
Estimates of Paper and Wood Recovery for Recycling and Potential for Additional Recovery in the United States

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Abstract

Quantities of paper and wood recovered for recycling in the United States were estimated for 1994, based on production and end-use data. The estimates included quantities recovered for recycling into new paper and paperboard products, exports of recovered paper, and quantities of paper and wood materials recovered and recycled into other products, including cellulose insulation, molded pulp products, fiberboard products, wooden pallets, animal bedding, mulch, particleboard, hardboard, reclaimed lumber, flooring, roof systems, siding, plastic lumber, and other composite products. Additional quantities of paper and wood that could be recovered annually were also estimated for 1993, based on maximum potential recovery from municipal solid waste, new construction and demolition debris, and primary timber processing. Current and potential recovery estimates indicate that wood and wood fiber recycling technology could exploit a large resource base if efficient technology is developed to fully utilize this resource.

Introduction

Based on material consumption and end-use data, we estimated quantities of paper and wood materials

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recovered for recycling in the United States for 1994. Principal categories of commercial uses were identified and relative quantities were compared. We identified some innovative or novel commercial product developments. Additional recovery potential from municipal solid waste, construction and demolition debris, primary timber processing residues, and other sources were also identified. We provided figures and tables with data to compare relative magnitudes of recycling among all categories of uses and potential additional recovery quantities.

Paper and wood recovery

Paper and paperboard

The largest single use for recycled wood fiber in the United States has remained paper and paperboard. By 1994 more than 470 individual pulp, paper, and paperboard production facilities, consumed 28 million metric tonnes of recovered paper in the production of paper, paperboard, and related products in the United States (3). The average utilization rate for recovered paper for the entire industry in 1994 was about 34 percent (2). This was a gain of 7 percentage points since 1990, with more than 8 million tonnes of added recovered paper consumption in just the last 4 years. In addition to domestic consumption, 7 million metric tonnes of recovered paper were exported in 1994 for recycling in other countries. Thus, in 1994, 35 million metric tonnes of paper and paperboard were recovered in the United States for use in production of recycled paper and paperboard products, representing by far the

largest single element of all wood and wood fiber recovered for recycling in the United States (about 95% of the total quantity).

In 1994, growing demand for recovered paper finally caught up with growth in supply. During the year, recovered paper prices increased substantially in the United States, abruptly ending the so-called "glut" in wastepaper markets that had prevailed in the early 1990s. By late 1994, real prices for most recovered paper commodities had returned to the high end of their long-run historical range, and prices continued to increase in 1995. Boosted by record product demands in domestic and global markets and higher prices for most paper and paperboard products, producers in the United States were able to maintain higher rates of recycling despite increased recovered paper prices. We anticipate that growth in paper recycling will likely be slower in the late 1990s than it has been in recent years, as greater recovered paper prices may tend to reduce incentives for investment in new recycling capacity.

Insulation and related products

The cellulose insulation industry was estimated to be the second largest recycler of wood fiber in the United States in 1994, using mainly recovered paper as raw material. Cellulose insulation consisted chiefly of pulverized or fiberized paper, treated with the retardants (inexpensive inorganic chemicals such as borax). Cellulose insulation was produced mainly as a dry bulk product. It was used as a loose fill for insulation of attics and walls, where it was usually poured or blown into place. It was also sometimes mixed with water and adhesives for application as a wet spray. Cellulose insulation constitutes only a small fraction of the entire building insulation market in the United States, holding a market share of about 4 percent according to recent industry estimates (5). The building insulation market in the United States has been dominated by fiberglass insulation and plastic foam panel products for many years.

The number of cellulose insulation producers has declined from a peak in the late 1970s. By 1995, there were reportedly 55 separate producers of cellulose insulation (9) with about 70 plants operating in the United States, using primarily old newspapers and other recycled paper as raw material (6). Average plant output was around 7,000 tonnes per year. More than twice as many plants had been in operation 10 years earlier. In 1994, estimated annual production of the entire industry was about 500,000 metric tonnes (6).

Molded pulp products

The molded pulp products industry was estimated to be the third largest recycler of wood or wood fiber in the United States. There were reportedly 13 producers of molded pulp products in the United States by the early 1990s, with annual consumption of recovered paper estimated at upwards of 300,000 metric tonnes (5). Molded pulp products were used primarily in packaging (protective packaging in shipping containers, food packaging, such as food service trays, and egg cartons), horticulture (plant pots), and furniture. However, the large protective packaging market has long been dominated by polystyrene and other plastic foam packaging materials.

Fiberboard products

The fiberboard products industry was estimated to be the fourth largest consumer of recycled wood fiber in the United States. Several producers of fiberboard products were reportedly using recycled wood fiber exclusively in 1995 (9). Two large producers reportedly used recycled paper, both producers had manufactured fiberboard products from recycled paper for many decades at production facilities located in the Northeast. Another producer located in the Pacific Northwest was reportedly using waste wood diverted from landfills. Several other fiberboard producers reportedly used smaller proportions of recycled paper as fiber input (typically 10% to 30%; the remainder of fiber inputs derived from virgin wood fiber via defibrated or groundwood pulping processes). Fiberboard products have been used traditionally for subflooring, light sheathing, structures for deadening noise, insulating, and other applications. One furniture manufacturer also introduced a line of children's chairs fabricated from fiberboard made with 100 percent recycled paper.

Acoustical ceiling panels were another category of fiberboard product that was reportedly manufactured in part from recycled paper. Such products have been used for many years, mainly as a component of suspended ceiling systems designed to provide acoustical insulation. In 1995, two major U.S. producers reportedly used varying amounts of recycled paper, ranging from 20 to 90 percent of fiber input depending on market availability and type of product being produced (9).

Wood fiber strips for concrete expansion joints were another type of wood fiber product that has been used for many years in the United States. In 1995, two large U.S. producers of fiberboard prod-

ucts were reportedly using some recycled wood fiber in production of fiber strips for concrete expansion joints (9).

Several producers were also reportedly manufacturing rigid composite fiberboard panel products with inorganic minerals, such as perlite or portland cement, using varying proportions of cellulose fiber from recycled paper (2% to 35%). Such panels were used as fire barriers or fire protection board (e.g., in fire doors), and also as subflooring for ceramic tile floors, and for roofing systems (9).

In addition to traditional fiberboard products, by 1995 there were several producers of less traditional lightweight fiberboard panels reportedly made from recycled paper. These included two producers of lightweight honeycomb or molded hollow core fiber panels (e.g., "spaceboard" concept) made from recycled paper. These panels were designed for use as veneer cores for lightweight doors and furniture, or for portable walls and partitions, or pallet slips. The quantity of material used in these products was quite small relative to other fiberboard products (< 1%).

Precise data on tonnage of recovered paper consumed in fiberboard and related products were not available. A review of reported mill capacities for all producers of fiberboard and medium density fiberboard (MDF) in the United States suggested that the annual consumption of recovered paper in fiberboard and MDF production was probably around 275,000 metric tonnes in 1994.

Wooden pallets and containers

According to recent studies at Virginia Polytechnic Institute (VPI), the wood pallet and container industry recovered the equivalent of 15 percent of annual pallet production for repair or recycling into pallets or other uses (7). With use of wood in pallets and containers at roughly 10 million metric tonnes in 1994, the tonnage of wood recovered in pallets was estimated to be approximately 1.5 million metric tonnes. It was noted in the VPI study that pallet recovery was increasing by about 20 percent per year, and use of ground pallet material for particleboard, hardboard, and mulch was also increasing.

Pallets that were simply inspected or repaired and reused might not technically be "recycled," inasmuch as they were not used to produce new products. Also, the term "recycled" would not apply to wood used as fuel, landfilled, or composted. In addition, in the report by Bush et al. (7), the quantities of wood used for particleboard, hardboard, and molded pulp products were accounted for separately

in this report under those product categories. Thus, considering only the quantities of pallets that were actually disassembled for recycling of lumber, along with quantities used for mulch and plant bedding, it was estimated that perhaps 250,000 metric tonnes of pallet wood was recycled into pallets and mulch in 1994.

Animal bedding

The use of shredded paper (chiefly old newspapers) for animal bedding has become increasingly popular in the United States since the early 1980s. Paper bedding has been found to be most useful for dairy cows, particularly in northern regions where it could provide additional insulation in winter months. Precise national data on consumption were not available, but an estimate of roughly 100,000 tonnes was made for the United States in 1991 based on available state and local data (5).

Cellulose mulch

By 1995, 24 U.S. manufacturers produced cellulose mulch and ground cover products, used mainly for soil protection, erosion and moisture control in lawn seeding, and landscaping applications (9). Cellulose mulch was primarily made from old newspapers, telephone books, and other grades of wastepaper. Most producers were small business enterprises. One producer in the Northeast reportedly used recycled wood (e.g., demolition waste and used pallets, etc.) in addition to recycled paper. In application, mulch is often mixed with grass seed and water, and sprayed with a water cannon in a process called "hydromulchmg." Precise national data were not available on the tonnage of recycled wood or paper used in cellulose mulch, but an estimate of nearly 100,000 tonnes was made in the early 1990s (5).

Particleboard and hardboard

One major U.S. producer of particleboard was reportedly using recycled wood by 1995. Located in the Pacific Northwest, this producer used wood recovered from used wooden pallets for a fraction of wood raw material requirements (reportedly up to 20%). In addition, one U.S. producer of hardboard in the Pacific Northwest also reportedly used recycled wood recovered from pallets, crates, and demolition waste, for approximately 50 to 7.5 percent of wood input requirements. However, in the United States, most of the wood raw material for particleboard and hardboard has generally consisted of virgin wood fiber (chiefly wood residues from sawmills and plywood mills along with smaller amounts of round-

wood). Assuming that roughly 1 percent of wood products of particleboard and hardboard were recycled wood in 1994, the annual tonnage recycled would be approximately 50,000 tonnes.

Reclaimed lumber and flooring

By 1995, the Hams Directory (9) reported that 26 producers of reclaimed lumber and 18 producers of reclaimed wood flooring were operating in the United States. All were generally small business enterprises, established since the early 1970s. They used wood salvaged from various sources, chiefly from old wooden structures, old factories and mills, and abandoned railroad cars, along with wood salvaged from sources, such as riverbeds, docks, farm buildings, used pallets, shipping crates, and wine vats.

Producers of reclaimed lumber and flooring were dispersed geographically across the United States. The products consisted of various species ranging from hardwoods to softwoods. Data were not available on total production or consumption of recycled lumber and flooring in 1994, but the quantity was thought to be less than 50,000 tonnes (assuming that the average producer had the capacity of a small sawmill).

By 1995, at least four producers made furniture exclusively with reclaimed or recycled wood, using wood from old buildings, pallets, shipping crates, and other salvage sources (9). Some salvage firms also specialized in reclaiming unique artifacts, such as old fireplace mantles from demolition sites.

Roof systems and siding

At least eight producers of roof shingles, roof tiles, and siding products were using varying proportions of recycled wood fiber to produce composite products in 1995 (9). Four producers of asphalt roof shingles were using dry felt paper fiber in their products in 1995, although most leading producers of roof shingles had shifted to using fiberglass instead of paper fiber. In addition, some newer types of wood fiber and inorganic composite roofing and siding products were being produced in 1995. Four producers reportedly made composite roof tiles, shakes, or siding products using wood fiber and portland cement or diatomaceous earth (9). Three of those producers used recycled paper, with ratios of 10 to 20 percent recycled fiber in the finished products. The fourth producer used wood residues, in a ratio of 33 percent. The inorganic composite siding products occupied only a small share of the siding market in 1995, a market dominated by other

forms of siding, such as vinyl siding, vinyl clad siding, and wood panel siding.

Plastic lumber and panels

In addition to reclaimed lumber (consisting of solid wood), by 1995 there were 40 producers of recycled plastic lumber and posts in the United States (9). Recycled plastic lumber was made primarily with an extrusion molding process and most producers used recycled plastic as the only raw material. However, two producers reportedly made a composite product using up to 50 percent wood residues combined with plastic, and at least two others made a plastic and fiberglass composite. At least one producer made an extruded composite material for door and window fabrications, using 50 percent recycled plastic and 50 percent industrial wood residues.

Most plastic lumber producers were relatively small enterprises serving specialized markets. All were established since the early 1970s, and most since the early 1980s. The output of the average producer was just a fraction of the output of a large conventional sawmill, for example. A common application for plastic lumber was in waterfront docks, piers, and decking, where it substituted for conventional treated lumber. In addition, several dozen producers made outdoor furnishings from plastic lumber-type materials, including items such as benches and picnic tables (9). Recycled plastic was used as the only raw material in most cases. However, in several cases a composite of 50 percent recycled wood and recycled plastic was used in outdoor furnishings.

In addition to plastic lumber and related products, there were 15 producers of recycled plastic panels in the United States by 1995. Panels were produced in dimensions similar or identical to those of conventional nonstructural wood panels (e.g., like hardboard panels), and in some cases they were marketed for similar applications (e.g., sheathing and subflooring). Variations in color, thickness, and density allowed for different applications by plastic fabricators. Only one producer reportedly had developed a composite wood and plastic panel product, using 50 percent wood residues and recycled plastic. As with producers of plastic lumber, the average output of recycled plastic panel producers was relatively small; most were small business enterprises established since the early 1980s.

The total quantity of recycled wood used in plastic lumber and panels was estimated to be very small or

negligible, as the few producers who were actually using wood in composites were reportedly using wood residues (virgin wood fiber) rather than recycled or reclaimed wood.

Other recycled products using wood

Several other miscellaneous construction products were produced in the United States in 1995 using recycled wood or wood fiber. One producer of permanent concrete form work produced a permanent type of wall system using a composite of reinforced concrete and reclaimed wood fiber. The structural components of the wall system reportedly contained 85 to 90 percent reclaimed wood fiber, filled with concrete and reinforced with rebars (9). This composite wall was designed with good insulative and load-bearing properties. Similar products have been manufactured in Europe for decades.

Another novel category of recycled product was a molded resin composite that resembled quarry stone but contained recycled wood fiber. One producer has manufactured molded stone composites since 1989 using recycled fiber (9). The product was designed to simulate quarry stone and is a composite of 15 percent recycled paper, gypsum, resin, and natural coloring compounds. This product could be cut with an ordinary saw and installed with nails or glue. The product has been used for wall veneer systems and decorative interior moldings. Another producer intended to start production of a granite-like resin composite in 1995 that would contain up to 40 percent recycled fiber.

Various recycled paper and paperboard products were also used in construction products in 1995, chiefly gypsum wallboard panels and roofing felts. Gypsum wallboard panels were made principally from solid natural or synthetic gypsum (obtained by concentration of fly ash from power boilers), surfaced with 100 percent recycled paperboard. One producer also made a more novel type of gypsum wallboard that was a rigid composite of blended gypsum and cellulose fibers from recycled old newspapers (15% cellulose fiber). Except for the latter product, paper industry data for recycled paperboard have subsumed data on the recycled fiber used in gypsum wallboard facing. Likewise, paper industry data on construction paper and board production have subsumed data on roofing felts and other construction paper and board.

Summary of recovery and use in 1994

Table 1 shows all estimated quantities of wood and wood fiber materials recovered and recycled among principal uses in the United States in 1994. In summary, it was estimated that approximately 37 million metric tonnes of paper and wood materials were recovered annually in the United States for use in recycled products, of which roughly 99 percent was recovered paper and about 1 percent was recycled solid wood. The bulk of these recycled materials, about 95 percent, was used to produce recycled paper products, four-fifths of the materials was recycled in the United States, and one-fifth was exported for recycling in other countries.

Figure 1 illustrates the relative magnitudes of the various uses for comparison. The paper and paperboard sector, including exports, was by far the leading category in total tonnage. As discussed, several innovative commercial products have appeared in recent years, including various composite products using wood and inorganic materials or wood and plastics. However, the actual quantity of wood or wood fiber recycled in such products in 1994 was estimated to be relatively small.

Potential recovery

In addition to paper and wood materials already being recovered for use in recycled products, quantities of wastepaper and wood waste remained unrecovered in the United States. Although much of this material was low quality or perhaps unrecoverable, some could be potentially recovered and used in recycled products.

TABLE 1.-Estimated quantities of wood and wood fiber materials recovered for recycling among all principal use categories in the United States, 1994.

Use category	Approximate quantity recycled (metric tonnes)
Paper and paperboard	28,100,000 (Paper)
Recovered paper export	7,000,000 (Paper)
Insulation and related	500,000 (Mostly paper)
Molded pulp products	300,000 (Mostly paper)
Fiberboard products	275,000 (Mostly paper)
Wooden pallets	250,000 (Wood)
Animal bedding	100,000 (Paper)
Mulch	100,000 (Paper)
Particleboard, hardboard	50,000 ^a (Wood)
Reclaimed lumber	50,000 ^a (Wood)
Roof systems, siding	50,000 ^a (Paper)
Plastic lumber, other	10,000 ^a (Wood)

^a These figures are educated guesses and not based on survey data.

Three principal sources offered significant potential for additional recovery of paper and waste wood: municipal solid waste, new construction and demolition waste, and wood residues from primary timber processing facilities. Total quantities of waste generated, disposal burdens following recovery for recycling and composting, and maximum amounts potentially recoverable were evaluated for each source. Wood waste from other smaller sources was identified, but these sources are not included in this analysis.

Municipal solid waste

Municipal solid waste is waste from residential, commercial, institutional, and industrial sources. It includes discarded durable goods, nondurable goods, containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic waste. Figure 2 illustrates estimated proportions of various types of materials generated in municipal solid waste within the United States in 1993 (8). Municipal solid waste typically includes things such things as discarded packaging, appliances, automobile tires, newspapers, clothing, boxes, disposable food service items, office and classroom paper, wooden pallets, and cafeteria waste. However, it does not include waste from certain other sources, such as new construction and demolition waste, automobile bodies, municipal sludges, combustion ash, sewage waste, and industrial process wastes that may or may not be discarded in municipal waste landfills or incinerators.

An estimated 188 million metric tonnes of municipal solid waste were generated in the United States in 1993 (8). Except for brief periods of economic recession, quantities have increased steadily in recent decades, rising from 80 million tonnes in

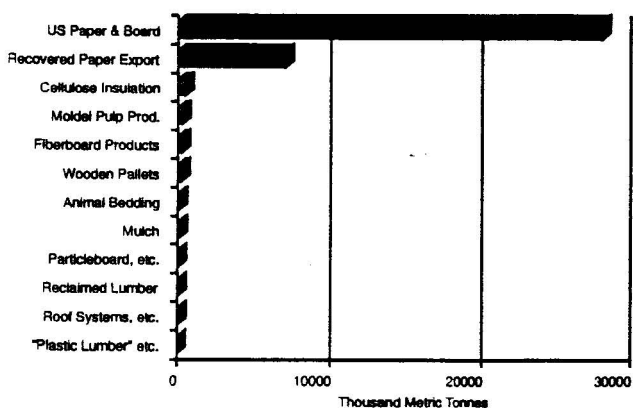


FIGURE 1. -Quantities of wood and wood fiber materials recovered for recycling among principal uses in the United States, 1994.

1960. Between 1960 and 1990, quantities increased at an average annual rate of 2.8 percent per year. However, since 1990, the rate of increase has been just 1.5 percent per year. Projections indicate that the quantities of municipal solid waste generated annually in the United States will approach 200 million metric tonnes by the year 2000. This would represent an average annual increase of just 0.7 percent per year from 1993 to 2000. Thus, although total municipal solid waste is increasing, it appears to be increasing at a declining rate, and it is expected to continue to do so in the near future.

A wide variety of wood and wood fiber materials was included in estimated municipal solid waste quantities, including significant quantities of waste-paper, wood waste, and yard trimmings (which include some wood). These materials are the main elements of municipal solid waste that provide a potential resource for additional recovery of wood or wood fiber for commercial uses. Wood waste includes such items as wooden furniture and cabinets, pallets and containers, scrap lumber and panels from other than new construction or demolition activities, wood waste from manufacturing facilities, and a variety of other miscellaneous products. The wood waste category of municipal solid waste does not include roundwood or unprocessed timber. However, yard trimmings do include tree trimmings and removals, as well as leaves, grass clippings, and brush.

Wastepaper.—In the United States, wastepaper has long remained the largest single component of material generated in municipal solid waste. In 1993, 71 million metric tonnes of wastepaper represented about 38 percent of all municipal solid waste generated in the United States (8). It was estimated that a gross disposal burden of nearly 47 million metric tonnes of wastepaper remained in 1993, after recovery for recycling and composting. Most of this

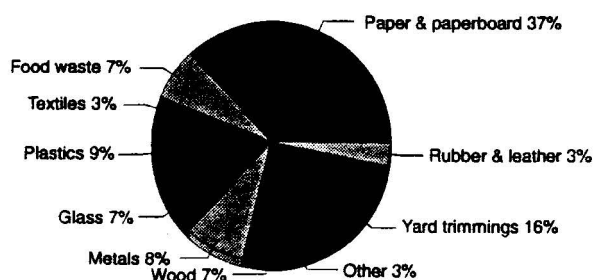


FIGURE 2. -Municipal solid waste generated in the United States, by-weight, 1993.

wastepaper was destined for disposal by landfilling, combustion, or other means.

Of the wastepaper destined for disposal, we assumed that the maximum additional recovery potential for recycling was about 28 million tonnes in 1993 (i.e., 60% of the 47 million tonne disposal burden). Note that much of this material may be very low quality (e.g., contaminated with food or industrial wastes, or mixed with other waste materials) such that it may be very costly or difficult to recycle into commercial products that are safe and acceptable to consumers. The 60 percent assumption was therefore only an approximation, based on recognition that at least 20 percent of all municipal solid waste disposal volume was incinerated, and additional quantities would remain unrecoverable even under more favorable economic circumstances.

Yard Trimmings. — Yard trimmings were the second largest material component of municipal solid waste, with 30 million tonnes generated in 1993, representing about 16 percent of all municipal solid waste (8). Approximately 6 million tonnes of yard trimmings were recovered for recycling or composting, leaving a burden of about 24 million tonnes for disposal by landfilling, incineration, or other means. A recently completed report on urban tree residues (13) estimated that in 1993, 95 percent of all urban tree and landscape residues were wood residues, by volume, and 5 percent were leaf and grass clipping residues. This suggests that the disposal burden for woody residues alone amounted to roughly 23 million tonnes in 1993. Assuming, as for paper and paperboard, that about 60 percent of this disposal burden could be available for recycling, the potential for recovery of woody residues from yard trimmings in municipal solid waste was roughly 14 million tonnes in 1993.

It should be noted, however, that three-fourths of this material was estimated to be in the form of chips, which were often commingled with twigs and leafy materials from tree trimmings, and the remainder was in the form of randomly sized tree trunks and limbs (13). Such material was generally undifferentiated by tree species and was not graded or harvested according to any standard logging practices. Thus, at best, the wood in yard trimmings might be similar in quality to whole-tree chips, which have been used conventionally for fuel in the pulp and paper industry. Some would likely be much lower quality, mixed with twigs, leaves, grass clippings, dirt, or other debris. Thus, yard trimmings from municipal solid waste would be inferior in

quality to conventional pulpwood chips, and certainly much lower in quality and uniformity than most timber harvested commercially for industrial uses.

Wood Waste. — It was estimated that a total of 12.4 million metric tonnes of wood waste in municipal solid waste were generated in the United States (nearly 7% of all MSW in 1993). Of this total, 1.2 million tonnes were reportedly composted or recovered for recycling, leaving a burden of 11.2 million tonnes for disposal by landfilling, incineration, or other means. Assuming, as for paper and paperboard, that about 60 percent of this disposal burden was potentially recoverable for recycling, it was estimated that the annual recovery potential for wood waste from municipal solid waste was about 7 million tonnes in 1993.

New construction and demolition waste

In the United States, new construction and demolition waste originates from two distinctly different sources, with different characteristics and different potential for separation and recycling. Wood wastes from new construction originate principally from the construction of 1) new single-family and multifamily houses and 2) new nonresidential building and construction sites. Wood wastes that originate at new nonresidential building and construction sites are generated in smaller amounts compared with construction at new single-family and multifamily houses. Demolition wastes originate at any site where a building or other structure is being demolished.

Wood waste from new construction tends to be much cleaner than demolition waste and is more uniformly derived from contemporary wood products. Demolition waste contains wood that is usually contaminated with other materials such as paints, nails, fasteners, wall covering materials, and insulation, and typically contains a more diverse mix of materials, including old wood and unconventional materials. New construction waste can be separated on the job site with a small amount of additional effort by the builder; however, source separation of waste at a demolition site is usually more costly and less efficient. Conventional demolition practices in the United States would have to be radically altered to achieve efficient source separation. For these reasons, new construction waste and demolition waste were evaluated separately.

New construction waste. — Statistical information on types and amounts of waste generated in new construction in the United States was sketchy, lim-

ited to anecdotal information or a few local case studies. However, since nearly all single-family and low-rise multifamily residential structures built in the United States in recent decades have used traditional wood-frame building technology, information on this type of construction was used to extrapolate local data to national estimates of wood waste generated in new construction.

Specific waste generation rates were obtained from a recent case study that was conducted in the Portland, Oregon, metropolitan area (10). These rates were applied to the total floor area of each type of structure built in the United States in 1993 to develop estimates of total wood waste generated in new residential construction. According to the Portland data, waste wood represented 10 percent of the wood used in new residential construction. Total waste estimates were adjusted to provide estimates for new nonresidential construction and for residential repair and remodeling.

In 1993, 1.13 million new single-family houses were built in the United States, with an average floor area of 195 square meters. Also 153,000 multifamily living units were built in 1993, which averaged nearly 100 square meters of floor area per unit (17). Total wood products used in new residential construction was estimated to be 27.1 million tonnes (4,12). Applying the 10 percent waste factor from the Portland study, it was estimated that 2.7 million tonnes of wood wastes were generated in new residential construction in 1993.

Residential repair and remodeling activities typically use the same types of materials and construction techniques as new single-family residential construction. Total wood products use in residential repair and remodeling was estimated to be 25.8 million tonnes (11,18), just slightly less than new residential construction. Thus, based on the 10 percent figure for new residential construction, it was estimated that 2.6 million tonnes of wood waste were generated in 1993 by residential repair and remodeling activities.

Estimates for wood products used in new nonresidential construction in 1986 (14) were the basis for estimates for 1993. New nonresidential construction in 1993 was estimated to use about 8.6 million metric tonnes of wood products, or about one-third of the amount required for new residential construction. Low-rise, light-frame nonresidential buildings, such as stores and office buildings, typically use wood products and construction techniques similar to new residential construction; therefore, the waste gen-

eration rates would probably be similar. However, a large share of nonresidential construction consists of larger nonresidential building projects, such as warehouses, factories, high-rise buildings, public buildings, as well as highways, which typically do not use wood as their primary construction material, or use building techniques that are very different from residential construction. Information needed to accurately estimate waste generation in nonresidential construction was not unavailable. However, lacking empirical data, it was assumed that waste generation rates in nonresidential construction were similar to those of residential construction.

It was estimated that wastes generated in all new construction in the United States in 1993 (new single-family and multifamily residential, residential repair and remodeling, and new nonresidential) included 6.1 million tonnes of wood and roughly 0.2 million tonnes of paper and paperboard. Based on data from the new residential construction study in Portland, approximately 88 percent of this material would be potentially recyclable, or 5.4 million tonnes. Using these estimates, new construction in the United States generated a disposal burden amounting to roughly 6 million tonnes of wood waste in 1993, with a recovery potential for recycling of roughly 5 million tonnes of wood.

Demolition waste.—Demolition waste is the heterogeneous mixture of waste materials generated by demolishing buildings or other structures. It typically contains aggregate stone and brick, concrete, wood, paper, metal, insulation, glass, and other contemporary building materials. Depending on the age and type of structure, demolition waste it may also contain hazardous materials, such as asbestos, lead-based paints and finishes, mercury, PCBs, or other contaminants. The amount of demolition waste generated in the United States has been estimated over the years, usually for specific localities. The estimates also typically include construction waste, since in many cases buildings are demolished and replaced by new construction resulting in commingling of demolition and construction waste. Also, available estimates have been correlated to local population density. In general, urban areas tend to generate more construction and demolition waste per capita than suburban or rural areas. The construction and demolition generation rates from the New York Solid Waste Management Board for 1991 (16) were used to estimate demolition waste quantities for the entire United States in 1993.

Based on the New York data, we estimated total construction and demolition waste quantities for the United States by extrapolating waste generation rates across resident population estimates by community size in the United States in 1993. Amounts of new construction waste (estimated above) were then subtracted from total C&D waste, resulting in an estimate of demolition waste generated in the United States in 1993. Data from a demolition waste composition study (16) were then used to estimate proportions of waste wood and paper and paperboard in the demolition waste. This resulted in estimates of 23 million tonnes of wood and 0.3 million tonnes of paper and paperboard generated in demolition waste in the United States in 1993.

The potential for recovery of wood from demolition waste was difficult to estimate, lacking broad economic experience or data on which to base our estimates. However, factors such as poor physical characteristics, heterogeneous sourcing, and contamination of wood in demolition waste would certainly make recovery and recycling of this material more difficult than wood in construction waste, for example. Therefore, it was assumed that only about one-third of the wood materials in demolition debris could be recovered for recycling, and none of the paper and paperboard would be recovered for recycling. Thus, it was estimated that approximately 7 million tonnes of wood materials in demolition waste had the potential to be recovered for recycling in 1993.

Primary timber processing mill residues

Primary timber processing facilities (e.g., sawmills and plywood mills) in the United States generate large quantities of wood residues in the form of bark, chips, sawmill slabs and edgings, sawdust, and peeler log cores. In 1991, it was estimated that 26 million tonnes of bark and 74.5 million tonnes of wood residues were generated by primary timber processing facilities in the United States (15). However, most of these wood residues were already being used as fuel or as fiber raw material to produce other products, primarily pulp and paper products. In 1991, only 6 percent of the wood residues and 5 percent of the bark residues were not being used, creating a disposal burden of only 4.3 million tonnes of wood waste and 1.4 million tonnes of bark waste.

The proximity of the unused residue supplies to production facilities that could use the material was a major obstacle limiting its use. Much of the unused wood residue was generated in remote rural saw-

mills, such as the Intermountain West. Unused bark residue, although potentially valuable as a fuel or as a mulch-type material, has generally low utility for wood-based products. Since U.S. lumber and plywood production quantity changed little between 1991 and 1993, we used the 1991 mill residue data as an approximation of residue quantities available in 1993. Potentially, all wood and bark wastes were recoverable as raw material for wood products, but it must be recognized that transportation logistics and costs would limit additional recovery of this material.

Other sources

In 1993, there were various other sources of wood waste and wastepaper in the U.S. economy. These included wood that was chemically treated with preservatives, such as old railroad crossties, switch ties, bridge timbers, telephone poles, utility poles, pier timbers, and dock timbers. Chemical treatments and costs of collection make recovery and utilization of this material very difficult. Much was simply left on site. Other sources of wood waste included trees, brush and limbs pruned during maintenance of utility right-of-ways, industrial wood waste and waste paper that was generated outside the municipal solid waste stream, and logging residues left in the woods. Some of this material was being recovered and used, some was being burned, and some of it was being landfilled.

The total amount of wood plus paper and paperboard available from these other sources (except logging residues) was fairly small compared to the major sources of material discussed previously. For example, a total of 12.3 million railroad crossties were replaced in 1993, representing an estimated volume of 1.2 million cubic meters. Replacement ties were all chemically treated wood. Wooden bridge and switch tie replacement added an additional 0.1 million cubic meters. The combined total was equivalent to 0.8 million metric tonnes. Generously assuming that half of the original ties were sound enough to be recovered for recycling into some kind of product, only about 0.4 million tonnes of wood would have been available for recycling from all railroad tie replacements in the United States in 1993. Although wood from such sources may become more useful in the future, we did not include it in our estimates because of relatively small quantities and difficulty of recycling.

TABLE 2.—Annual disposal of wood and waste-paper materials derived from principal waste sources in the United States in 1993 (after recovery for raw material, recycling, or composting), and recovery potential for recycling or raw material use (beyond conventional energy recovery).

Material	Waste wood		Wastepaper	
	Disposal burden	Recovery potential	Disposal burden	Recover potential
	----- (million metric tonnes) -----			
Municipal solid waste	34	21	47	28
New construction	6	5	0.2	(negligible)
Demolition	23	7	0.3	(negligible)
Primary timber	4.3 (wood)	4.3 (wood)	--	--
Processing	1.4 (bark)	1.4 (bark)		
Total	69	39	47.5	28

Summary of disposal burden and potential for recovery potential

Table 2 summarizes estimated wood waste and wastepaper disposal burdens from municipal solid waste, new construction and demolition waste, and primary wood processing facilities. The table also summarizes estimated recovery potential for recycling and raw material use beyond the quantities already recovered for wood raw material, recycling, composting, or energy. Figure 3 shows relative magnitudes of potentially recoverable materials from these sources in 1993.

We emphasize that although large quantities were estimated to be potentially recoverable, many factors would affect economic availability and commercial utility of these materials. Those factors would include physical quality and condition of the materials, commingling of wastepaper and wood wastes with other types of waste, mixing of wood species and types, contamination of waste materials, physical location of the materials, lack of grading standards for wood wastes, lack of uniformity, costs associated with acquiring, transporting, processing the materials into a recyclable raw materials, product quality standards, and other considerations. Thus, the estimates of potential for recovery estimates should be regarded only as upper bounds or maximum recovery potentials for recycling and not as quantities that might actually have been used efficiently or economically.

Concluding remarks

About 37 million metric tonnes of paper and wood materials were recovered in the United States for recycling into new products in 1994, according to available production and end use data. About 95 percent of this material was used to make recycled paper products: four-fifths used in the United States and one-fifth exported to other countries for that

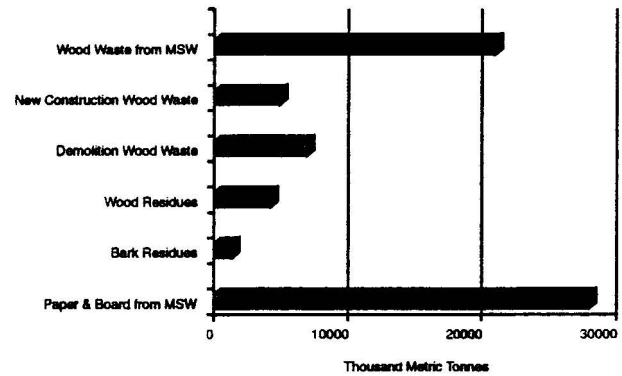


FIGURE 3.—Quantities of wood and wood fiber materials potentially recoverable for recycling from principal waste sources in the United States, 1993.

purpose. Much of the remainder was recovered paper used for other purposes, such as cellulose insulation, molded pulp products, and fiberboard. Only about 1 percent of total recovery was solid wood, mostly consisting of recycled wooden pallets.

Although more than 36 million tonnes of paper products and less than 1 million tonnes of solid wood materials were being recovered for recycling annually in the United States in 1994, there was a substantial additional potential for recovery, particularly for wood, but also for paper. Although demand caught up with supply in recovered paper markets during 1994, potentially recoverable volumes of wood remained vastly in excess of current demands for such material. The additional potential for recovery potential of solid wood materials for recycling was estimated to be roughly 39 million tonnes annually from municipal solid waste, new construction and demolition wastes, and primary timber processing facilities, based on data for the year 1993. Additional potential for recovery potential of paper from MSW was estimated to be around 28 million tonnes annually in 1993.

Additional potential for recovery of wood and wood fiber materials for recycling in the United States, totaling 67 million tonnes in 1993, was considerably greater than actual recovery of such materials (e.g., 37 million tonnes by 1994). We emphasize, however, that much of the unrecovered material was low quality, lacking in uniformity, difficult to recover, commingled with other wastes and contaminants, and therefore difficult to utilize in commercial product applications, especially material from sources such as demolition debris and yard wastes. Nevertheless, we estimated combined recovery potential, including current recovery and additional potential, was estimated to be more than 100 million tonnes annually. This combined figure is roughly equivalent to half the total annual U.S. timber harvest, suggesting that wood and wood fiber recycling technology could substantially extend the wood and wood fiber resource base if more efficient recycling technology could be developed to fully utilize this resource.

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