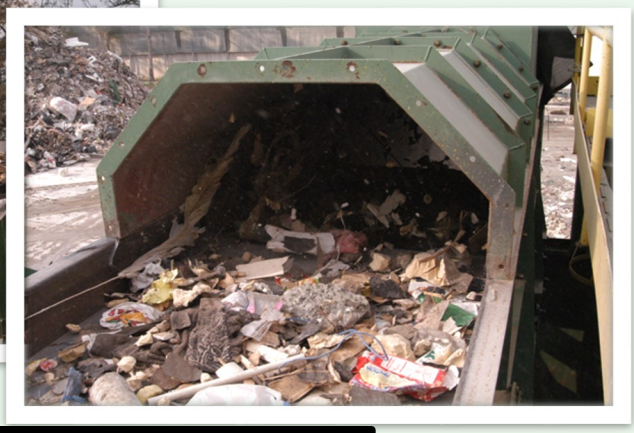
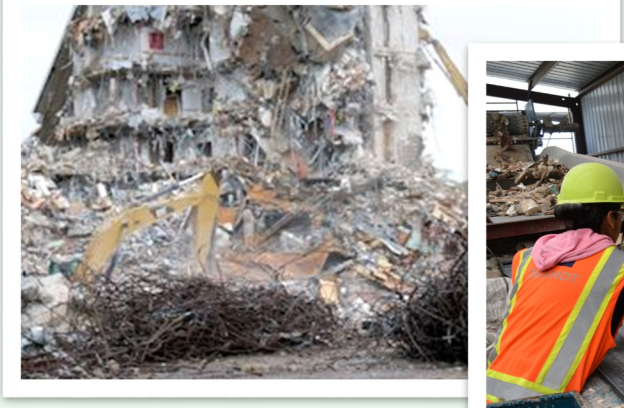
Benefits of Construction and Demolition Debris Recycling in The United States



CDRA
Construction & Demolition
Recycling Association



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Sustainable Management of Contruction and Demolition Debris: The Role of The Construction and Demoltion Recycling Association

Construction and demolition debris (C&D) represents one of the largest components of the solid waste stream in the United States. Statistics regarding C&D quantities, characteristics, and management in the US have not been tracked in the same detail as municipal solid waste (MSW). C&D includes materials generated from road construction and related infrastructure projects as well as from the demolition, construction, or renovation of building structures.

Although historically a large amount of C&D has been disposed of in landfills, in recent decades a vibrant industry has evolved centered on the recycling and recovery of the resources contained within C&D. In the US, C&D materials are used as substitutes for virgin materials in construction projects, raw ingredients for new product manufacture, and fuels for energy production. Today, many of these materials are recycled at C&D recycling facilities, and the non-profit trade association, Construction and Demolition Recycling Association (CDRA) represents the diverse group of member companies and agencies from the many C&D material recycling disciplines.

While promoting and defending the environmentally sound recycling of C&D materials generated in the United States (US) and in other countries, CDRA has accomplished numerous legislative action. Many states across the US have felt the advantageous accomplishments of CDRA, such as fighting bans to use C&D wood as a fuel product, overcoming barriers to the acceptance of post-consumer products such as with asphalt shingles, and working with others to fund studies, produce white papers and projects on C&D recycling materials.

One current interest of CDRA is to quantify the benefits of C&D recycling in the US In order to characterize the benefits of C&D recycling, amounts of C&D generated and recycled has been estimated. With this study CDRA can provide the C&D recycling industry quantifiable environmental, economic, and social benefits associated with recycling material components of C&D. This can provide C&D recyclers and CDRA members with insight on the future direction of CDRA recycling and an understanding of the practices that provide the best recycling benefit.

CDRA Mission

Provide positive support and representation to the industry and CDRA members in legislative and rule-making venues that impact the recycling business.

Act as an advocate to promote C&D recycling and the recycle business in every manner possible that benefits CDRA members.

Facilitate and sponsor CDRA member interaction between the membership companies and further facilitate interaction between the membership and the many specialized services that can potentially benefit the membership such as equipment, financing, insurance and other specialized third party resources.

CDRA members use a combination of mechanical equipment and trained employees to separate debris from construction, demotion and renovation projects into marketable commodities

Materials in Constuction and Demolition Debris

Scrap Metal

Wood

Asphalt Shingles

Gypsum Drywall

C&D materials comprise of a diverse material stream, where generation originates during the construction, renovation, and demolition of buildings, roads, bridges, and other structures. The components of C&D vary depending on activity type and structural components. Broadly, the C&D stream is comprised of concrete, wood, metal, asphalt pavement, drywall, land-clearing debris (LCD), and a variety of other minor constituents.

C&D represents a substantial fraction of the overall materials and discards generated as a result of human activities, at amounts similar to the magnitude of municipal solid waste (MSW). The materials are generated in varying amounts based on factors such as project type, project size, age of structure, condition of structure, and geographic location.

According to the 2014 US EPA study to estimate nationwide C&D composition (upon disposal) from a compilation of actual C&D characterization studies, wood, roofing materials, other materials, and concrete were estimated to be the top four materials disposed of in the greatest amounts (by mass). While, roofing and other material categories were found in greater fractions in landfilled C&D compared to the composition of C&D overall. In Table 1, common materials of C&D are presented.

Table 1. Common materials present in C&D

Material	Description
Portland Concrete	Consists of a mixture of cement paste and aggregates. The paste, composed of Portland cement and water, coats the surface of the fine and coarse aggregates which then forms the mixture into a rock-like mass.
Asphalt Pavement	Also called bituminous concrete or asphalt pavement, this material is a mixture of fine and course aggregate with the asphalt (approximately 6% by mass) serving as the binder
Wood	Construction products manufactured from wood include dimensional lumber, plywood, oriented strandboard (OSB), fiberboard, posts, and poles. Residential homes commonly utilize wood products as a major construction material.
Asphalt Shingles	Common roofing material used for sloped roods containing 30-40% asphalt and underlain by asphalt soaked felt or paper.
Gypsum Drywall	Drywall is a manufactured building product in the form of a panel that is used for interior wall and ceiling surfaces in buildings, primarily composing of gypsum (~90%) and paper surfacing and backing.
Metal	Numerous construction materials manufactured of metal are encountered in C&D. These include steel in structural supports, flashing and siding systems, and as part of plumbing and electrical utilities.
Packaging Materials	C&D recyclers recover packaging materials such as cardboard and plastic.
Fines	In the process of separating C&D components from one another for recycling, mechanical screens are used to sift out larger from finer material. A product of this operation known as C&D fines consists of soil and small pieces of concrete, brick, wood, and other C&D materials.

Benefits of Constuction and Demolition Debris Recycling

The benefits of recycling are now widely recognized by the public, and participation in local recycling programs has become a way of life for most US citizens. These efforts focus on familiar components of our municipal waste stream such as plastic, glass and metals containers, and paper and cardboard products from printed documents and packaging materials. In a similar manner, members of the CDRA work to recycling materials such concrete, wood, and asphalt generation from the construction, renovation and demolition of our nation's buildings, roads and infrastructure.

Diverting C&D materials from landfill disposal and instead recycling them into new products provides not only an environmental benefit through saving natural resources and reducing possible pollution from landfills, but also creates jobs and adds money to local economies. While the general benefits of recycling are well understood, quantifying the meaningful benefits to society and the environment has always been a challenge. Using information from its membership, current statistics from national organizations, and the latest science on computing gains from recycling, the CDRA tracks the benefits of C&D recycling in the US.

Benefits of C&D Recycling

- Natural resource savings
- Avoided landfill disposal
- Energy savings
- Reducing carbon footprint
- Job creation
- Economic benefits

Natural Resource Savings

C&D recycling provides a source of natural materials that would otherwise have to be mined from the earth. Aggregate produced from crushing concrete and brick provide a substitute for virgin rock sources, gypsum from drywall can be used instead of naturally mined gypsum, and when metals such as steel, aluminum and copper are recovered, they offset some of the demand to extract these elements from the earth. Recycling wood and cardboard to produce fuel, mulch and new products lessens the requirement for timber harvesting. These resource savings have a direct connection with decreasing greenhouse gases and saving energy from not having to mine.

Avoided Landfill Disposal

Every ton of C&D recycled results in that much less material being buried in the ground through landfilling. In addition to less land areas needed for landfilling, environmental issues associated with C&D disposal are lessened. For example, one problem frequently encountered with C&D debris landfills is the production of hydrogen sulfide, a foul-smelling gas demonstrated to pose a human health risk. Recycling scrap drywall from construction into new drywall or agricultural products thus prevents the formation of this noxious gas. Lastly, along with less land area needed and environmental benefits, the long-term costs associated with operating and maintaining these landfills in the future become decreased.

Benefits of Constuction and Demolition Debris Recycling

Job Creation

C&D recycling facilities utilize a combination of manual separation and mechanical equipment. More employees are needed to recycle C&D compared to burying the materials in a landfill. When value-added products are created at C&D recycling facilities, critical employees move the incoming material onto the processing line, the workers are assigned to hand-pick out desired commodities from the mixed debris, processing, marketing, and transporting the recycled products off-site to their second life.

Economic Benefits

C&D landfills and C&D recycling facilities both operate under a model where a tipping fee is charged to customers to dispose of their materials. Unlike landfills, however, C&D recycling facilities transform the materials into products that are sold to manufacturing operations or directly to customers, spawning greater economic benefit to the local economy. The second life of these materials are valuable for other sectors of the economy, especially mills and manufacturing plants who purchase the recyclables to produce products.

Energy Savings

The big energy savings from C&D recycling stems from replacing virgin materials needed to manufacture new products with recycled products. This reduces the energy required for the extraction of the raw materials they replace, and thus saves energy. For example, when scrap steel recovered as part of the demolition of a building is utilized to manufacture new steel, much less energy is required compared to using virgin materials (iron ore) to make the new products. Not only can some C&D materials be used as a virgin material substitute, they could also be used as fuel substitutes for making energy.

Reducing Carbon Footprint

Since the use of recycled materials in a product or process often requires less net energy compared to the use of virgin materials, recycling has the potential to result in an overall reduction in net energy use and the resulting greenhouse gas (GHG) emissions associated with this energy use. Like the savings associated with energy requirements, when new products are manufactured with materials recycled from C&D, less fuel is required in the manufacturing process, therefore less carbon dioxide is emitted to the atmosphere.

The Constuction and Demolition Debris Recycling Industry

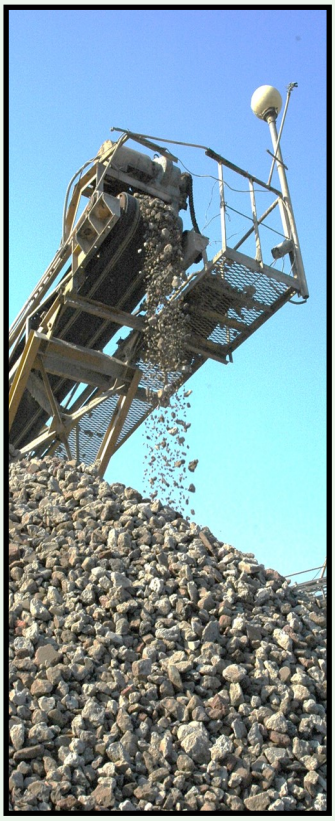
CDRA members reflect the diversity of the C&D recycling industry, and include demolition contractors, debris haulers, aggregate crushing operations, mixed C&D processing facilities, equipment manufacturers, and end market facilities, all playing a major role in recovering materials that would otherwise be disposed of in a landfill and giving them new life. Demolition contractors historically have gone to great lengths to recover value from the construction materials recovered as part of the demolition process; some operate mobile crushing and screening plants to create value-added products directly at the job site.

The C&D recycling industry continues to grow in the US. Some components (e.g., concrete) are commonly recycled because of existing economic reasons. But other components, especially those with low market value and that require processing to separate from the rest of the C&D stream, are often challenging to recycle.

Many state and local governments have demonstrated that regulations and policies can play a major role to promote C&D recycling, and municipalities or other entities interested in growing C&D recycling in their area should look to these successes as examples.

Potential methods of C&D recycling include: requiring all debris to pass through a recycling facility, increasing the landfill tipping fee for C&D materials, and requiring contractors to pay an upfront deposit that is only returned after debris are recycled.

C&D materials are often source separated at the job site, when there are large amounts of C&D generated or



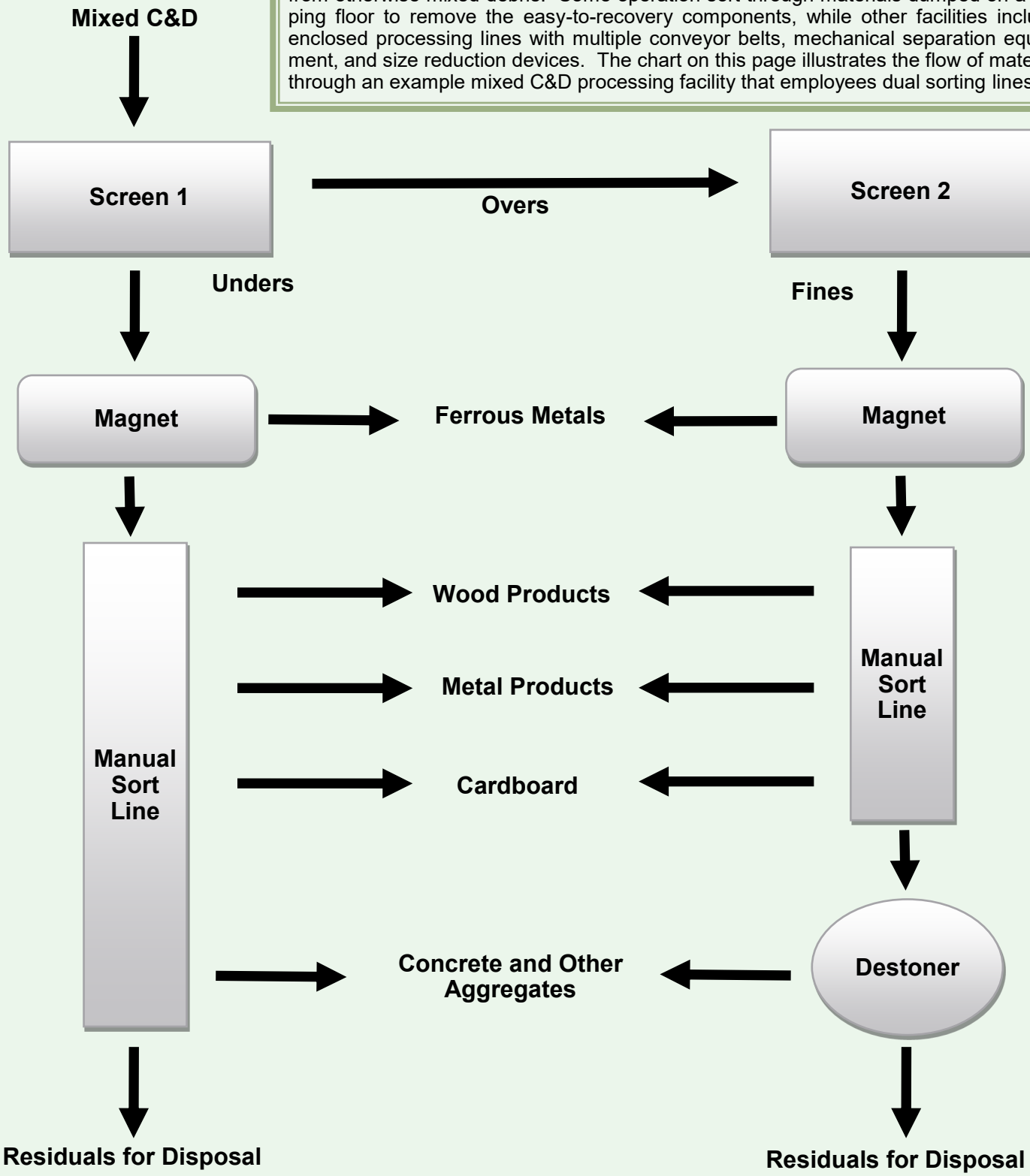
when most of the C&D consists of one type of material (i.e., demolition projects with debris that are mostly concrete). When a site produces smaller or more diverse C&D, the debris goes to a mixed C&D processing facility, or C&D materials recovery facility (MRF), where materials are processed and separated. Most C&D facilities are considered dirty MRFs, receiving the entire waste stream then separating out the recycled materials. Materials are separated by a combination of mechanical and manual separation. This process often involves crushing the waste in the early stages of the process to assist separation of the materials.

Many CDRA members operate dedicated facilities for the processing of C&D materials. Concrete crushing operations accept loads of concrete, brick, block and paving materials and employ a suite of size-reduction, screening, and magnetic separation technologies to create products for use in new construction. Mixed C&D processors take mixed loads of debris from construction and demolition sites and using a combination of mechanical equipment and trained employees to separate materials such as wood, concrete, metal, asphalt, drywall and cardboard from one another and process these for shipment to customers. Some facilities accept specific C&D components, such as drywall or asphalt shingles, either from other C&D recyclers or directly from generators, and process these materials into value-added products.

A major factor in the success of a C&D recycling operation is the level of contamination of the material. The purity of a recovered product is directly related to a higher resale price. Therefore, it is imperative that the waste stream is handled in a meticulous way.

Recycling Facilities for Mixed C&D

CDRA members use a variety of approaches to separate recyclable components from otherwise mixed debris. Some operation sort through materials dumped on a tipping floor to remove the easy-to-recovery components, while other facilities include enclosed processing lines with multiple conveyor belts, mechanical separation equipment, and size reduction devices. The chart on this page illustrates the flow of material through an example mixed C&D processing facility that employees dual sorting lines.



Markets for Constuction and Demolition Debris Materials

Portland Concrete

Portland cement concrete is often produced in large amounts. It can also be used for other natural stone replacements. The primary end market for crushed PCC is a replacement for construction stone used in road and building construction. In many states, the Department of Transportation (DOT) provides specifications for use of crushed concrete in road base or similar applications. The use of crushed PCC as an aggregate in new PCC or in new asphalt pavement has been explored, but lack of established DOT specifications has limited this practice in the US. Other common uses of PCC include rip-rap for erosion control, clean fill material, and artificial reefs.

Crushed concrete is commonly used as a replacement for construction aggregate

Wood

Ground wood can be used for fuel, landscape mulch or to make engineered wood products

Wood products include dimensional lumber, engineered wood products, and round posts or poles for outdoor use. Some wood components may be salvaged prior to demolition for their reuse potential. Most wood products end up recycled as either fuel for industrial facilities or power plants, or as landscape mulch. In some cases, recovered wood is used by facilities that manufacture new wood products such as particle board. Depending on the targeted market, C&D recyclers separate out some types of wood from others (e.g., treated wood) to meet desired product quality. While, high value wood can be remanufactured into new wood products, lower value markets include use as fuel, mulch, and animal bedding.

Gypsum Drywall

In some areas of North America (particularly the Northwest), scrap drywall is used in the manufacture of new drywall. Gypsum drywall manufacturing facilities often recycle a small amount of their scrap into the manufacturing process, and thus they can accommodate some amount of recycled material. As gypsum is an ingredient in the manufacture of Portland cement, some cement plants have attempted to utilized recycled drywall. This practice has been limited in the US because of the need for a large and constant supply of uniform material. In many areas of the US, gypsum from drywall has been utilized as a soil and plant amendment. Gypsum is already used for many crops as a sulfur and calcium source. Some recyclers market a gypsum powder resulting from crushed drywall, while others further process the gypsum to produce specialty agricultural products (e.g., gypsum pellets).

Gypsum separated from drywall is used to make new drywall or as an agricultural product

Markets for Constuction and Demolition Debris Materials

Asphalt Shingles

Asphalt shingles can be used in the manufacture of new asphalt pavement. In some parts of the US, asphalt shingles are heavily recycled as an ingredient in the production of new asphalt pavement. Sources of recycled asphalt shingles include both shingle manufacturer's scrap and material from roofing jobs (post-consumer). Prior to use in the asphalt pavement production process, the shingles must be adequately processed, including removing foreign materials, grinding, screening, and nail removal with a magnet. Shingle processing for recycling occurs both at fixed facility locations or through mobile grinders. While the type of equipment used to process shingles is similar to those used for other C&D materials (such as wood), some vendors specifically market size reduction equipment as ideally suited for shingle processing.

Asphalt shingles are commonly used in new asphalt pavement for roads

Metals

Steel, aluminum, brass and copper are among the metals commonly recycled from C&D

Scrap metal recycling is a major industry in the US, and much of this material comes from metal once found in buildings or other infrastructure. Historically large quantities of C&D metals are targeted for removal prior to demolition and recycling. Demolition contractors often target this metal for removal because of its value. When mixed with other debris, C&D recycling use magnets and similar equipment to extract this resource. The scrap metal market is well established and C&D recyclers operators will market their metals to these facilities or through brokers.

Fines

At mixed C&D processing facilities, smaller materials are screened out from larger ones as part of the separation process. C&D fines, typically on the order of 1-inch is size or less, contain soil and small pieces of concrete, asphalt, wood and gypsum. When used as alternative daily cover at landfills, C&D fines reduce the amount of clean soil that needs to be placed in the landfill. C&D fines that meet necessary chemical characteristics have been used as a substitute for clean soil in non-structural fill applications. Much of the remaining material on a C&D processing line has a high calorific value and thus has the potential to be used as a fuel source.

C&D fines replace virgin soil as landfill cover or non-structural fill Material

Quantifying the Benefits of Constuction and Demolition Debris Recycling in the United States

Total C&D generation is determined by the sum of the generation quantities for the three following categories: reclaimed asphalt pavement (RAP), bulk aggregate, and mixed C&D. These where mixed C&D originates largely from building construction, renovation and demolition, and is typically managed by landfilling or processing at a mixed C&D recycling facility. While bulk aggregate generation occurs from construction and demolition of roads and bridges as well as 'other structures'. And RAP is generated from the milling of asphalt pavement roads.

The category generation was estimated by summing the estimated material components of corresponding to each category (Appendix, Table 7). The estimation approach followed an MFA and Non-MFA approach.

The MFA approach uses national production and usage data for a material, and based on average material lifetimes, estimates waste generation of that component in the year of interest, in this case, 2014. The MFA estimate examined: Portland cement concrete (PCC), wood, drywall, asphalt shingles, steel, and brick. Whereas, the Non-MFA approach estimates generation of glass, plastic, fines, carpet, and cardboard.

The overall analysis performed to estimate the total amount of C&D generated in the US, resulted in an estimated total 583 million tons of C&D generated in the US for 2014 (Appendix, Table 7). The majority of this material consists of bulk aggregate (PCC and asphalt concrete), assumed to be generated in a source segregated stream.

Prior analysis in the 2012 estimate utilized a different approach to estimate generation. That analysis relied on 1) MFA conducted to estimate C&D waste for the year 2002 and used the number of US building permits issued in 2012 and 2002 to scale the amount of C&D waste estimated for the year 2002 to 2012 and 2) US State C&D recycling and disposal data for 2011 (eight states reporting).

The current estimate relied on an updated MFA which was performed for the year 2014, so no scaling based on a surrogate parameter was necessary. Furthermore, the 2014 estimate accounted for a new parameter estimates, Non-MFA materials. The 2014 analysis resulted in an approximate 23% increase in predicted C&D generated from 2012.

Step 1

Estimate mass of C&D in the United States by component (Page 12)

Step 2

Estimate the amount of each component recycled and landfilled (Page 13)

Step 3

Apply appropriate scaling factors, to estimate:

- **Landfill Space Saving (Page 14)**
- **Energy Savings (Page 15)**
- **Greenhouse Gas Savings (Page 16)**
- **Job Creation (Page 17)**
- **Economic Benefit (Page 17)**

Material Categories Definitions:

- **RAP**
  C&D waste generated through the milling of roads and bridges.

- **Mixed C&D**
  Heterogeneous mix of C&D components, generally generated through construction and demolition of buildings and other structures.

- **Bulk Aggregate**
  Materials stream consisting of a homogenous mixture of aggregate type materials (Portland cement concrete and

Constuction and Demolition Debris Generation Estimate

Material Categories Estimate:

- **RAP (Appendix, Table 7)**

Based on NAPA reported data from the 2014 survey of asphalt pavement contractors. The amount of asphalt accepted in 2014 as reported by NAPA is first divided by 0.99 to reflect a 99% recycling rate (consistent with US EPA MFA methodology), then the internal ratios of reuse pathways are used to estimate the total amount of asphalt waste generated in 2014 reused through each pathway.

Some asphalt concrete is managed as part of the mixed C&D stream, reportedly recycled by mixed C&D facilities (as reflected in facility collected data) and landfilled as mixed C&D waste (as reflected in waste composition studies) not accounted for in the NAPA data.

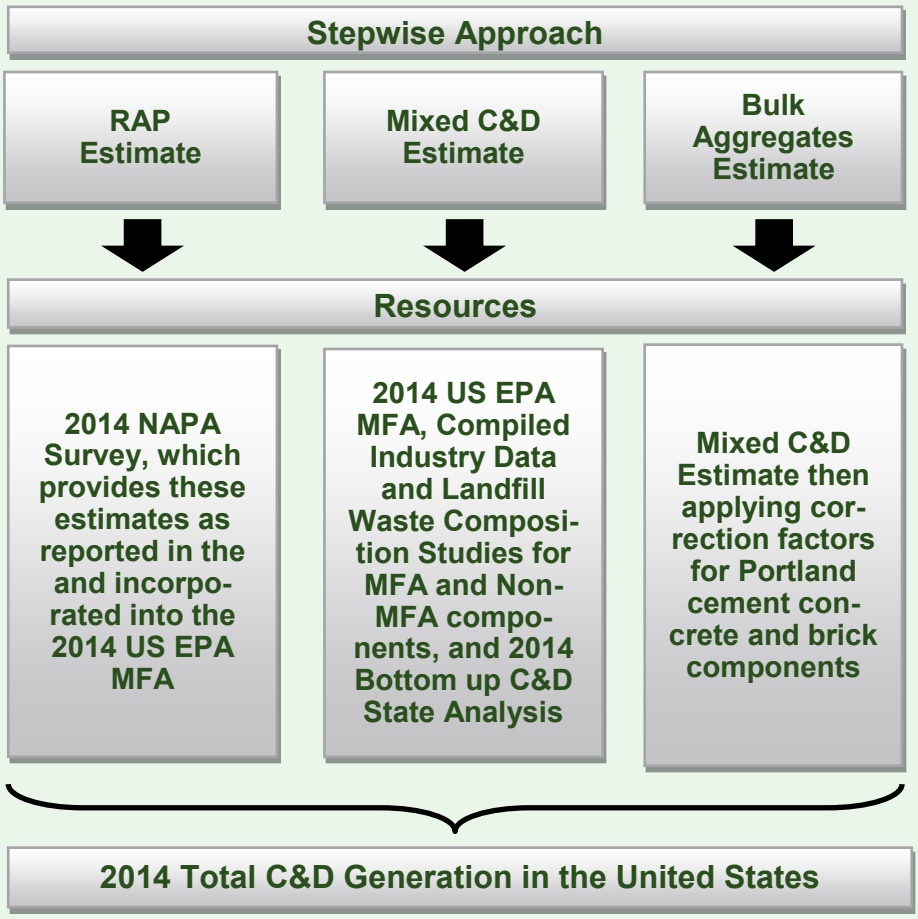
- **Mixed C&D (Appendix, Table 7)**

Data from 49 full-scale mixed C&D recycling facilities, regardless of whether end use pathway data are presented (estimates preliminary composition of the mixed C&D recycled stream) and data from the C&D landfilled waste composition studies (estimates preliminary composition of the mixed C&D landfilled stream) are used. This data is normalized to the MFA and Non-MFA segments of the Mixed C&D materials stream so that the sum of all percentages when only accounting for either MFA or Non-MFA components equals 100%. .

Non-MFA components reflected in the C&D landfilled waste composition studies include: asphalt, organics, fines, and 'other materials' (glass, plastic, carpet, and cardboard). MFA components include reclaimed asphalt pavement, concrete, asphalt shingles, gypsum drywall, wood, and bricks. Wood is used as a baseline material (C&D wood is assumed only to be generated in the mixed C&D stream lack of source separated wood handling operations). Quantities of additional materials recycled and disposed are derived from this total, wood-based mixed C&D estimate.

- **Bulk Aggregate (Appendix, Table 7)**

The interviews of mixed C&D recycling facilities were not expected to fully account for bulk aggregate recycling (concrete and brick), because this material is often recycled and landfilled as a homogenous waste stream not by mixed C&D recycling facilities, but by processors solely managing this material. Total concrete and brick generated as bulk aggregate was calculated by subtracting the amount accounted for in mixed C&D (recycled and landfilled) from the 2014 US EPA MFA total. The recycling and landfilling of bulk aggregate is estimated using a recycling rate of 85% (based on interviews of professionals in the aggregate recycling industry, conducted as part of the CDRA White Paper- The Benefits of Construction and Demolition Debris Recycling in the United States).



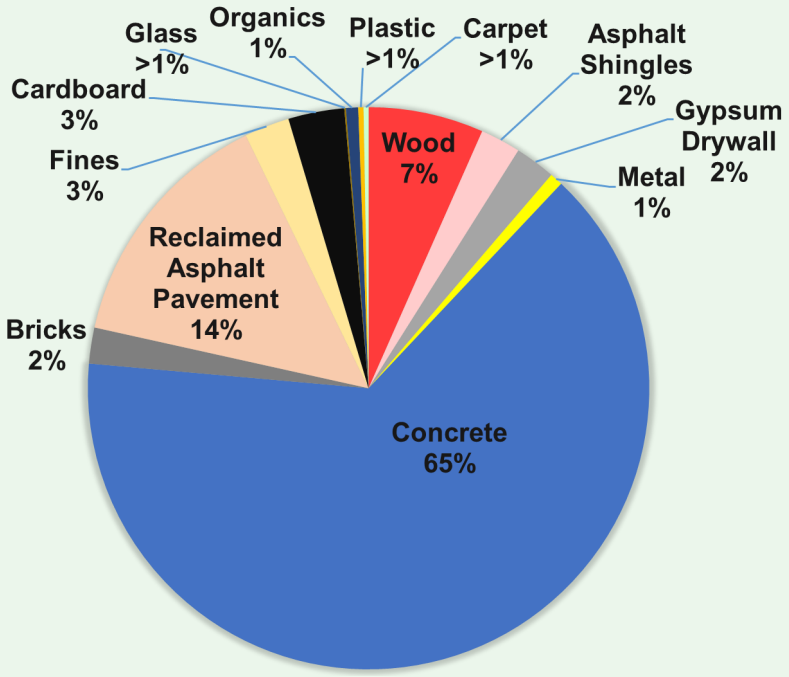


Figure 1. Estimated Composition of C&D in the US in 2014

Constuction and Demolition Debris Recycling in The United States

Many CDRA members recycled C&D long before recycling was a common practice for municipal garbage in the US, especially for materials such a metal and concrete. As a result of society's attention to reducing landfill disposal and its growing push to conserve natural resources, recycling of C&D has become a favorite target for state and local governments trying to increase their recycling rate. Some C&D materials are easily separate from other at the point of generation, and thus these materials may be processed and shipped to market directly from the point of generation. For other materials, dedicated recycling facilities perform necessary separation and transformation of C&D from waste to commodity.

The analysis here evaluated the recycling of all three of the major C&D sectors: mixed C&D, bulk aggregate, and RAP. Statistics provided the NAPA report that 99% of the RAP was recycling in the US in 2014, predominantly in the manufacture of new hot mix asphalt pavement. For bulk aggregate, a recycling rate of 85% was assumed based on feedback from industry members; this value is not currently tracked on a national basis and the CDRA will continue to survey industry members to refine this amount. The mixed C&D recycling rate was based on a range of data reported by US states, and was estimated at 38%. See Figures 2-4.

For each C&D category, the recycled fraction of the C&D generated was estimated. It was assumed that aggregate, wood, steel and cardboard would be targeted at all C&D material recovery facilities for recycling, but only a fraction of facilities would target drywall (10%), asphalt shingles (20%), and C&D fines (50%).

RAP was calculated as the total sum of all generated milled asphalt minus the quantity landfilled. The end use categories accounted for in NAPA's statistics include remanufacture as hot or warm mix asphalt (HMA/WMA), aggregate, cold mix asphalt, other, and landfill. For RAP, NAPA provides data supporting a recycling rate of over 99% (92% in new asphalt and 8.7% as aggregate).

The C&D generation estimates in Table 8 in the appendix and the recycling rates for each C&D category were used to estimate the total amount of CCD recycled in the US; these results are presented in Table 8. The overall recycling rate for C&D was estimated to be 73% (37% for mixed C&D, 85% for bulk aggregate, and 99+% for RAP).

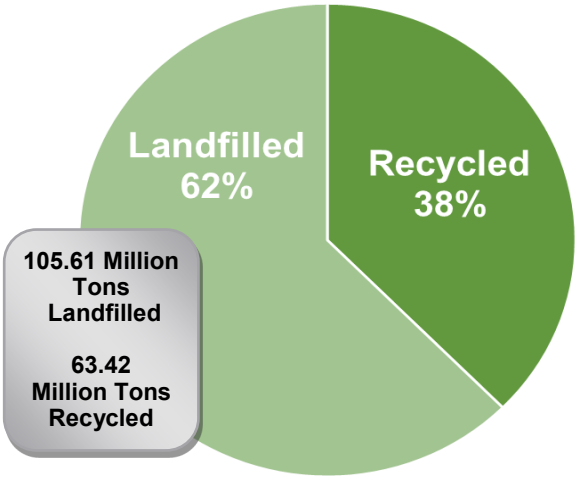


Figure 2. In the US in 2014 estimated management of Mixed C&D

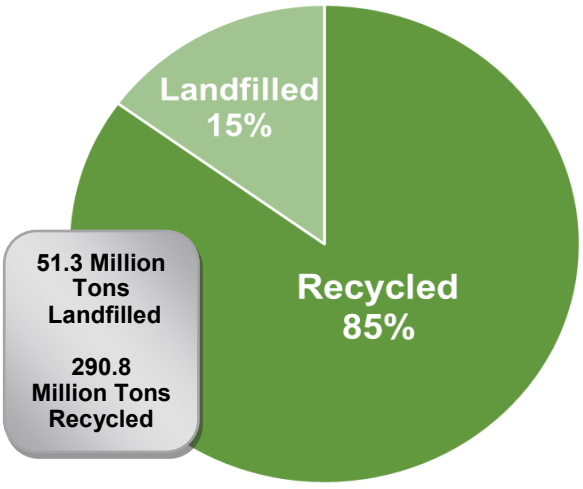


Figure 3. In the US in 2014 estimated management of Bulk Aggregate

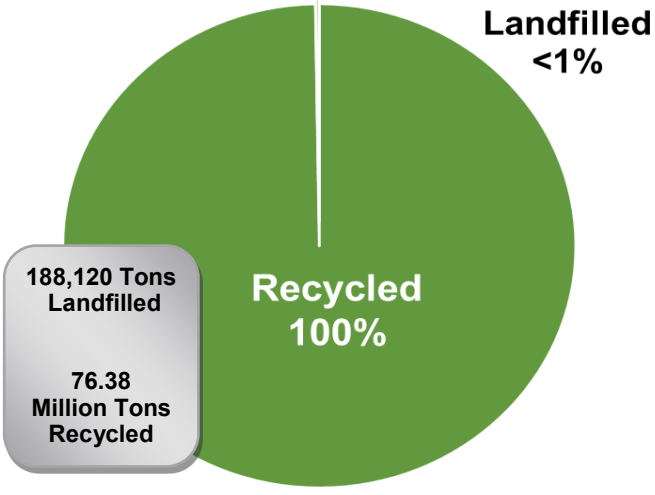


Figure 4. In the US in 2014 estimated management of RAP

Constuction and Demolition Debris Recycling Benefits: Providing Jobs & Economic Benefits

Providing Jobs

The recovery of materials through recycling requires more employees per amount of material processed as compared to landfill disposal. An objective of the survey was to gather information on the number of jobs associated with C&D recycling. Table 5 provides the resulting jobs per million tons of C&D recycled on an annual basis for both mixed C&D recycling facilities and bulk aggregate facilities.

The C&D recycling industry supports approximately 28 thousand direct jobs. Jobs provided by landfilling was not evaluated.

Table 5. Millions tons recycled of each category and the corresponding jobs

Recycled Material	Million Tons	Jobs per Million Tons of Annual C&D Recycled	Thousands Jobs Produced
Mixed C&D	63.4	233	14.8
Bulk Aggregate	290	45.0	13.3
Total	**430**		**27.9**

Economic Benefits

Economic benefits of C&D recycling were based on data gathered from the survey of mixed C&D and bulk aggregate processing facilities. Facilities were asked and gave responses related to the following:

- Financial investment (property acquisition, improvements, equipment)
- Revenue from sale of recyclable commodities
- Tax related expenses
- charitable contributions
- other services provided to the community

A set of survey questions focused on the financial investment that facility owners made in the development of their facility, including property acquisition, site improvements, and capital equipment expenditures. The sum of these three investment categories were summed and normalized to the total amount of debris processed to develop a scaling factor that could be used to estimate the total financial investment associated with the facility capacity necessary to process the total amount of C&D recycled in a year. Separate estimates were made for mixed C&D facilities and bulk aggregate facilities.

A second set of survey question targeted C&D recycling facility output in terms of revenue. Total revenue was aggregated and normalized to the amount of debris processed to develop a scaling factor that could be used to estimate the total direct economic output of US C&D recycling facilities. See the Table 6 below.

Economic multipliers were applied to the output (revenue) to account for indirect and induced effects of C&D recycling on the economy (National Recycling Coalition's "US Recycling Economic Information Study" by R W Beck); no specific mixed C&D or bulk aggregate industry multiplier was provided in this study, so the general multipliers for "recycling and reuse" were applied.

Indirect effects are C&D recycling facilities place demands on supplying industries and calculated using an economic multiplier of 1.7- "Type 1" Induced effects are workers associated with the direct and indirect industries spend earnings on goods and services and calculated using an economic multiplier of 2.36- "Type II"

Table 6. Estimated Economic Output of C&D Recycling Industry

Recycled Material	Million Tons	Capital Expenditures (Billion)	Direct Revenue (Billion)	Direct & Indirect Revenue (Billion)	Direct, Indirect,& Induced Revenue (Billion)
Mixed C&D	63.4	$3.45	$3.42	$5.82	$8.09
Bulk Aggregate	290	$3.17	$6.51	$11.1	$15.3
Total	**430**	**$6.63**	**$9.94**	**$16.9**	**$23.4**

Constuction and Demolition Debris Recycling Benefits: Energy Savings

Energy Savings results from avoidance of raw materials extraction and transport, as well as energy gained from combustion of select wastes. The estimated masses of C&D materials recycled were used along with the WARM emission factors for energy savings to estimate an overall energy savings resulting from C&D recycling in the US in 2014. A total of 682 million (million BTU) were found calculated as being saved in 2014, a value equivalent to 117 million barrels of oil. The materials accounting for the bulk of this savings were metals.

The recycled quantities presented in were multiplied by the appropriate emission factors from WARM to estimate the annual energy savings by recycling. The results of this analysis are presented in Table 3 and Figure 5. The emission factors were acquired from the most recent WARM spreadsheet provided on the US EPA website– version 14. The net difference in energy factors between landfilling and recycling was used for all materials except wood. For wood, the net difference between landfilling and combustion emission factors, since the primary market for recycled wood is fuel product, rather than recycle into new materials.

Emission factors used from WARM corresponded to a scenario where landfill gas is collected at a national average rate, and flared rather than used to produce energy. The emission factor for mixed metals was used for the category 'steel and other metals' and that reported for dimensional lumber was used for C&D 'wood'. While for the category 'fines' no energy factors exist which resulted in no energy savings estimated.

Other Savings:

A total of **682 million (million BTU) avoided energy** is equivalent to:

- **10.25 million** Passenger vehicles driven for one year
- **2.20 million** Garbage trucks of waste recycled instead of landfilled
- **5.46 billion** Gallons of gasoline consumed
- **5.12 million** Homes energy use for one year
- **12,260** Wind turbines installed
- **1.72 billion** Incandescent lamps switched to LEDs
- **14.1** Coal-fired power plants in one year
- **1.25 billion** Tree seedlings grown for 10 years
- **45.9 million** Acres of US forests in one year

Table 3. Energy savings of each C&D material using WARM factors

Material	Energy Savings Million (Million BTU)
Wood	109
Asphalt Shingles	1.91
Gypsum Drywall	11.2
Metal	164
Concrete	117
Bricks	0.67
RAP	150
Cardboard	87.5
Glass	0.40
Organics	6.25
Plastic	21.7
Carpet	11.3
Total	**682**

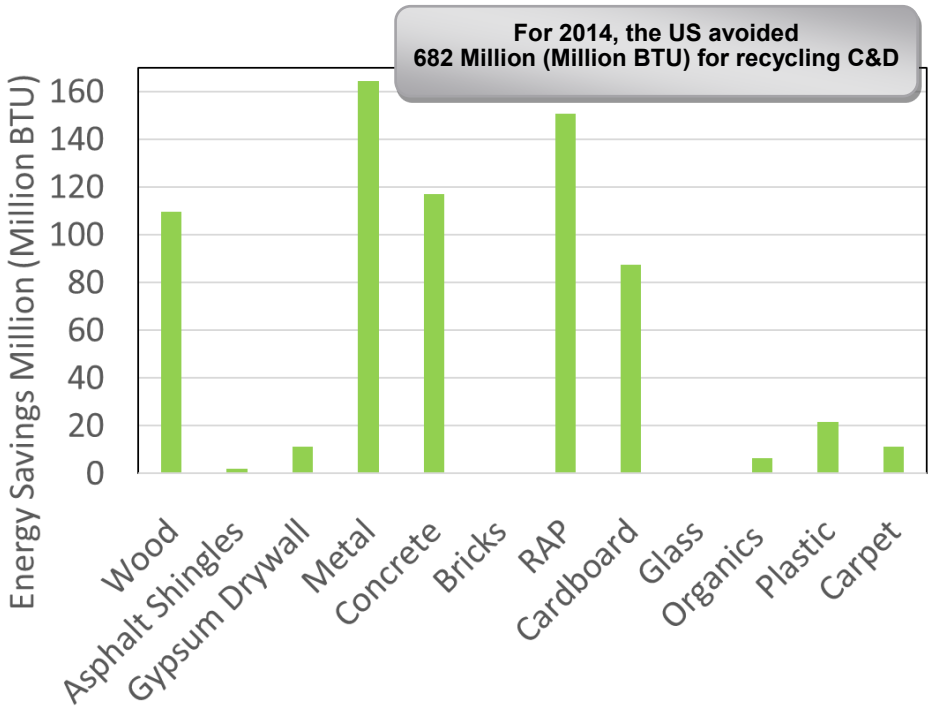


Figure 5. Energy savings associated with recycling each material

Constuction and Demolition Debris Recycling Benefits: Greenhouse Gas Eimission Reductions

Other Savings:

A total of **43.9 million MTCO$_2$E Avoided** is equivalent to:

- **9.27 million** Passenger vehicles driven for one year
- **1.99 million** Garbage trucks of waste recycled instead of landfilled
- **4.94 billion** Gallons of gasoline consumed
- **4.64 million** Homes energy use for one year
- **11,093** Wind turbines installed
- **1.56 billion** Incandescent lamps switched to LEDs
- **12.8** Coal-fired power plants in one year
- **1.13 billion** Tree seedlings grown for 10 years
- **41.6 million** Acres of US forests in one year

Waste Reduction Model (WARM) emission factors represent EPA estimated net environmental benefits or burdens (in terms of greenhouse gas (GHG) emission reduction and energy savings) from recycling or combusting a given commodity as compared with landfilling that same commodity. In some cases, an increase in GHG production occurs as a result of recycling, this is the case for drywall and wood. WARM assumes wood does not decay to produce GHG in a landfill environment, thus producing a carbon sequestration benefit which outweighs the GHG benefit of combusting wood for fuel – the assumed recycling pathway in this analysis. One of the materials accounted for in this analysis, C&D 'fines', is not accounted for in the model and thus, does not have a corresponding environmental benefit related to recycling quantified as part of this analysis. While, organics do have emission factors, there are no associated factors for recycling organics, thus not accounted for in this scenario.

When recovered C&D materials are used as a fuel source (e.g., combustion wood), the use of fossil fuels may be offset. Also, when recovered C&D materials are used to substitute virgin inputs, GHG production is generally (though not always) decreased and a net environmental benefit is produced.

In a similar fashion as the energy savings estimate, the recycled quantities of each material were multiplied by the appropriate energy factors from WARM to estimate the annual net metric tons of CO_2 equivalent resulting from recycling. The results of this analysis are presented in the Table 4 and Figure 6.

Table 4. Metric Tons of CO_2 Equivalent avoided of each C&D material using WARM factors

Material	Total Million MTCO$_2$E Avoided
Wood	-5.41
Asphalt Shingles	0.14
Gypsum Drywall	-0.35
Metal	10.8
Concrete	9.24
Bricks	0.05
RAP	7.76
Cardboard	19.8
Glass	0.05
Plastic	0.58
Carpet	1.24
Total	**43.9**

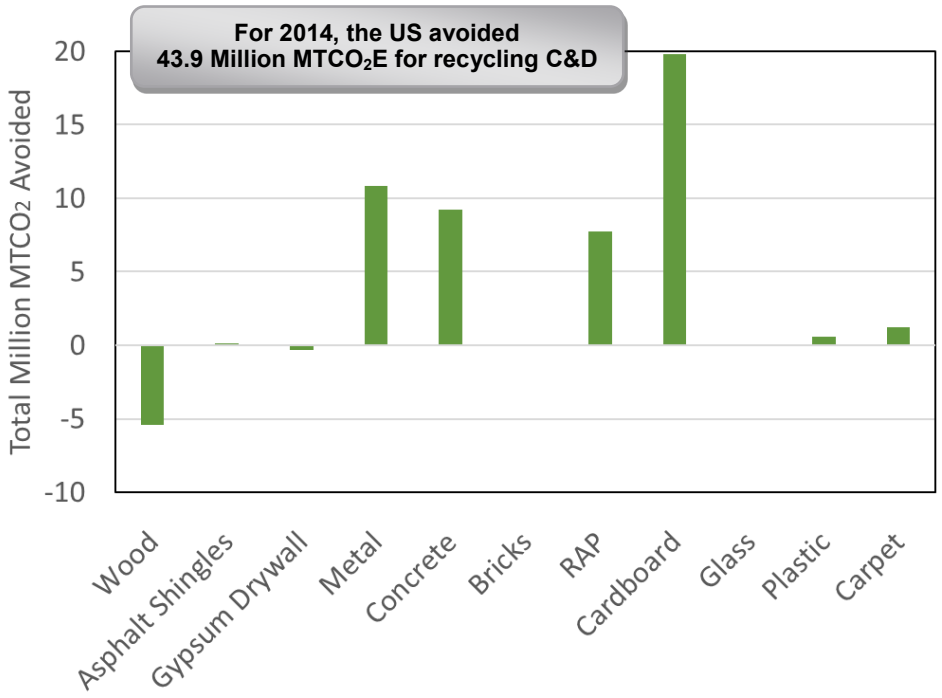


Figure 6. Avoided greenhouse gas associated with recycling each material

Constuction and Demolition Debris Recycling Benefits: Avoided Landfill Disposal

An additional benefit of avoiding the landfilling of C&D materials includes reduced required construction of landfill related infrastructure and associated cost savings. Avoiding disposal of C&D in MSW landfills is of particular benefit because of the avoidance of costs associated with landfill operation– generally heightened for MSW sites as opposed to C&D only landfills. At MSW landfill sites, costly gas and leachate collection and monitoring systems are often employed.

C&D recycling results in an avoidance of used landfill space. Using the recycled material estimates in Table 2 the landfill area avoided was estimated (in acres associated with a 50-ft depth of debris). The bulk densities of the landfilled materials were assumed to be 1,200 pcy, 2,200 pcy, and 2,000 pcy for mixed C&D, bulk aggregate, and RAP, respectively. The results are presented in Table 2; over 5,534 acres of landfill area is avoided being used on a yearly basis because of C&D recycling.

Table 2. Millions of tons recycled of each category and the corresponding acres saved from recycling instead of landfilling

Recycled Material	Million Tons	Acres Saved*
Mixed C&D	63.4	1,310
Bulk Aggregate	290	3,277
RAP	76.3	947
Total	**430**	**5,534**

***Assuming landfill is 50ft deep**

Problems with landfills

While landfills are certainly not the most efficient use of the natural environment and its resources, C&D landfill can pose several environmental risks that would be avoided if the material were recycled instead. C&D is not as inert as once commonly thought.

Rainwater coming into contact with landfilled C&D does produce a leachate that contains chemicals that can negatively affect underlying groundwater quality. And when drywall is disposed of in a C&D landfill, naturally occurring bacteria can convert the sulfate extracted from the gypsum into hydrogen sulfide, also referred to as H_2S. Most noted for its strong rotten-egg odor, H_2S can also be deadly at high concentrations and can pose chronic health impacts at low concentrations

Future of Constuction and Demolition Debris Recycling

This report provides an estimate of several different benefits of the C&D recycling industry in the US As C&D generation, disposal and recycling have not historically been well documented, the methods used for estimating benefits relied on a number of assumptions (C&D amount, composition, and disposition). Notably, that amount of bulk aggregate (concrete processed by mobile and fixed crushing plants) generated is the largest category, yet it is also the one with the least data. In the future as C&D data are more rigorously tracked and as forecasting methods are refined, generation and benefit projections will change. Regardless, the results of this analysis provide strong evidence of the economic, social and environmental benefits associated with the C&D recycling industry.

CDRA members and others in the C&D recycling industry resulting in a total of 430 million tons of C&D recycled in 2014, an amount accounting for 73% for the total C&D materials stream. Reclaimed asphalt pavement and bulk aggregate such as concrete accounted for the majority of this recycled amount, accounting for 99.% and 85% respectively. Although in some parts of the US mixed C&D recycling facilities recycle large amounts of C&D, the overall recycling rate for this sector was 37%.

Part of CDRA's mission is to promote the development of new markets for C&D materials and to help overcome obstacles currently in place. Membership in the CDRA supports these efforts. Stay tuned for future CDRA meetings and announcements.

C&D Markets Development Needs and Opportunities

- Crushed concrete as aggregate in new concrete products
- Recovered wood as an ingredient in engineered wood products
- Growth of drywall recycling as agricultural amendment, new drywall, and cement manufacture
- Processing of fines to produce value-added soil and aggregate replacements
- Wood and asphalt shingles as a fuel source in cement kilns

CONTACTS AND RESOURCES

State Regulatory Profiles

In 2013 the CDRA Executive Committee of the Board of Directors launched a "50 State Regulatory Profile Initiative." The goal of the initiative was to provide CDRA members with access to regulatory information affecting C&D recycling in all 50 states in one convenient location. Through this effort, the following information for each state was collected:

- A "Regulatory Summary" of how C&D recycling works;
- Listing of the Primary Statute(s) affecting C&D recycling;
- Primary Regulations Affecting C&D Recycling;
- Key Definitions;
- State Agency Web Links;
- Studies and Documents of Interest Involving C&D;
- Key Agency Contact People;
- A listing of "Progressive Regulatory Programs" adopted in the State;
- A listing of current "Regulatory Challenges" to the advancement of C&D recycling;
- Inventory of any "Sister Associations" that exist in the state engaged in solid waste management, recycling and/or C&D management.

For more information, contact or visit:
www.cdrecycling.org/state-profiles
Email: info@cdrecycling.org
Call: 866-758-4721

Recycling Certification

The re-use of Construction and Demolition (C&D) waste materials reserves more raw materials for the use of future generations and is a growing industry.

The Certification of Recycling Rates (CORR) program was established to provide credible, ISO-level third-party certification of C&D facilities' true recycling rates. CORR is administered by the Recycling Certification Institute (RCI). The Recycling Certification Institute (RCI) was created to meet this growing need for reliable recovery and recycling reporting by C&D recycling facilities.

For more information, including scheduling a recycling rate certification or to register your facility with the Institute, contact or visit:
www.recyclingcertification.org.
Email: info@recyclingcertification.org
Call: 1-916-242-8287

RECYCLING CERTIFICATION INSTITUTE

Material Websites

CDRA continues to focus on maintaining a vision for the future for C&D debris recycling over disposal. The Association has worked in coordination with the recycling industry and others to develop websites specific to asphalt shingle, concrete and gypsum drywall recycling.

Concrete Recycling

By weight, concrete is the most recycled material in the United States.
For more information, visit ConcreteRecycling.org.

Drywall Recycling

One of the more difficult to recycle materials in the US is gypsum wallboard.
For more information, visit DrywallRecycling.org.

Shingle Recycling

Asphalt shingles have several excellent engineering characteristics that allow them to be used in different applications.
For more information, visit ShingleRecycling.org.

Asphalt Pavement Recycling

Asphalt pavement is typically reused to create new asphalt pavement.
For more information, visit AsphaltPavementRecycling.org.

APPENDIX: DATA TABLE

Table 7. Total generation estimates of each category in the US in 2014

	Total Generation (Million Tons)			
Material	**Mixed C&D**	**Bulk Aggregate**	**RAP**	**Total**
Wood	38.6			38.6
Asphalt Shingles	13.5			13.5
Gypsum Drywall	13.5			13.5
Metal	4.35			4.35
Concrete	33.1	342		375
Bricks	12.1			12.1
Reclaimed Asphalt Pavement	6.93		76.5	83.4
Fines	15.1			15.1
Cardboard	18.8			18.8
Glass	0.53			0.53
Organics	4.10			4.10
Plastic	1.77			1.77
Carpet	1.66			1.66
Total	164	342	76.5	583

Table 8. Management practices tonnage estimates for each category in the US in 2014

	Mixed C&D (Million Tons)		Bulk Aggregate (Million Tons)		RAP (Million Tons)	
Material	**Recycled**	**Disposed**	**Recycled**	**Disposed**	**Recycled**	**Disposed**
Wood	13.5	25.1				
Asphalt Shingles	1.28	12.2				
Gypsum Drywall	3.90	9.69				
Metal	2.48	1.87				
Concrete	17.2	15.9	290	51.3		
Bricks	1.77	10.2				
Reclaimed Asphalt Pavement	1.21	5.72			76.3	0.19
Fines	13.0	8.51				
Cardboard	5.91	12.9				
Glass	0.17	0.36				
Organics	2.38	1.72				
Plastic	0.56	1.21				
Carpet	0.52	1.14				
Total	63.4	105	290	51.3	76.3	0.19
Recycling Rate	**37.5%**		**85.0%**		**99.7%**	

Table 9. Final end uses estimates of recycled C&D materials in the US in 2014

Material	Landfilled (Million Tons)	Recycled (Million Tons)		Recycled Total (Million Tons)
Wood	25.1	Fuel	9.08	13.5
		Mulch	2.82	
		Remanufacture	1.47	
		Compost	0.15	
Asphalt Shingles	12.2	Fuel	0.03	1.28
		Remanufacture	1.18	
		Aggregate	0.08	
Gypsum Drywall	9.69	Agricultural	3.49	3.90
		Remanufacture	0.41	
Metal	1.87	Remanufacture	2.48	2.48
Concrete	67.2	Aggregate- Road Base	250	308
		Aggregate- Drain Rock	6.30	
		Aggregate- Other Construction	20.6	
		Remanufacture	30.2	
Bricks	10.3	Aggregate	1.77	1.77
Reclaimed Asphalt Pavement	5.91	Remanufacture	67.8	77.5
		Aggregate	9.20	
		Other	0.56	
Fines	8.51	Landfill Cover	5.60	6.66
		Fill Material	0.52	
		Road Base	0.53	
Cardboard	12.9	Remanufacture	5.91	5.91
Glass	0.36	General Recycled	0.17	0.16
Organics	1.72	Compost/Mulch	0.72	2.38
		Fuel	1.66	
Plastic	1.21	Remanufacture	0.37	0.55
		Fuel	0.18	
Carpet	1.14	Remanufacture	0.01	0.52
		Landfill Cover	0.51	
Total	**158**	**-**	**424**	**424**

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