B. Construction and Demolition (C&D) Recycling

> One architect who wanted to sort and recycle construction waste met resistance from the construction workers. He motivated the crew in a time-honored fashion—with beer. On Fridays, he showed up with a case. If the recyclables had been sorted, the carpenters got the beer; if not, they didn't. After the first time the architect left without giving the construction crew the beer, the recyclables were sorted every time.
>
> —From *A Primer on Sustainable Building,* Rocky Mountain Institute

See **Appendix I: Recycling Markets** *for a discussion of handling procedures and potential end-users with respect to typical C&D materials.*

The objective of this learning unit is to understand job-site waste prevention issues by characterizing construction and demolition debris, investigating strategies for its recovery, analyzing the economics of recycling C&D materials, and identifying markets and end-users for recycled materials.

B.1.1 Discussion:
Construction & Demolition Materials Recovery

Figure 11: Clean Dozen™ master categories developed by Urban Ore, Inc. For more information, see A.2.1 Discussion: Materials Recovery.

inert

1. unable to move or act
2. sluggish in action or motion
3. not readily reactive with other elements; forming few or no compounds.

In the Netherlands, mineral aggregate for construction is mined in the upland east and is eventually deposited after demolition in the more urbanized lowland west. Forty square kilometers of excavation in one region of the country precedes one-and-one-quarter square kilometers of landfill in the other each year. One soils scientist estimates that construction must stop altogether by the year 2000, to prevent the topographic inversion of their country.[1] While the effect of this material flow may not be as severe in other places, the phenomenon in the Netherlands demonstrates the need to address how we dispose of construction and demolition (C&D) debris.

An analysis of C&D studies conducted for the Clean Washington Center and the Vermont Agency of Natural Resources indicates that, due to inadequate or nonexistent definitions of “C&D debris,”an overwhelming amount of incomplete data exists. Because most waste characterization studies label all C&D constituents as “inert,” it is no wonder there are conflicting reports. Without specific and standardized categories, everyone “sees” waste differently. If we do not identify the material, it does not exist.

In most areas, municipal solid waste facilities keep “inert” C&D debris separate from municipal solid waste, which includes household and commercial trash. Inert waste is not readily reactive with other elements or compounds. This distinction is assumed to be a characteristic of C&D debris, which is therefore permitted to be disposed of in a landfill with less stringent groundwater leachate controls. However, some components of C&D debris can be categorized as “hazardous

Hazardous Material	C&D Debris That May Contain It
asbestos	shingles, siding, insulation
creosote	railroad ties, telephone poles, marine pilings
fuel, oil, gasoline	fuel storage tanks, wood from barns or other outbuildings
pentachlorophenol	veneers, laminated wood, freshwater pilings
lead	wood painted with lead-based paint
mercury	wood painted with mercury-based paint

Figure 12: Hazardous Materials in C&D Debris
(C. T. Donavan Associates, Inc.)

waste": materials that are corrosive, toxic, flammable, or reactive. These materials should be separated and disposed of according to state hazardous waste regulations.

Materials resulting from the construction and demolition of buildings and infrastructure constitute a major share (10–15%) of the total municipal solid waste stream[2]; natural disasters such as floods, earthquakes, and hurricanes greatly increase these percentages. Construction debris is the result of off-cuts and packaging and is usually clean and separated from other wastes as soon as it is created—exceptions include spent caulk tubes and paint buckets, which may not be recyclable due to residual contaminants. Because the assembly of materials and production of waste is predictable, very little additional labor is necessary to reuse or recycle construction debris.

Figure 13: Concrete with rebar can be crushed and separated for recycling

On the other hand, demolition debris is produced in huge quantities over a short period of time and is inherently contaminated from the start, making it much harder to separate. A wide array of conglomerated materials are nailed, glued, screwed, bolted, welded, or cemented together in the form of wall and roof assemblies. Depending on the construction methods and materials, conservative disassembly (building deconstruction) may be cost-effective.

Figure 14: Clearly labeled recycling bins are key to source separation recovery strategies

The recovery of C&D debris consists of collecting and sorting the material prior to delivery to a reuse or recycling facility. Recovery strategies include source separation, time-based removal by a hauler, and off-site commingled processing at a recovery facility.

Source Separation

The success of job-site source separation relies on the ability of the workers to keep materials clean and sorted. Contaminated materials will not be accepted for recycling: in order for savings to take place, bins must be identified and workers and subcontractors must be held responsible. Multiple bins are required for each type of material, and each is hauled to or picked up by a recycler or other business that can make use of it. On large projects, roll-off bins are strategically placed to receive the materials as they are generated. The economics of this strategy are motivated by high landfill tipping fees and the availability of accepting facilities.

Figure 15: Time-based hauling makes sense when construction phases generate mounds of homogeneous material

For more on time-based removal, see **B.1.2 Case Study: Clean It Up Mark!**

Figure 16: Commingled C&D debris ends up at the inert landfill in Latah County, Idaho

See also **C.3.1 Discussion: Conservative Disassembly**

Time-Based Removal

Time-based removal by hauler takes advantage of the fact that on residential and smaller commercial projects, only one major type of waste is produced during each phase of construction. The waste hauler is contracted to separate and remove the materials before they become mixed with the materials from the next phase of construction. Space for multiple bins is not required, making this strategy attractive for urban infill projects and for builders that do not want the responsibility. A possible disadvantage to time-based hauling is that if crews are not contributing to job-site recycling, they are less likely to factor waste prevention into their construction practices.

Commingled Processing at Recovery Facility

Commingled delivery to a centralized recovery facility is a mechanically intensive option that is becoming more available in many urban areas, especially in the wake of natural disasters. Using a sophisticated system of crushers, shakers, screens, magnets, and blowers, larger recovery operations can achieve diversion rates as high as 82%.[3] Similar to time-based removal, commingled delivery to a recovery facility relieves the builder of the burden of recovery, and no additional space is required for multiple bins. Next to conservative disassembly techniques, commingled recovery is the best solution for recycling demolition debris. The disadvantage to current mechanical separation technology is that it produces relatively low-value materials with a high capital investment in equipment.

B.1.2 Case Study: Clean It Up Mark! (Portland, Oregon)

Builders of residential and small commercial construction benefit from job-site recycling, because as much as 95% of their waste is recyclable and is unmixed. On the other hand, the situation is complicated by the fixed costs of Dumpster rentals and landfill tipping fees. In Portland, Oregon, tipping fees for C&D debris are high, around $75/ton, and recycling is a growing industry allowing innovative entrepreneurs to fill the position once held by waste haulers.

Run by Mark McGregor, Clean It Up Mark! works with builders and developers, handling their site clean-up and waste hauling. Clean It Up Mark! separates and hauls materials from the job-site on a time-based recovery approach. Typically, job-site visits coincide with the completion of each major stage of construction. The first time the Clean It Up Mark! crew goes to the site may be when the framing is complete and the piles of debris consist of lumber stock and sheathing off-cuts. The second visit is when the outer skin of the building is complete and the waste is mostly roofing, siding, and painting debris. The last visit will pick up the cardboard, carpet, and trim scraps associated with interior work. Gypsum wallboard is normally handled separately by the drywall contractor. The majority of the materials McGregor recycles are untreated solid wood and engineered wood products.

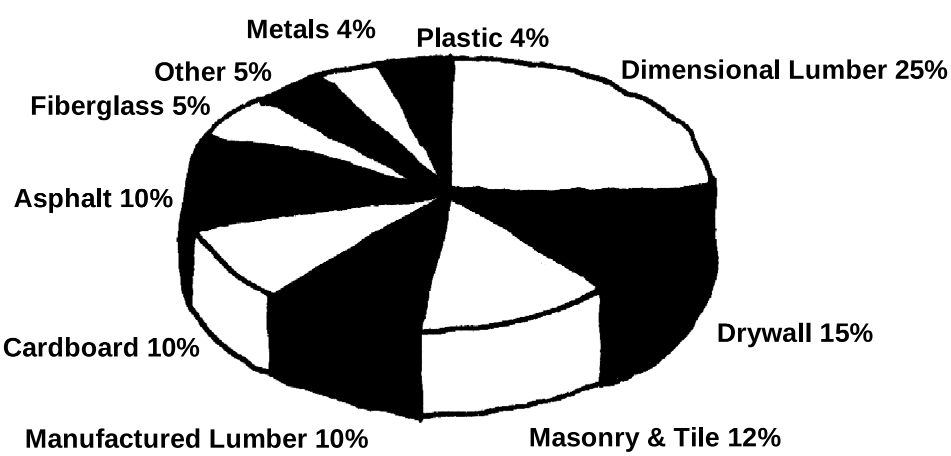

Figure 17: Residential Construction Debris
(Toronto Homebuilders Association)

Offered as a package based on the square footage of a building, Clean It Up Mark! is attractive to general contractors because the cost is agreed upon before the job commences, and the builder may save up to 25% in disposal costs.[4] McGregor is able to take advantage of the fact that old-fashioned waste haulers charge by volume at the job-site, while the landfill charges by weight. By finding a less costly recycling outlet for heavy materials such as wood, additional money is saved when landfilling any unrecyclable leftovers such as miscellaneous plastics and composites.

Clean It Up Mark! is an innovative and successful service for small-scale builders and developers in Portland and serves as an example for other areas with high landfill charges. However, it is a service geared to a particular segment of the building industry, and larger-scale projects or regions with minimal recycling opportunities require different solutions.

B.1.3 Exercise: C&D Debris Analysis

Objective

To visit a job-site to discover what C&D debris looks like (how we can characterize it), decide how it should be handled, and explore the availability of recovery strategies.

Preparation

In order for this exercise to be meaningful and successful, good communications with the builder and owner is necessary. Permission is required by both. The architect for the project, especially if local, can be a good initial contact: contractors are notoriously difficult to get in touch with, and owners can sometimes be hard to track down.

Execution

One option is for students to complete this exercise as a series of "snapshots" of several sites over a short time, comparing quantities of phase-related waste generated at a range of sites. Another option is for students to conduct a more in-depth, whole-project analysis of a single job-site, observing the dynamics of waste generation over many phases of work. Whichever approach is taken, **Appendix IV: C&D Debris Analysis Worksheet** will help track the materials. Use the conversion figures to help estimate quantities. It will also help to have a bathroom-type scale on site to "spot-check" estimates.

Material	lbs./yd.^{2}	tons/yd.^{2}	yd.^{2}/ton
Cardboard	100	0.050	20.0
Wood	300	0.150	6.7
Mixed Waste	350	0.175	5.7
Gypsum wallboard	500	0.250	4.0
Rubble	1,400	0.700	1.4

Figure 20: C&D Debris Conversion Figures
(Metro Portland Solid Waste Department, Portland, Oregon)

Figure 18: A "snapshot" of construction debris

Contractors are to attach to the bid packet a completed Waste Management Plan that outlines how any waste will be removed from the site. The Waste Management Plan shall include:

1. *Types of waste materials produced as a result of work performed on the site.*
2. *Estimated quantities of waste produced.*
3. *Identification of materials with the potential to be recycled.*
4. *Cost savings accrued by recycling rather than disposing of waste in landfills.*
5. *On-site storage and separation requirements.*
6. *Transportation methods.*
7. *Destinations.*

Figure 19: Sample Bid Specification Language (The Kasian Kennedy Design Partnership)

B.2.1 Discussion: Recycling Economics

The proximity of "ecology" and "economy" in the *American Heritage Dictionary* is not coincidental. Both economy and ecology share the Greek root *oikos*, meaning "management of the household." Ecological systems provide the necessary conditions for any economic system. Therefore, industry should be the leading steward of the environment. However, the narrow view of current growth-based economic systems ignores the ecological costs of doing business. Increasingly, resource depletion and pollution are revealing the weaknesses that exist within our traditional "take-make-waste" economic paradigm.

ecology

1. the science of the relationships between organisms and their environment.
2. the study of the detrimental effects of modern civilization on the environment, with a view toward prevention or reversal through conservation.

economy

1. careful, thrifty management of resources, such as money, materials, or labor.
2. an orderly, functional arrangement of parts; on organized system.
3. efficient, sparing, or conservative use.

In the U.S. Pacific Northwest region, economists have noticed a substantial transition occurring from a traditional natural resource extraction-based economy to a high-tech economy. The overall growth in employment and income indicates that, even though the extraction industry is shrinking, the overall economy is flourishing. The driving force behind the new regional economy is the quality of life that attractive natural environments afford. Therefore,

> the highest-value use of a forest, river, or other resource will be to protect and enhance it, because this will strengthen one set of forces that is creating new jobs and higher incomes. . . . Job gains in industries that do less damage to the environment will offset job losses in the more pollution-intensive industries.[5]

An enhanced recycling economy enables the widespread utilization of post-consumer, C&D, industrial, and agricultural byproducts, thereby sustaining our "natural capital" and life-support systems.

Our current economic-political system subsidizes both the extraction of natural resources, or virgin materials, and their disposal through landfill and incineration. These subsidies take many forms, including property tax abatements for disposal sites, antiquated legislation like the Mining Law of 1872 (which makes "all valuable mineral deposits" on public lands "free and open to exploration and purchase"), and below-cost timber sales on public lands. In addition, industry is not always held responsible for the environmental degradation that may occur: environmental costs are externalized. According to the "polluter pays" concept, industry should internalize these costs paid indirectly by the taxpayer and transfer them directly to the consumer.[6] Removing government subsidies is one way to give consumers the opportunity to buy goods according to their "true costs." Given the choice, who would pay extra for gross inefficiency and unsustainable business practices?

Figure 21: Quality of life and biodiversity maintained by the conservation of natural resources

Ecological tax reform is another method for creating a level playing field. Currently, some industries voluntarily internalize the environmental costs associated with resource extraction by investing in strategies that reduce their demand for virgin materials and minimize their production of wastes. While altruistic motives are admirable, ecological tax reform would result in the shifting of the tax system away from personal incomes toward virgin resources, energy, and waste. Besides encouraging companies to invest in closed loops that do not degrade the environment, ecological tax reform lowers labor costs without lowering personal incomes. If implemented in Germany and Sweden as planned, these industries will gain an advantage over companies that have the highest paid workers.[7]

Figure 22: Industrial-scale clearcutting, especially on steep slopes and near bodies of water, causes widespread ecological degradation

Unfortunately, our society perceives economy and ecology as being adversarial. Public policy, government, and politics in general have great difficulty in achieving common ground. One hears about "what the economy is doing to the environment" and "the economic costs of environmental controls." The resolution lies somewhere within the emerging realm of industrial ecology: wastes are not wasted (landfilled or incinerated) but become valued ingredients of other products.

See **A.3.1 Discussion: Industrial Ecology**

In spite of conflicting public opinions, many states have legislated solid waste mandates that encourage the development of a recycling economy. For example, California mandates a 25% reduction in landfill consumption by the year 1995 and 50% by 2000.[8] Because C&D is a major constituent of solid waste (up to 30%), government and industry are looking at ways to develop recycling markets for it. The National Recycling Coalition's "Buy Recycled Business Alliance"; the Washington Department of Community, Trade and Economic Development; and Seattle's Business and Industry Recycling Venture are some examples of organizations at the national, state, and local levels seeking to improve the recycling economy. The availability of local and regional markets for recovered materials is critical to the long-term financial success of C&D recycling.

Assuming there are available end-uses for the recovered materials, the immediate recovery of C&D debris makes economic sense if the total net financial cost of recovery is less than the cost of landfilling or incinerating. Landfills and incinerators for post-consumer trash are becoming more expensive to site and operate due to the high cost of control technologies necessary to minimize groundwater and air pollution. In the process of incineration (waste-to-energy), pollution that would normally enter the atmosphere is converted and condensed into heavy metals and dioxins, which require expensive disposal in hazardous-waste landfills. Many municipalities unable to cope with these very real costs have chosen to site an inert C&D landfill (with less expensive controls) locally and transfer their household and commercial waste to a privately managed regional landfill. In a rural area where land is relatively inexpensive, the economics of recycling are such that it costs less money to landfill C&D debris. The tipping fee in Moscow, Idaho, is a mere $20/ton compared to $75/ton in Portland, Oregon. In densely populated areas like northern New Jersey where NIMBY* attitudes rule, tipping fees exceed $140/ton.[9]

Urbanized areas within the Pacific Northwest region of the U.S. are on the cutting edge of C&D debris recycling, thanks to the efforts of solid waste agencies, construction contractors, and private consulting firms. The Portland-based River City Resource Group (RCRG) and Seattle-area O'Brien & Company offer their services to design and construction professionals, and are dedicated to finding ways to make the best use of materials with the biggest positive economic impact.

Since 1991, the efforts of RCRG and the Metro Portland Solid Waste Division, relatively high landfill tipping fees ($58–$75/ton), and an exceptionally well-developed and growing recycling economy (40–50 facilities) have contributed to diverting over 42% of Portland's C&D debris.[10] Over the last few years, RCRG has worked on some of the region's most

*"Not in my backyard!"

eye-catching building projects including the $265 million Rose Garden Arena built by Turner Construction Corporation. With the help of RCRG, Turner implemented the largest job-site recycling program in the country, recovering more than 96% of the construction and demolition debris and saving almost $200,000.[11] RCRG developed a waste management plan that includes bid specification language, solicitation of and agreements with haulers, on-site setup and monitoring, subcontractor education, monitoring and tracking of debris leaving the site, and conducting a cost / benefit analysis on the results of the waste management plan.

Turner, one of the largest construction enterprises in the country, and its sustainability director, Ian Campbell, have begun setting the industry standard in sustainable construction. With the incredible resources of a trans-national corporation at his disposal, the visionary Campbell speaks of "aligning the construction industry along the cycles of nature" and "biodegradable building products that are composted after demolition." These are not the proclamations of an ivory tower academic. A building contractor of Turner's stature stimulates the recycling economy with every completed project.

B.2.2 Case Study: Metro Headquarters (Portland, Oregon)

Figure 23: Metro Headquarters by Thompson Vaivoda Architects in Portland reused an existing concrete frame. (Erik Barr)

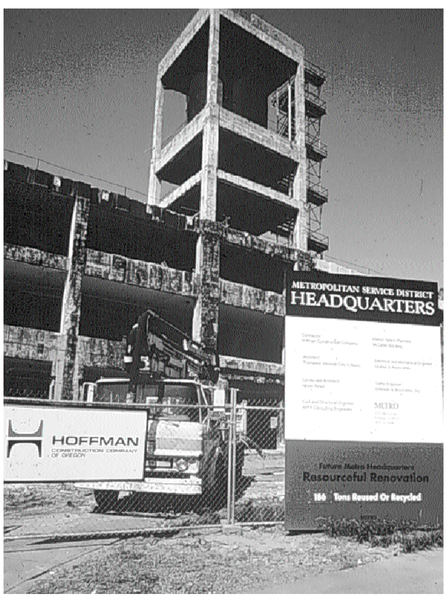

Figure 24: An old Sears store was gutted, and the materials were either reused or recycled. (Metro Portland Solid Waste)

Metro, the regional government serving the Portland area, is responsible for growth management and land-use planning; solid waste management; operation of the zoo, regional parks, and greenspaces programs; and technical services to local governments. Between January 1992 and April 1993, a Sears department store building was renovated into almost 200,000 square feet of new office space for Metro. The project included pre-demolition salvage, adaptive reuse, job-site recycling, and the use of recycled-content building materials. Recycling and salvaging costs including the additional labor for separating materials and self-hauling to recycling processors totaled $15,000. The net savings due to lower recycling fees and payments received for salvaged materials totaled $35,000.

Before demolition, local non-profits and salvage companies removed 159 tons of materials. For example, Rejuvenation, Inc., reused 18,000 square feet of hardwood flooring, saving $1,500 in removal and disposal costs. Besides the 20 tons of flooring, an additional 124 tons of wood, nine tons of carpet, two tons of doors and fixtures, and four tons of landscaping shrubs were salvaged. Preserved for reuse in the building were decorative cast medallions, a two-story water tank that was converted into a meeting room, and metal latticework. The gutted reinforced concrete frame of the original building was adapted to the new office spaces, saving $2 million compared to the costs of demolition and new construction.

Source separation by the general contractor and subcontractors resulted in recycling more than 725 tons of drywall, wood, mixed metals, and corrugated cardboard. In addition, at least 7,000 tons of brick, concrete, sand, and dirt were diverted from the landfill. Some of the material was used on-site to fill elevator shafts and backfill around the building foundation, while the remainder was used as clean fill material at nearby sites. Excluding rubble and dirt, over 75% of the remaining construction and demolition debris was recycled.

To support markets for recovered materials, a range of recycled products were used. These include: foam insulation from polystyrene scraps, rock wool insulation from steel slag, ceiling tile from old newspaper, primer from reprocessed latex paint, gypsum wallboard from construction scraps, floor tiles from waste glass, restroom partitions and locker room benches from HDPE plastic, resilient flooring from tires, wheel stops from mixed plastics, and landscaping soil from yard debris.

The Environmental Protection Agency awarded Metro a $30,000 grant to document the project. To order a copy of the handbook and video for architects, builders, and contractors, contact the Metro Solid Waste Department, 600 NE Grand Ave., Portland, Oregon 97232-2736, or call (503) 797-1650.

Figure 25: reused medallions from existing building. (Erik Barr)

Figure 26: hardwood flooring salvaged by a local reuse business (Metro Portland Solid Waste)

B.2.3 Exercise: Recycling Economics Analysis

Objective

To investigate the economic feasibility of C&D debris recycling at a job-site.

See **Appendix I: Recycling Markets** for a discussion of handling procedures and potential end-users with respect to typical C&D materials.

Preparation

This exercise is a continuation of **B.1.3 Exercise: C&D Debris Analysis** where students identify reuse and recycling facilities that accept different components of C&D debris. A review of typical handling procedures and recycling markets, provided in **Appendix I: Recycling Markets**, is recommended. The appropriate local, county, and state solid waste divisions will also be able to provide a great deal of information regarding fees, facilities, and markets.

Figure 27: wood waste at chipping facility (top) and
Figure 28: demolition debris being chipped on-site (above) (KPG, Inc.)

Execution

The major tasks are to conduct an economic analysis of job-site recycling, using **Appendices V and VI: Recycling Economics Worksheets**, and support the analysis with some research into local and regional markets for recovered materials. Where does the material go? Who are the end users? What are their material specifications? In order to complete the worksheets, it will be necessary to research tipping fees in the area for both landfilled and recycled materials, hauling costs, container fees, and labor rates.

B.3.1 Endnotes for Construction and Demolition Recycling

[1] Kevin Lynch, *Wasting Away* (San Francisco: Sierra Club Books, 1990), 84.

[2] Edward von Stein and George M. Savage, "Current Practices and Applications in Construction and Demolition Debris Recycling," *Resource Recycling* (April 1994): 85.

[3] Nadav Malin, "What's New in Construction Waste Management?" *Environmental Building News* 4, no. 6 (November / December 1995): 13.

[4] Chris Donnelly, "Construction Waste," *Fine Homebuilding* (February 1995): 72.

[5] T. M. Power, ed., "Economic Well-Being and Environmental Protection in the Pacific Northwest," *A Consensus Report by Pacific Northwest Economists* (December 1995), 10–12.

[6] Paul Hawken, *The Ecology of Commerce* (New York: HarperCollins, 1993), 189.

[7] Sarah van Gelder, "The Next Reformation," *In Context*, no. 41 (Summer 1995): 21.

[8] Kevin Brooks, Brian Torone, Cassandra Adams, and Laura Demsetz, "Making Construction and Demolition Debris Recycling Profitable: The Roles of Public Policy and Innovative Project Management," in *Proceedings of the Construction Congress*, sponsored by the Construction Division of the American Society of Civil Engineers, San Diego, 22–26 October 1995, 397.

[9] Judd H. Alexander, *In Defense of Garbage* (Westport, CT: Praeger Publishers, 1993), 81

[10] Marnie McPhee, "The Power of Positive Consulting," *In Business* (November / December 1995): 27.

[11] Ibid.