Materials Characterization Paper
In Support of the
Advanced Notice of Proposed Rulemaking –
Identification of Nonhazardous Materials That Are Solid Waste

Construction and Demolition Materials – Building-Related C&D Materials

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1. Definition of Building-Related Construction and Demolition Materials

Building-related construction debris and demolition (C&D) materials are commonly grouped as a single type of material, despite the fact that these two material streams come from different processes.[1] Construction materials originate from construction, repair or remodeling activities. This materials stream typically consists of a variety of building products (such as concrete, roofing, gypsum wallboard, wood products, plastics, insulation, tile, and metal) as well as the packaging materials that building materials arrive in (such as cardboard and plastics). Construction materials are usually generated as a result of cutting a material down to size for installation or purchasing materials in excess of what is needed. Wood materials consists of wood scraps from dimensional lumber, siding, laminates, flooring (potentially stained), laminated beams, and moldings (potentially painted). Demolition materials are generated from the dismantling of buildings or the removal phase of remodeling. Typical constituents include concrete, wood, metal, insulation, glass, carpet, and other building materials. Debris from this process is often painted or chemically treated or is fastened to other materials, making separation difficult (NESCAUM 2006). For the purposes of this summary, wooden railroad crossties and wooden utility poles are also characterized as demolition materials.

This summary of C&D debris focuses largely on the scrap wood generated from construction and demolition activities, as this is the main C&D constituent beneficially used as a fuel. EPA has also expressed interest in obtaining information on the beneficial use of C&D plastics and rubber, particularly fuel applications of these materials. The major plastic components of C&D materials (vinyl siding and PVC piping), however, can contain 57 percent chlorine (Commission of the European Communities, 2000). Information on the quantities of vinyl siding and PVC piping combusted in energy recovery facilities is not readily available. In addition, rubber does not appear to be a major component of C&D debris. This C&D summary does not include a detailed examination of either C&D plastic or rubber.

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[1] Building-related C&D debris does not include debris generated from the construction and demolition of roads. The available data suggest that most road-related debris is not useable as a fuel; therefore, we exclude these materials from this document.

2. Annual Quantities of C&D Materials Generated and Used

(1) **Sectors that generate C&D Materials:**

- Construction Materials are produced by NAICS 236: Construction of Buildings (U.S. Department of Labor 2008). Demolition Materials are produced by NAICS 238910: Site Preparation Contractors (U.S. Census Bureau 2007).

(2) **Quantities and prices of C&D Materials generated:**

- EPA estimates that 164 million tons[2] of building-related C&D debris were produced in 2003. Approximately 47 percent of this was generated through construction and renovation activities, and 52 percent was generated through demolition activities (Franklin 2005).
- Of the 164 million tons of building-related C&D materials generated in 2003, EPA estimates that between 33 and 49 million tons[2] was C&D wood (Franklin 2005).
- As corroboration for EPA's 2003 estimate of C&D wood debris generation, a USDA source estimates that approximately 39.35 million tons of C&D wood were generated in the U.S. in 2002. Of this, approximately 30 percent originated in construction activities and 70 percent in demolition activities (McKeever 2002).
- Approximately 50 percent of C&D wood debris (20.28 million short tons) is of acceptable size, quality, and condition to be considered available for recovery. Factors limiting "availability" include contamination and the commingling of wood with other nonwood building products (McKeever 2002).
- The quantity data presented above do not reflect the generation of scrap railroad ties or utility poles. A 1995 analysis indicates that 13 million wooden crossties are removed from railroad service each year (WasteAge 1995). A 2000 analysis reports that 1 to 2 million wooden utility poles are replaced each year (Choong et. al. 2000, pg 1).
- The available data on the market price of ground wood includes a range of values. Data for 2000 show a range of $11.16 to $12.50 per ton, while 2006 data suggest a range of $15 to $20 per ton (Krause 2000, Goldstein 2006). These prices vary by region, with prices in the Northeast lower than in the West (Krause 2000).

(3) **Trends in generation of C&D Materials:**

- Information on the trend in C&D wood debris generation is not readily available; however, between 1998 and 2003 the generation of all building-related C&D rose by approximately 17 percent, from 136 million tons in 1998 to 164 million tons in 2003 (EPA 1998, Franklin 2005). Assuming that this growth rate applies to building-related C&D wood debris, the generation of this debris grew from 28 to 42 million tons in 1998 to 33 to 49 million tons in 2003.
- Trends in the generation of C&D debris tend to mirror the trend in economic activity (McKeever 2002). That is, a strong economy generally results in more

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[2] Data currently under revision.

construction and demolition activity. For example, the annual percentage change in U.S. Gross Domestic Product (GDP) in 2006 decreased from 2.8 to 2.0 in 2007. During the same time period, total U.S. new housing starts decreased from 1,800 to 1,355 (thousands) (U.S. Census Bureau 2008, U.S. Department of Commerce 2008).

- On a more local scale, the rate of C&D debris generation is heavily influenced by a number of area-specific factors including the age of the building stock (SWANA 2002b).[3]

3. Uses of C&D Materials

(1) **Fuel uses of C&D Materials:**

- C&D wood residues are commonly used for boiler fuel. The biomass can either be combusted directly to heat a conventional type of boiler and produce steam for power production, or it can be converted into gaseous components (carbon monoxide, hydrogen, methane, and other inert gases) through gasification. In contrast to incineration, which fully converts the input debris into energy and ash, gasification deliberately limits the conversion so the biomass is converted into the intermediate products of gas and charcoal, which can be used for further energy recovery (NRI).
- Oven-dry wood produces approximately 9,000 Btu/lb when burned (SWANA 2002a).
- Information on the quantity of C&D materials combusted for energy recovery is unavailable.
- Railroad ties are in demand for combustion due to their low moisture content. In addition, because most crossties are creosote-treated, the chips reportedly allow boilers to burn at a higher temperature than they would with untreated wood chips. Furthermore, treated wood chips from railroad ties reportedly leave less combustion residue behind than untreated chips (WasteAge 1995).
- Asphalt shingles can be used as fuel in cement kilns, and the mineral components remaining after combustion can serve as raw material for the cement (EPA 2008, p. 23). However, while the use of asphalt shingles as fuel is an established market in Europe, this use is limited in the United States because of air pollution concerns and concerns about the previous use of asbestos in older shingles (Shingle Recycling.org 2007).

(2) **Non-combustion uses of C&D Materials:**

- EPA estimates that 48 percent (65.6 million tons) of C&D materials were recovered for beneficial use (including recycling and use as a fuel) in 2003 (Franklin 2005). A corresponding estimate specific to wood C&D is not readily available.
- Approximately 3,500 C&D recycling facilities are operating in the U.S. (Franklin 2005).

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[3] Although disaster debris is not considered C&D material, the construction of new structures following a natural disaster increases the generation of construction debris.

- Additional markets for C&D wood include flooring, feedstock for engineered woods, landscape mulch, soil conditioner, animal bedding, compost additive, and sewage sludge bulking medium. Reusing wood as lumber can potentially yield revenues 20 to 32 times higher than those from selling wood for fuel or mulch. Similarly, recycling wood to the manufacturing of engineered wood products can potentially generate revenues four times greater than the revenues generated from selling the same amount of wood for fuel or mulch. However, processing and handling costs associated with the reuse of lumber and engineered wood product feedstock options are also much greater than those associated with using debris wood for fuel or mulch. Therefore, some of the revenues associated with more "high-end" applications are offset by greater processing and handling costs (SWANA 2002a).
- More than half of scrap railroad ties are reused in landscaping, fencing, construction, retaining walls and as fuel for utilities and other plants (WasteAge 1995).

(3) **Quantities of C&D Materials landfilled:**

- Most C&D materials are non-hazardous and are frequently accepted at C&D and municipal solid waste (MSW) landfills, depending on the state and local laws governing disposal (EPA 2004).[4]
- As indicated in Exhibit 1, EPA estimates that 98.4 million tons of building-related C&D debris were disposed in 2003 (Franklin 2005). A corresponding estimate specific to wood C&D is not readily available.
- A 1994 EPA survey identified approximately 1,900 active C&D landfills in the United States. (EPA 1998).
- In 1998, EPA estimated that 45-60 million tons of C&D debris were disposed of in permitted C&D landfills. This amount is equal to about 35-45 percent of the estimated 136 million tons of building related C&D debris produced that year (EPA 1998).
- Less than half of scrap railroad ties are landfilled (WasteAge 1995).

(4) **Quantities of C&D Materials stockpiled/stored:**

- Construction and demolition debris is not believed to be stockpiled in significant quantities. The data sources consulted for the development of this document provided no indication that large quantities of C&D materials are stockpiled.

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[4] The primary exception to this is wood treated with chromated copper arsenate (CCA).

Exhibit 1: C&D Material Quantities Generated and Managed in 2003

Material	**Quantity Generated** (million short tons)	**Quantity Recycled or used as Fuel** (million short tons)	**Percent Recycled or used as Fuel**	**Quantity Disposed** (million short tons)	**Percent Disposed**
Building Related C&D Materials	164 million	65.6	40%	98.4	60%
Sources: Franklin 2005					

4. *Management and Combustion processes using C&D Materials*

(1) **Types of units using C&D Materials:**

- C&D wood is used by wood-fired industrial boilers and burners.

(2) **Sourcing of C&D Materials:**

- Wood from C&D activities becomes available as combustion fuel through a variety of methods, but it is typically sent to a processing facility by municipal haulers, private haulers, construction companies, or individual households. After the wood is processed according to combustor specifications, it is delivered to combustion facilities (NESCAUM 2006).

(3) **Processing of C&D Materials:**

- Prior to use as fuel, scrap wood typically requires removal of non-wood materials and processing into chips. Fuel specifications for combustors usually include minimum and maximum chip sizes, amount of C&D fines, maximum moisture content, and maximum contaminant levels (NESCAUM 2006).
- A "hog" (also called a shredder or tub grinder) is used to process construction and demolition wood materials. The hog uses rotating hammers and stationary anvils to smash, crush and tear large wood into smaller fragments. The maximum output particle dimension of hogged fuel is typically less than 3 inches. Hogged fuel often has a high moisture content and a significant ash content (from 2 to 20 percent) (Natural Resources Canada 2000).

(4) **State status of C&D Materials use as fuel:**

- According to state responses to a 2006 survey by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), two states—Maine and Michigan—have approved the use of wood C&D (excluding railroad ties) as fuel on at least one occasion. In addition, the following states have approved the use of railroad ties as fuel on at least one occasion: Maryland, Pennsylvania, Iowa, Michigan, and North Dakota.[5]

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[5] The ASTSWMO survey also indicates that New York and North Carolina have approved the use of recovered wood materials as a fuel on at least one occasion but does not specify whether these approvals apply to

5. C&D Materials Composition and Impacts

(1) **Composition of C&D Materials:**

- As indicated in Exhibit 2, EPA estimates that concrete rubble makes up 40 to 50 percent of building-related C&D materials and that wood makes up 20 to 30 percent of this material.

Exhibit 2: Average Composition of Building-related C&D Materials

Building-Related C&D Material	**Quantity Generated (million tons)**	**Percent of C&D Debris Stream**
Concrete Rubble	66 to 83	40-50%
Wood	33 to 49	20-30%
Gypsum Drywall	8 to 25	5-15%
Asphalt Roofing	2 to 16	1-10%
Metals	2 to 8	1-5%
Bricks	2 to 8	1-5%
Plastics	2 to 8	1-5%
Total	**164**	**100%**

Source:
Sandler 2003

- A 2004 analysis of the composition of C&D wood chips used as fuel conducted by the Maine Department of Environmental Protection found that approximately 60 percent were untreated wood, 20 to 26 percent were C&D fines, and less than 10 percent were painted wood, pressure-treated wood, non-burnables, and plastic (NESCAUM 2006).
- The rapid growth in the use of CCA-treated wood into the 1990s may translate into future growth of this material as a component of C&D. While information on national generation rates is not readily available, some states do have data. For example, approximately 450 tons of CCA-treated wood was disposed of in Florida in 1996, and this figure was expected to quadruple by 2006. Recovered wood from C&D processing facilities in Florida was found to contain, on average, six percent CCA-treated wood in 1996. It should be noted that Florida's utilization of treated wood may be greater than utilization in many states due to the extensive use of treated wood for marine applications (Iida 2004).

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the beneficial use of finished wood products or vegetative debris generated through land-clearing or natural disasters (ASTSWMO 2007, p.B-42).

(2) **Impacts of C&D Materials use:**

- ***Cost Impacts:*** The net cost impacts associated with beneficial use applications for construction and demolition materials depend on the avoided input or fuel costs for facilities that use these materials and the cost of beneficial use itself. Both of these vary by C&D material and application, as fees charged at the processing site for delivered loads of recovered wood are based in part on local competitive disposal market rates. Construction wood and chemically treated wood often incur higher tipping fees, whereas a number of operations will pay for sawmill residue. The unit fuel savings for C&D used as a fuel (e.g., C&D wood burned in a boiler) would equal the savings from the fuel replaced net of the cost of the C&D wood and processing costs. Estimates of the average price of processed wood used as fuel in 2000 ranged from $11.16 to $12.50 per ton net of transportation (Krause 2000). The going rates of fossil fuels that could be readily replaced by C&D wood are as follows:[6]
    - Natural Gas (Industrial): $7.35 / million Btu (MMBtu) (EIA 2008a, Table 20)
    - No. 2 Distillate (Industrial): $16.80 / MMBtu (EIA 2008b, Table 36)
    - Residual Fuel Oil Average: $9.19 / MMBtu (EIA 2008b, Table 38)
    - Coal – Average Delivered Price in 2006: $2.23 / MMBtu (EIA 2007, Table ES1)
- ***Emissions Impacts of Using C&D Wood Debris as a Fuel:*** To evaluate the environmental impacts of burning C&D wood debris, we examined the emissions associated with burning wood debris in a boiler and compared these values to the emissions associated with the combustion of conventional fossil fuels, as summarized in Exhibit 3. The estimates in the exhibit suggest that the combustion of wood results in higher PM emissions than natural gas or distillate oil, but lower PM emissions than coal or residual oil systems. The data in Exhibit 3 also suggest that wood results in lower SO_2 emissions than most conventional fuels. The estimated NO_x emissions associated with wood combustion are similar to those associated with distillate and lower than the NO_x emissions for other conventional fuels.[7]

  The emissions profile of treated woods or wood with lead paint may differ from the values presented in Exhibit 3. For example, concerning the combustion of railroad ties, the creosote in the ties increases the combustion temperature, resulting in a more complete combustion of some organics such as benzene, formaldehyde, and dioxins. However, the creosote itself contains 200 to 300 chemicals (Reid 2002). In addition, wood treated with chromium copper arsenate

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[6] To express these values as dollars per Million Btu (MMBtu), the following thermal conversion factors were used: 1,031 Btu per 1,000 cubic foot of natural gas, 138,690 Btu per gallon of Number 2 distillate, 149,690 Btu per gallon of residual fuel oil, and 22,473,000 Btu per short ton of coal (EIA 2005, Tables A1, A4, and A5).

[7] We note that the emission factors for wood presented in Exhibit 3 represent averages for wood-burning boilers. In addition, the wood reflected in the emissions data may include wood other than C&D wood debris. Emission factors for conventional fuels are based on typical boilers in use in North America in the late 1990s.

(CCA-treated wood) contains arsenic, copper, and chromium that may be emitted when this wood is combusted (Iida et al. 2004). Similarly, lead may be emitted during the combustion of lead-painted wood. Information on the magnitudes of these emissions is not readily available.

- ***Lifecycle Emissions Impacts:*** Use of C&D wood debris as a replacement for traditional primary fuels may eliminate the environmental impacts associated with extraction and processing of traditional fuels. In addition to the emissions impacts of combustion described above, Exhibit 3 lists the quantities of the total cradle-to-gate emissions ("Combustion plus Upstream") for these fuels based on typical processes in the United States in the late 1990s, with wood scrap combustion presented as an indicator of the emissions likely from the combustion of C&D wood debris. Note that there may be impacts associated with the processing of C&D wood debris into useable fuel that are not accounted for in the values presented in the exhibit. In addition, there may be alternative uses (e.g., composting) that are environmentally preferable to combustion.

Exhibit 3: Comparative Impacts of Wood Combustion versus Alternative Primary Fuels

Pollutant	Wood[1]	Coal		Distillate Fuel Oil		Residual Fuel Oil		Natural Gas	
	Combustion	Combustion	Combustion plus Upstream	Combustion	Combustion plus Upstream	Combustion	Combustion plus Upstream	Combustion	Combustion plus Upstream
	------------------------------------ lb./MMBtu ---------------------------------								
Criteria Pollutants									
PM2.5	-	-	-	-	-	-	-	-	-
PM10	0.019	0.054	0.054	0.011	0.011	0.093	0.093	0.009	0.009
PM, unspecified	-	-	0.246	-	0.012	-	0.012	-	0.004
NOx	0.167	0.482	0.504	0.173	0.234	0.367	0.428	0.301	0.417
VOCs	-	0.006	0.014	0.001	0.363	0.002	0.367	0.009	0.524
SOx	0.008	1.446	1.469	0.209	0.394	1.593	1.781	0.073	1.985
CO	1.511	0.068	0.085	0.036	0.082	0.033	0.079	0.058	0.282
Pb	$1.33\mathrm{x}10^{-4}$	$8.93\mathrm{x}10^{-6}$	$9.19\mathrm{x}10^{-6}$	$4.60\mathrm{x}10^{-6}$	$5.61\mathrm{x}10^{-6}$	$5.80\mathrm{x}10^{-5}$	$5.90\mathrm{x}10^{-5}$	-	$2.72\mathrm{x}10^{-7}$
Hg	-	$2.05\mathrm{x}10^{-6}$	$2.14\mathrm{x}10^{-6}$	$1.58\mathrm{x}10^{-6}$	$1.77\mathrm{x}10^{-6}$	$8.67\mathrm{x}10^{-6}$	$8.85\mathrm{x}10^{-6}$	-	$7.18\mathrm{x}10^{-8}$

Source:
Franklin Associates 1998.
Note:
"-" signifies data not available; may equal zero.
[1] Estimates of the metals emissions associated with the combustion of CCA-treated wood are not readily available.

The emission information presented in this table is derived from Life Cycle Inventory (LCI) data, as compiled by Franklin Associates. LCI data identifies and quantifies resource inputs, energy requirements, and releases to the air, water, and land for each step in the manufacture of a product or process, from the extraction of the raw materials to ultimate disposal. The LCI can be used to identify those system components or life cycle steps that are the main contributors to environmental burdens such as energy use, solid waste, and atmospheric and waterborne emissions. Uncertainty in an LCI is due to the cumulative effects of input uncertainties and data variability.

There are several life cycle inventory databases available in the U.S. and Europe. For this paper, we applied the most readily available LCI database that was most consistent with the materials and uses examined. These LCI data rely on system boundaries as defined by Franklin Associates, as described in the documentation for this database, available at: http://www.pre.nl/download/manuals/DatabaseManualFranklinUS98.pdf.

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