Construction & Demolition

COMMODITY PROFILE

North Carolina Department of Environment and Natural Resources
DIVISION OF POLLUTION PREVENTION AND ENVIRONMENTAL ASSISTANCE

MARKETS ASSESSMENT 1998

OVERVIEW

Construction and demolition (C&D) debris is defined as "waste or debris resulting solely from construction, remodeling, repair, or demolition operations on pavement, buildings, or other structures."

Construction, renovation, and demolition jobs produce varying quantities of the following materials:

- Wood (clean scrap lumber)
- Brick and block (aggregates)
- Wood (painted or treated)
- Gypsum wallboard
- Manufactured wood (plywood, etc.)
- Cardboard
- Miscellaneous fines
- Asphalt shingles (scrap or tear-off)
- Metals (pipes, wire, conduits, structural beams, etc.)
- Asphalt pavement
- Miscellaneous plastics (PVC, HDPE, etc.)
- Land clearing debris
- Concrete (with and without re-bar)
- Salvageable materials (i.e., windows, doors, fixtures, etc.)

This commodity profile characterizes the overall C&D waste stream in North Carolina. Information pertaining to the recovery of road construction, repair, and demolition debris is presented separately from building-related C&D debris in this report. Limited data were available on the total generation of road debris. Thus, it could not be added to the generation figures for building-related C&D debris, although it is likely a large component of the overall C&D waste stream. Available information pertaining to road debris generation, recovery, and markets is presented first, followed by the analysis of building-related C&D debris.

Land clearing debris is not included in this report. Although it is sometimes considered to be a component of the overall C&D waste stream, and some of the material is disposed in landfills, little information exists on the quantity of the material generated or the amount of material recovered nationally or in North Carolina.

Approximately 2.5 million tons of building-related C&D debris were generated in North Carolina during 1997. This represents approximately 25 to 30 percent of the total waste stream. A majority of that material was disposed in municipal solid waste landfills (MSWLFs), construction and demolition landfills (C&DLFs), and land clearing and inert debris landfills (LCIDLFs). Because of difficulty in accurately determining the amount of C&D wastes entering these disposal facilities, other methods were used to estimate generation.

The estimated recovery for 1997 was approximately 153,000 tons, or roughly six percent of the C&D waste stream. Salvage and reuse activities at demolition/deconstruction job sites comprised a majority of recovery. Additional recovery was recorded by several mixed C&D debris processing facilities.

The supply of C&D debris is considerably greater than the current demand from C&D recyclers in North Carolina. C&D debris recycling is based on cost-avoidance (i.e., a reduced tipping fee) and not revenue generation. Thus, the quantity of C&D debris recovered is directly related to the cost of disposal. In areas of the country where landfill tipping fees are significantly higher, more material is being diverted. However, in North Carolina where tipping fees average $24 per ton for C&D landfills, there is less incentive for C&D recycling. A majority of C&D debris continues to be disposed in North Carolina's abundant and relatively inexpensive landfills.

To improve markets for C&D debris, a greater recycling infrastructure needs to be developed. In doing so, cost-effective means for diverting more of the materials should be emphasized, so that recovery operations are competitive with landfill disposal costs.

Road Construction, Repair, and Demolition Debris

Road debris results from the construction, maintenance, repair, or demolition of public and private road systems, bridges, parking lots, and driveways. Debris produced at these jobs primarily consists of asphalt pavement and concrete and includes land-clearing debris, metals, and a variety of aggregates.

SUPPLY

Generation

No information was available on the total amount of road debris generated nationally or locally. Generation figures are difficult to estimate, due to the durability and relatively long lifetime of materials. Additionally, fluctuations in the amount of roadwork completed year to year changes the annual quantities of debris generated. The amount of road work completed is affected by factors such as state and federal funding, weather and weather related disasters, the quality of materials used in the construction of a road, and the quality of maintenance throughout its life-cycle.

Recovery

Materials generated from road projects are either directly reused on-site, transported to central collection and recycling facilities, or disposed in MSWLFs, C&DLFs, or LCIDLFs. Because of reduced disposal costs at LCIDLFs, it is likely that these landfills are most frequently used for road material disposal.

Only one study found attempted to quantify the total amount of all road debris recovered nationally. According to this study, 81 aggregate processors throughout the United States recovered approximately 104 million tons of aggregates during 1997.[1]

When the asphalt pavement portion of road debris is considered separately from concrete, the quantity of material recovered can be estimated. According to the Carolina Asphalt Pavement Association, in 1997 its members produced a total quantity of 12.5 million tons of asphalt pavement, representing an estimated 95 percent of the total market in North Carolina.[2] According to a separate source, approximately 15 percent of recycled asphalt pavement (RAP) is used in the production of new hot mix asphalt pavement.[3] Thus, approximately 1.9 million tons of RAP were used. Because almost all asphalt pavement is recovered, it can be assumed that 1.9 million tons is close to the total quantity of asphalt pavement debris produced per year in North Carolina.

A survey of several mobile aggregate processors in North Carolina identified approximately 325,000 tons of concrete and other aggregates being recovered. Some materials were processed on-site, and other materials were processed at LCIDLFs. LCIDLFs are allowed to contain a certain portion of building related C&D debris, thus it cannot be assumed that 325,000 tons of road debris was recovered. Additionally, no data were available on the total generation of concrete debris to compare to these recovery figures.

With large public highway construction, repair, or demolition projects, a significant portion of the resulting asphalt and concrete materials are reused on-site because of cost savings over virgin materials. According to the North Carolina Department of Transportation (NCDOT), limited amounts of material are disposed during major highway projects. Most concrete is left untouched when repairing highways. Top layers of asphalt are milled or scraped off roads, then either are directly reapplied using special machinery or transported to an asphalt batch plant to be reprocessed. In cases where roads need to be demolished and moved, NCDOT contractors are required to prevent materials from being landfilled. No information was available on the total amount of material recovered from private contractors completing road demolition and replacement projects on state highways.[4]

For smaller public and private road projects, however, materials are more likely to be disposed in LCIDLFs. Limited data is available at the state level pertaining to the types and quantities of materials entering LCIDLFs. LCIDLFs are not required to report to the state on the quantity of material entering the facility (as most do not have scales). Without a detailed characterization of incoming materials and quantities entering such facilities, it is uncertain how much road debris is being brought to these facilities.

Markets

Aggregate recycling is most likely to be successful when a mix of the following is favorable: transportation dynamics, disposal and tipping fee structures, resource supply / product markets, and municipal support. Aggregate recycling rates are greatest in urban areas where replacement of [road] infrastructure is occurring, natural aggregate resources are limited, disposal costs are high, or strict environmental regulations prevent disposal.[5]

End products for recycled asphalt, concrete, and other aggregates range from high-end uses such as reclaimed and reprocessed asphalt pavement to lower-end uses such as road base or solid fill. The amount of source separation and processing determines the value of the end product.

- **Concrete:** Source separated concrete can be ground into a relatively high quality aggregate or gravel substitute for use as a road base material. Gravel for use in road construction ranges from approximately $8 to $15 per ton delivered to the site.[6] Aggregates are more expensive in eastern North Carolina where there are less natural aggregates in the coastal plain.

  NCDOT has tested the use of recycled concrete and found that it passes all performance tests. More extensive use of crushed concrete by NCDOT could greatly expand markets for this material.[7] However, North Carolina is a large producer of crushed rock and gravel from quarries. To compete with natural sources, recycled aggregates must be cost-competitive and greater or equal in quality.

- **Asphalt Pavement:** Source separated asphalt pavement can be recycled into a new pavement product. Scrap asphalt or recycled asphalt pavement (RAP) is mixed with virgin materials in percentages ranging from five to 25 percent. Some asphalt-producing companies accept asphalt scrap from their own operations as well as from demolition contractors and other sources willing to deliver it to their facilities.[8] Materials delivered to the site typically are accepted at no charge, provided they are free of other materials. Asphalt pavement reclamation is a well-established practice used mostly by asphalt plants because of cost savings over virgin materials.

Building Related Construction and Demolition Debris

SUPPLY

Generation

Traditionally, the generation of building-related C&D debris was estimated to be around 30 million tons a year nationally. During the past few years this number has come into question, with many C&D experts feeling 30 million was too low. In June 1998 the U.S. Environmental Protection Agency (EPA) released a report concluding that approximately 135 million tons of C&D were generated in the United States in 1996.[9]

Unfortunately, developing a per capita generation figure and applying it to North Carolina's population would significantly overestimate the amount of C&D generated in North Carolina. Although North Carolina is growing rapidly, this

Figure 1. Estimated Generation of C&D debris from Residential Sources in 1997 and 2002 (tons)

Residential	**1997**	**2002**
Construction	304,203	322,797
Single-Family Starts	*269,089*	*285,546*
Multi-Family Starts	*35,114*	*37,251*
Renovation	704,053	747,086
Demolition	637,986	676,981
Total Residential	**1,646,242**	**1,746,864**

growth is limited to a few regions of the state. North Carolina is still predominantly a rural state. The generation of C&D, therefore, was calculated on a regional and state level by applying the best numbers available to North Carolina-specific scenarios.

There are two major categories for C&D debris: residential and non-residential. Each category is further divided into three sub categories: construction, renovation, and demolition. This breakdown presents the main types of building activities and allows generation estimates to be developed based on existing data. This section represents an overview of the calculations, assumptions, and methodology used to estimate the generation of C&D debris in North Carolina during 1997.

Estimates for 2002 also are provided in this section, but are not described in detail. All estimates for 2002 are based on current per capita generation applied to North Carolina Office of State Planning population estimates for July 1, 2002. Estimates for 2002, therefore, do not account for future construction practices or unanticipated growth. Unlike many recyclable commodities, the generation of C&D debris is closely linked with local economies and can be quite variable. It is, therefore, unknown if per capita estimates for 2002 will over- or underestimate actual generation.

An overall characterization of C&D debris is provided at the end of this section. Individual characterizations of each category (i.e., residential renovation) are depicted in appendices to this report.

Certain materials were omitted from this report. For example, C&D debris generated from public utilities and military facilities was omitted because of a lack of available data. Thus, generation estimates provided underestimate the total quantity of waste generated from all C&D activities. Limited data were available to estimate the generation of land clearing debris from each activity characterized below; however, because of the wide range of management options available (i.e., open burning, LCID landfills, etc.), these wastes are not discussed in this report and require further investigation.

Residential Construction

Several methods for estimating waste from residential construction starts in North Carolina were considered, including using the value of construction put in place and the actual number of construction starts. Given that the number of construction starts for both single-family and multi-unit structures were available for 1997, this was the method used.

According to the North Carolina Department of Labor (NCDOL) statistics, there were 54,654 single-family starts and 16,074 multi-unit starts during 1997.[10] Multi-unit starts are defined as individual units within a larger building (i.e., a six unit apartment building would represent six starts).

The average square footage of housing units in 1997 was then applied to the starts for each housing category to generate an overall square footage per housing category. The National Association of Home Builders (NAHB) estimates that the average single family house built in 1997 was 2,150 ft^2 and the average multi-family unit was 1,095 ft^2.[11]

Using empirical data obtained from EPA, generation of waste was estimated to be 4.58 lbs./ft^2 for single-family construction and 3.99 lbs./ft^2 for multi-family construction. Applying these figures to the estimated square footage resulted in an estimated total generation of 304,203 tons of residential construction waste. A more detailed breakdown is provided in Figure 1.

Residential Renovation

Debris generated from the renovation of residential and non-residential buildings is perhaps the hardest component to estimate. For purposes of this assessment, renovation debris is defined as debris generated from the renovation, improvement or repair of structures. Renovation debris commonly consists of debris generated from both construction and demolition activities, but is considered an individual category. For example, replacing a wooden deck would generate debris from the deck's demolition, as well as debris from the scrap materials in constructing the new deck. All wastes generated during this deck replacement would be considered renovation debris. Renovation projects also range greatly in size, cost, and waste generated. Because of do-it-yourself projects and the small scale of some improvements, it is difficult to track renovations through standard permitting records.

Because of these constraints, a method similar to that used by the EPA was used to estimate North Carolina generation. A conversion factor of 0.56 lbs. of waste generated per dollar of renovation (in 1996 dollars) was developed based on EPA's recent characterization.[12] This conversion is based on EPA's total estimate of waste generated from residential renovations in 1996 divided by the total dollar spent on such renovations.

Data from the U.S. Department of Commerce (USDOC) was then used to estimate the value of residential improvements and repairs for North Carolina.[13] These data were available only for the "South Region" and were extrapolated to represent North Carolina based on population.[14] This figure was then deflated three percent to 1996 dollars, representing just more than $2.5 billion.[15] Applying the conversion factor (0.56 pounds per 1996 dollar) provided a generation estimate of 704,053 tons of renovation debris in 1997 (Figure 1).

Residential Demolition

The generation of residential demolition debris was estimated twice during this assessment based on two separate estimates for the number of residential demolitions occurring in North Carolina. Rather than choose one estimate over the other, both estimates were averaged and the subsequent average was used as the best estimate.

The first estimate of the number of demolitions occurring in North Carolina was based on USDOC data for the "South Region" and includes demolitions caused by disasters. This resulted in the "South Region" having a disproportional number of demolitions. In this case, the "South Region" represented 36 percent of the population, but accounted for 45 percent of all residential demolitions. Although all states included in the "South Region" are prone to disasters, several states, other than North Carolina, were more prone to severe destruction from disasters than the majority of the states. Therefore, it was assumed that directly using the estimate obtained from the USDOC would overestimate the number of demolitions in North Carolina. Extrapolating for North Carolina, it was found that 9,085 residential demolitions occurred in 1997.[16] This figure is based on the average number of demolitions occurring between 1980 and 1993 and assumes the average over time is relatively constant.

The second estimate was derived from EPA's characterization, indicating there were 245,000 intentional demolitions (not disaster related) per year in the United States.[17] Extrapolating based on North Carolina's population resulted in 6,811 demolitions per year. This number, however, underestimates the number of demolitions occurring in the state due to the lack of any disaster related demolitions.

The two estimates were averaged to develop an estimate that accounted for, but did not overestimate, disaster-related demolitions. The resultant average of the two estimates equated to 7,948 residential demolitions per year. Based on EPA estimates, it was assumed that the average demolition in 1997 was 1,396 ft^2 and generated 115 pounds of waste per square foot.[18] Applying these data to the averaged North Carolina demolition estimate resulted in a generation estimate of 637,986 tons of residential demolition debris in 1997. The estimated generation of C&D debris from residential sources in 1997 and 2002 is reported in Figure 1.

Non-Residential Construction

Similar to residential construction, several methods for estimating non-residential construction waste generation figures were considered. Because it would be difficult to characterize the average size of a non-residential building constructed during 1997, it was decided that non-residential construction starts did not provide adequate information to estimate construction waste generation. Estimating the generation based on the value of construction put in place in 1997 was chosen as the most appropriate method.

Although statistics for the value of construction put in place were available from both the State of North Carolina and the USDOC, numbers from the latter were used because DOC provided statistics on public construction (i.e., schools, government buildings, etc.). The USDOC data also provided a more detailed breakdown of all non-residential construction.

Applying national data within the context of one state, however, created a problem. To accurately apply national statistics at the state level, a growth factor was developed based on residential housing starts. It was assumed that residential and non-residential construction are directly related (i.e., if residential construction is occurring at a rate greater than the national average, non-residential construction is likely occurring at a similar rate). Using detailed NCDOL statis-

Figure 2. Estimated Generation of C&D debris from Non-Residential Sources in 1997 and 2002 (tons)

Non-Residential	1997	2002
Construction	163,176	173,140
Renovation	392,496	416,486
Demolition	317,095	336,476
Total Non-Residential	**872,767**	**926,103**

Figure 3. Total Estimated Generation of C&D Debris in North Carolina in 1997 and 2002 (tons)

	1997	2002
Residential		
Construction	304,203	322,797
Renovation	704,053	747,086
Demolition	637,986	676,981
Non-Residential		
Construction	163,176	173,140
Renovation	392,496	416,486
Demolition	317,095	336,476
Total	**2,519,000**	**2,672,967**

tics on the number and value of housing starts in 1997, an overall value for residential construction was developed.[19] This value was then compared to USDOC data on the value of construction nationally in 1997 adjusted to represent North Carolina's population.[20] It was found that the actual value of construction based on North Carolina data was 1.23 times greater than that estimated using national data.

Based on 1.23 times the per capita value of construction, the actual value of construction put in place in North Carolina in 1997 was then estimated to be approximately $7.81 billion dollars.[21] This figure was applied to empirical data obtained from EPA's characterization of C&D debris that estimated an average non-residential construction cost of $93.12 per square foot in 1997 dollars and an average generation of 3.89 pounds of waste per square foot. This resulted in an overall generation estimate of 163,176 tons.[22] Figure 2 provides generation estimates for 1997 and 2002.

Non-Residential Renovation Debris

The generation of non-residential renovation debris, which includes improvements and repairs, was estimated in a similar manner to residential renovation debris. Since it is believed that most non-residential renovations can be identified through permit records, NCDOL statistics were used to determine the value of non-residential renovations.[23] It was found that non-residential renovations cost slightly more than $1.4 billion in 1997. Compared to the value of residential construction put in place, $1.4 billion appears to be a low estimate. It is likely that the estimated generation of non-residential renovation debris, illustrated in Figure 2, underestimates the actual amount of debris generated. Some material likely is missed in the calculation from unpermitted activities and public renovation projects.

No conversion factor was available to convert the cost of non-residential renovations to pounds of waste. Therefore, it was assumed that residential renovations create a similar amount of waste per dollar as non-residential renovations. The estimate used for residential renovations, 0.56 lbs. per 1996 dollar was used for the conversion. The cost estimate was deflated by three percent to represent 1996 dollars and subsequently applied to 0.56 lbs. per dollar of renovation.[24] This resulted in an estimate of 392,496 tons on non-residential C&D debris generated in 1997 (Figure 2).

Non-Residential Demolition

Records of non-residential demolitions occurring in North Carolina were available from a report by the North Caro-

Figure 4. Sources of All C&D Debris in North Carolina

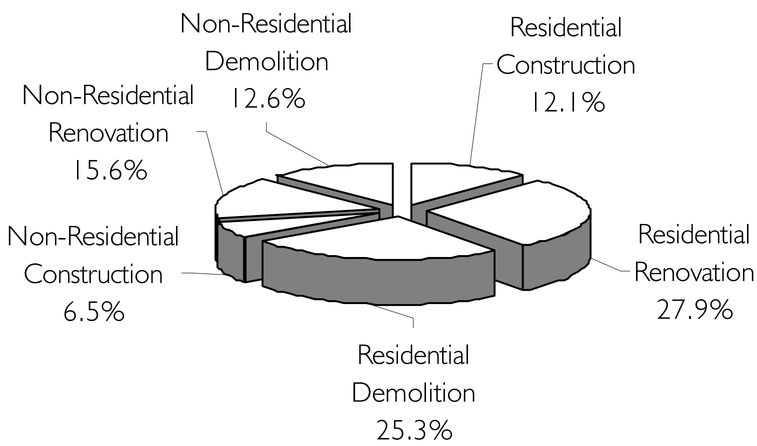
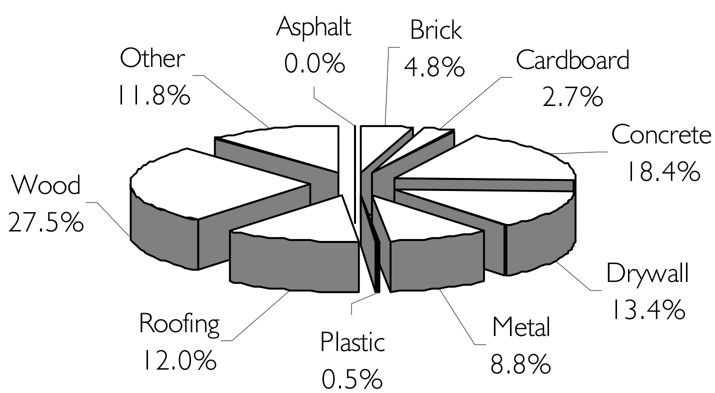


Figure 5. Overall Composition of C&D Debris



lina Division of Epidemiology and were used for estimating generation.[25] In most cases the report provided the square footage of the demolished building. In instances where no square footage was provided, the building was assumed to be 13,300 ft^2 based on EPA estimates.[26] Compilation of this data resulted in a total of 4,091,546 ft^2 demolished in 1997.

The overall square footage then was applied to a U.S. EPA estimated 155 pounds of waste per square foot demolished.[27] As can be seen in Figure 2, this resulted in an estimated 317,095 tons of non-residential demolition debris generated during 1997.

Characterization of C&D Debris

Although the actual composition of C&D debris varies widely with the type of structure and specific C&D activities, the waste stream can be characterized in a very general sense. (To truly understand the C&D waste stream, each aspect of the waste stream should be characterized separately.) Figure 3 provides an overall estimate for C&D generated in North Carolina during 1997 and 2002, and Figures 4 and 5 provide characterizations of C&D debris by source and waste stream components.

About 65 percent of all C&D generated in North Carolina is from residential sources. Debris from residential sources can be further broken down as 18 percent construction, 43 percent renovation, and 39 percent demolition. Non-residential sources generate the remaining 35 percent of C&D debris. The makeup of the non-residential portion is similar to the residential portion, with 19 percent from construction, 45 percent from renovation and 36 percent from demolition. Figure 4 provides a breakdown of C&D debris sources for the entire waste stream.

Figure 6. Generation and Recovery of C&D Debris in North Carolina

	1997
Generation	2,519,000
Recovery	152,874
Percent	6.07%

Several characterization studies examined during this assessment identify individual components of C&D debris. Unfortunately, these studies vary widely in the detail of the component breakdown and the sources of the C&D debris. Figure 5 illustrates the overall composition of C&D debris based on one of the studies.[28] This study was chosen because it accounts for all six types of C&D generating activities defined in this report, and the components identified are similar to those discussed in this report.

Recovery

Figure 6 summarizes generation and recovery of C&D debris in North Carolina during 1997. As showed in Figure 6, an estimated 2.5 million tons of C&D debris were generated in 1997, representing approximately 22 percent of North Carolina's total waste stream. Limited infrastructure exists for C&D recycling in North Carolina, and only about 153,000 tons were reported recovered during 1997, or roughly six percent of the C&D waste stream. A majority of recovery took place through salvage and reuse activities at demolition / deconstruction job sites. Additional recovery was recorded from several mixed C&D debris processing facilities. Based on the recent growth of recycling infrastructure, recovery is expected to increase, but insufficient data were available to make projections for 2002.

It is likely that some amount of clean wood from C&D debris is being processed along with materials such as trees and brush, resulting from land clearing activities. These types of material typically are made into a mulch or compost product. However, the amount of C&D wood that ends up mixed with land clearing debris is not known and is not included in recovery.

DEMAND

Disposal of C&D Debris

The demand for C&D debris is affected mainly by the available landfill options in the state and their respective prices. A majority of C&D debris managed in North Carolina is disposed in landfills ¾ more specifically, in C&D landfills, municipal solid waste landfills, and in some cases land clearing and inert debris landfills. The following descriptions represent a brief overview of each type of facility.

Municipal Solid Waste Landfills (MSWLFs)

- Definition: "Municipal solid waste landfill unit means a discrete area of land or an excavation that receives household waste, and is not a land application unit, surface impoundment, injection well, or waste pile, as defined under 40 CFR Part 257. Such a landfill may be publicly or privately owned. A MSWLF unit also may be permitted to receive other types of non-hazardous solid waste. A MSWLF unit may be a new MSWLF unit, an existing MSWLF unit or a lateral expansion." 15A NCAC 13B .1602(17).
- Number of facilities: During fiscal year 1996-97, there were 66; currently, there are 46 (including those under construction).
- Average Tip fee: $29.91/ton
- Tons of C&D received: Unknown, but likely more than one million tons during fiscal year 1996-97.
- Other: MSWLFs have to meet stricter environmental regulations than C&D landfills. All unlined MSWLFs in the state closed as of January 1, 1998. This change resulted in a number of facilities closing or converting to C&D landfills, which do not require liner systems.

C&D Landfills (C&DLFs)

- Definition: C&D debris landfills, although not defined by statute or rule, generally are allowed to accept C&D debris, debris acceptable in land-clearing and inert debris landfills, and other waste approved by the N.C. Division of Waste Management.[29]
- Number of facilities: In fiscal year 1996-97, there were 30 (including four stockpiles); currently, there are 41.
- Average tip fee: $23.66/ton, although volume-pricing systems are still in place.[30]
- Tons of C&D received: 1,009,000 tons of debris were disposed of at C&D landfills in fiscal year 1996-97, representing shipments from 46 of North Carolina's 100 counties. The extent to which all of the waste came from C&D related activities as opposed to land clearing activities could not be determined.
- Other: Many MSWLFs scheduled to close as of January 1, 1998, had remaining capacity. To maximize this capacity and to minimize closure costs, many of these landfills were converted to C&D landfills. Currently, there are 22 C&D landfills operating on closed MSWLFs. C&D landfills generally can accept land clearing debris and other inert material.

Land-Clearing and Inert Debris Landfills (LCIDLFs)

- *Definition*: "Land clearing and inert debris landfill means a facility for the land disposal of land clearing waste, concrete, brick, concrete block, uncontaminated soil, gravel and rock, untreated and unpainted wood and yard trash" 15A NCAC 13B .0100(54).
- *Number of facilities*: Unknown.
- *Average tip fee*: Unknown. Facilities generally charge by the cubic yard or truckload.
- *Tons of C&D received*: Unknown. Only certain components of C&D debris are acceptable at LCID landfills.
- *Other*: The operation of LCID landfills are regulated, but not to the extent of MSWLFs or C&D landfills. Because of the localized permitting structure, little information is available about the number of facilities, the capacity in place, tip fees, waste handled, etc.

C&D Landfill Tipping Fees

Landfill tipping fees within the state largely affect the amount of C&D recovery taking place. Most C&D recovery facilities charge a per ton fee close to landfill disposal fees to cover the associated hauling, handling, and processing costs. Most C&D recycling operations are based on costing less than disposal. Thus, for C&D recycling operations to be cost competitive, their processing costs should be less than the average tipping fees in that local area.

During fiscal year 1996-97, 26 C&D landfills and four C&D stockpiles received slightly more than one million tons of waste. Tip fee data were available for 25 of the C&D landfills and ranged from $8 ton to $40 per ton. The average tip fee was $23.66 per ton, and the median tip fee was $22 per ton. C&D stockpiles averaged a disposal fee of $23 per ton. Although all facilities reported a tip fee based on tonnage, some North Carolina facilities also use volume-based fees.

The 30 C&D disposal facilities received waste from 46 of North Carolina's 100 counties, indicating substantial amounts of C&D debris were disposed in municipal solid waste landfills (MSWLFs). The average tip fee for North Carolina MSWLFs in 1997 was $29.91.

As of September 20, 1998, 49 C&D landfills were operating or under permit review: 19 were stand-alone C&D landfills, 22 were operating on closed MSWLFs, and eight C&D landfills were under permit review.[31]

The effects on tipping fees of the increase in the number of C&D disposal facilities are not yet known. It is expected that as the number of landfills increases, the increase in competition likely will lower tipping fees.

C&D Recovery Efforts

C&D recycling efforts include source separated and mixed material recovery. Source separated recovery requires separation of the materials at the job site. Each material type is transported to a distinct processing facility or end market. With mixed material recycling, aggregated materials are collected together, then separated at a processing facility. A discussion of these recovery options is provided below. Successful implementation and cost savings of these programs are dependent on local tipping fees, construction density, distance to recycling and disposal options, and market value of materials.

Source Separated Recovery

As with traditional recyclables, the materials in C&D debris maintain their highest recycling value when source separated at the job site. While separated materials may be reused or processed in higher value-added applications, mixed material often is processed into a wood stream for mulch or fuel and an aggregate stream suitable for gravel or fill, which have relatively low value.

Construction/Renovation

In construction site recycling, many players are involved in the process of getting materials to the market. The first is the construction contractor, second is the hauler, and third is the material processor/recycler.

Role of the Contractor

Job-site recovery requires greater education of a construction company's workers and careful education and agreements with subcontractors. While managing source separation adds to the already busy schedule of the site foreman, potential exists for greater cost savings to the project as a whole.[32]

Separation of waste materials at the job site actually can reduce disposal and other costs related to construction. In addition to preserving of the value of the material, separation can reduce costs on the construction site by making usable materials available. For example, site separation of scrap wood makes it easily available for use when a shorter piece of lumber is required. The Home Builder Recycling Initiative reported that framers learned to look for usable wood in the discard pile when it was source separated and easy to identify.[33]

The average disposal cost for residential construction in the Triangle area of North Carolina is about $0.50/square foot of construction.[34] The homebuilder or commercial construction contractor actually can save on hauling costs by contracting with someone to remove materials in a manner that preserves their value for reuse and recycling. This hauler often will charge a lower fee than that charged by a hauler who takes mixed materials to a landfill for disposal.

A study of construction waste generation and site separation in Cary, North Carolina, identified the willingness of homebuilders and their subcontractors to separate materials for recycling. Although immediate or long-term cost savings were frequently cited as reasons for recycling in the future, the two most often cited motivations were not related to cost. Seventy-six percent of respondents said they would recycle simply because it makes sense, and 71 percent cited their responsibility to society/environment as a motivating factor.[35]

A guidance document for reducing waste for commercial construction entitled *WasteSpec* was developed in North Carolina by the Triangle J Council of Governments.[36] A study of commercial construction projects that used *WasteSpec* to reduce and recycle their wastes determined that in all but one of the 12 projects surveyed, the cost of the project remained the same or was reduced compared to what it would have been otherwise.[37]

Role of the Hauler

The hauler wishing to make a business of collecting source separated construction waste must evaluate potential increased transportation and labor costs, decreased disposal costs, and revenues from the sale of some recyclable items.

The cost of transporting separated materials most often is higher than that of collecting a pile or roll-off container of mixed waste and transporting it to a disposal facility. Proper collection of sorted material may require a truck with separate areas for segregated materials, as well as more than one trip to a site. Processing facilities for separated wastes may be closer or farther away than the single disposal site for mixed waste.

Site separation of materials is made easier by close attention to the construction schedule. For example, a majority of wood debris is generated in framing a house and can be collected separately. The installation crew also generates gypsum wallboard waste in a concentrated time period. In cases where wallboard subcontractors haul their own waste, the load is generally all wallboard scrap and easily recovered for recycling.

Disposal costs of the collected material are either eliminated or reduced when source separated material is collected. In the cases where there is a market for a material, revenue actually is generated by this action. (For market prices of selected materials, see the latter part of this section.) In cases where markets are not well developed, a reduced tipping fee often may be offered by landfills for items such as source separated, clean (unpainted, untreated) wood waste.

As described above, the hauler may face additional costs in managing source separated wastes including specialized hauling equipment and the possibility of increased transportation costs (transportation costs depend on the location of the recycling facility in relation to the current disposal option). However, a survey of homebuilders in Wake County indicated 53 percent would be willing to source separate wastes if hauling costs were equal to that of disposal. Another 31 percent would be willing to pay zero to five percent more for source separated hauling for recycling, and 11 percent indicated they would be willing to pay five to 10 percent more. Six percent indicated they would be willing to source separate for recycling only if disposal costs decreased.[38]

Deconstruction

When a building is no longer useful to its owners in its present state, a hierarchy of waste management options in order of preference includes restoration on site, moving the home to another site, deconstruction, and demolition.

Restoration of older homes and commercial buildings preserves the highest value of the building. If the land has become more valuable for another use, an historic home might be moved to another location for restoration. Preservation North Carolina and the North Carolina Historic Preservation Office promote this method of using older buildings.[39, 40] These agencies work to find new owners and restorers for historic homes and, when necessary, find new owners and new locations for homes that must be moved.

Deconstruction of buildings preserves the value of materials and architectural elements in a building by carefully removing items in a way that maintains their integrity. Deconstruction can be partial or complete. In partial deconstruction, usable items like mantelpieces, doors, wood flooring, and cabinets are removed for reuse before the rest of the building is demolished. This method is used by private and non-profit organizations to recover the most valuable elements of historic buildings that must be demolished. Non-profit groups that use partial deconstruction include Habitat for Humanity of Wake County and Architectural Salvage of Greensboro. These two groups recover materials for resale to fund operations.

Complete deconstruction means dismantling a building in a way that recovers all components, even the framing, for reuse or recycling. Older buildings, commercial or residential, often contain valuable timbers and hardwood flooring, as well as the other elements discussed in the text on partial deconstruction. Timber framing can be reused or made into wood flooring. A number of companies operating in North Carolina that process old timbers into wood flooring. They purchase timbers from deconstruction projects in North Carolina and throughout the United States. Bricks from large, older commercial buildings, such as tobacco and other warehouses, are valuable when cleaned of their mortar. Metals are recoverable from commercial buildings of any vintage. A small number of North Carolina businesses provide complete deconstruction of older homes, and the North Carolina Cooperative Extension Service has published a film on the deconstruction process.[41]

Deconstruction of a material for recycling involves the work of the deconstruction manager or firm and the processor or end-user of the site separated material.

Role of the Deconstruction Firm or Manager

Factors that affect the economic viability of deconstruction include labor cost, equipment needs, value of materials, and location of markets. The labor costs for deconstruction of a building are much higher than that of demolition. Deconstruction takes more time and requires an additional amount of skilled labor to remove materials in a form that is later valuable. While deconstruction of a single family home may require as little as an assortment of crowbars, deconstruction of larger commercial facilities may require more heavy-duty and specialized mechanical equipment.

The value of materials in the building determines whether the extra labor required is worth the time and effort. Older homes often have interesting architectural elements, wood flooring, and other materials highly valued by people renovating existing homes or interested in bringing classic elements into a new construction project. The common rule of thumb in the home deconstruction business is that selling the wood floor should cover labor cost of the complete deconstruction. The sale of the other recovered materials represents potential profit that could be made on the project.

Large timbers and brick construction can make an old warehouse or other commercial facility worth deconstructing. These large timbers are sold for construction or are often re-sawn to make valuable wood flooring. Bricks from these deconstruction projects are cleaned of their mortar by hand and may reach distant reuse markets. Metals commonly are recovered from both deconstruction and demolition projects.

Mixed Materials Recovery

Like source separated materials processing, three parties are involved in mixed materials recycling: the contractor, the hauler, and the recycler/processor.

Mixed C&D materials typically are collected at job sites in large roll-off containers ranging in size from 10 to 50 cubic yards. The contractor places all C&D materials into a container, making sure to keep out MSW. To the hauler and contractor, the process essentially is the same as with materials destined for a C&D debris landfill.

Materials are taken from construction, renovation, and demolition job sites and transported to a stationary processing facility. The different C&D components are separated mechanically or manually. Basic mechanical separation includes screening, grinding, and magnetic separation. More sophisticated processes can include air or water separation to remove heavier aggregates, such as brick and block, from the lighter debris, such as wood and cardboard. Depending on the degree to which materials are separated, end products can include a recycled aggregate for a gravel substitute, wood chips for fuel or mulch, recyclable cardboard, plastics, and miscellaneous soil-like materials or fines.

Mixed Materials Recovery Costs

For the contractor and hauler, prices for this service need to be comparable to that of disposal. The hauler charges the contractor a straight fee per load or breaks down the cost to include a tipping fee (i.e., a per ton fee) plus a hauling charge to the facility. Either way, the hauler still charges the contractor a price similar to a disposal fee at the landfill.

Generally, costs associated with start-up, daily operations, and maintenance of this type of operation make it the most expensive type of processing. Tipping fees at mixed C&D processing facilities are very close to the average landfill tipping fees in a given area. (For example, the average tipping fee for C&D in North Carolina is approximately $24 per ton.) The main advantage to mixed materials recovery over source separated recovery is that the contractor does not need to spend additional time and money separating out materials at the job site. All or most materials are simply transported to a central processing facility.

The value of end products resulting from mixed processing depends largely on the purity of materials after separation. For example if wood materials contain a large amount of aggregate, then the resale value as a fuel would be minimal. Additionally, the cost of transporting materials to mar-

Figure 7. Average Prices for Metal as of September 1998

Material	Price
Mixed Aluminum	$640/ton ($.32/lb)
Mixed Steel	$20-$60/ton ($.01-$.03/lb)
Copper	$1,573/ton ($.79/lb)

Sources: 1) Recycling Times, The Markets Page, September 14, 1998, Pp. 8-9.
2) http://www.amm.com/inside/1998/81015key.htm

ket needs to be taken into account to accurately determine the net value of end products.

MARKETS

Whether from source separated or mixed materials recycling, the individual components of C&D all have different uses and values. Because of the wide variety of materials that make up C&D debris, and their distinctly regional markets, it is not possible to generalize the overall economics of C&D recycling for the entire state. For recycling market information specific to a given county or region of North Carolina, please refer to the *Directory of Markets for Recyclable Materials* produced by North Carolina's Recycling Business Assistance Center. Below is a brief discussion of the markets for these C&D components: metals, cardboard, plastic, aggregates, drywall, asphalt shingles, and wood.

Metals

Metals make up approximately nine percent of the C&D waste stream.[42] Source-separated metals from construction or demolition debris are typically the highest value material, and are more commonly recovered than disposed. Aluminum, steel, and copper are the most common metals found in C&D debris. These materials are typically accepted at all salvage yards directly from the contractor. If large enough volumes are being generated at a job site, metal recyclers will sometimes site containers for free, or at a minimal cost to cover transportation.

According to the U.S. Geological Survey, the second largest source of Iron and Steel scrap is from demolished steel structures.[43] With the increasing capacity of steel mini-mills in the United States that produce steel products made primarily from scrap, the United States steel making industry undoubtedly will increase efforts to reclaim additional amounts of steel from construction and demolition debris recycling activities.

Figure 7 shows the average price paid for aluminum, steel, and copper in September 1998. For further information on metal prices, review the Metal Cans Commodity Profile.

Old Corrugated Cardboard (OCC)

OCC makes up approximately three percent of the overall C&D waste stream. As a component of the construction debris waste stream, however, it is a bit larger ¾ four to six percent. The fact that OCC is used primarily as a packaging material makes it a prime target for separation on-site. Construction site recycling is perhaps the most logical location to recover corrugated cardboard from C&D debris.

In North Carolina, at least 30 communities have disposal diversion ordinances (DDOs) that limit management options for corrugated cardboard. Penalties associated with these ordinances range from increased tipping fees to load refusal. Although these DDOs usually apply to municipal solid waste landfills (MSWLFs), significant quantities of C&D debris are disposed at such facilities.

OCC processors are abundant in North Carolina. A search of the Recycling Business Assistance Center's *Directory of Markets for Recyclable Materials* identified 84 processors or end-users servicing the state.

Processors currently are paying approximately $7.50 per ton for loose OCC and about $17.50 per ton if baled. Also, opportunities exist to ship baled OCC to end-users, which currently pay in the $50 to $60 per ton range.

Current prices paid for OCC are low, and a review of the OCC commodity profile indicates they are expected to remain low for some time. Although prices are low, the abundance of markets and the ease of separation still allow for opportunities to offset disposal costs through on-site recovery. OCC is a component of C&D debris that can be easily targeted by companies specializing in construction site recycling.

Plastic

Plastic makes up approximately .5 percent of the C&D waste stream. The two most recoverable plastics in construction waste are vinyl siding and HDPE buckets. Two plastic processors in the state currently accept vinyl siding and some local governments are adding collection points for this material. One local government program is receiving $40/ton loose or $100/ton for baled siding that is transported from the collection point by the processor.

Initial research indicates that HDPE plastic buckets appear to have a high reuse value. When separated at the Home Builder's Recycling Initiative project sites, workers took them home.[46] No markets were located for these buckets.

Aggregates

Aggregates are among the largest portion of the C&D waste stream, representing approximately 23 percent of the total weight. Aggregates include asphalt pavement, concrete, reinforced concrete, cinder block, brick, glass, rock, sand, soil, and miscellaneous fines that result from construction, renovation, or demolition of residential and commercial structures.

The largest amounts of aggregates are generated from demolition of commercial concrete or brick structures, and from foundations of residential structures. All these materials can be combined and processed to produce a low-grade gravel substitute or solid fill material. However, the following individual aggregate components are more valuable when source separated:

- **Miscellaneous fines:** Mostly made of soil and small aggregates, fines are derived from screening C&D debris. This material can be given away as fill or sold as a soil product depending on the material's quality. The quality of the resulting product is related to the materials from which the debris was originally screened. Material screened from mostly aggregates will more than likely be a relatively homogenous soil-like product. However, fines derived from construction or demolition of wooden structures will obviously have wood mixed with the soil. Additionally, with fines screened from debris resulting from the demolition of wooden structures, painted wood is a concern because of the potential for lead paint contamination.

- **Concrete:** makes up approximately 18.4 percent of the building related C&D waste stream. For information on the markets for recycled concrete, please refer to the road debris section of this commodity profile.

- **Brick:** makes up approximately five percent of the total C&D waste stream. Whole bricks have a significant re-sale value for direct re-use. Bricks are used in restoration projects and for aesthetic purposes in residential and commercial building. Crushed brick can be used as a road base aggregate similar to concrete and has established markets as a landscaping product as well.

Drywall

Drywall, also referred to as sheetrock and wallboard, makes up an estimated 13 percent of the C&D waste stream.[44] Scrap drywall from the manufacturing process and from new residential, including the manufactured housing industry, and commercial construction currently are being recovered. However, drywall from renovations or demolition is not typically considered to be recyclable since most of the material is painted or treated.

Drywall is composed primarily of gypsum or calcium sulfate and a paper backing. As a pH neutral and absorbent material, recovered gypsum may be used for applications such as cat litter and as a spill absorbent product. Gypsum also is used in agricultural applications in North Carolina as a soil amendment. Gypsum adds calcium, sulfur, and some boron to the soil, is pH neutral, and loosens clay soils.[47]

Because extensive processing must occur to create these refined products, gypsum recyclers typically charge a tipping fee competitive with the average landfill tipping fees in North Carolina.

Asphalt Shingles

Asphalt shingles make up approximately 12 percent of the total C&D waste stream.[48] Some scrap asphalt shingles from the manufacturing process and from new construction currently are being recovered. However, shingles from roof replacements (tear-off shingles) are not being recovered because some shingles previously were made with asbestos. Until a cost-effective means for testing tear-off shingles for asbestos is developed, they will continue to be disposed of in landfills.

A potentially large market exists for asphalt shingles as an additive to asphalt pavement. Asphalt shingle scrap along with other tar-based materials (such as tarpaper and flat roof asphalt aggregate) can be processed into road paving mix. Scrap must first be ground and nails and ferrous metals removed with a magnet before being mixed with recovered asphalt and primary materials for new paving mixes. The fiberglass component of shingles can have a beneficial effect in making the mix more durable or water repellent.[49]

Because of extensive processing costs incurred in grinding, screening, and blending the shingles in an asphalt pavement mix, tipping fees are close to the average landfill tipping fees in North Carolina.

Wood

Wood makes up approximately 28 percent of the C&D waste stream. Clean wood waste from construction sites has many uses with the most valuable being re-use. However, dimensional lumber scrap (i.e.2 x 4s) may not be acceptable for structural purposes unless the grade stamp is visible. The industry in the United States is considering certification methods for grading used lumber.

Clean dimensional lumber scrap can be finger-jointed into longer pieces. This practice is becoming common in the Pacific Northwest and a North Carolina company began operations in October 1998. Finger-jointed lumber is generally straighter than ordinary two-by-fours and is approved for structural use.

Clean dimensional lumber scrap also can be made into mulch or used as a component of compost. The price paid for a ton of clean dimensional lumber will vary based on the size of the load and the distance to the processing facility. Most mulch facilities have the ability to chip or grind lumber, but the price paid for mulch ranges from free to $2.50 per ton in the United States.[49]

Because it is kiln dried, dimensional lumber chips have a high fuel value. A national study reports prices for processed wood for fuel to be $8-20 per ton.[50] Prices quoted from North Carolina markets range from $12-$25 per ton.[51]

Wood waste from demolition sites is more likely to contain paint or other contaminants. For this reason, it is not generally usable as soil amendment, but may be used as fuel depending on the level of contamination.

CONCLUSION

The supply of C&D debris is considerably greater than the current demand for recovery. C&D debris recycling is based on cost-avoidance and not necessarily revenue generation. Thus, the quantity of C&D debris recovered is directly related to the cost of disposal. In areas of the country where landfill tipping fees are significantly higher, more material is being diverted. However, in North Carolina, where tipping fees average $24 per ton, there is less incentive for C&D recycling. A majority of C&D debris continues to be disposed in North Carolina's relatively inexpensive landfills.

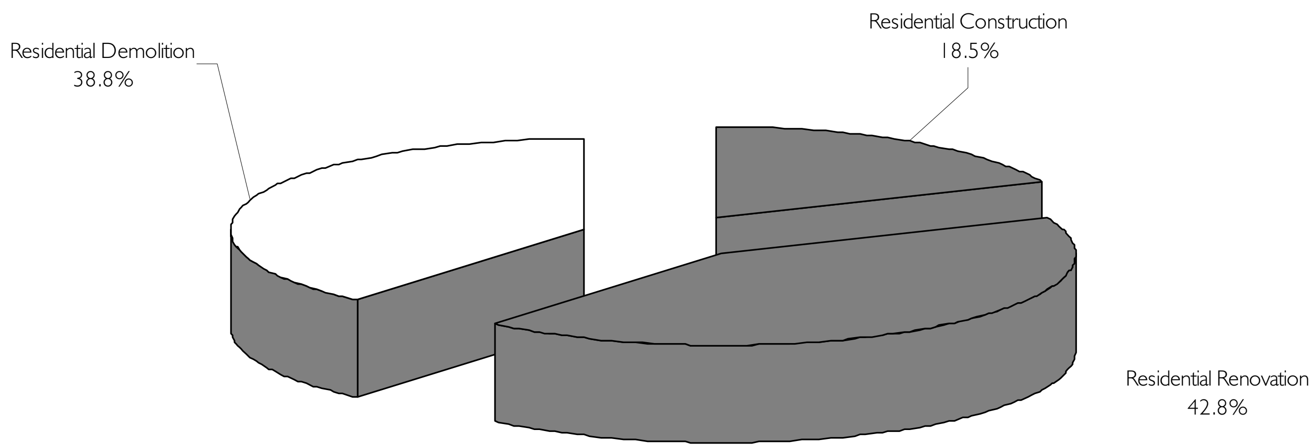
To increase demand for C&D debris, the State of North Carolina should continue encouraging reuse and recycling infrastructure development, placing emphasis on recovery processes that are cost-comparable to landfilling. The following are specific recommendations for accomplishing this goal.

RECOMMENDATIONS

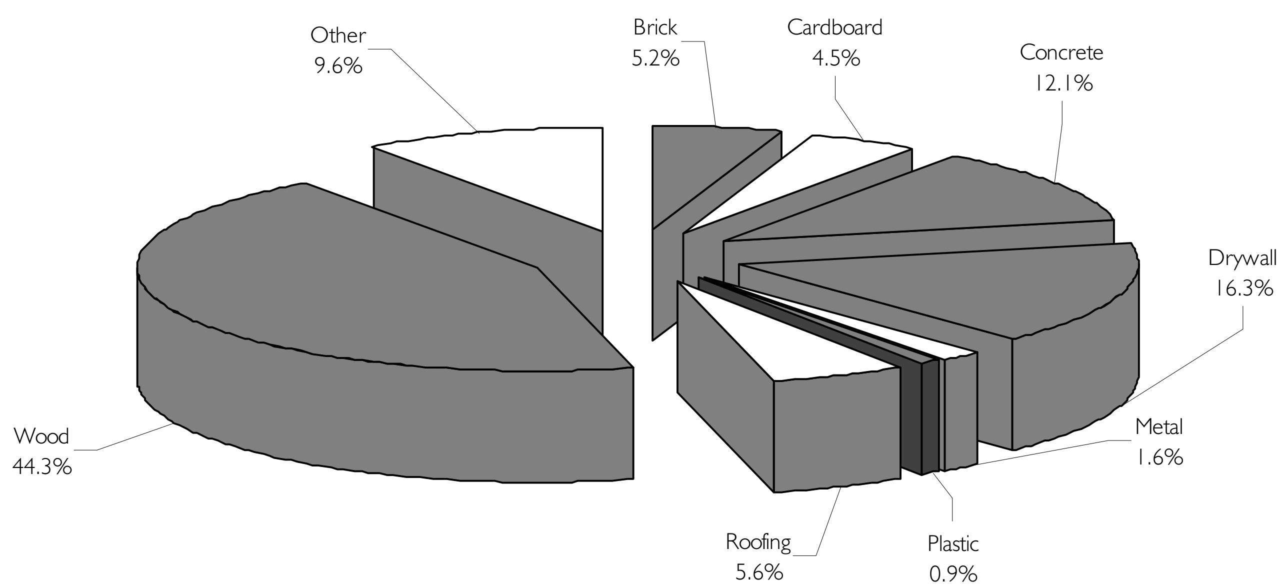
- *C&D Processing Costs Study:* DPPEA should consider conducting a study to evaluate mixed materials processing on or adjacent to landfill sites. Such a study could determine the most cost-effective means of diverting materials directly from the landfill.
- *Education:* North Carolina should continue fostering the reduction and recycling of C&D wastes through education of citizens, homebuilders, contractors, and local government officials. The state should work cooperatively with homebuilders associations, green-building advocates, and other groups promoting the responsible use of these resources. This education can take the form of meetings, workshops, and publication, and dissemination of continued research on the management of this sizeable waste stream.
- *Disposal Diversion Ordinances:* For applicable materials, such as corrugated cardboard, local governments should be encouraged to expand disposal diversion ordinances (DDOs) to cover C&D disposal facilities. Based on 1996-97 C&D landfill disposal figures, it is likely that more than 30,000 tons of corrugated cardboard were disposed in C&D landfills.
- *Grants:* DPPEA should offer funding to local governments through the Solid Waste Reduction Assistance Grants for the further development of C&D material recycling programs, such as collection of vinyl siding or other targeted materials.
- *Pallet Recovery:* The infrastructure exists to recover a greater number of pallets. (See *Wooden Pallets Commodity Profile*.) Approximately 3,750 tons of pallets were generated from C&D related activities in 1997. The disposal of pallets in C&D landfills should be banned statewide.
- *LCID Characterization:* Very little is known about land clearing and inert debris landfills (LCID LFs) in North Carolina. DPPEA should consider conducting a study of such landfills to determine the current capacity, the quantity of waste accepted, the characterization of waste entering LCIDs, public benefit or need for LCIDs, the tipping fees, and the methods for regulating the materials entering the facilities (i.e., the use of scales and the inspection of materials).
- *Buy Recycled Initiatives.* DPPEA should continue supporting initiatives of the NCDOT in using recycled C&D materials in place of virgin materials in transportation related projects. DPPEA also should recommend further use of recycled C&D materials with other state agencies, such as State Construction.

APPENDIX 1
Characterization of Residential C&D Debris

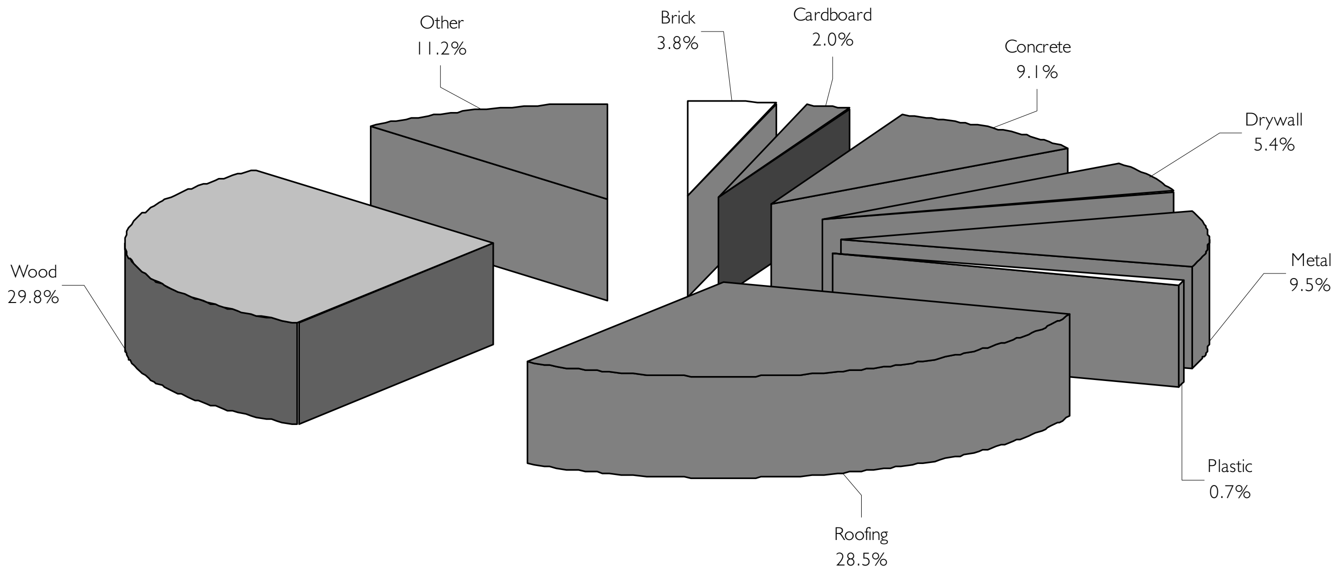
Sources of Residential C&D Debris



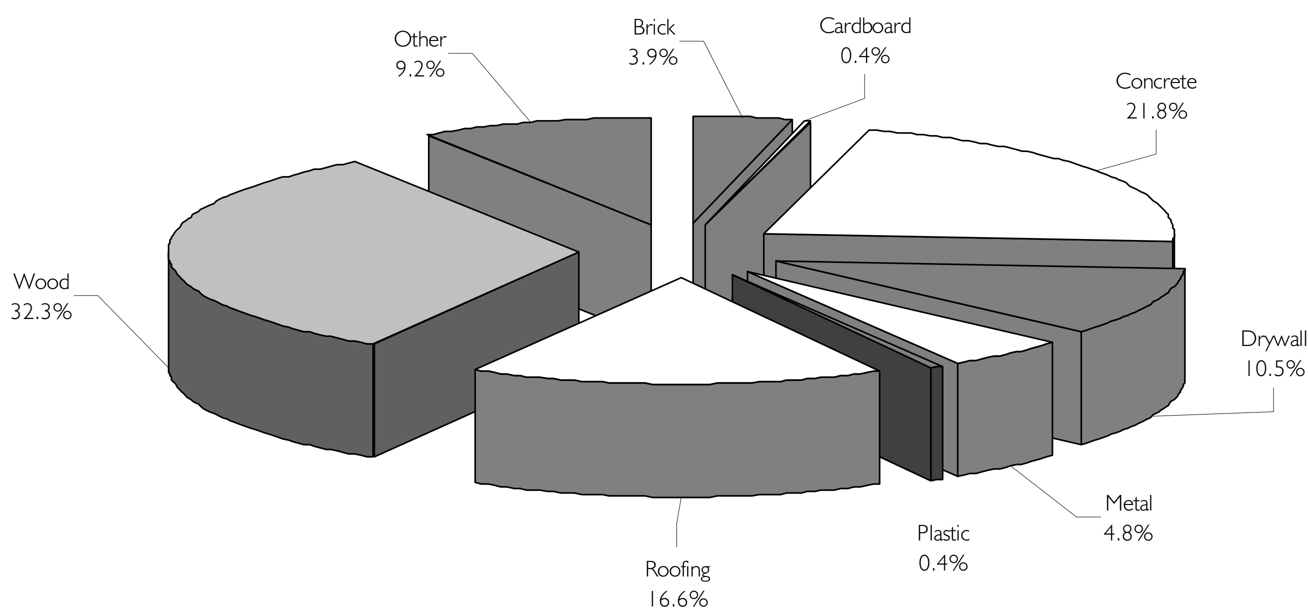
Composition of Residential Construction Debris



Composition of Residential Renovation Debris



Composition of Residential Demolition Debris



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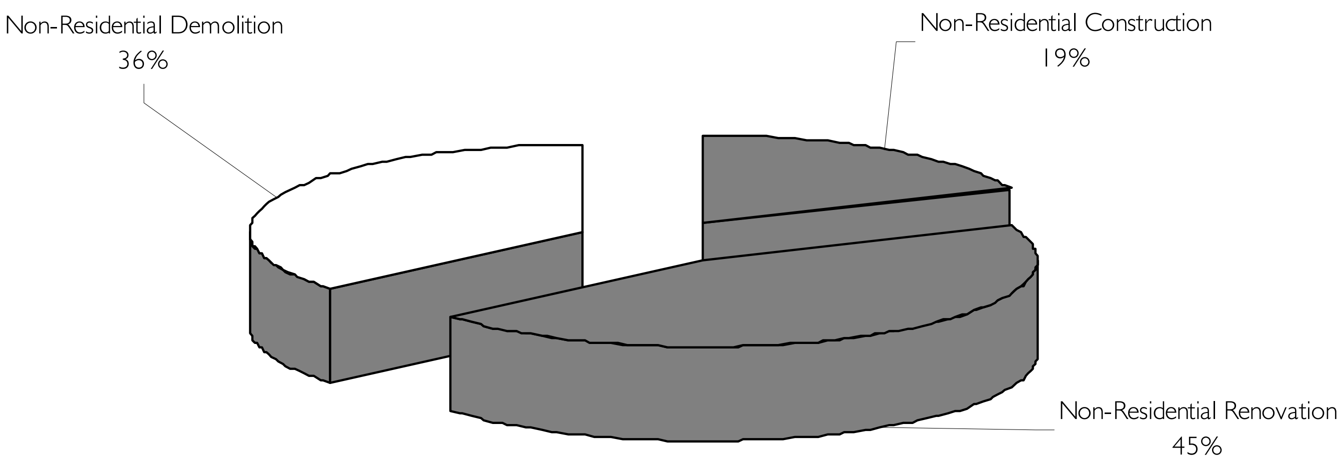
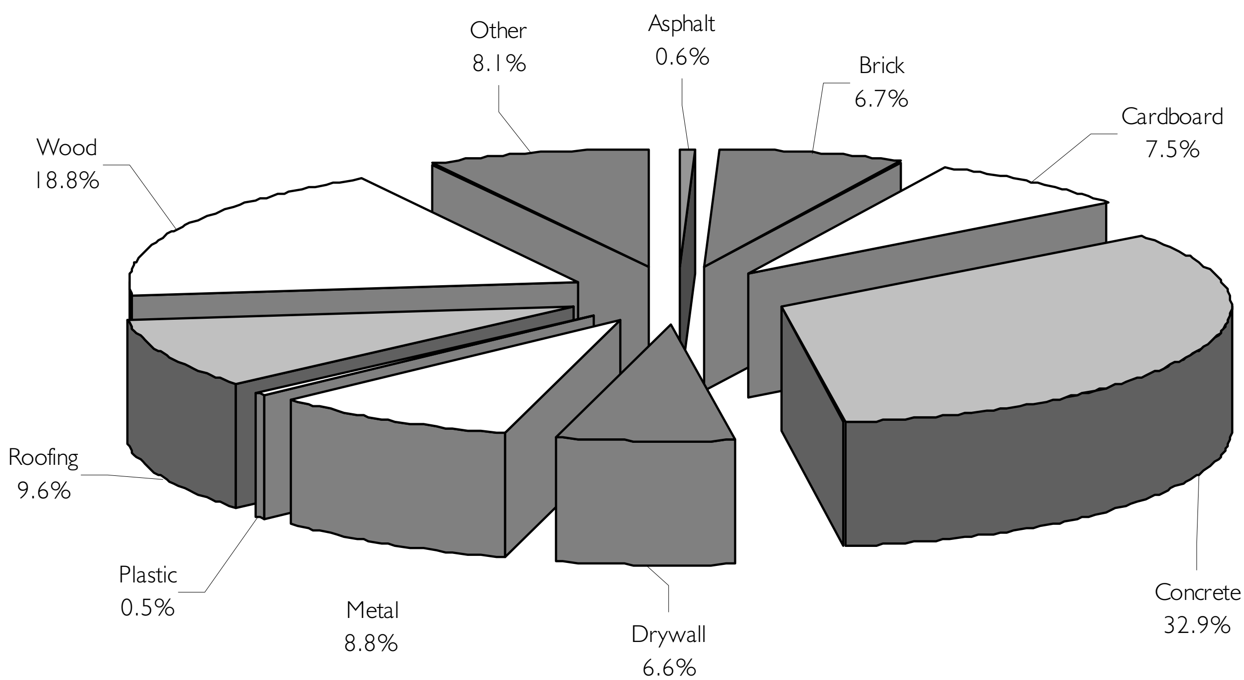
APPENDIX 2
Characterization of Non-Residential C&D Debris

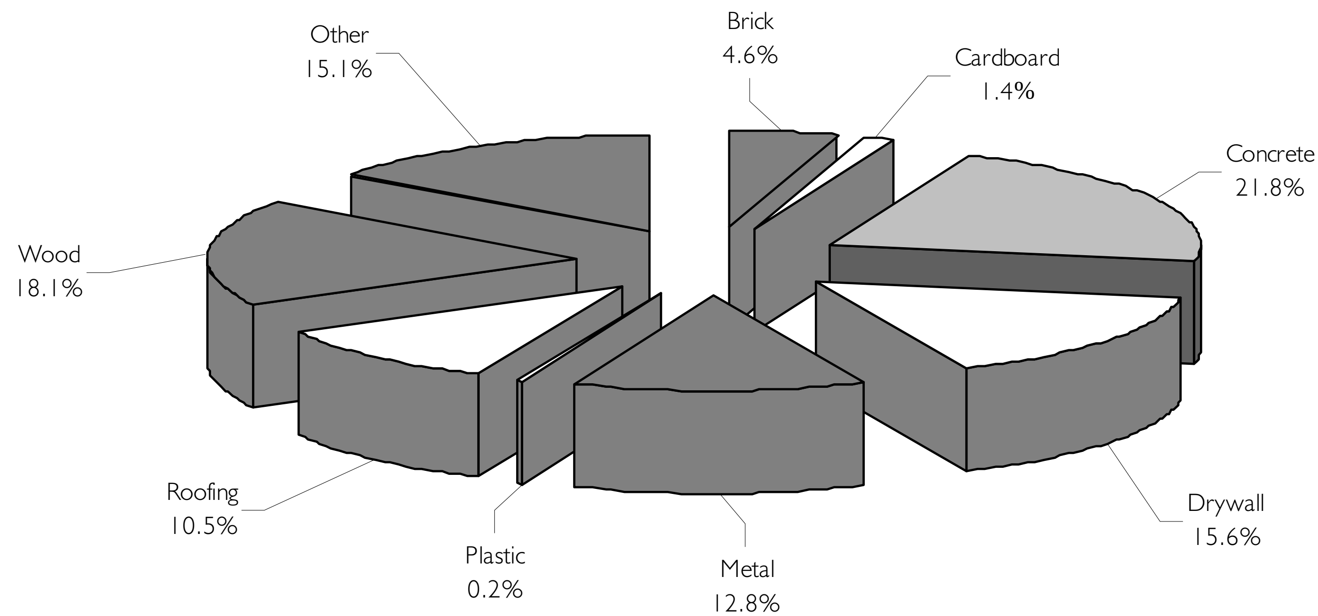
Sources of Non-Residential C&D Debris



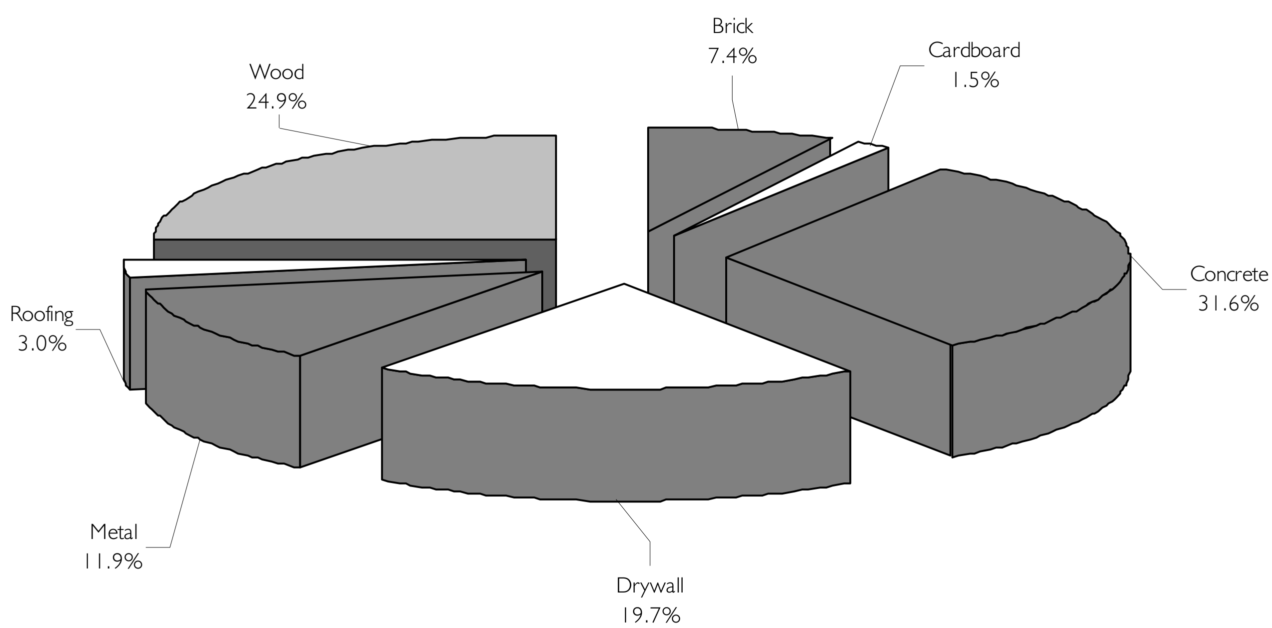
Composition of Non-Residential Construction Debris



Composition of Non-Residential Renovation Debris



Composition of Non-Residential Demolition Debris



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