construction, approximately 4.3 million tons of waste wood were generated in 1998. Recoverability was estimated to be 2.8 million tons, or about 65 percent of that generated.

Expenditures for new nonresidential construction totaled $367 billion, and expenditures for nonresidential repair and remodeling were estimated to be an additional $128 billion in 1998 (Bureau of the Census 1994). These levels of construction used an estimated 6.6 million tons of wood products and generated nearly one million tons of waste wood, with about 900,000 tons available for recovery.

Overall, about 55.2 million tons of wood products were used for construction in the United States in 1998, resulting in the generation of nearly 8.7 million tons of waste wood (Table 1). Nearly 6.6 million tons (76 percent) of this waste were considered to be available for recovery. About 2.1 million tons of the generated waste wood was already being recovered or was not usable. During the 1990s total construction waste wood exhibited a somewhat downward trend, from 10.3 million tons in 1990 to 8.7 million tons in 1998. Waste wood available for recovery was somewhat more constant ranging from a high of 7.0 million tons in 1994 to a low of 6.3 million tons in 1995. These trends do not reflect changes in generation rates or recoverability but changes in the mix of construction activities conducted in a given year. Generation and recovery rates were based on weighted averages from case studies conducted during the

Since 1990, the estimated amount of wood available for recovery has fallen from 42.3 million to 29.6 million tons. Nearly all of this decline is from reductions in the disposal of wooden pallets and woody yard trimmings.

mid-1990s and were held constant during the estimation period.

### DEMOLITION WASTE DATA

Demolition waste is a heterogeneous mixture of building materials and other building related items 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. Estimates of demolition waste have been made over the years for specific localities. These estimates generally include new construction waste and are often based on the size of the resident population. (Urban areas tend to generate more C&D waste per capita than do suburban or rural areas.) In 1998, Franklin Associates under contract to the U.S. Environmental Protection Agency (1998) reviewed all relevant demolition waste case studies. Based on these studies, they estimated that 64.8 million tons of demolition waste were generated in 1996. This is equivalent to about 1.3 lb (0.6 kg) of demolition waste per person per day. Based on this rate and changing population, about 66 million tons of demolition waste were generated in 1998. Case studies examining the mix of materials entering C&D landfills indicated that, on average, about 40 percent of C&D waste was wood. Thus, about 26.4 million tons of demolition waste were generated in 1998 (Table 1).

Demolition waste recovery is difficult to determine. The characteristics of demolition waste and the varied demolition practices make it more difficult to recover and recycle than construction waste. Existing demolition waste recycling operations are very sensitive to contamination. Entire loads of demolition waste are typically rejected at the recycling facility if contaminated. Only about 15 percent of the wood by weight (38 percent by volume) received at one Massachusetts demolition waste recycling facility was usable (McElvenny 1995). These figures are for a specific operation that generate a single product and are based on primary crushing of the incoming demolition waste to achieve uniform material size. Differences in treatment technology, products manufactured, and source of demolition waste affect the utilization rate. Based on an assumed initial overall 30 percent recovery rate with steady improvement over time, approximately nine million tons of wood demolition waste was considered to be recoverable in 1998.

Trends in demolition waste generation during the 1990s are entirely based on the changing size of the nation's resident popu-

An estimated 65.8 million tons of wood residues and 24.5 million tons of bark were generated last year at primary timber processing mills in the United States.

lation because generation rates were on a per capita basis. This results in a slow but steady increase in demolition waste generation over time. New information that can be related to economic indicators such as gross national product or housing starts is needed to improve demolition waste estimates

Overall, about 35.1 million tons of C&D wood waste were generated in 1998 (Table 1). About 25 percent was from construction activities and 75 percent from demolition activities. Of this, about 15.5 million tons or 44 percent of the waste wood generated was considered to be of an acceptable size, quality, and condition to be potentially available for recovery. Approximately 42 percent of the recoverable waste wood was from construction. About 19.5 million tons of waste wood were already being recovered, combusted, or not usable. C&D waste wood generation averaged about 34.5 million tons/year during the 1990s, ranging from a low of 33.8 million tons in 1991 to a high of 35.1 million tons in 1998. Amounts of waste wood available for further recovery tended to increase slightly during the estimation period, due to slowly rising demolition waste recoverability.

### TIMBER MILL RESIDUES AND OTHER SOURCES

Primary timber processing mills in the United States generate large amounts of residues in the form of bark, sawmill slabs and edgings, sawdust, and peeler log cores. An estimated 24.5 million tons of bark and 65.8 million tons of wood residues were generated in 1998 (Table 1), based on mill residue production in 1996 and trends in industrial roundwood production (Howard 1999, Forest Service 1999). Nearly all mill residues were used to produce other products, primarily paper, nonstructural panels,

Once a disposal problem for producers and consumers alike, solid waste is increasingly playing a more important role in satisfying consumer demands for wood-based products.

and fuel. Just two percent of the bark (600,000 tons) and two percent of the wood residue (1.3 million tons) were not used. This unused residue (1.9 million tons) is considered to be available for further recovery. (Secondary timber processing mill residues are included in MSW. These mills include those manufacturing furniture, millwork, and pallets along with other manufacturers.)

Many other sources of waste wood exist. These include chemically treated wood from railroad ties, telephone and utility poles, and pier and dock timbers, and untreated wood from logging operations, chipped brush and limbs from utility right-of-way maintenance, and industrial waste wood outside the MSW stream. Some of this material is being reused, burned, or disposed of in hazardous waste landfills but much is being 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 residues) are fairly small compared with MSW, C&D waste, and mill residues.

For example, in 1996, approximately 13.6 million railroad ties were replaced (Railway Tie Association 1997). These ties weighed approximately 0.8 million tons, and if half of this wood were sound, about 0.4 million tons of wood would be recoverable. This is about 20 percent of the recoverable wood residue from primary timber processing mills, the smallest by far of the three major waste wood sources. Although wood from other sources may eventually become a valuable resource, it is not included here because of the smaller volumes or obstacles to recovery.

## SUMMARIZING THE DATA AND MARKET TRENDS

An estimated 162.4 million tons of waste wood were generated in the United States in 1998 from the municipal solid waste (MSW) stream, construction and demolition (C&D) activities, and primary timber processing mill operations. Much of this was used to produce new products, used for fuel, or was not suitable for recovery. Of the total amount generated, 29.6 million tons (about 18 percent) were suitable for additional recovery. In comparison, an estimated 225 million tons of products were made from industrial roundwood in 1998. Recoverable waste wood was therefore equivalent to about 13 percent of all timber products produced.

Overall, about 41 percent of the recoverable waste wood was from MSW, 53 percent from C&D waste, and just six percent from primary timber processing mill residues. Since 1990, the estimated amount of wood available for recovery has fallen from 42.3 million to 29.6 million tons. Nearly all of this decline is from reductions in the disposal of wooden pallets and woody yard trimmings. The rate of decline in these two categories is already beginning to slow, and large future declines are not expected.

Although many advances in waste wood collection, processing and utilization are being made, many more technical and economic obstacles need to be overcome before much of the recoverable waste wood can be recycled. Waste wood is finding limited niche markets for furniture and other consumer goods, is beginning to be used to supplement traditional sources of furnish by several nonstructural panel manufacturers, and is being used to produce both garden and hydro mulch products.

Perhaps one of the more important recycling success stories is the rapid growth in wooden pallet recycling. Prior to 1990, most wooden pallets were destined for the landfill or boiler after only a few trips. These pallets are now being repaired and recycled at increasing rates. About one-third of all pallets produced annually are now made from recycled pallet parts. Solid wood waste, once a disposal problem for producers and consumers alike, is now a valuable resource and is increasingly playing a more important role in satisfying consumer demands for wood-based products. ■

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