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

Construction and Demolition Materials – Disaster Debris

December 16, 2008

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1. Definition of Disaster Debris

Each year, natural disasters, such as wildfires, floods, earthquakes, hurricanes, tornadoes, and winter storms, generate large amounts of debris. This poses a challenge for public officials who must manage this debris in a manner that is as efficient and cost-effective as possible. The debris resulting from natural disasters often includes building materials, sediments, vegetative debris, personal property, and other materials (EPA 2008, p. 11). Generally, this material has not been discarded. Rather, it is the product of a natural disaster.

2. Annual Quantities of Disaster Debris Generated and Used

(1) **Sectors that generate Disaster Debris:**

- Disaster debris may be generated by any sector affected by a natural disaster (e.g., households, businesses, government, etc.).

(2) **Quantities and prices of Disaster Debris generated:**

- While each natural disaster is unique, the top two natural disasters that created the greatest recorded amounts of disaster-related debris in the United States were Hurricane Andrew in 1992 (43 million cubic yards (CY) of debris) and Hurricane Katrina in 2005 (over 100 million CY of debris) (Luther 2006, p. 2).
- The annual generation of disaster debris depends on the frequency and severity of the natural disasters that occur during any given year and the location where these disasters occur.
- The market price of disaster debris varies by constituent. Based on the U.S. price of woody biomass, however, vegetation debris could generate revenues of approximately $5 to $15 per ton (Yepsen 2008, p. 51).

(3) **Trends in generation of Disaster Debris:**

- The generation of disaster debris is episodic. Information on disaster debris trends is not readily available.

3. Uses of Disaster Debris

(1) **Fuel uses of Disaster Debris:**

- A large percentage of disaster debris is vegetative debris, which is commonly used as boiler fuel. Oven-dry wood produces about 9,000 Btu/lb when burned, and it can be converted to liquid or gaseous fuel. Mixed wood debris with some green wood has a Btu value typically near 7,300 Btu/lb, and debris with higher percentages of green wood would have lower Btu values. In addition, it is possible to produce different forms of solid fuel, such as charcoal, from wood debris (SWANA 2002a, pp 4, 18).

- Wood debris associated with disasters is heterogeneous, and can include treated wood, such as wooden utility poles, railroad ties, and some lumber from decks, fences, landscaping materials, and wood bridges. Treated wood contains chemical preservatives that can contaminate recycled wood products. These woods can be combusted in certain energy recovery facilities, provided the facilities comply with existing federal, state and local requirements, but they should not be "open burned" in piles or combusted in air curtain incinerators (ACIs). In general, treated wood should be handled separately from vegetative debris being recycled (EPA 2008, pp 24, 30).
- Similarly, other materials in disaster debris such as plastics and paper may also have fuel value and be able to be combusted in some energy recovery facilities, but the heterogeneity of these materials in the debris stream may present a technical limitation to this application (EPA 2008).
- A notable trend in the use of disaster debris as a fuel is the increased export of U.S. disaster debris to Europe. Due to European greenhouse gas regulations, woody biomass sent from North America to Europe is commanding a price of $100 to $125 per ton. However, despite the financial incentive provided by foreign markets, the exportation of disaster debris is often limited by several practical considerations. For example, communities affected by disasters are usually focused on clearing disaster debris as quickly and conveniently as possible, and often lack the local infrastructure to store, process, and ship high quantities of debris produced in such situations (Yepsen 2008, p. 51). In addition, it is sometimes necessary to quarantine debris from a region to address potential issues with pests. For example, parts of Louisiana have Formosan termites and this debris was therefore difficult to ship to potential users after Hurricane Katrina (EPA, 2008, p. A-2).
- 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 a well-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 Disaster Debris:**

- Non-combustion beneficial use applications of vegetative disaster debris include composting, land spreading (i.e., spreading debris across empty land to facilitate biodegradation), and agricultural applications (Alexander 2008, p. 13).
- Asphalt roofing shingles can be reused in hot-mix asphalt (NAPA 1997, p. 1).
- Metal in disaster debris can be recycled into other metal products (EPA 2008, p.23). In addition, other types of debris, such as household white goods,

electronics, concrete, and asphalt pavement, can in some cases be recovered for recycling. (EPA 2008, p. 22).

(3) **Quantities of Disaster Debris landfilled:**

- While the precise quantity of disaster debris disposed in landfills depends on the natural disaster and the community affected, the majority of disaster debris is landfilled or open burned (Yepsen 2008, p. 51). This occurs partly out of necessity and convenience, as the focus of most communities is to clear material as quickly as possible after a disaster.

(4) **Quantities of Disaster Debris stockpiled/stored:**

- In many cases, the lack of storage capacity prevents disaster debris from being stockpiled (Yepsen 2008, p. 51).

4. Management and Combustion processes for Disaster Debris

(1) **Types of units using Disaster Debris:**

- Vegetative disaster debris can be ground into chips and used by wood-fired industrial boilers and burners. In addition, municipal energy recovery facilities can in some cases manage mixed debris as well as vegetative debris (EPA 2008).

(2) **Sourcing of Disaster Debris:**

- Communities affected by natural disasters, or state or Federal governments, typically hire private contractors to remove and dispose of disaster debris.

(3) **Processing of Disaster Debris:**

- To process vegetative disaster debris, contractors typically use grinders to reduce debris into chips. With respect to the beneficial use of vegetative debris as a fuel source, the challenge with grinding is that it is better suited to volume reduction than the production of the uniform chips needed by biomass fuel plants. However, if communities hire a processor accustomed to producing biomass fuel, the debris can be ground into chips that meet combustor specifications (Yepsen 2008, p. 51).
- The economics of utilizing biomass are challenging: the expense of shipping woody biomass, which has a high volume to weight ratio, has traditionally limited use to a 50 or 100-mile radius around disaster sites (Yepsen 2008, p. 51).
- Processing disaster debris is complicated by several factors: the effects of the disaster on transportation infrastructure, the large quantities of debris produced, the unpredictability of the quantity and location of generation, the need for quick removal, and the tendency of disaster debris to be composed of a mixture of materials (potentially including contaminants) (Yepsen 2008, p. 51). In addition, debris from certain regions may require quarantine due to pests (EPA 2008, p. 6).

(4) **State status of Disaster Debris use as fuel:**

- According to state responses to a 2006 survey by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), the state of Florida has approved the use of vegetative hurricane debris as fuel on at least one occasion. Both New York and North Carolina have approved the use of recovered wood materials as a fuel source on at least one occasion, but it is unclear whether these approvals apply to vegetative debris or the beneficial use of finished wood product. In all three states, these uses do not appear to have pre-approved status, suggesting that a case-by-case approval process for designation of beneficial use is in place in these states (ASTSWMO 2007, p.B-41-42).

5. Disaster Debris Composition and Impacts

(1) **Composition of Disaster Debris:**

- Hurricane-related disaster debris is generally 76 percent vegetative, 17 percent mixed, 7 percent construction and demolition, and 1 percent white goods (Alexander 2008, p. 8). Other types of disaster debris will have varying composition, and may include components such as ash (e.g., from wildfires) or sediment (e.g., from floods).

(2) **Impacts of Disaster Debris use:**

- ***Cost Impacts:*** Natural disasters impose significant costs on affected communities. The disposal of disaster debris represents just one of the costs of a natural disaster, but the beneficial use of this debris can, in some cases, lessen these costs. Overall, however, the net cost impacts associated with the beneficial use of disaster debris depend on the circumstances of the disaster and are uncertain. For example, while disaster debris may be valuable as a fuel source, transportation costs and time-sensitivity can make landfill disposal the most cost-effective management option (EPA 2008, p. 22).

  While the net cost impacts associated with the beneficial use of disaster debris are uncertain, the fuel cost savings of fuel-related beneficial use applications can be measured based on the value of the fuel that the debris would replace. The recent prices of conventional fossil fuels that may be replaced by this material are as follows:

  - Natural Gas (Industrial): $7.35 / 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 Combustion:*** Emissions associated with the use of disaster debris are likely to depend on the specific material used as a fuel. As indicated above, however, vegetative debris (e.g., wood) can represent approximately 76 percent of disaster debris. Thus, as an illustrative example, Exhibit 1 compares the emission factors for wood with the corresponding values for conventional fuels that disaster debris may displace. 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 1 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.[1]

The emissions profile of treated woods or wood with lead paint may differ from the values presented in Exhibit 1. For example, concerning the combustion of railroad ties, 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 (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 disaster 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 1 lists the quantities of the total cradle-to-gate emissions for these fuels based on typical processes in the United States in the late 1990s, with wood scrap combustion presented as a proxy for disaster debris. Note that there may be impacts associated with the processing of disaster debris into useable fuel that are not accounted for in the values presented in Exhibit 1. In addition, there may be alternative uses (e.g., composting) that are environmentally preferable to combustion.

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[1] We note that the emission factors for wood presented in Exhibit 1 represent averages for wood-burning boilers.

Exhibit 1: Comparative Impacts of Wood Combustion versus Alternative Primary Fuels

Pollutant	Wood	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	1.33x10^{-4}	8.93x10^{-6}	9.19x10^{-6}	4.60x10^{-6}	5.61x10^{-6}	5.80x10^{-5}	5.90x10^{-5}	-	2.72x10^{-7}
Hg	-	2.05x10^{-6}	2.14x10^{-6}	1.58x10^{-6}	1.77x10^{-6}	8.67x10^{-6}	8.85x10^{-6}	-	7.18x10^{-8}

Source:
Franklin Associates 1998.
Note:
"-" signifies data not available; may equal zero.

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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