**Construction and Demolition (C&D) Materials Scoping Study:**
**C&D Generation and Management Methodology**
**U.S. Environmental Protection Agency**
**Office of Resource Conservation and Recovery**
**October 2012**

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## INTRODUCTION AND SCOPE

The United States Environmental Protection Agency (USEPA) is considering the addition of construction and demolition (C&D) waste to its municipal solid waste (MSW) characterization report series. To support such an effort, this memo presents a detailed methodology for developing estimates of C&D waste generation that EPA may update on a regular basis. The contractor also specifies options for using the limited data available on C&D waste generation to estimate ranges for annual rates of C&D recycling and disposal.

C&D waste includes a variety of materials that may be generated from different processes (e.g., construction, renovation, demolition, land-clearing, and natural disasters). The methodology presented in this document is specific to Portland cement concrete and steel in roads, bridges, and other infrastructure, and building-related C&D waste made up of the following materials: Portland cement concrete, steel, asphalt shingles, gypsum wallboard and plaster, wood, and brick & clay tile. The scope of materials included in our proposed methodology does not include disaster debris or land-clearing debris.

In the first section of this memo, the contractor reviews existing approaches for estimating the annual rate of C&D waste generation, presents the contractor's recommended approach for estimating the annual rate of generation, and summarize the data necessary for implementation of this approach. The document follows with the contractor's recommended methodology for characterizing C&D management.

## C&D GENERATION METHODOLOGY

This section reviews existing approaches for quantifying the annual rate of C&D waste generation and presents our recommended approach for estimating the annual rate of generation for each of the six materials identified above.

### EXISTING APPROACHES FOR ESTIMATING C&D GENERATION

As an initial step in developing the recommendations presented in this memo, the contractor briefly reviewed prior studies on the generation of C&D to identify and evaluate the methods employed in these analyses. Many of these studies rely on construction, demolition, and renovation activity data for the residential and non-residential sectors, combined with characterization data on the amount of C&D waste per square foot constructed or demolished (Yost and Halstead, 1996; EPA, 1998; Reinhart et. al, 2003; EPA, 2009). For example, to estimate building-related C&D generation associated with construction, several studies in the literature use the approach represented by Equation 1.

(1) $W_x = C_{\$X} \times {ft^2}/{\$} \times {W}/{ft^2}$

Where:

$W_x$ = construction waste generated in year $X$;

$C_{\$x}$ = value of construction put in place in year $X$; and,

$ft^2/\$$ = number of square feet constructed per dollar of construction value.

$W/ft^2$ = waste generated per square foot of construction.

While this methodology provides an initial attempt at understanding C&D waste generation, the method does not account for the wide variances in construction costs per square foot across different geographical regions. For example, a square foot of construction in the northeastern United States will likely cost substantially more than the same square foot of space constructed in the Midwest. Additionally, the amount of waste generated per square foot is highly variable depending on geographical region and regional building practices.

Other studies (Wang et. al., 2004) rely on construction and demolition permit data and the average amount of waste generated per square foot. The approach estimates annual C&D waste generation according to Equation 2:

(2) $W_x = P_X \times {ft^2}/{P} \times {W}/{ft^2}$

Where,

$W_x$ = waste generated in year $X$;

$P_x$ = number of permits in year $X$; and,

$ft^2/P$= square footage of construction, demolition, or renovation per permit.

$W/ft^2$ = waste generated per square foot of construction.

This approach allows the user to develop a composite estimate of square feet per permit that reflects varying levels of construction activity across different parts of the country, if sufficient data are available. Data on non-residential demolition permits, however, are no longer available nationally. Additionally, demolition and renovation often occur without a permit, which can lead to underestimates of C&D waste generation.

A limitation of the two methodologies outlined above is that they rely on numerous variables for which reliable data are not regularly available on a national scale and whose values are highly variable and uncertain.

As an alternative to these approaches, Cochran and Townsend (2010) approach the estimation of C&D waste generation from a different perspective.[1] Instead of generating "typical" housing or waste per square foot estimates, the study relies on historical consumption data for various construction materials and projects when these materials are likely to be discarded and become waste. In short, Cochran and Townsend approach the generation issue with a top-down (materials use) rather than a bottom-up approach (waste characterization).

[1] K.M. Cochran and T.G. Townsend, "Estimating construction and demolition debris generation using a materials flow analysis approach." *Waste Management*, 30 (2010) 2247-2254.

### RECOMMENDATION: C&D WASTE GENERATION METHODOLOGY

The contractor recommends that EPA employ the methodology outlined in Cochran and Townsend (2010) to estimate the generation of C&D waste. Relative to the other approaches described above, the Cochran and Townsend methodology relies on more readily available data and uses fewer uncertain assumptions. Moreover, the Cochran/Townsend approach is relatively straightforward to implement. We outline this methodology below.

#### Summary of Proposed Methodology

The Cochran and Townsend methodology uses a materials flow approach to examine the amount of materials that go into service in a given time period and then predicts when those materials will reach the end of their service life and become waste. The method also captures material that becomes waste at the time of construction. Thus, this approach estimates C&D waste generation for a given year as the sum of two components:

1. Materials discarded during construction; and
2. C&D material becoming waste during demolition and renovation.[2]

Equations 3 and 4 below illustrate how both of these components may be calculated.

(3) $C_{w,y} = M_y \times W_c$

Where:

$C_{w,y}$ = amount of material discarded during new construction in year *y*;

$M_y$ = the amount of a given material consumed by the U.S. in year *y*; and,

$W_c$ = the percent of material that is discarded (i.e., waste rate) during construction or renovation.

(4) $D_{w,y} = M_{(y-l)} - C_{w,(y-l)}$

Where:

$D_{w,y}$ = the amount of demolition waste generated either during renovation, at the end of the useful life of a material, or during demolition in year *y*;

$M_{(y-l)}$ = the amount of a material used for the construction of buildings and other structures demolished in year *y*. This equals the amount consumed in year *y-l*, where *l* is the service life of the material.

$C_{w,(y-l)}$ = amount of material discarded during construction in year *y-l*.

Based on Equation 4, the estimated amount of C&D waste generated in a given year is dependent on the service life of various construction materials. Because the service life of a material is highly variable, the contractor recommends expression of service life as a range. This also will result in C&D waste generation estimated as a range for a given year. For example, if EPA estimates the amount of lumber waste generated in 2008 ($D_{w,2008}$) based on an estimated service life of 50 to 100 years with a central estimate of 75 years, the resulting equations would be:

$C_{w(2008)} = M_{(2008)} \times W_{c(2008)}$

[2] Waste generated during renovation is spread across these two components. Waste generated during the installation/construction portion of renovation projects is reflected in the first component, and waste generated during the removal/demolition portion of renovation projects is reflected in the second component.

$$D_{w,(2008)} = M_{(1958)} - C_{w(1958)} \quad \text{(50-year service life), or}$$

$$= M_{(1933)} - C_{w(1933).} \quad \text{(75-year service life), or}$$

$$= M_{(1908)} - C_{w(1908)} \quad \text{(100-year service life).}$$

As noted above, the resulting generation estimated will be a range to reflect the uncertainty in the material's service life.

### NECESSARY DATA

Based on Equations 3 and 4, the data necessary to implement the Cochran and Townsend approach include estimates of: 1) the amount of material discarded at the time of construction; 2) material service lifespans; and, 3) historical material consumption.

#### Percent of Material Discarded During Construction

To estimate the total C&D waste[3] generated in a given year, EPA will require estimates of the percent of material discarded during new construction. Cochran and Townsend (2010) present estimates of these values for each material included in the scope of this methodology document. Based on the contractor's review of the sources used by Cochran and Townsend, the contractor recommends that EPA use the values provided by Cochran and Townsend. Exhibit 1 summarizes these values.

**EXHIBIT 1. PERCENT OF MATERIAL DISCARDED DURING CONSTRUCTION**

| MATERIAL | PERCENT (%) DISCARDED |
|---|---|
| Concrete | 3 |
| Wood products | 5 |
| Wallboard | 10 |
| Steel | 0 |
| Asphalt Shingles | 10 |
| Brick and Clay Products | 4 |
| Sources: As cited in Cochran and Townsend (2010), DelPico (2004), and Thomas (1991) | |

#### Material Lifespan

Estimating when a given material will likely come out of service and enter the waste stream requires information on the material's lifespan. For example, if a material with a 20-year service life was used for a construction project in 1990, it would have been discarded in 2010. This can be shown by the equation outlined previously:

$$D_{w(2010)} = M_{1990} - C_{w(1990)}$$

[3] As noted above, C&D waste for the purposes of this memo includes steel in roads, bridges, and other infrastructure, and building-related C&D waste made up of the following materials: Portland cement concrete, steel, asphalt shingles, gypsum wallboard and plaster, wood, and brick & clay tile.

Cochran and Townsend (2010) provide estimated service life ranges for each material included in the scope of this methodology document. The contractor's review of the sources cited by Cochran and Townsend and corroboration with values from other sources, including (for some materials) the United States Geographical Survey (USGS) 2010 Minerals Yearbook, suggests that the data used in the report are reliable and appropriately applied. The contractor therefore recommends that EPA use the service life estimates presented by Cochran and Townsend. These values are presented in Exhibit 2.

### HISTORICAL CONSUMPTION DATA

Implementation of the material flow approach that we propose requires detailed data on the historical consumption of C&D materials for construction purposes. Specifically, EPA will need material sales data that encompass the range of lifespans for each C&D material. For example, to estimate the amount of wallboard waste generated in 2010, EPA will need material sales data from the years 1935, 1960, and 1985.[4] Below we discuss the historical consumption data we identified for each target material, as well as assumptions necessary to isolate the portion of consumption associated with the construction of buildings, roads, and other infrastructure.

**EXHIBIT 2. LIFESPAN VALUES**

| MATERIAL | ESTIMATED LIFESPAN RANGE | TYPICAL LIFESPAN |
|---|---|---|
| Concrete | 50 to 100 years (buildings)<br>23 to 40 years (roads and infrastructure)<br>20 to 50 years (other structures) | 75 years (buildings)<br>25 years (roads and infrastructure)<br>30 years (other structures) |
| Wood Products | 50 to 100 years (lumber, plywood)<br>20-30 years (wood panel products, veneers) | 75 years (lumber, plywood)<br>25 years (wood panel products, veneers) |
| Wallboard | 25 to 75 years | 50 years |
| Steel | 50 to 100 years | 75 years |
| Asphalt Shingles | 20 to 30 years | 25 years |
| Brick | 50 to 100 years | 75 years |
| Clay Tile | 15 to 25 years | 20 years |
| Sources:<br>As cited in Cochran and Townsend (2010): Zapata and Gambatese (2005), Katz (2004), Park et al. (2003), Scheuer et al. (2003), Junnila and Horvath (2003), Chapman and Rizzo (2002), Cross and Parsons (2002), Thormark (2002), Keoleian et al, (2001), Horvath and Hendrickson (1998), Bolt (1997), and Packard (1994). Additional corroboration with USGS (2010). | | |

#### Portland Cement Concrete

EPA may derive estimates of historical concrete consumption from cement consumption data published by the USGS for the years 1900 to 2010.[5] Cochran and Townsend estimate that approximately 10 to 17 percent of concrete (11 percent being typical) is Portland cement by volume and that the densities of cement and

[4] This reflects a 25 to 75-year lifespan for wallboard and a central lifespan value of 50 years.

[5] Kelly, T. and Matos, G. USGS Historical Statistic for Mineral and Material Commodities in the United States, Data Series 140. 2011. Available at http://minerals.usgs.gov/ds/2005/140/. Accessed August 2012.

concrete are 3,150 kg/m$^3$ and 2,300 kg/m$^3$, respectively. Based on these values, one ton of cement represents 6.64 tons of concrete.[6]

Prior to 1975, the USGS reports cement consumption in aggregate, which reflects Portland cement as well as masonry cement. To develop consumption estimates specific to Portland cement, the contractor recommends that EPA assume that Portland cement accounts for 96 percent of total cement consumption. This is based on the USGS end-use consumption data for 1975 through 2003 which show that Portland cement accounts for 95.3 to 96.5 percent of cement sales.

The contractor notes that not all concrete is used in construction applications. EPA will therefore need to distribute consumption of concrete across different uses: building construction, streets and highways, and other. The Portland Cement Association (PCA) estimates that 47 percent of Portland cement was used in buildings in 2002, 33 percent was used in streets and highways, and 20 percent was used in other structures.[7] Data on the distribution across these applications are not available for prior years. In the absence of such data, the contractor recommends that EPA use the following approach to estimate concrete consumption by application:[8]

1. Calculate the total amount of concrete consumed for a given year based on the USGS consumption data for Portland cement and the assumption of 6.64 tons of concrete per ton of Portland cement, as derived above.

2. Using PCA's data on the distribution of cement between buildings, streets and highways, and other uses in 2002 and Census data on the value of construction put in place for each concrete application in 2002[9], calculate a series of "ton-to-dollar" ratios that represent the amount of concrete used per dollar of construction for each concrete application. For example, if (hypothetically) 300 million tons of concrete were used in building applications in 2002 and construction spending on buildings was $8 billion, this would imply 0.0375 tons of concrete per dollar of building construction put in place.

3. Apply the ton-per-dollar ratios derived in Step 2 to the Census Bureau's historical estimates of the value of construction put in place for each concrete application (buildings, streets and highways, and other applications)[10] to develop annual estimates of the tonnage of concrete used by application. For example, if the results of Step 2 suggest 0.0375 tons of concrete per dollar of building construction and $5 billion in buildings was put in place during a given year, this would suggest 188 million tons of concrete was consumed for building applications that year (0.0375 tons/$ × $5 billion).

4. The sum of the three values derived for a given year from the previous step will not necessarily match the aggregate estimate of concrete consumption derived in Step 1. To reconcile these estimates, EPA may distribute the aggregate tonnage of concrete consumption implied by historical cement consumption (estimated in Step 1) across the three concrete applications in proportion to the consumption values

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[6] The contractor derived this value as follows: 6.63 tons of concrete per ton of cement = 1 ton cement × 2000 pounds per ton × 2.205 kg per pound / 3,150 kg cement per m$^3$ cement / 0.11 m$^3$ of cement per m$^3$ concrete × 2,300 kg concrete per m$^3$ concrete / 2.205 kg per pound / 2000 pounds per ton.

[7] Portland Cement Association (2002) as referenced in K.M. Cochran and T.G. Townsend, *op cit.*

[8] This approach reflects the contractor's understanding of the approach outlined in Cochran and Townsend (2010). The contractor requested clarification from one of the authors, but they have not yet responded.

[9] U.S. Census, Value of Construction Put in Place data series, http://www.census.gov/construction/c30/previousseries.html.

[10] U.S. Census, *op cit*.

derived in Step 3 (i.e., the values derived from the ton/$ estimates). For example, if EPA estimates concrete consumption of 100 million tons for a given year based on Step 1 and 60 percent of the concrete consumption estimated in Step 3 is for building-related applications, the estimated concrete consumption for building applications that year would be 60 million tons (60 percent of 100 million tons).

### Wood

C&D waste includes three categories of wood: lumber, used for housing applications; wood panel products such as medium density fiberboards; and plywood and veneers, used for various building applications. The USGS publishes and regularly updates consumption data for each of these categories: lumber data are available from 1900 through 2009; wood panels data are available from 1916 through 2009, and plywood data are available from 1900 to 2009.[11] While virtually all wood panels and plywood veneer are used in building applications, not all lumber is used in building applications (e.g., lumber may be used in furniture). According to the USDA Forest Service, approximately 78 percent of lumber is used for building construction.[12]

### Gypsum Drywall and Plasters

Historical consumption data for gypsum are available from USGS for the years 1900 through 2010, and are updated by USGS on a regular basis.[13] For the years 1975 through 2010, USGS distributes these consumption data across the various end uses of gypsum, including prefabricated products and plasters and Portland cement.[14] These data will allow EPA to isolate gypsum used in building construction over the 1975-2010 period, during which time approximately 75 percent of gypsum was used in drywall and plasters. To estimate building-related consumption pre-1975, the contractor recommends that EPA apply this 75 percent value to the total consumption value reported by USGS.

### Steel

The USGS publishes steel end-use consumption data from 1979 through 2010 by consumption category (i.e., construction, transportation, service centers and distributors, and other).[15,16] The construction category includes steel used in buildings, as well as steel used in bridges and other infrastructure. For years prior to 1979, the USGS data do not distinguish between different uses of steel. A 1976 Census Bureau report, however, includes information on construction-related steel consumption from the early 1900s through 1970.[17] The contractor recommends that EPA use this source for 1970 and earlier years. To capture construction-related steel consumption for the years between 1970 and 1979, the contractor recommends that EPA interpolate between the 1970 and 1979 values.

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[11] Kelly, T. and Matos, G., *op cit*.

[12] Howard, J. 2007. U.S. Timber Production, Trade, Consumption, and Price Statistics: 1965 to 2005. Research Paper FPL-RP-637. Madison, WI. p.5.

[13] Kelly, T. and Matos, G., *op cit*.

[14] Kelly, T. and Matos, G., *op cit*.

[15] Kelly, T. and Matos, G., *op cit*.

[16] Fenton, M. USGS Minerals Yearbook 2003-2010: Iron and Steel. Table 3. http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/. Accessed August 2012.

[17] United States Census Bureau. 1976. The Statistical History of the United States: From Colonial Times to the Present. Basic Books, Inc. New York.

### Asphalt Shingles

Historical data on asphalt shingle sales in the U.S. are not readily available, though estimates may be derived by combining information from various sources. The Asphalt Roofing Manufacturers Association (ARMA) reports annual sales of 13 to 18 million metric tons in the early 2000s.[18] In addition, it is widely known that coarse granules are an important material used in the production of asphalt shingles.[19] Because the USGS has published data on crushed stone used as roofing granules for the 1975-2010 period, EPA may use the change in roofing granule consumption, as reported by USGS, as an indicator of the change in asphalt shingle consumption.[20] More specifically, EPA may assume that asphalt shingle consumption changes in proportion to roofing granule sales, as reported by USGS. For example, if roofing granule sales in a given year are 20 percent less than the value reported in 2002 (using 2002 as a base year for the early 2000s), EPA could assume that asphalt shingle consumption is also 20 percent lower that year relative to 2002.

### Bricks and Clay Tile

The contractor proposes that EPA use historical sales data for brick from the USGS Minerals Yearbook and the US Census Bureau's 1976 *Statistical History of the United States: From Colonial Times to the Present*. The USGS publishes clay end-use statistics for the years 1975 through 2010, which include bricks. For the years 1895 through 1970, the Census Bureau's *Statistical History* includes estimates of bricks consumed for building construction. Because the U.S. Census Bureau data are expressed in terms of the number of bricks consumed, EPA will need to convert the Census values to tons. The contractor recommends that EPA use the conversion factor in Cochran and Townsend of 550 bricks per metric ton (approximately 4 pounds per brick). Neither the USGS nor Census sources include consumption data for the years 1971 through 1974. The contractor recommends that EPA interpolate between the 1970 and 1975 values to generate estimates for this period.

For clay tile, EPA may use historical sales data from the USGS Minerals Yearbook for the years 1975 through 2010. Because the maximum lifespan of clay tile is approximately 25 years, data for earlier years are not necessary.

Below in Exhibit 3, we show a sample of the historical sales data EPA may use to calculate C&D waste generation.

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[18] As cited in Cochran and Townsend, *op cit*.

[19] Cochran and Townsend (2010) surveyed shingle recyclers and generate a weight of granules per shingle range of 20-38 percent by mass.

[20] Willett, J. USGS Minerals Yearbook 2003-2010: Stone, Crushed. Table 9. http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/. Accessed August 2012.

## EXHIBIT 3: HISTORICAL SALES DATA BY MATERIAL (METRIC TONS), 1910-2010

| YEAR | PORTLAND CEMENT[1] | WOOD PRODUCTS | | | GYPSUM DRYWALL AND PLASTERS[3] | STEEL | ASPHALT SHINGLES[4] | BRICKS | CLAY TILE |
|---|---|---|---|---|---|---|---|---|---|
| | | LUMBER[2] | WOOD PANEL PRODUCTS | PLYWOOD AND VENEERS | | | | | |
| 1910 | 12,500,000 | 36,036,000 | Not required, given lifespan | 250,000 | 1,899,000 | 2,539,000 | Not required, given lifespan | 18,000,000 | Not required, given lifespan |
| 1920 | 16,100,000 | 27,924,000 | | 260,000 | 2,311,000 | 3,704,000 | | 10,300,000 | |
| 1930 | 26,200,000 | 23,400,000 | | 580,000 | 2,961,000 | 3,934,000 | | 9,290,000 | |
| 1940 | 20,900,000 | 24,336,000 | | 1,240,000 | 3,462,000 | 4,232,000 | | 7,450,000 | |
| 1950 | 39,300,000 | 29,952,000 | | 2,040,000 | 7,702,000 | 5,442,000 | | 11,500,000 | |
| 1960 | 53,300,000 | 28,002,000 | | 4,510,000 | 10,843,000 | 6,125,000 | | 12,600,000 | |
| 1970 | 64,800,000 | 33,696,000 | | 7,980,000 | 10,768,000 | 5,566,000 | | 12,200,000 | |
| 1980 | 67,448,000 | 35,256,000 | 6,540,000 | 7,800,000 | 12,500,000 | 10,800,000 | TBD | 13,460,000 | 331,000 |
| 1990 | 77,971,000 | 47,268,000 | 7,550,000 | 9,540,000 | 17,500,000 | 11,000,000 | TBD | 12,340,000 | 744,000 |
| 2000 | 105,320,000 | 53,430,000 | 9,990,000 | 9,600,000 | 23,800,000 | 18,400,000 | TBD | 13,330,000 | 517,000 |
| 2010 | 68,400,000 | N/A Data Published to 2009 | N/A Data Published to 2009 | N/A Data Published to 2009 | 10,400,000 | 16,300,000 | TBD | 5,988,000 | 358,000 |

Notes:

Pre-1975 and post-2003, USGS reports cement consumption in aggregate. The contractor assumes that 96 percent of this is Portland cement based on USGS consumption data for the years 1975 through 2003 which show that Portland cement accounted for 95.3 to 96.5 percent of annual cement consumption during this period.

Lumber values reflect portion of lumber sales associated with construction. Based on data from the U.S. Forest Service, the contractor assumes that 78 percent of total lumber sales are for construction purposes. See Howard, J. 2007. U.S. Timber Production, Trade, Consumption, and Price Statistics: 1965 to 2005. Research Paper FPL-RP-637. Madison, WI. p.5.

USGS pre-1975 sales data for gypsum are reported in aggregate and do not separate gypsum sales for wallboard and plaster from sales for other applications. Based on the USGS data for 1975 through 2010, approximately 75 percent of gypsum sold during this period was used in drywall and plasters. To estimate gypsum sales for drywall and plasters pre-1975, we apply this 75 percent value to the total consumption value reported by USGS.

Cochran and Townsend (2010) refer to USGS sales data for crushed stone used as roofing granules as the source for their estimates of asphalt shingle sales, but the data the contractor identified from USGS do not match the value referenced by Cochran and Townsend. The contractor submitted a clarifying question to one of the authors but has not yet received a response.

## C&D MANAGEMENT METHODOLOGY

The addition of C&D waste to EPA's MSW characterization report would require assessment not only of C&D waste generation but also estimates of the management of this material. Specifically, the report would ideally include information on the amount of C&D waste disposed in a given year and the quantity recycled for key materials. Ideally, a methodology for estimating the amount of C&D disposed and recycled would draw from material-specific, representative management data for the entire U.S. Such data, however, are not readily available. The limited data that are available include the following:

***C&D recycling data***: A limited number of states publish information on the tonnage of C&D waste recycled within the state based on data reported by C&D processing facilities, recyclers, and haulers. Many of these states also publish estimates of the total generation of C&D within the state's boundaries. In some cases, these C&D data are reported by material, and in others the data are reported in aggregate. The states for which recent C&D recycling data are available include Florida, Illinois, New York, Washington, Oregon, Massachusetts, and Virginia. Exhibit 4 summarizes the data available from these states. While these data may form the basis of an estimated C&D recycling rate, it is important to note the limitations of these data, including the following:

- The scope of materials included in state C&D data may vary by state. For example, some states may include disaster debris in their data, while other states exclude this material.
- States that report information on the recycling of C&D waste may not be representative of the U.S. as a whole. For example, states interested in achieving a high recycling rate for C&D waste may be more inclined to report on recycling activities within their borders than states that do not report.
- States may differ in their approach for estimating the tonnage of C&D waste recycled within the state. Thus, the recycling rates included in or derived from state data may not be directly comparable. For example, some states may count combustion of C&D wood for energy recovery as reuse while others would consider this disposal.

***C&D disposal data***: Several states compile information on the disposal of C&D waste within their boundaries. The estimates developed for some of these states reflect sampling data for waste received by municipal solid waste management facilities (e.g., MSW landfills), while others are based on data specific to C&D landfills. The disposal estimates for a limited number of states (e.g., Georgia) reflect disposal in both MSW and C&D landfills. While these studies often provide significant detail on the disposal of C&D waste, many do not estimate the generation rate of C&D, complicating efforts to estimate the disposal rate from these data In addition, many states do not disaggregate C&D by material and therefore include many materials outside the scope of the methodology presented in this memo (e.g., carpeting). The data for some states may also reflect imports of C&D waste from out of state. Exhibit 5 summarizes the disposal data available for seven select states.

## EXHIBIT 4. SUMMARY OF AVAILABLE STATE-LEVEL RECYCLING DATA

| STATE | YEAR | MATERIAL SPECIFICITY | DATA REFLECT ROAD AND BRIDGE WASTE | DATA REFLECT DISASTER DEBRIS |
|---|---|---|---|---|
| Florida | 2010 | • Concrete<br>• Wood<br>• Drywall<br>• Shingles<br>• Various others | Yes | Yes |
| Illinois | 2009 | • Lumber<br>• Treated and untreated wood<br>• Concrete<br>• Bricks<br>• Gypsum board<br>• Shingles<br>• Plastics<br>• Other | Yes | No |
| Massachusetts | 2009 | • Total C&D<br>• C&D wood | No | No |
| New York | 2010 | Highly detailed, including:<br>• Brick<br>• Aggregate and concrete (excl. aggregate recycled onsite)<br>• Bulk metal<br>• Drywall<br>• Wood<br>• Shingles | Yes | No |
| Oregon | 2010 | • Roofing<br>• Gypsum wallboard<br>• Carpeting | No | No |
| Virginia | 2011 | • Total C&D | Yes | No |

Sources:

1. Florida Department of Environmental Protection. *Construction and Demolition Report: Recovery Statement Year 2010*. Retrieved August 2012 from http://www.dep.state.fl.us/waste/categories/recycling/SWreportdata/10_data.htm.
2. Illinois Department of Commerce and Economic Opportunity, *Illinois Commodity/Waste Generation and Characterization Study. Report: May 22, 2009.*
3. Massachusetts Department of Environmental Protection. *2009 Massachusetts C&D Waste Handling Facility Data Summary*. 2010. Retrieved from http://www.mass.gov/dep/recycle/reduce/managing.htm#data. Accessed August 2012.
4. New York Department of Environmental Conservation. *Dataset 2010 Generation, Disposal and Recycling Data. New York Division of Materials Management*. Provided by New York Department of Environmental Conservation, August 2012.
5. Oregon Department of Environmental Quality (2010). *2010 Material Recovery and Waste Generation Rates Report*. October 2011.
6. Virginia Department of Environmental Quality. *Solid Waste Managed in Virginia During Calendar Year 2011*. June 2012.

### EXHIBIT 5. SUMMARY OF DISPOSAL DATA FOR SELECT STATES

| STATE | YEAR | MATERIAL SPECIFICITY | DISPOSAL REFLECTED IN DATA |
|---|---|---|---|
| Connecticut | 2009 | Disposal reported separately for:<br>• Asphalt/brick/concrete<br>• Wood<br>• Asphalt roofing<br>• Drywall<br>• Carpet<br>• Carpet padding | MSW disposal facilities (waste to energy facilities and landfills). Unclear whether data reflect C&D landfills. |
| Georgia | 2009 | Highly detailed data by material. | MSW Landfills<br>C&D Landfills |
| Maryland* | 2009 | C&D disposal reported in aggregate | C&D Landfills |
| Michigan* | FY 2009-2010 | C&D disposal reported in aggregate. | Estimates based on data for ALL landfills in the state. |
| North Carolina* | FY 2010-2011 | C&D disposal reported in aggregate | C&D Landfills |
| Utah | 2011 | C&D disposal reported in aggregate | C&D Landfills<br>Unclear whether C&D reported reflects MSW landfills. |
| Wisconsin | 2009 | Disposal reported separately for:<br>• Shingles<br>• Untreated wood<br>• Treated wood<br>• Rock/concrete/bricks<br>• Drywall<br>• Pallets<br>• Other ferrous scrap<br>• Bulky items | MSW Landfills |

*Indicates that data updated annually.

Sources:

1. Georgia Department of Natural Resources, *Statewide Construction and Demolition Debris Characterization Study*, June 2010.
2. DSM Environmental Services, *Connecticut State-wide Solid Waste Composition and Characterization Study, Final Report*, May 26, 2010.
3. Michigan Department of Environmental Quality, *Report of Solid Waste Landfilled in Michigan October 1, 2009 – September 30, 2010*, April 7, 2011.
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7. Utah Department of Environmental Quality Division of Solid & Hazardous Waste, "Disposal Facilities, Recyclers and Disposal Volumes, http://www.hazardouswaste.utah.gov/Solid_Waste_Section/disposalfacilities.htm, accessed September 14, 2012.

## RECOMMENDATION: C&D MANAGEMENT METHODOLOGY

As indicated above, the contractor identified numerous limitations in the state-level recycling and disposal data for C&D. Based on these limitations, it is unclear whether the disposal or recycling data—or some combination of the two—would be better suited for deriving estimates of C&D recycling and disposal rates. To address this uncertainty, the contractor recommends that EPA perform a comparative assessment of the recycling and disposal rates implied by both sets of studies (i.e., the recycling-focused state studies versus the disposal-focused studies). This would allow EPA to develop a more in-depth understanding of the limitations associated with the data and to assess the reasonableness of the results derived from the recycling data relative to those derived from the disposal data. The approach that the contractor recommends for this comparative assessment would involve the following steps:

1. ***Compile state-level recycling and disposal data***: As an initial step, EPA will need to compile all of the recent studies and data available from states on the recycling and disposal of C&D waste. Some states such as Florida update their data on an annual basis, whereas the reporting by other states does not follow a regular schedule. EPA would therefore need to assess the availability of data for each state individually. Although the irregular release of recycling and disposal data from some states may complicate the use of state data for the assessment of C&D waste management, at any given time there are several states for which fairly recent (4 years old or less) C&D management data are available. The contractor therefore recommends that EPA periodically update its comparative assessment of recent state-level data and, as appropriate, refine its approach for characterizing the management of C&D waste. Because the landscape of available data on C&D waste management will evolve over time, periodic updates to EPA's methodology will ensure that the methodology reflects the most recent data.

2. ***Develop C&D generation estimates for each state included in the comparative assessment.*** Estimation of the recycling and disposal rates (i.e., the percent of C&D recycled and the percent disposed) will not only require estimates of recycling and disposal tonnages for each state but also the tonnage of C&D generated. For those states identified in Step 1 that report C&D generation quantities, the contractor recommends that EPA use these values. For states without generation values, the contractor recommends that EPA develop state-level generation estimates by (1) applying the methodology outlined above to develop a national generation estimate, and (2) estimating the portion of generation associated with the state in question by assuming that generation is distributed across the states in proportion to construction sector GDP in each state. These data are available for the years 1963 through 2010.[21] Pre-1963, the contractor recommends that EPA use the distribution of population as an approximation for the distribution of construction activity across states.

   The contractor recommends that EPA apply this approach separately to the demolition and new construction portions of the C&D waste stream. Because the amount of demolition waste generated in a given year is a function of construction activity in years past, EPA should use *historical* state-level construction activity data to distribute the demolition portion of generation. For example, if EPA were analyzing the generation of asphalt shingle waste for the year 2010, the Agency would use construction data from 1980 and 1990 to distribute the tonnage of shingle waste generated from demolition across the states. This reflects the 20 to 30 year lifespan for asphalt shingles.

   While the demolition portion of C&D reflects historical construction activity, the construction-related portion reflects *current* construction activity. The contractor therefore recommends that EPA use construction activity data for the current year to distribute the construction portion of generation to the

[21] These data are available at http://www.bea.gov/regional/.

states.  For example, if a state accounted for 5 percent of construction-related GDP in 2010, EPA would allocate 5 percent of construction-related C&D generation (i.e., C&D excluding demolition waste) in 2010 to that state.

3. ***Estimate state-specific recycling and/or disposal rates***: Recycling and disposal rates may be estimated from the recycling, disposal, and generation estimates compiled under Steps 1 and 2.  Using the data available for a given state, the contractor recommends that EPA develop both recycling *and* disposal rates for that state.  Although many of the state studies are specific to recycling or disposal, recycling data may be used to estimate disposal rates and *vice versa*.  For example, for a state that reports recycling data, EPA would estimate the disposal rate as $(1 - r)$, where $r$ equals the recycling rate. Similarly, when using state-level disposal data, EPA could estimate the recycling rate as $(1 - d)$, where $d$ equals the disposal rate.

   When estimating the state-specific recycling and disposal rates, the contractor recommends that EPA use material-specific data where possible.  This will minimize the likelihood that the recycling and disposal rates estimated by EPA reflect materials that EPA does not plan to include in the MSW characterization reports.  For materials where data specific to the material of interest are unavailable, EPA could derive a recycling or disposal rate based on the aggregate rates reported in the state-level data and the material-specific rates.  For example, if the *aggregate* recycling rate in a state's data suggest that 10 million tons of C&D is recycled and the *material-specific* recycling rates account for 7 million tons of recycled C&D, this would imply that 3 million tons of the other C&D materials (those for which material-specific recycling rates are unavailable) are recycled.  If 12 million tons of this material is generated in the state, this would suggest a recycling rate of 25 percent (3/12).

   The contractor also recommends that EPA's assessment of data for states where only disposal data are available focus on those states where the disposal data reflect disposal in both C&D and MSW landfills. Data that reflect only one or the other may lead to underestimation of the disposal rate.

   After estimating C&D recycling and disposal rates, EPA may wish to corroborate these rates with data available from industry groups, such as the National Demolition Association.  The contractor attempted to obtain C&D recycling and disposal data from various industry associations prior to developing this document but none of the organizations that the contractor contacted were able to provide data.

4. ***Synthesize disposal and recycling rates***: The previous three steps will yield (1) a series of recycling and disposal rates based on states with C&D recycling data and (2) a separate set of recycling and disposal rates for states that report C&D disposal quantities.  Because of the uncertainties outlined above regarding the state-level recycling and disposal data, the contractor does not recommend that EPA use the results from Step 3 to develop point estimates for the disposal and recycling rates.  Instead, the contractor recommends that EPA develop ***ranges*** of disposal and recycling rates.  The Agency would then compare the recycling and disposal rate ranges derived from the recycling data to the corresponding ranges derived from the disposal data (see Step 5).

5. ***Evaluate disposal and recycling rate ranges***: EPA's evaluation of the competing recycling and disposal rate ranges should focus on the similarities and differences between the two:

- Are the low and high ends of the ranges similar? Does this vary by material?  Does this change if the ranges are based on the second highest and second lowest values (to remove outliers)?
- To what extent do the ranges based on the recycling data overlap with those derived from the disposal data?

If the comparison shows little similarity between the rates based on recycling data and those based on disposal data, further evaluation of the state-level recycling and disposal data would be warranted to identify the factors that explain these differences and what these differences mean for the relative quality of the recycling/disposal data.

EPA's selection of disposal and recycling rates for use in the MSW characterization report will depend, in part, on the findings of this comparative assessment, as well as follow-up research to explore the strengths and limitations of the individual state data sources. Through this process, EPA may conclude that some of the data points that inform the recycling/disposal rate ranges described above are unreliable. The contractor recommends that EPA exclude these data from the pool of recycling/disposal data that inform its final estimates of the recycling and disposal rates for C&D waste. Using the remaining data points that EPA considers to be reliable, the contractor recommends that the Agency develop separate recycling/disposal rate ranges for two groups of states: (1) states where landfill tip fees are above the national average and (2) states where landfill tip fees are below the national average.[22] For each of these two groups, the contractor recommends that EPA specify the recycling and disposal rates as a range to account for the uncertainty in the underlying data. Once these ranges have been finalized, EPA may estimate the tonnage of C&D recycled and the tonnage disposed by applying these disposal and recycling rates to generation estimates for the corresponding states, as derived from the approach presented in the previous section.

[22] State-level tip fees are available from *Waste & Recycling News*. See http://www.wasterecyclingnews.com/article/20120720/NEWS01/120729997/tipping-fees-vary-across-the-u-s.