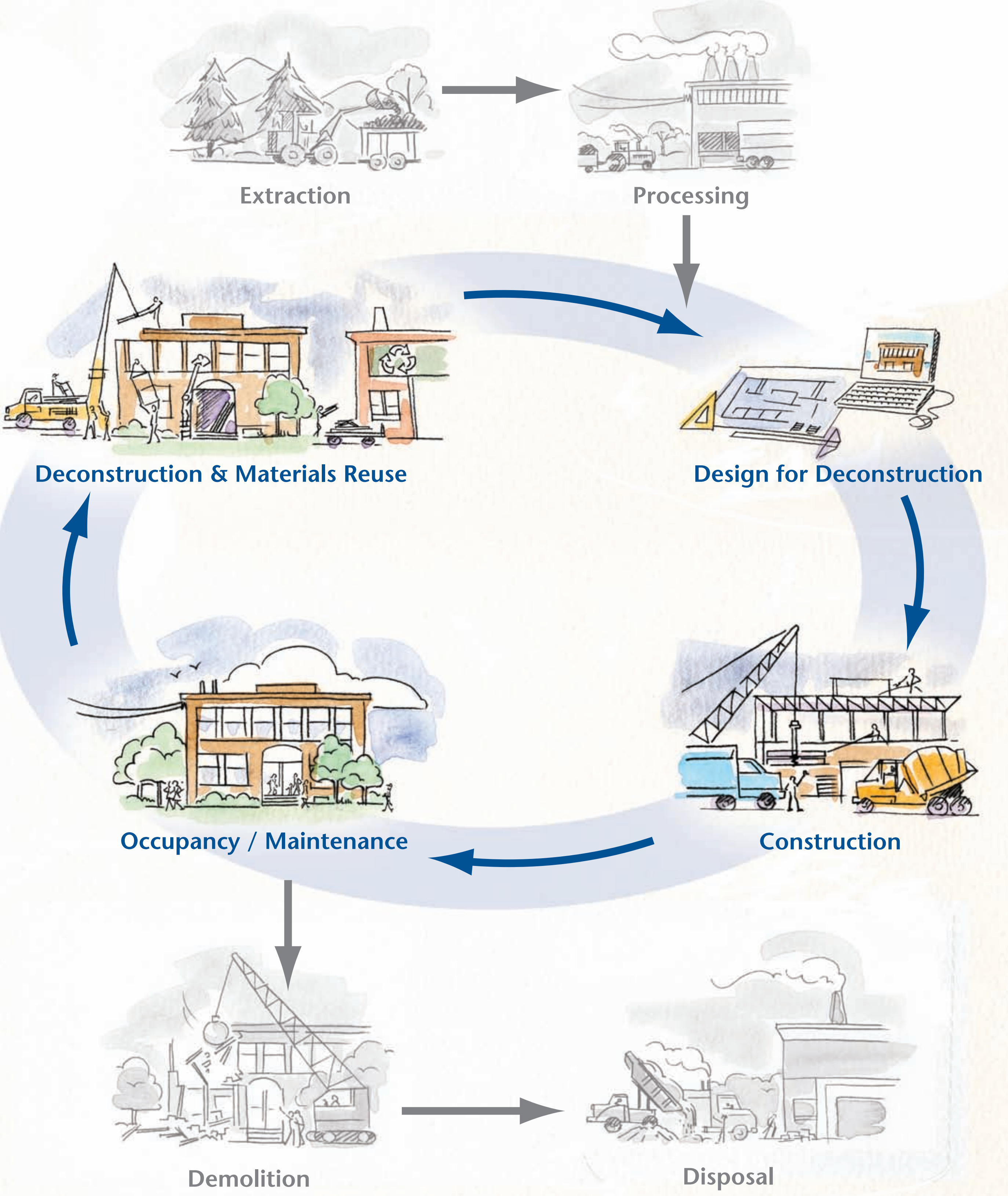
Lifecycle Construction Resource Guide



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SECTION 1

INTRODUCTION: LIFECYCLE CONSTRUCTION

Putting buildings up, renovating them, taking them down—together, these construction-related activities have a substantial environmental footprint. Two measures of this footprint stand out:

- Building construction uses large quantities of natural resources—by the U.S. Geological Survey's estimate, construction activities consume 60 percent of the raw materials, other than food and fuel, used in the U.S. economy.[1]

- The nearly 160 million tons of annual building construction-, renovation-, and demolition-derived wastes (commonly referred to as C&D materials) account for nearly one-third of the nation's non-hazardous solid waste generation.

Approximately 60 percent of the nation's building related C&D materials end up in landfills, contributing to our solid waste management challenges. Some demolition-derived wastes are recycled at relatively high rates and become valuable inputs to other materials. For example, concrete is incorporated into the aggregate material used for road construction, asphalt shingles become a component of the asphalt used to pave roadways, and gypsum wallboard becomes an input into the manufacture of portland cement.

If projections are accurate, the scale of construction, renovation, and demolition activity in the first 30 years of this century will be substantial. By one estimate, the amount of built space in the U.S. will grow from approximately 300 billion square feet in 2000 to nearly 430 billion square feet in 2030. In addition to the 130 billion square feet of new construction that will occur, more than one quarter of the buildings that existed in 2000 are expected to be replaced by 2030.[2] In short, buildings will continue to consume large amounts of resources and will continue to represent a significant source of solid waste. While this might be viewed as a growing challenge, it can also be viewed as an opportunity to employ sustainable building practices on a larger scale.

STATE AND LOCAL CATALYSTS FOR LIFECYCLE CONSTRUCTION

- **California.** The 1989 Integrated Waste Management Act required all counties and municipalities in California to use source reduction, recycling, and composting to achieve diversion of at least 50 percent of solid waste by 2000, relative to 1990 levels. As a result, numerous counties and municipalities have adopted waste management plans that include a requirement that all buildings scheduled for demolition be made available for deconstruction.
- **Boulder, Colorado.** The Boulder residential building code encourages "cost-effective and sustainable residential building methods to conserve fossil fuels, water and other natural resources, to promote the reuse and recycling of construction materials, reduce solid waste, and to promote enhanced indoor air quality" (Chapter 10-5.5, Boulder Revised Code, 1981). A mandatory Green Points program for new residential construction (including renovations and additions) awards points for deconstruction, recycling, and materials reuse.
- **King County, Washington.** The county's Solid Waste Division encourages lifecycle construction by providing a wide range of resources and tools on its website, including sample language for deconstruction specifications and a guide to Design for Deconstruction (DfD) (http://www.metrokc.gov/dnrp/swd/construction-recycling/index.asp).
- **Massachusetts.** A 2006 amendment to the state's waste disposal regulations, imposing a ban on the landfilling of asphalt pavement, concrete, metal, and wood wastes, created a strong incentive to increase the rate of C&D waste recycling and reuse.

An Alternative Approach: Lifecycle Construction

The possibility of an alternative approach, one that moves beyond tearing down buildings and throwing away the pieces, is not a new concept. For many years, demolition professionals across the country have selectively "deconstructed" buildings, salvaging reusable materials that would otherwise become part of a dead-end waste stream. Deconstruction of these high-quality building materials not only diverts wastes from landfills, it also saves energy and reduces greenhouse gas emissions by reducing the need to extract and process raw materials and ship new materials long distances, conserves natural resources, and reduces the environmental impact of waste disposal. Deconstruction also gives rise to a new industry comprising skilled jobs and commercial opportunities. And yet, while individual examples of the successful realization of these benefits are easy to find, much of this building practice's potential continues to go unrealized.

Not surprisingly, given that deconstruction can be more labor- and time-intensive, and thus will generally cost more than demolition and disposal, the challenge has been making a strong business case for this non-traditional practice. When a market for salvaged materials exists, however, the business case can quickly come into focus. If recovered materials can be resold for more than the incremental cost of recovery, deconstruction should be preferred (all else being equal). In addition, less material waste means decreased disposal costs, another economic benefit. The business case is strengthened by a consideration of the value of deconstruction's sound environmental benefits, benefits that a building owner or developer cannot as easily put a dollar value on, but that contribute to the achievement of sustainability objectives. For example, by reducing the need for manufacturing of new building components, industry can lower energy use and thus reduce greenhouse gas emissions.

Multiple factors are at work to create a groundswell of support for deconstruction as an integral component of a "lifecycle" approach to building construction, including a growing consumer interest in "greener" buildings as well as state and local initiatives to address the large volumes of C&D materials entering the waste stream (see text box). A broad definition of lifecycle construction is: "the design of building materials, components, information systems, and management practices to create buildings that facilitate and anticipate future changes to and eventual adaptation, disassembly, or dismantling for recovery of all systems, components, and materials."[3]

This definition is not to be mistaken for a one-size-fits-all prescription for future building projects, but rather represents a set of principles that can transform the way we think about, create, and modify our built environment.

Lifecycle Construction Opportunities

Under ideal circumstances, buildings would be designed for deconstruction and built using materials recovered from other buildings that themselves had been designed for deconstruction. In reality, of course, it is not possible to achieve a completely closed-loop building lifecycle (i.e., to eliminate the need for any new materials or systems). But adhering to lifecycle construction principles whenever possible can provide meaningful benefits by reducing the energy and resource consumption required to produce the necessary building materials and systems and by reducing solid waste. In the near term, three specific lifecycle construction practices will offer the greatest potential:

- **Deconstruction—**Deconstruction of older buildings that were not designed for deconstruction, with reuse of salvaged materials in other building projects whenever possible;
- **Design for Deconstruction (DfD) and Materials Reuse—**Construction of new buildings using DfD principles and, where possible, incorporating salvaged building materials; and
- **Green Building—**Retrofitting and new construction of buildings to include green building elements such as sustainable site planning, energy efficiency, safeguarding water and water efficiency, conservation of materials and resources, and improved indoor environmental quality.

This document will highlight the former two elements—deconstruction, which accounts for much of the current lifecycle building activity, and DfD and materials reuse, where a growing number of examples are occurring. Although not the focus of this document, it should be noted that the latter concept of green building is an integral part of Lifecycle Construction. The green building movement has gathered momentum through green building certification programs, most visibly the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) building certification program, and helps advance other lifecycle construction concepts such as reuse of salvaged materials. A number of green buildings resources already exist, and can be accessed through the EPA's green building website at http://www.epa.gov/greenbuilding.

It is also important to recognize that the building construction industry will not be transformed overnight, with all demolition being replaced by deconstruction and all new construction incorporating DfD. Aside from the impracticality of such a shift, the reality is that not all building projects are appropriate candidates for deconstruction or DfD. For example, buildings constructed before 1950 are, in general, better candidates for deconstruction since they contain higher value wood and are less likely to have complicated fasteners and glues. However, it is entirely appropriate to consider the feasibility, and the potential benefits, of lifecycle construction practices in any building project. To transform the industry, demolition should incorporate successful aspects of deconstruction, and deconstruction should look towards the demolition industry to improve their techniques. Eventually these industries should converge to offer an approach that provides the most efficient use of materials possible.

Purpose of This Guide

The purpose of this guide is to introduce a broad range of building project participants to the opportunities and challenges associated with lifecycle construction, with a focus on building deconstruction, materials reuse, and design for deconstruction. The primary means for presenting this information is a series of six case studies, including descriptions of lifecycle construction projects that received support, as "Innovations Pilot Projects," from the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response (OSWER).

Through the case studies, the document highlights what are emerging as best practices as well as key lessons that can aid in the planning and implementation of future projects. It is important to note that this document is not a "how-to" manual; a significant and growing body of information exists describing in great detail how to deconstruct a building and how to design a building for deconstruction. This document identifies these resources and encourages the reader to consult them as the next step in considering, planning, or implementing a lifecycle construction project.

Who Should Read This Document?

This document is intended for people involved in the planning of building projects who are not already familiar with lifecycle construction concepts. Interested readers are expected to include federal, state, and local officials as well as members of the construction and demolition industry such as demolition professionals, architects, developers, and construction managers. In general, the guide is for people who are in a position to advocate for lifecycle building and to develop and oversee implementation plans.

Organization of the Document

Sections 2 through 4 focus on deconstruction, materials reuse, and design for deconstruction respectively. Case studies at the end of each section highlight recent, successful efforts to put lifecycle construction principles into practice. Section 5 provides a categorized list of resources that offer more in-depth information on the lifecycle construction topics touched upon in this document.

SECTION 2

Deconstruction

Background

Deconstruction is a technique practitioners are using to salvage valuable building materials, reduce the amount of waste they send to landfills, and mitigate other environmental impacts. It is the disassembly of a building and the recovery of its materials, often thought of as construction in reverse. Today, the appreciation of the lifespan and value of materials has become diminished in the context of a more disposable society in which new is assumed to be better. Technological innovation and increased availability of materials, coupled with a growing economy, population, and desire for more individualized space, has increased the demand for commercial and residential development, typically using new materials.

According to the National Association of Home Builders (NAHB), the size of an average home in the United States jumped 45 percent between 1970 and 2002, from 1,500 to over 2,200 square feet, while the number of people living in each home decreased from an average of 3.2 people to 2.6 people. This meant more demolition, and renovation, of older structures to allow for new and bigger structures.

Demolition using heavy equipment is the traditional process for building removal. Modern demolition equipment removes structures quickly, destroying the materials within and creating solid waste destined for landfills. Some recycling does occur during the

demolition process, most typically concrete, brick, metal, asphalt pavement, and wood. However, landfill costs in many states are still low, enabling wasteful disposal practices. Although certain areas in the United States are beginning to restrict disposal of construction and demolition (C&D) waste in order to promote recycling and reuse (see Section 3), some states still have local landfill tipping fees as low as $9.95 per cubic yard.[4, 5]

Environmental impacts from construction and demolition activities are sizeable, both upstream and downstream. Large amounts of energy and resources go into the production of new building materials. This results in the loss of natural habitats during the extraction phase; increased consumption of non-renewable resources; greenhouse gas emissions in the extraction, manufacturing, and transportation phases; and emissions of various other air and water pollutants as by-products of manufacturing. Downstream, impacts from the disposal of building related C&D material include operational and odor issues and economic losses through inefficient resource use.[6, 7] Construction and demolition also produces large quantities of waste. A recent estimate developed by the EPA as part of their forthcoming report, *Characterization of Building-Related Construction and Demolition Debris Materials in the United States*, calculated that 164 million tons of building related C&D debris was generated in the United States in 2003.[8] Demolition accounts for roughly 48 percent of the C&D waste stream.[9]

This Section describes how deconstruction can work to offset the environmental impact of the building related C&D industry, focusing on salvaged material perceptions, types of deconstruction, the role of demolition, and key considerations when planning a deconstruction project. Two case studies are also presented in this document highlighting recent, successful projects incorporating deconstruction. Case Study 1 at the end of this section describes the deconstruction of a single residence row house in Philadelphia, Pennsylvania. Case Study 2, at the end of Section 3, highlights a unique deconstruction project that leads to an immediate reuse opportunity in a new construction project.

Resources Not Waste

Deconstruction advocates are working to change the perception that older building materials are "waste." In fact, many of these materials are valuable resources. However, according to EPA, only 20 to 30 percent of building-related C&D material was recycled or reused in 1996.[10] This gap presents an opportunity to capture valuable resources.

Deconstruction is becoming a complement to or a substitute for demolition worldwide, including in the United States where a market is emerging. Brad Guy, a leader in the deconstruction field and president of the Building Materials Reuse Association, has found that there are currently over 250 active deconstruction programs throughout the United States. Such programs recognize the potential and benefits of this process, which include:

- **Reduction of Waste and Debris—** According to the Deconstruction Institute, in order to sustain human society into the next century, resource efficiency will have to increase by a factor of 10. The materials salvaged through deconstruction help replenish the construction materials market, rather than add to the amount of waste in landfills. In fact, studies indicate that deconstruction can reduce construction site waste by 50 to 70 percent.[11] This not only helps extend the life of the existing landfills, but also decreases disposal costs for developers by minimizing the amount of building related C&D material they are responsible for at the end of a project.[12]

EMBODIED ENERGY

A major factor in determining a building's lifecycle impact, Embodied Energy is the amount of energy consumed to produce a product, in this case building materials. This includes the energy needed to:

- Mine or harvest natural resources and raw materials;
- Manufacture the materials; and
- Transport the materials.

By extending the life of building materials, deconstruction and materials reuse preserve this embodied energy, minimizing the need for further energy use.

- **Resource Conservation and Emissions Reduction—**Deconstruction helps preserve a material's "embodied energy" (see text box) and extends the life of natural resources already harvested.[13] This minimizes the need to produce new materials—in turn saving more natural resources and reducing production impacts such as emissions. For instance, a dominant benefit of deconstruction and the reuse of salvaged materials is the reduction in greenhouse gas emissions.

  Using materials salvaged from deconstruction projects also reduces the demand to ship materials typically sourced and manufactured long distances from their ultimate use. This helps support the local economy as well as further reduce air emissions. Deconstructing a building also provides the opportunity to recycle any of the material that cannot be reused. Although the recycling process uses some energy and raw materials, and emits pollution, it is still a more sustainable option than disposing of materials.[14]

- **Economics Benefits—**New end use markets, including salvaged material resellers and other small businesses, are being created to support deconstruction activities. Other economic benefits include job creation, workforce development training, lower building material cost, and revenue generation through salvaged materials sales. Avoided demolition debris disposal costs are a benefit when considering the transportation and disposal costs, as well as disposal restrictions, in certain U.S. states. Additionally, property owners can realize tax deductions that include the value of the building and its materials if they are donated to a non-profit organization.

- **Historic Preservation—**Many buildings slated for deconstruction contain historic materials such as moldings, doors, mantels and other artistic elements that can be used to beautify other buildings and preserve architectural history.

- **Community Support and Revitalization—**Deconstruction yields social benefits in a number of ways. Projects can be used to educate the public about sustainable development issues and the construction industry. Salvaged materials offer the community lower cost options for building materials. Reusing historical building materials preserves cultural traditions. In addition, important partnerships necessary at times to affordably and effectively complete a project can be created between government, non-profits, historical societies, and other organizations. For instance, Habitat for Humanity volunteers have participated in deconstruction projects to offset the cost of labor. Cities have also incorporated deconstruction into their community revitalization plan to help renovate, remove, or remodel buildings.

- **Green Building Certification Credit—** Incorporating deconstruction in a project can also earn points towards certification under the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program and other local green building rating programs. For instance, developers can get up to three points by diverting C&D material from landfills. Projects can also earn credits through the salvage and reuse of materials in a project's design. According to *Wa$tematch*, New York City's materials exchange and solid waste reduction program, deconstruction is an efficient way to achieve a LEED rating. Compared to other techniques, such as installing advanced HVAC units and designing high-tech building envelopes, deconstruction is an inexpensive and more straightforward option.

Despite its benefits, deconstruction is currently not a one-size-fits-all solution. Common obstacles to its universal implementation are an increase in project time and labor requirements (including labor oversight), which influence cost. However this is not the case for all projects. Case studies have shown that deconstruction can be cost-competitive with demolition. With the proper planning, implementation, and a few days of flexibility, deconstruction is a feasible, worthwhile, and beneficial building removal method. As construction professionals become more familiar with necessary techniques, and more effective methods are devised through pilot projects, its integration can be expected to increase.

Types of Deconstruction

Two distinct types of deconstruction can take place on a project—non-structural and structural. *Non-structural deconstruction*, also known as soft-stripping, is a simpler method of deconstruction that demolition contractors have used for years and has more immediate financial benefits. Many projects already incorporate some non-structural deconstruction activities prior to demolition, though there is still room for the conventional demolition industry to integrate this practice more broadly. *Structural deconstruction* consists of more involved recovery activities that require more time and resources to implement. To offset the costs of these activities, projects aim to salvage higher value materials. A complete deconstruction project would undertake both structural and non-structural deconstruction. Table 2-1 further describes these deconstruction types:

Table 2-1. Non-Structural and Structural Deconstruction

Deconstruction Type	Description	Characteristics	Types of Salvaged Materials
Non-Structural *(i.e. soft-stripping)*	The removal for reuse of any building contents that do not affect the structural integrity of the building.	• Requires less planning and coordination than structural deconstruction. • Materials can be viewed and removed without much destructive access. • Uses few tools, and materials are salvaged relatively easily with minimum safety concerns. • Does not have a significant effect on project schedule	• Finish flooring • Appliances • Cabinetry • Windows/doors • Trim • HVAC equipment • Fixtures/hardware • Fireplace mantels
Structural	The removal, for reuse, of building components that are an integral part of the building, or contribute to the structural integrity of the building.	• Involves a range of tools and mechanization • Heightened safety consideration, and longer time-frame. • Materials removed are typically large, rough products that are reused as building materials or remanufactured into value added products such as chairs, tables, and surface coverings.	• Framing • Sheathing • Roof systems • Brick/masonry • Wood timbers/ beams • Wood rafters • Floor joist system

Source: Adapted from U.S. Department of Housing and Urban Development (2000, 2001).

Deconstruction Versus Demolition

While complete deconstruction is the preferred and most sustainable method for removing or renovating a structure, it is not always the most applicable depending on the type of building and its components. What types of buildings are ideal candidates for complete deconstruction? According to the Department of Housing and Urban Development (HUD) highly deconstructable buildings have one or more of the following characteristics:

- **Wood-framed—**Wood framed buildings, especially those with heavy timbers and beams or with unique woods such as Douglas fir, American chestnut, and old growth southern yellow pine, are ideal for deconstruction because of their straightforward "stick by stick" construction, as well as the reuse versatility of the salvaged lumber.[15]
- **Contain specialty materials—**Certain materials such as hardwood flooring, multi-paned windows, architectural moldings, and unique doors or plumbing/electrical fixtures have a higher resale value than can help offset deconstruction costs.
- **High-quality brick laid construction with low-quality mortar—**Buildings constructed with these materials allow relatively easy break-up and cleaning.
- **Structurally sound—**Buildings that are weather-tight will have less rotted and decayed materials, maximizing the potential for deconstruction.

Often buildings with these structural and material characteristics were built prior to 1950, when basic construction techniques were simpler, used less complex connectors and systems, and had higher quality materials. Structures built after 1950, on the other hand, often contain a lower percentage of wood; more engineered lumber and composite materials; more complex connectors (i.e. pneumatic nails instead of hand-driven nails); and more complex systems within building walls, ceilings, and floors (i.e. plumbing, wiring, HVAC), making deconstruction activities more difficult and costly, and reducing the amount and value of materials available for reuse.[16]

For those buildings that do not meet one or more of these criteria, partial deconstruction is an excellent option. In these cases, a combination of deconstruction and demolition can be and is often used. For example, some projects are using heavy equipment to lightly knock over building sections, making it easier to recover materials. Also, demolition companies are increasingly incorporating deconstruction up-front to remove valuable parts of a structure prior to demolishing the building.[17] NAHB has stated that while an entirely wood-framed building may be cost-effectively deconstructed, buildings constructed with masonry will likely require a combination of deconstruction and heavy mechanical demolition. The integration of manual deconstruction with traditional mechanical demolition methods has been shown to be time- and cost-competitive when compared with traditional demolition alone.

Finally, in cases where deconstruction is entirely infeasible, recycling of demolition waste is always a more sustainable option than sending waste to landfills or incinerators.

Key Considerations When Planning a Deconstruction Project

Deconstruction is an exciting and emerging lifecycle construction technique, with potential to improve the sustainability of the C&D industry. However, as a budding approach to building removal, its benefits are still new and in many cases unknown to construction professionals. In addition, time constraints and higher labor costs associated with deconstruction activities can be a barrier to their wider use. Successful deconstruction mitigates any increase in cost through effective project planning to minimize project time delays and maximize the resale of quality salvaged materials.

As the U.S. Department of Defense (DoD) has learned through deconstructing decommissioned military bases, the way to make deconstruction work economically is to complete it in a reasonable time frame and incorporate creative ways of offsetting additional costs such as labor. Properly implemented, deconstruction can be cost-competitive with a typical demolition operation, particularly when a building contains sufficient amounts of reusable materials that can generate revenue and minimal hazardous materials that increase deconstruction costs.[18] At Fort Gordan, Georgia, for example, DoD used a Recycling Rights Auction to achieve the successful deconstruction of 25 installation buildings. Approximately eighty-percent (by weight) of each structure's building materials were recovered, including wood, metal piping, wiring, ductwork and vinyl siding. The estimated deconstruction costs associated with the Recycling Rights Auction were $3.00 per square foot, compared to the estimated demolition cost of $4.75 per square foot.[19]

Similar savings were achieved in the Riverdale Village Housing Development deconstruction in Maryland. A cost comparison conducted of the complete disassembly and salvage of the project's four residential units showed that the total cost for the deconstruction ($4.50-$5.40 per ft^2) was competitive with a standard demolition approach (estimated at $3.50-$5.00 per ft^2). [20] Combining hand deconstruction and mechanized building removal techniques is also a way to keep costs competitive. In fact, experience demonstrates that a combination of hand and mechanical techniques can have roughly equivalent economic efficiency as 100 percent hand deconstruction. In one case that

DECONSTRUCTION ON MILITARY BASES —FORT KNOX

For a number of years, the Department of Defense (DoD) has been a leader in pursuing deconstruction at military bases that are realigning their operations or being closed. The 1998 *Non-Hazardous Solid Waste Diversion Rate Measure of Merit* describes the goal of reducing the amount of non-hazardous solid waste sent to landfills by 40 percent. Deconstruction helps the Department reach this goal by reducing the amount of building related material entering on-site military C&D landfills. Fort Knox in Kentucky is one active base that has found success with deconstruction. Over a three-year period, they deconstructed 258 buildings, diverting 150,000 tons of material from landfills. This saved $1.5 million in landfill disposal costs and $1.2 million in demolition costs. Other examples throughout the country include Fort McClellan in Alabama, Fort Ord in California, Fort Gordon in Georgia, and Fort Campbell along the Tennessee/Kentucky border.

Source: U.S. Department of Defense. (2003). Deconstruction Guide for Military Installations, accessed at: https://frptoolbox.erdc.usace.army.mil/frptoolbox/library/docs/16.pdf.

used this hybrid approach, total labor hours were reduced by 44.6 percent with only a seven percent reduction in salvaged materials by weight.[21]

Below are typical issues, many linked to a project's cost, to consider when managing a deconstruction project.

Proper Management of Salvaged Materials

- **Assessment of Salvaged Materials—**A deconstruction project can involve an array of salvageable materials. When sold in the reuse market, some of the higher-end materials bring in a premium price, at times more than their original value because they have become rare over time or hold historic value. However, more common materials may not have significant resale value, and could earn much less than their original value. For this reason, it is vital to include a professional on the project team who can conduct a survey to gauge the amount, type, quality, and resale value of salvageable materials from the candidate building. This survey should also assess how best to handle materials that cannot be reused but can be recycled, and those that should be discarded. Knowing this information before a project begins will help determine whether deconstruction is a feasible option, and if so, gives the team more knowledge with which to plan proper disassembly methods.

  The National Defense Center for Environmental Excellence (NDCEE) is currently developing a construction and demolition model (Decon 2.0) for the DoD to aid in deconstruction planning. Decon 2.0 will be PC-based decision-making tool that allows users to input building characteristics to assess the feasibility of proceeding with a deconstruction project—including type and quantity of materials, and potential costs to demolish versus deconstruct. The model is targeted for release in late 2007.[22]

- **Local Materials Reuse Market—**Currently, the salvaged materials market in the United States consists of independently run retail stores that collect materials and resell them to the construction industry and to private individuals. This market is growing in response to the increase in the supply of used materials brought on by new disposal regulations and structural and non-structural deconstruction. Project managers should analyze the materials reuse markets in their areas early, and identify which resale outlets are available for recovered materials. See Section 3 for more detail on the materials reuse market and its role in lifecycle construction.

- **Transportation and Storage Costs—**If salvaged materials are not resold or redistributed directly from the site, or if they are not immediately reused in new construction at the site, there can be added cost for transportation of materials or storage of materials until an adequate avenue for their use is found.

Public Funding and Partnerships

Public funding and/or partnerships are commonly utilized to defray deconstruction project costs. Federal, state and local government agencies across the country offer grants to help fund pilot projects, and often explore new techniques to streamline the deconstruction process and reduce costs for future projects. For instance, many of the case studies in this document received funding from EPA. This includes Case Study 1 at the end of this section, which explores the "panelization" approach, a technique that can help reduce the amount of time it takes to complete a deconstruction project.

Successful partnerships between local government, not-profit organizations, local businesses, historic commissions, or developers have also been created to support deconstruction. For example, StopWaste.Org, a California public agency, entered into a partnership with the Port of Oakland and the non-profit Youth Employment Partnership. With StopWaste.org's funding, this project was able to deconstruct and remove a three-acre Port of Oakland warehouse while providing jobs and job training and salvaging 800 tons of demolition waste. Setting up partnerships with local recyclers and used building materials organizations (for–profit as well as non-profit) before a project begins is also a smart strategy to help quickly and effectively move materials post-recovery.

Labor and Timing

Structural deconstruction takes a few days longer than demolition because of the time needed to recover materials from the building in a way that minimizes damage and preserves the material's value. This often equates to more labor hours and higher costs. An average 1,500 ft^2 wood-framed house can take an average of eight to ten days to deconstruct with a crew of four to six workers; it may take a crew of two or three people only two days to demolish the same building and haul away debris using heavy machinery. In some cases, the added time alone can present a problem for property owners planning to redevelop the land immediately after current buildings are removed—for them "time is money." Even when the increased time for deconstruction is not a concern, the additional labor costs must be considered.

Profits from reselling salvaged building materials can offset additional deconstruction labor costs, and are an impetus for proper assessment and management of the salvaged materials. However other options exist to help decrease costs. As mentioned, some deconstruction project managers utilize volunteers identified through organizations such as Habitat for Humanity. Also, unskilled workers can be brought on-site as trainees who help with the project in exchange for job training in construction skills.

It should also be noted that bringing in the right construction professionals with appropriate experience is a necessity. This includes not only someone on the project who is knowledgeable about salvaged materials, as mentioned above, but also workers with past deconstruction and demolition experience.

Safety and Environmental Impacts

Hazardous materials, particularly lead-based paint and asbestos containing materials, are frequently present in older buildings and are a key consideration in many deconstruction projects.[23] The need to handle these materials safely throughout the deconstruction process could affect the time and cost it takes to complete a project.

- **Lead-based paint (LBP)—**The U.S. Census Bureau estimates that in 1999 there were 24 million housing units at risk of lead paint hazards.[24] In older properties LBP is found in interior walls and trim, windows and doors, and exterior surfaces. Its presence can affect the cost effectiveness of structural and non-structural deconstruction projects, because it limits the amount of lumber that can be reused or resold, increases worker safety expenses, and often results in higher costs for LBP removal procedures.

The feasibility of deconstructing a building containing LBP materials is very project specific. In many situations LBP may not be present in the main mass of wood on a project, but rather only on a few areas such as window trims. Considerable unpainted wood materials may still be present, including stud joists, flooring, and rafters, so the small amount of LBP coated materials would not meaningfully affect project costs. In such cases, the best option is to dispose of the LBP wood. Where a large amount of LBP coated materials is present, removing the lead based paint is not often feasible. At a deconstruction project in Gainesville, Florida, for example, the cost of salvaging and stripping the LBP-covered wood was greater than the estimated salvage value (see Case Study 2 at the end of Section 3).

Removing LBP may be cost-effective when dealing with a high value wood such as oak, southern yellow or other pines, American chestnut, and Douglas fir. Beyond the species of wood, a wood's value is also determined by the original grade, the extent of damage from such things as nail holes and decay, and the size of the lumber. For instance, industry professionals prefer salvaged lumber that is at least 6-feet long with at least 2- by 4-inch dimensions.[25] A significant amount of wood from a large-scale project such as the removal of multiple buildings from a decommissioned army base, may make it possible to defray costs of LBP treatment of wood.

The practicality of removing and salvaging LBP-coated wood is case specific. With strong regulations limiting the use of LBP coated materials, direct reuse of any materials coated with LBP is not recommended. The Consumer Product Safety Commission has regulations limiting its use, and HUD recommends eliminating its use in all consumer products. It must be stressed that if a project manager does decide to cut, grind, sand or otherwise manipulate the LBP wood, proper safety techniques, including containment of the dust, must be utilized to ensure worker safety. The highest standards in handling the materials should be followed.

- **Asbestos containing materials (ACM)—** According to OSHA, inhaling or ingesting asbestos fibers can cause certain cancers and serious lung damage that often does not appear until years after exposure.[26] Since the early 1980s, when these hazards became evident, building projects, including those involving deconstruction and demolition, have been subject to very strict regulations concerning asbestos removal.

  Two types of ACM occur in buildings: friable and non-friable. *Friable* ACM is defined as having the capability, when dry, to be crumbled, pulverized, or reduced to a powder by hand pressure.[27] If a building contains friable materials, regulations require that it be removed prior to building removal. According to EPA rules, *non-friable* ACM, such as asphalt roofing shingles and floor tiles, "need only be removed prior to building removal if the material's condition is such that the material has become,...or is likely to become friable during the building removal process." If it is necessary to remove the asbestos, a licensed asbestos abatement professional must be hired. Otherwise non-friable materials can be disposed of in landfills suitable for building-related C&D material, according to local rules.

When considering whether to deconstruct a building, the amount and type of asbestos present is a serious consideration. If the asbestos is friable, then it would need to be removed regardless of whether the project involves demolition or deconstruction. No special removal action is needed for non-friable asbestos in the case of demolition; however, all such materials must also be removed in deconstruction projects because of the hands-on nature of the work. Often this is not a deal breaker in determining the viability of a building project if the amount of asbestos is low; however, large amounts of non-friable asbestos may increase the cost, decreasing the cost-competitiveness of the project.

Summary

It is apparent that simply demolishing unwanted older buildings and disposing of the debris is not a sustainable practice. A new and enduring lifecycle building approach is necessary, one that does not end at the landfill, but that is cyclical and judicious. Existing structures should be deconstructed to reuse materials to the greatest extent feasible, whether it is through partial or whole deconstruction.

Many construction and demolition professionals are eager to make deconstruction an everyday practice, as seen by the number of pilot and other projects occurring nationwide. Realistically, an array of issues must be taken into consideration if a deconstruction project is to be successful, cost being highest on the list. Industry perceptions are also a challenge. Often construction and demolition professionals are used to constructing and/or removing buildings without thinking beyond the building's lifetime, the value of minimizing disposal costs, or the value of materials in the existing structures. Deconstruction is not yet a common practice, so many remain unacquainted with the process and have not yet considered incorporating it into their projects. Supporters are also still in the learning stages, and continue to develop innovative methods and techniques to improve the process. Government policies and building codes are beginning to address the sustainable disposal of older building materials, and the incorporation of used materials into new buildings. This continued communication, education, project development, and technique exploration will expand deconstruction's acceptance throughout the industry.

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CASE STUDY 1:
Susquehanna Avenue Row-House Deconstruction Project

Project Type	Deconstruction - Panelization
Location	3224 Susquehanna Avenue Philadelphia, Pennsylvania
Building Type	Single Residence Row House
Size	1,935 ft^2
Owner	City of Philadelphia
Completion Date	April 2006

Project Goal

Conducted as part of the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response (OSWER) Innovations Pilot Program, the Susquehanna Avenue project in Philadelphia was designed to find cost-effective ways of dismantling structurally unsound row houses and reusing the building materials. Thousands of abandoned buildings in Philadelphia are slated for demolition in one concentrated geographic area. Could these buildings be deconstructed instead, despite high labor rates in this dense urban city? Would the quantity and value of the reclaimed lumber in the roof and floors offset the salvage costs? By choosing a fairly typical abandoned row house to deconstruct, this project set out to address these questions.

One specific technique explored in this project was panelization, an innovative method that can potentially maximize the recovery of wood materials, stone, and face brick for reuse while minimizing labor costs and on-site time. This project was also intended to promote creative techniques for waste reduction and pollution prevention and serve as a model for other organizations considering building deconstruction. The OSWER Innovations Pilot Initiative funded the project with a $73,300 grant to the Institute for Local Self-Reliance. Other project partners included the University of Pennsylvania's Hamer Center for Community Design Assistance, the City of Philadelphia's Neighborhood Transformation Initiative, and Kevin Brooks Salvage (KBS), the deconstruction contractor for this project.

Building Description

The Susquehanna Avenue home was chosen as part of the city of Philadelphia's Neighborhood Transformation Initiative (NTI). One of NTI's basic goals is to eliminate some of the numerous vacant and structurally unsound buildings that are blighting influences on the City's neighborhoods, which includes demolition of 10,000 such housing units throughout Philadelphia.

The project house was a three-story 1,935-ft^2 row house located in Philadelphia's Strawberry Mansion neighborhood. Once home to Philadelphia's wealthiest families, this neighborhood has experienced economic decline and urban decay since the mid-twentieth century. However, the housing stock of the area represents a range of exuberant Victorian housing styles with bay windows, corner turrets, generous porches, rich architectural details, and other materials with probable salvage value. In addition to its salvage potential, this project was favorable for deconstruction because it is a row house that shares common walls with adjacent homes. Although it is possible to remove one house without compromising the structural integrity of adjoining homes, row houses must be removed using a combination of smaller mechanized equipment and hand demolition—the same types of labor used in deconstruction.

Project Highlights

Cost-Competitiveness

Most notably, the Susquehanna Avenue Project demonstrated that deconstruction can be cost-competitive with hand demolition when there are sufficient recoverable materials with market value to offset higher labor costs. Deconstructing this building took 10 days, from March 27 to April 7, 2006. In contrast, demolition of the building would have taken roughly three days. The resulting labor cost difference was more than made up through reselling the project's salvaged materials. Table 2-2 compares the project's cost data with average costs for both hand and mechanized demolition. Overall, the net cost per square foot to deconstruct the Susquehanna Project was $8.94. This falls within the cost range of an average hand demolition project ($7.75 - $9.30), and is higher than the cost range of an average project using mechanized demolition ($7.50-$7.75).

The Philadelphia housing stock has architectural elements that have an added artistic value and higher worth when sold as architectural items, rather than recycled as scrap iron or metal. Material like this can help re-

Table 2-2. Comparison of Susquehanna Pilot Deconstruction vs. Average Demolition Costs

	Deconstruction	Hand Demolition	Mechanized Demolition
Gross costs/unit [1,2]	$23,823	$15,000–$18,000	$14,500–$15,000
Salvaged materials revenues/unit [3]	$6,530	$0	$0
Net costs/unit	17,293	$15,000–$18,000	$14,500–$15,000
Square footage/unit[4]	1,935	1,935	1,935
Net costs/sq ft	$8.94	$7.75–$9.30	$7.50–$7.75

Source: The Hamer Center for Community Design and the Institute for Local Self-Reliance, 2006.

[1] *Deconstruction costs are based on amount paid to Kevin Brooks Salvage, the deconstruction contractor for this project, for deconstruction of one three-story unit (3224 Susquehanna Ave) and exclude the costs to parge/stucco party wall. Demolition costs are based on estimates provided by the city of Philadelphia for a three-story unit, excluding parge and stucco of any party walls.*

[2] *NTI pays prevailing wage rates for labor.*

[3] *Includes total amount of materials sold or used by KBS. Does not include materials not yet sold. If included, net cost/sq ft would be $8.42.*

[4] *Square footage is based on measurements of the 3224 Susquehanna Ave three-story unit.*

duce the net cost of deconstruction methods, as they can garner a price three or four times the removal cost. Overall, this project diverted bricks, lumber, metal, and architectural features from disposal, with a total recovered materials value of $7,530. As of December 2006, $6,530 of the materials have been sold or directly used by Kevin Brooks Salvage. The remaining $1,000 worth of materials will be sold at Found Matter, a Philadelphia architectural salvage store. The final data from the deconstruction of 3224 Susquehanna may show a lower net cost if these additional recovered materials are sold.

Panelization Method

This project introduced the "panelization" technique as a viable approach for deconstruction contractors. Panelization involves dismantling and removal of complete sections of a building, which are then transferred to an off-site location for further separation. For instance, workers on this project were able to cut out entire sections of the floor and roof, mechanically lift them to an adjacent open lot, and salvage much of the materials.

This new mechanized and panelized approach to deconstruction allows for highly efficient reuse of roof and floor structural lumber, enables quicker access to properties by redevelopers, and helps reduce exposure to safety hazards. Although still being refined, this method has the potential to be more economical than disassembling materials on site, reducing the overall project cost.

Lessons Learned

The Susquehanna Avenue Project was a success for its cost-competitive outcome, but also because of the practical lessons the project team learned—both positive and negative—that can be applied to future deconstruction projects.

Improving Practices to Avoid Higher Costs

Project partners believe that costs could be even lower on future projects if the following improvements are made:

- On-time dumpster placement, removal, and replacement procedures—Delays in placing and removing full dumpsters at the Susquehanna Avenue project site resulted in additional labor costs because workers had to handle some waste materials more than once.
- Improving the economy of scale by removing more than one house at a time—The original goal was the deconstruction of two adjoining housing units that would have resulted in a lower cost per unit than from removal of a single unit.

Learning Curve for New Panelization Approach

One of the successes of this project was introducing panelization as a viable technique for deconstruction contractors. While the contractor states that the panelization process was more costly than using his regular disassembly approach, he attributes some of the added expense to his inexperience in using this new technique. He is open to using panelization in future work, especially for commercial and industrial buildings where there are no adjacent properties that can be damaged, and believes the technique is cleaner and can require less on-site time than traditional approaches.

Team Collaboration

Innovative initiatives such as the Susquehanna Avenue project can be challenging because they require all parties involved to think and act differently from their normal practices. When removing the materials, deconstruction teams must address aspects of the project on-site as they arise, to allow for work to be carried out as easily, and with as little damage to the material, as possible. Crew collaboration is necessary throughout the project, so that the value of the materials is understood and the necessary approaches to remove them, based on this value, are properly communicated. This project was successful in part because of the project team's willingness to work together and use creativity in addressing obstacles, such as the efforts they undertook in determining the best removal method for the artistic turrets.

Need for an Expanded Materials Reuse Retailer

According to Linda Knapp, the project coordinator from the Institute for Local Self-Reliance, Philadelphia lacks a large retail yard to buy and sell used building materials. The city's existing smaller outfits satisfy some of the need, but a larger one would boost the deconstruction/materials reuse market, increase the demand for used building materials in the region, and expand the market to smaller projects and contractor firms.

Project Promotion to Increase Education and Awareness

In addition to showing the cost competitiveness of deconstruction, this project also garnered press, industry, and public attention. *The Philadelphia Inquirer* real estate writer Alan Heavens recognized the innovative nature of the Susquehanna Avenue Project in his feature article entitled "Old Homes Become Donors for New Ones" in the Sunday edition on April 16, 2006. Later, Mr. Heavens gave a photographic presentation of the project at the National Association of Real Estate Editors' 2006 Spring Journalism Conference in Charlotte, North Carolina. The Institute for Local Self Reliance, a major project partner, also presented the project findings to the Delaware Valley Green Building Council Board of Directors, the City of Philadelphia's NTI, the Sustainable Business Network Steering Committee, members of the American Institute of Architects/Philadelphia Chapter Committee on the Environment, and members of the Mid-Atlantic Consortium of Recycling and Economic Development Officials.

In addition, the Susquehanna Avenue project inspired owners of other neighborhood buildings to step forward and reclaim three of the buildings that were designated for demolition. Together, such outcomes have had a direct influence on increasing local demand for deconstruction services.

Project Contacts

Mike Giuranna, Solid Waste Specialist
U.S. EPA, Region 3
Philadelphia, PA
Tel: 215.814.3298
giuranna.mike@epa.gov

Linda Knapp
Institute for Local Self-Reliance
Philadelphia, PA
Tel: 215.843.7364
E-mail: lknapp@netreach.net

Brad Guy
(Formerly of Pennsylvania State University)
410 Margaret Morrison Hall
School of Architecture
Carnegie Mellon University
Pittsburgh, PA 15213
Tel: 814.571.8659
E-mail: guy_brad@yahoo.com

Kevin Brooks Salvage (KBS)
Kevin Brooks
Tel: 215.848.5029
E-mail: ktbsalvage@verizon.net

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SECTION 3

Materials Reuse

Introduction to Materials Reuse

Building materials may retain structural or aesthetic value beyond their lifespan in a given building. This value is captured through *materials reuse*, a practice that can occur independently from or in conjunction with deconstruction and other lifecycle construction activities. As a component of lifecycle construction, it is an essential step in completing the loop. The concept of "Reduce, Reuse, Recycle" identifies reuse as midway between initial reduction of resource use and resource recycling in a hierarchy of limiting environmental impact. Reducing initial resource use avoids the impact entirely, as well as any need for reuse or recycling. However, reusing materials is preferable to recycling them because less remanufacturing and processing is required, and less associated waste is generated. In its broadest definition, materials reuse is the practice of incorporating previously used materials into new projects. In the context of lifecycle construction, salvaging finish features, stripping interior components, and deconstruction all make building materials available for reuse.

Similar to deconstruction, the major benefit of materials reuse is the resource and energy use that is avoided by reducing the production of new materials. Materials reuse also salvages materials with characteristics that are generally unavailable in new materials. For example, lumber with desirable structural and aesthetic qualities such as large dimensions (especially timbers) and knot-free fine grain can be found in walls of old buildings. Such items have a high reuse value as a combined structural and finished surface piece. Note that it is less important what species of tree the wood came from than the way it has been used and the state it is in after such use.

Certain challenges accompany the numerous benefits of this critical step in the lifecycle construction process. These include the need to verify material quality (e.g., lumber grade) and the variability of available material quantities, which fluctuate with the level of deconstruction activity.

This section describes the opportunities for materials reuse, the market for reusable materials, and challenges associated with materials reuse. Three case studies at the end of the section highlight projects that incorporate materials reuse. The first case study describes a joint venture deconstruction/materials reuse project that features immediate reuse of salvaged materials. The second case study describes a residential construction project that incorporates significant amounts of reusable materials. The third case study highlights a used building materials retail store within the growing market for reusable materials.

Implementation of Materials Reuse

Materials reuse can occur on both large and small scales. Depending on the availability of materials and the desired future use, materials reuse can involve: a) whole buildings, b) building assemblies, c) building components, d) remanufacturing of building components, and/or e) reuse of individual building materials without modifications to them. These are defined below.

a) Whole Building—Involves relatively minor changes to a building's structure that often adapt it to a new use (e.g., transforming a factory into lofts).

b) Building Assemblies—Defined as "a collection of parts fitted together into a complete structure" (e.g., pre-fabricated walls).[28]

c) Building Components—May be subassemblies or other structures that are not complete on their own (e.g. doors with jambs).

d) Remanufacturing—Adds value to a material by modifying it (e.g., re-milling framing lumber for use as trim. Note that this differs somewhat from recycling because the wood is not entirely reprocessed, and retains its basic form).

e) Building Materials—Reuse of any individual type of material such as lumber or stone (e.g., brick from an old structure used in a new landscape design without modifying it).

Individual building materials and finish pieces are the most commonly reused. Primary among these is lumber, but steel beams, stone, brick, tile, glass, gypsum, and plasterboard, as well as doors, windows, and cabinets are also routinely successfully reused. At a larger scale, building components are ideal for reuse, while the ultimate reuse includes entire building assemblies, such as panelized walls or floors that can be wholly incorporated into new projects.

To help promote more materials reuse and recycling, the City of Seattle produced an "index of materials reuse" that identifies suitable materials for reuse, recyclable materials, and those that should be disposed of, as well as information on potential environmental and health concerns associated with some materials.[29] The following table provides examples adapted from the index.

TABLE 3-1. MATERIALS REUSE INDEX

Material	What to Reuse	What to Recycle	What to Dispose	Environmental and Health Concerns
Wood	timbers, large dimension lumber, plywood, flooring, molding, lumber longer than six feet	unpainted and untreated wood unfit for reuse	painted, pressure-treated and rotting wood	lead paint, structural integrity (grade)
Roofing Materials	retain sheathing in good condition, terra cotta and slate tiles	metal materials, asphalt and untreated cedar shingles	treated cedar shingles	possible asbestos content
Landscape Materials	timbers, stone, concrete	untreated, unpainted wood unfit for reuse	painted, pressure-treated and rotting wood	treated wood may contain arsenic

Some materials in buildings that are scheduled for demolition are not reusable due to degraded structural or aesthetic value or contamination, but estimates suggest that a substantial amount of salvageable materials are available in the U.S. The USDA Forest Service Forest Products Lab (FPL) reports that the equivalent of 250,000 single-family homes in the United States are demolished each year. This represents almost 1.8 million cubic meters of salvageable structural lumber available per year, equivalent to three percent of the annual U.S. softwood harvest.[30]

While steel recycling rates are higher than those of any other material in the U.S., indicating that steel is regularly employed for many uses prior to final disposal, there is relatively little reuse of steel from end-of-life buildings. However, as outlined in the introduction to this section, reuse typically involves less resource and energy use than recycling. See the accompanying textbox for an example of successful steel reuse.

STEEL REUSE—UNIVERSITY OF TORONTO STUDENT CENTER

Construction of the University of Toronto's Scarborough Student Center, completed in 2004, used steel made available by the demolition of a gallery at the Royal Ontario Museum. Sixteen of a total 300 tons of steel used in the Student Center came from the museum. This steel was re-fabricated to meet design goals for the new student center and used in the same way as new steel. The deconstruction bid included cutting the steel beams to size. They were torch-cut, not sheared, to retain the greatest possible lengths of useable material. In this case, the beams were re-fabricated with bolt connections, offering a single method for construction, and one that would allow future building disassembly and material reuse. The costs of deconstruction, transportation and refabrication were comparable to costs of purchasing the same amount of new steel.

Source: Edmonds, J., V. Straka, and M. Gorgolewski. University of Toronto Scarborough Campus Student Centre, Toronto, Ontario. Reuse-Steel Organization. Accessed at: http://www.reuse-steel.org/projects.aspx.

According to the Steel Recycling Institute, 65 percent of reinforcement bars and other steel construction elements were recycled in 2005, while 97.5 percent of structural beams and plates used in construction were recycled.[31] A 2004 publication estimated that the total lifecycle cost of a ton of steel in the UK was a third less and required only 20 percent of the energy needed for production, fabrication, erection, collection (reclamation), and landfilling when it was reused, than when it was produced new and landfilled at the end of its use. The primary savings came from avoided landfill use and production avoided through reuse. While recycling provides some of the same benefits by avoiding use of a landfill, it still requires refabrication, and therefore does not achieve the same degree of savings or environmental benefits as reuse.[33] Steel is more easily reuseable when bolts, as opposed to welded joints, are used to connect it with other parts of a building.[34]

The types and quantities of materials available for reuse vary by region. For example, Chicago, Illinois has a large stock of old brick from its days as a major brick-producing center in the 19th and early 20th centuries. Companies such as Colonial Brick Company, and Chicago Antique Brick, Inc. are able to supply used brick, and to specialize in particular types and colors of salvaged brick. As cities undertake redevelopment initiatives, or major public works, unique supplies of building materials may become available. See The Big Dig House sidebar exhibit on this page for a unique example of a public works project as the basis for a residential construction project incorporating materials reuse.

The current market opportunities for reusable materials are primarily at the individual building materials scale, and often revolve around local availability of lumber, steel, brick, and some building components such as doors and windows.

ROAD MATERIAL REUSE—THE BIG DIG HOUSE

In a unique example, Single Speed Design LLP (SsD), a Cambridge, Massachusetts-based design firm, saw Boston's Big Dig, a massive public works project to reconfigure Boston's roadways, as a ready source of building materials. SsD built a house in Lexington, MA that included a total of 600,000 pounds of salvaged structural steel and other materials from the Big Dig. SsD has plans to build a larger scale urban building in Cambridge, MA with additional salvaged materials from the Big Dig, and to export the idea for reusing road materials in buildings to other cities.

Sources: Single Speed Design, Works: http://www.singlespeeddesign.com/works/

Metropolis Magazine article on the proposed Big Dig building: http://www.metropolismag.com/html/content_0604/gen/index.html

Market for Salvaged Materials

Marketing deconstructed material is a critical step in lifecycle construction, as it provides revenue to offset the higher labor costs of deconstruction. The current market for salvaged or reusable materials primarily comprises individual re-sale stores that collect locally available materials (through donations, salvage, or deconstruction) and sell them at retail locations. The size of these stores varies, as do their services, and the degree to which they modify or prepare materials for sale. The Building Materials Reuse Association maintains an online directory of used building materials organizations, contractors, deconstruction and reuse related organizations totaling 1,235 listings in all fifty states and Washington, D.C.[35] See the Resources List at the end of this Section for more details. The following examples illustrate the current variety of these organizations.

The Boston Building Materials Resource Center (BMRC) is one example of a used building material organization. BMRC accepts donations and has a two-fold mission of providing low-income homeowners with affordable building supplies, and reducing the burden of construction waste on landfills. Home improvement classes, in-home consultations, and a do-it-yourself window repair shop are also provided.[36] Other retailers such as Stardust Building Supplies in Phoenix and Mesa, Arizona, and the RE Stores in Bellingham and Seattle, Washington (see Case Study 4 in this section), The ReUse People (TRP) in Alameda, California, and Build It Green! NYC accept donations and also actively stock their stores by providing deconstruction services and then selling the salvaged materials. The RE Stores obtain approximately 20 percent of their materials from deconstruction, while TRP deconstructs up to 90 percent of the materials it re-sells.[37]

In contrast to the stores mentioned above, Habitat for Humanity operates over 380 used material "RE Stores" throughout the United States, some of which sell used and surplus building materials that are donated from individuals, building supply stores, contractors, and demolition crews. The stores are run by local Habitat for Humanity affiliates; some operate their own deconstruction programs, while others rely on donations for obtaining materials. In the Austin, Texas affiliate store, most lumber sold comes from deconstruction.[38] Supplied by its approximately 30 to 40 deconstruction projects per year, 18 to 20 percent of the Dane County, Wisconsin RE Store's sales come from deconstructed materials.[39] The funds generated by sale of the materials support Habitat for Humanity's housing construction projects. [40]

Retailers are taking different approaches to improving their business in the growing market for used building materials. Some are expanding their operations geographically, while others are diversifying the services they offer. For example, TRP currently has offices and facilities in San Diego, Orange County/Los Angeles, and the San Francisco Bay Area, in addition to Seattle, WA and Boulder, CO, and is looking to expand further.[41] Building on the Dane County Habitat for Humanity RE Store's success, a handful of new Habitat for Humanity RE Stores have opened in Wisconsin in the last two years.[42] Pittsburgh's Construction Junction organization, among others, offers diverse events and programs to the community, including workshops on restoration of reusable material such as windows and doors.[43]

The issue of supply of materials is noted as a challenge to materials reuse by many reused materials retailers. In response to a need for more consistent and accessible supply, networks of suppliers and resources are beginning to emerge. Online directories, such as those published by the Building Material Reuse Association, also provide interested parties with listings and weblinks to salvage and reuse retailers throughout the country. In addition, the Reuse Development Organization, or ReDO, is an online reuse promotion organization that lists 139 'reuse centers' that carry reused building materials, and numerous waste exchange websites connect sellers and buyers of used materials. While these efforts provide an indication that there is momentum within the industry to make materials for reuse more widely available, it is uncertain at this time whether these typically local organizations will scale to a network large enough to meet supply and demand if deconstruction becomes a more dominant component of construction and demolition operations.

Materials Reuse Challenges

Materials reuse challenges include a range of issues from the perception of used materials as inferior for building, to the sometimes limited or inconsistent supplies. The next sections explore these challenges, while the case studies in this section give examples of how they can be addressed.

Supply and Scalability

While demand for used materials is apparently growing (see Case Study 4 in this section), supply of materials is noted by many as a barrier to the growth of the reuse market. Dependent on trends in residential and commercial renovations and replacements, materials for reuse may be in limited, unique, or inconsistent supply. While this can be a constraint on a contractor or carpenter who is looking for materials, it can also present an opportunity to implement innovative approaches incorporating both available used materials and new materials to achieve project goals. The following paragraph outlines some examples from the field.

Inspiration for the Green Compact home in Seattle, Washington came from finding materials at numerous sites across the city. (See Case Study 3 in this Section). The RE Store in Bellingham, Washington experiences high demand for used wood, and cannot always supply enough wood to meet the demand (See Case Study 4 in this Section). At the Dane County Habitat for Humanity RE Store in Wisconsin, cabinets, windows, doors, flooring, and tiles sell best, but inventory gluts of sinks and bifold or hollowcore doors are less easily sold.[44]

Larger used material yards could help provide more steady supplies of materials in some areas. For example, there is a need in Philadelphia for a large retail yard to buy and sell used building materials.[45] As is typical of many locations, the city's existing smaller outfits satisfy some of the need, but a larger one would help boost the deconstruction/materials reuse market, increase the demand for used building materials in the region, and expand the market to smaller projects and contractor firms.

Perceptions of Reused Materials

Used building materials may often be perceived as having lower quality than their new equivalents. This can be due simply to aesthetic differences such as nail marks remaining on wood, or to a concern that there is a greater risk in reusing building materials. For steel sections (beams, etc.), without the incentive of cost savings, most customers are likely to choose new components, perceived as more convenient and as having lower risk of potential structural flaws.[46] Further, lead-based paint and asbestos containing material can be present in older building materials (see Section 2). Although such materials are not and should not be reused or sold by salvage or materials reuse retailers, customers may still perceive them as a concern or risk when choosing to build with reused materials. Perceptions of reused materials may continue to improve as the number of projects that successfully incorporate them continues to grow. Assessing the quality of deconstructed materials can provide proof of its suitability for a building application and overcome these perceptions.

Because each deconstruction project may yield unique materials, it is difficult to generalize about the quality of used building materials. The USDA Forest Service's Forest Products Laboratory (FPL) has begun to investigate the quality of deconstructed wood. Wood is the most commonly reused building material, primarily because it is available in some form in most U.S. structures. The FPL tested a selection of deconstructed wood from two military bases to determine its suitability for reuse. By testing more than 900 pieces of wood, USDA concluded that due to damage caused by either the construction or deconstruction process (e.g., saw marks, nail holes, split edges), or age and decay of the wood (e.g., splitting, or termite damage), the quality of dimensional lumber from non-industrial military buildings is on average one grade lower than that of freshly sawn lumber.[47]

The grade reflects the overall quality of the wood and its strength. For example, Grades 1 through 3 are graded on how many knots appear in the board and how that affects the strength of the lumber. Because the value of lumber is tied directly to its quality, evaluating grades for reused lumber is an important step in making them available for reuse. Relatively few studies exist that evaluate the quality of used building materials. However, other tools exist for assessing the feasibility of conducting deconstruction (see Section 2), and for evaluating the environmental benefit of materials reuse.

Calculators are one such tool that can demonstrate the environmental value of reusing a given material compared to using its virgin equivalent. The NY Wa$teMatch organization

LUMBER QUALITY

A variety of measurements determine the quality of wood used in buildings. The grade stamp on lumber provides information on each. The key considerations are:

- **Species—**Different tree species have different natural strengths and properties (basic familiar groupings of species are the softwoods and hardwoods).
- **Moisture Content—**Lumber is categorized as having less or greater than 19 percent moisture. Green wood, or wood with more moisture content, will shrink and may change shape as it dries. Most deconstructed wood is likely to be dry, unless it has been exposed to the elements or to flooding or leaking in a building.
- **Grade—**Grades are based on how many knots appear in a piece of wood that affect its strength. In deconstructed wood, nail or bolt holes may be equated with knots for purposes of grading. Older wood from dry locations may have boxheart splits or "heart checks" that may diminish the beam strength of timbers.

Sources: Falk, B. 1999; and Penn State Agricultural Information Services, Penn State Pointers "Selecting the Proper Wood" and accompanying press relesase "Lumber grade knowledge can turn consumers into stud finders", 1999. Available at: http://www.aginfo.psu.edu/psp/02psp/02128.html offers a calculator that measures the avoided environmental impacts of reusing a material based on ten negative environmental impacts, and the embodied energy in the materials (See Section 2 for more about embodied energy).[48] Assessing the quality of materials for reuse, and evaluating the environmental benefits of avoiding use of new materials, provide important planning information for projects incorporating materials reuse.

RESOURCES

Used Material Index

City of Seattle, Seattle Public Utilities, Sustainable Building Program. Green Home Remodel/ Salvage & Reuse. Used Material Index. page 11. http://www.lifecyclebuilding.org/resources/Green%20Home%20Remodel.pdf.

'Unbuilding' Book

Falk, B., and B. Guy. 2007. Unbuilding: Salvaging the Architectural Treasures of Unwanted Houses. Taunton Press. Newtown, CT. 256 pp.

Reuse Handbook

Addis, Bill. 2006. Building with Reclaimed Components and Materials: A Design Handbook for Reuse and Recycling. Earthscan, Sterling, VA.

U.S. Forest Service Forest Products Lab articles and resources

http://www.fpl.fs.fed.us/staff/robert-falk.html#deconstruction

Calculator

NY Wa$teMatch Building Materials Reuse Calculator.
Available at: http://www.wastematch.org/calculator/calculator.htm

DIRECTORIES

Building Materials Reuse Association

http://www.buildingreuse.org/directory/ - Provides United States Directory of Building Reuse Suppliers.

U.S. Forest Service Directory

Falk, Robert H.; Guy, G. Bradley. 2005. Directory of wood-framed building deconstruction and reused wood building materials companies, 2005. Gen. Tech. Rep. FPL-GTR-150. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 113 p.

Reuse Development Organization

(ReDO). http://www.redo.org/

RESOURCES (Continued)

ORGANIZATIONS

Building Materials Reuse Association

http://www.buildingreuse.org/directory/ - Major national reuse organization. Hosts annual conference on deconstruction. Provides United States Directory of Building Reuse Suppliers.

New York Wa$teMatch

http://www.wastematch.org/index.htm - provides an online Materials Exchange, Technical Assistance, and information on Research and Development.

Habitat for Humanity RE Stores

http://www.habitat.org/env/RE Stores.aspx - Website gives directory of RE Stores.

Stardust Building Supplies

http://www.stardustbuilding.org/index.html

Build It Green! NYC

http://www.bignyc.org/

Northwest Building Salvage Network

http://www.nbsnonline.com/index.htm

The ReUse People

http://www.thereusepeople.org/AboutUs/

Summary

Materials reuse can be achieved on many scales, from doors and windows to entire buildings, and/or their major components. The degree of success for materials reuse projects depends on the availability and quality of materials, as well as the desired use in the new project. Some materials may be reused in their current condition, while others may require remanufacturing and refabrication.

Materials reuse can be implemented independently of other lifecycle construction activities, but holds its greatest environmental and cost-saving potential as a necessary step in the lifecycle building process. Deconstruction provides the materials for reuse, and Design for Deconstruction (DfD) is premised on the future reuse of materials. It is therefore a critical link between existing available materials, new projects that can ultimately be designed for easier disassembly in the future (See Section 4), and continued reuse of the materials.

The current market for both deconstruction and re-sale of used building materials is growing. An expanding body of literature and calculation tools, as well as local and federal government programs, are providing more information on assessing the quality and value of reusable materials, and recognizing the environmental and cost-saving benefits associated with them. These efforts support the industry as whole, and suggest there is sufficient interest, supply, and demand for its continued growth.

Section 3 Bibliography

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Personal Communication, Frank Byrne, Deconstruction Manager. Dane County Habitat for Humanity ReStore. April 25, 2007.

Shell, S., O. Gutierrez, L. Fisher, et al. 2006. Design for Deconstruction: The Chartwell School Case Study, for U.S. Environmental Protection Agency, Region 9. Accessed at: http://www.lifecyclebuilding.org/resources/DFD.pdf.

The Steel Recycling Institute. Steel Recycling Rates Fact Sheet. Accessed at: http://www.recycle-steel.org/PDFs/2005Graphs.pdf on March 21, 2007.

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CASE STUDY 2: Wesley House & Reichert House—Deconstruction and Materials Reuse

Project Type	Deconstruction - Panelization
Location	Gainesville, Florida
Building Type	Single Residential
Size	1,933 ft^2
Owner	Gainesville Regional Utility
Completion Date	January 2003

Project Goals

As one of the U.S. EPA Office of Solid Waste and Emergency Response (OSWER) Innovations Pilot Initiatives, the Wesley House/Reichert House case study is a unique example of how a deconstruction project and a new construction project can be linked to provide an immediate materials reuse opportunity. In January 2003, the Wesley House in Gainesville, FL was deconstructed and the re-useable materials were incorporated into the construction of a new community-oriented facility, the Reichert House, a social service agency under the auspices of the Black-on-Black Crime Task Force, a program supporting at-risk youth. The main goals of this design for reuse project were to:

- Deconstruct the Wesley House, an abandoned home in Gainesville that was being removed in order to make room for a planned Gainesville Regional Utilities (GRU) office facility expansion; and
- Maximize the reuse of the building materials made available through Wesley House's deconstruction to build a new building —the Reichert House.

Stakeholders also hope that this pilot project will promote and demonstrate that deconstruction can effectively facilitate building materials reuse and that it can be replicated in other communities or housing developments.

Building Descriptions

This project began with the deconstruction of The Wesley House, a 1,933-ft^2 single-family residence built in 1930. The house had outlived its usefulness, and its abandoned state threatened to attract negative elements to the community. The municipally owned Gainesville Regional Utility (GRU), whose offices and main parking lot were located on either side of the Wesley property, bought the abandoned home so that it could remove it and make room for a planned office facility expansion.

At the same time GRU was considering demolishing the Wesley house, Gainesville's Black-on-Black Crime Task Force was fundraising to build a new facility, the Reichert House, for its programs in Gainesville's older East Side of town (the same area where the Wesley House and GRU are located). One of the goals for this project was to incorporate building materials characteristic of this neighborhood into its construction.

Members of University of Florida's Powell Center for Construction and Environment (PCCE) saw an opportunity to achieve the goals of both of these projects by linking them together. The combination of the unwanted Wesley House, the Crime Task Force's need for building materials related to Gainesville's East Side to help construct its new facility, and the expertise and community-based programs of the University of Florida's PCCE presented a unique opportunity. By bringing together this diverse coalition of partners, the project demonstrates the wide range of needs that can be met with a well thought out building reuse project.

Project Highlights: Immediate Reuse of Materials Acquired Through Deconstruction

This project is unique for its immediate reuse of materials acquired through deconstruction – and is a model for future projects. Descriptions of innovative steps in this process follow.

Immediate Materials Reuse

Coupling deconstruction with a building project that can immediately reuse salvaged materials is optimal, making the Wesley House/Reichert House joint venture distinctive in its approach. Typically there is a gap in time between gathering salvaged materials from a deconstruction project and incorporating those materials into another construction project. Closing this gap by establishing a predetermined destination for materials, and being able to coordinate salvaged materials availability and reuse when conducting the pre-deconstruction inventory, is a more cost- and time-effective strategy. This also made it possible for timely communication between the Wesley House deconstruction project managers and the Reichert House's architect and client about the type of materials available, their structural qualities, and the final form they could take in the project. In all, 44 percent of the total mass of the Wesley House was salvaged for reuse, with 20 percent of it built directly into the new Reichert House, including:

- **Beadboard—**The beadboard recovered from the Wesley House was reused in the Reichert House as a decorative wall finish. New beadboard of similar appearance and quality would be very difficult or prohibitively expensive to acquire.
- **Brick—**The brick from the piers supporting the Wesley House were designed into a decorative wall treatment for the Reichert House lobby.
- **Flooring—**Salvaged flooring from the Wesley House was used to create the new flooring in the Reichert House—a practice considered the best reuse option for such material. This minimized any additional waste generation (no re-milling or cutting off portions of the wood) and required the least input of additional energy.
- **Lumber—**The main floor "heartpine" beams from the Wesley House were reused in the Reichert House's library as a ceiling element, and in the lobby/reception area where it was resawn into a solid wood countertop for the reception desk. These beams are highly durable, insect resistant, and attractive.

Creating a Design for Reuse Agreement

In order to communicate the goal of efficiency of reuse in the Wesley House/Reichert House joint venture (i.e. maximizing the total amount of reuse, as well as the visibility of the reused materials), the PCCE developed a "Design for Reuse Agreement." The architect of record was provided with this document, which included an inventory of available materials, design guidelines, and potential uses for materials. For the purposes of tracking the materials recovery rates and types, a preliminary estimate of the total materials in the building was also included before deconstruction work began. A list of the house's potentially reusable materials was created, categorizing materials by building assembly or component, estimated quantity, and condition. This document also detailed whether the material could possibly be reused or recycled, whether the material was un-reusable or un-recyclable, or if disposal or hazardous disposal was necessary.

This type of contract can serve as a model for other entities seeking to incorporate design for reuse into their building projects.

Lessons Learned

The Wesley House/Reichert House project team gained practical knowledge that can be applied to future deconstruction and materials reuse projects.

Costs Comparison of Deconstruction Versus Demolition

A comparison of the costs for deconstructing the Wesley House versus demolition showed that deconstruction could be more cost-effective.

Table 3-2. Cost of Demolition Versus Deconstruction

	Demolition	Deconstruction (without LBP materials)
Demolition Permit	$50	$50
Environmental	$0	$1,500
Labor	$1,625	$3,800
Disposal	$1,500	$980
Salvage	$0	-$3,300
Net Cost	$3,175	$3,030
Cost per Ft^2	$2.54	$2.42

In this case deconstruction was five percent less expensive than demolition would have been, primarily due to the resale of salvaged materials. This result does not include the cost savings to the new construction project using salvaged materials in lieu of new materials. Also, although LBP removal was explored in this deconstruction project (see below), the associated costs are not included in Table 2-2.

Economics of Removing Lead Based Paint

Older wood framed and clad buildings (generally those built before 1978) are very likely to contain lead based paint (LPB). Project managers for the Wesley House removed the lead paint from certain woods found in the Wesley House to determine if it would be a worthwhile effort to salvage all LBP-covered wood. It was determined that in this case it would not, as the cost of salvaging and stripping the LBP wood ($2,500) was much greater than the estimated salvage value of their material ($1,000). However, this is not the case with all salvaged wood, the value of which can vary based on wood type, original quality (grade), and the extent of any damage (i.e. nail holes, decay, discoloration). Other studies have found that salvaging wood siding can be successful and add value to the project.[49]

Project Team/Contacts

Pam Swingle
US EPA, Office of Solid Waste and Emergency Response
Innovations Work Group Program
Atlanta, GA
Tel: 404.562.8482
E-mail: swingle.pam@epa.gov

Brad Guy
(Formerly of Pennsylvania State University)
410 Margaret Morrison Hall
School of Architecture
Carnegie Mellon University
Pittsburgh, PA 15213
Tel: 814.571.8659
E-mail: guy_brad@yahoo.com

Timothy Williams
Powell Center for Construction and Environment
PO Box 115703
Gainesville, FL 32611-5703
Tel: (352)-273-1172

Other partners for this project include:

Gainesville Regional Utilities

Gainesville Police Department

Black-on-Black Crime Task Force

Brame Architects, Inc.—Architect-of-record for the Reichert House facility

Case Study Sources

Personal Communication with Brad Guy, Associate Researcher for the Hamer Center for Community Design Assistance and project manager for the Wesley House deconstruction, in February 2003.

Guy, B., and T. Williams. 2003. Final Report: Design for Deconstruction and Reuse—Distillation of a Home, accessed at http://www.buildingreuse.org/member_files/31/File/DfR03-20.pdf.

CASE STUDY 3: The Green Compact—Materials Reuse

Project Type	Materials Reuse in New Construction
Location	Seattle, Washington
Building Type	Single Family Residence
Size	1,270 ft^2
Owner	Gainesville Regional Utility
Completion Date	January 2005

Project Goals

This case study highlights the incorporation of materials reuse in the Green Compact residential green building project. Motivated by the City of Seattle's Built Green design competition, GreenLeaf Construction, Inc. (GreenLeaf) sought to maximize green building practices by incorporating new techniques and materials and to establish relationships with new partners. Built Green is an environmental building program in Washington State, developed in partnership with King County, Snohomish County, and other government agencies, that rates buildings for their green attributes and encourages better resource use. Specific project goals include enhanced source-separation for recycling of construction materials, education of subcontractors not trained in green building or salvaged materials use techniques, reduction or elimination of construction site runoff, and improved knowledge of green building practices and materials reuse in the City of Seattle.

Building Description

The 1,270 ft^2 Green Compact house is set back from the road on a small 3,402-ft2 city lot. Material reuse figures prominently among other green building features. In a technique that combines both materials reuse and the green building design concept of reducing resource use more generally, structural materials are employed as finished surfaces and reused materials are present throughout the building. For example, the concrete slab foundation also serves as the first level floor, and plywood, typically covered with other flooring, has a clear finish and serves as finish flooring in the upstairs and loft. Salvaged building materials are reused for both structural and finish features of the house.

Project Highlights

Deconstructed and Salvaged Materials

GreenLeaf Construction made materials reuse a major focus of the Green Compact project. Incorporating each of the steps in the "Three R's" hierarchy - Reduce, Reuse, Recycle - GreenLeaf minimized the resources used and construction waste generated from the project from start to finish. Beginning by choosing to fit the small house into only a portion of the lot, the need for materials was reduced by limiting the overall size of the project. As mentioned above, using structural materials to double as finished surfaces also reduced the need for materials. GreenLeaf also made significant use of reused, relatively cheap, but sustainable materials obtained from locations throughout the city. In fact, searching for salvageable material became a hobby as much as a business practice for GreenLeaf. Finding local sources of materials reduced overall transportation of materials, which limited the associated effort and pollution from travel to and from sites, and generated innovative use of available materials.

GreenLeaf used innovative means to meet the Built Green requirement for sustainable wood use, a requirement typically achieved by purchasing Forest Stewardship Council (FSC) certified lumber. In this case, GreenLeaf relied on salvaged lumber from the deconstruction of another house. This method reduced the cost of the wood, but did require additional time and labor. GreenLeaf crews hand deconstructed the roof and floor of a house in the Magnolia neighborhood of Seattle, and incorporated those materials into the estimated total of 2,800 board feet of salvaged lumber used in the Green Compact house. Approximately 90 percent of the framing lumber used in the Green Compact was salvaged. GreenLeaf re-milled the extra framing lumber, allowing some nail marks to show, and used it for the interior trim package. While the reclaimed lumber provides both structural and finish features, other salvaged items gave the house added character. A vintage steel stairway balustrade became a major feature of the house; salvaged stone was used to build countertops; travertine tile scraps were re-cut to build the shower; high school bleachers were fashioned into stair treads; salvaged doors were used in the interior; and outdoor walkways were built from salvaged broken sidewalk pieces. In addition, an estimated 1,200 pounds of brick and concrete were salvaged for use on the site. A butcher block, sink, and ship's ladder to access the loft were also salvaged. The beams in the Green Compact were formerly part of an old mill. All these items combined to create an entirely new home, though the individual component parts each had a prior use.

Site Waste Reduction

Careful use of machinery on the site prevented damage to existing concrete steps, sidewalk, and driveway approach, and thus there was no need to replace them. The Green Compact project teams managed the site carefully to avoid damaging existing features like the sidewalk mentioned above, and also to separate all waste on the site by category for recycling. With the assistance of Resource Venture, an organization that tracked the waste generated on site, the Green Compact project produced only 966 pounds of waste. All other materials were used or recycled, attaining a recycling rate of 86 percent. These recycling and reuse efforts had the added benefit of diverting construction materials from the landfill. Though it is now more common for GreenLeaf and others to achieve this level of recycling, this was a first for GreenLeaf at the time.

Partnerships

A number of partnerships between GreenLeaf and other businesses and organizations made the Green Compact project a success. From the outset, GreenLeaf was looking to elevate this project to the next level of sustainability, and of collaboration. This included engaging an architect willing to work with the small property and with the building team to generate the best outcome. This was initially a challenge due to the small site, and the creativity required for implementing reused materials. Once selected for the project, David Vandervort architects participated in choosing building materials as well as leading the design effort.

GreenLeaf also developed relationships with a local lumber yard that was eager to find a buyer for some of its salvaged materials with slight imperfections, and with the local used material retailers to locate and purchase other salvaged used materials. By working with the RE Store, GreenLeaf could bring its truck directly to deconstruction sites where RE Store crews were working, and have the first choice in salvaged materials. This saves transportation time, cost, and fuel by taking materials directly from a deconstruction site to the construction site.

Local government partnerships benefited the project in both its reuse and its recycling efforts. GreenLeaf recycled leftover site materials that could not be used on-site through King County's Construction Works Program. This County program provides free assistance and gives recognition to builders that reduce waste. The City of Seattle also provides information through its Sustainable Building Program. In addition to being an information resource, the city's inspectors worked with GreenLeaf to grade the used dimensional lumber instead of strictly requiring the more expensive, and not necessarily locally-sourced, FSC-certified lumber.

Lessons Learned

During the course of the Green Compact project, lessons were learned that can be applied to future deconstruction and materials reuse projects. By maximizing materials reuse, GreenLeaf identified areas where improvements and efficiencies could be made. The following lessons highlight challenges GreenLeaf is working to overcome in its ongoing and future projects.

Don't Try to Do Everything in a Single Project

This project was successful at achieving a variety of goals, but not without significant effort. GreenLeaf continues to incorporate many aspects of the Green Compact in its new projects, but is now more careful to spend time on those efforts that will yield successful results, based on past experience. For example, while salvaged materials continue to be a major source of building materials in GreenLeaf projects, crews are able to be more selective in acquiring workable components. GreenLeaf built a second Green Compact type house, and used deconstructed materials for approximately 40 percent of the building. GreenLeaf now sometimes employs a hybrid approach, incorporating some deconstruction, some salvage, some new materials, and varying degrees of other more traditional techniques. This allows them to meet all construction specification and schedules, which is not always possible when relying entirely on reused materials.

Experience Brings Down Costs

GreenLeaf Construction is committed to materials reuse in its projects, and to making the practice more widely recognized and accepted by both local government entities and green building certifiers. By catering to customers willing to pay a premium for unique design and green features, GreenLeaf is able to recover some of the costs of labor and time spent obtaining, preparing, and incorporating reusable materials. However, to date, incorporating deconstruction and materials reuse has resulted in additional cost to GreenLeaf. GreenLeaf is working to reduce these costs in the following ways:

- Developing a storage yard for reusable materials;
- Limiting the materials salvaged to those that are larger in size, and of quickly identifiable reuse value (e.g., GreenLeaf no longer salvages lumber less than 8', 2x6" or 2x8"); and
- Working closely with RE Store to minimize transportation time, and therefore costs, of obtaining materials, by bringing its truck directly to sites where RE Store is doing deconstruction.

Need for an Expanded Materials Reuse Retailer

Committed to reusing building materials in its future projects, GreenLeaf hopes that with improved awareness and support for materials reuse, larger, more reliably stocked reusable materials retailers will emerge. A centralized location for such materials would reduce time and transportation costs associated with obtaining reusable materials, and would help improve the market for these goods.

Need for Easier Certification of Reused Materials

GreenLeaf looks forward to easier certification of reused materials as sustainable. For the Green Compact house, GreenLeaf worked closely with inspectors to verify that its use of lumber from deconstructed buildings was indeed suitable and an appropriate way to meet the guidelines for the Built Green challenge. Having guidelines or certification for materials reuse will help improve the image of materials reuse, and dispel the sometimes-held belief that builders are trying to pass off 'junk' materials in their projects.

The combined successes and lessons of the Green Compact project will inform GreenLeaf Construction's future work, and continue to serve as valuable examples for others in the nascent industry.

Project Contacts

Jim Barger
GreenLeaf Construction, Inc.
jim@greenleafconst.net

Case Study Sources

GreenLeaf Construction, Inc.
http://www.greenleafconst.net/

Built Green Case Studies
http://www.builtgreen.net/studies/1064.html

Personal Communication, Jim Barger, GreenLeaf Construction, Inc., on February 22, 2007.

Photograph credit: Anna Stueckle

CASE STUDY 4: THE RE STORE—MARKETING REUSABLE BUILDING MATERIALS

Project Type	Used Building Material Retail Store
Location	Bellingham and Seattle, Washington
Founded	1993

PROJECT GOALS

The RE Store[50] is a project of RE Sources, a non-profit organization located in Bellingham, Washington with roots as a recycling advocacy group. RE Sources was one of the first groups in the nation to provide curbside recycling, and the RE Store grew out of the organization's goal of reducing waste and finding innovative ways to recycle and reuse it. Specifically, a former director at RE Sources was surveying local landfills and noticed the large volume of construction and demolition building materials in them. A request for proposals from Whatcom County for reuse projects spurred RE Sources to propose the RE Store, originally designed as a drop-off center for surplus building materials. Soon the first store was up and running in Bellingham.

The overall goal of the RE Store is to divert material from landfills. While originally focused solely on building materials, RE Stores now also accept and recycle electronic waste, and partner with other organizations (such as found art collaboratives and farming associations) to further their mission.

BUSINESS DESCRIPTION

Founded in 1993, the RE Store currently operates at two locations: Bellingham and Seattle, Washington. The stores sell a wide variety of used products from doorknobs and cabinets to bathtubs, dimensional lumber, windows, doors, and fireplace mantels. The stores' inventory comes from four sources:

- **Drop-offs—**individuals or building material suppliers donate goods;
- **Field salvage—**RE Store crews strip building interiors slated for demolition;
- **Pick-ups—**RE Store staff pick up goods of high value from donors; and
- **Deconstruction—**RE Store crews dismantle entire buildings.

Quantities and types of materials, and profit margin for the RE Stores, vary with each collection method. *Drop-offs* of materials by individuals supply the RE Store with saleable materials at no cost to the stores. Drop-offs constitute approximately 30 percent of materials obtained by the RE Stores. The *field salvage* *service* program is a successful model that regularly supplies interior building materials to the RE Stores. Field salvaging, which in combination with *pick-ups* supplies 40 to 50 percent of the RE Stores' stock, takes less time than deconstructing a whole building, and creates a supply of materials that is easy to sell. RE Store crews do the work, stripping building interiors before the building is demolished. *Pick-ups* are a free daily service offered by RE Stores that compensate customers who want to donate materials in exchange for store credit. *Deconstruction*, also carried out by RE Store field crews, and contributing about 20 percent of the RE Stores' materials, takes the most time (up to three times as long as a typical demolition) and therefore costs the RE Store most in terms of labor. RE Store bids on demolition projects against traditional demolition companies. To offset the added labor costs of deconstruction as compared with traditional demolition, the RE Store charges a service fee in addition to obtaining all the salvageable materials from the building, and any revenue generated from their sale. For all three of the above materials salvaging methods, owners receive receipts for donations and may use them to claim tax deductions. In addition, drop-off donors can opt for an in-store trade credit, worth 25 percent of the RE Store's sales price for the item they donate.

Getting Deconstruction off the Ground

The deconstruction field service program proved harder to get off the ground than the field salvage service. In fact, it was unsuccessful in its first iteration in Seattle, but by applying lessons learned from the Bellingham operation it was restarted in 2006 and is now operating successfully with crews located in Bellingham and Seattle.

Deconstruction seems to be a natural evolution for the RE Store—it is an easy way to supply a steady stock of material for the RE Stores, and saves considerably more material from landfills than recycling and salvage alone. The deconstruction crews (e.g., a four person team in Bellingham) are trained in all aspects of the RE Stores' operations to understand the full picture of the organization's mission of waste reduction, and the variety of reuse possibilities. Practices that have made deconstruction a successful component of the RE Stores' operations include 1) having an estimator conduct a preliminary assessment of the percentage of recoverable materials in a given project that the RE Store is bidding on and 2) developing relationships with individual contractors. The RE Store has benefited recently from an increased awareness of materials reuse in the building industry, support from State government agencies, and the rapidly growing trend in green building. For example, like the LEED certification program of the U.S. Green Building Council, the Built Green rating program in Washington has helped raise awareness about green building and resource use issues, and provides recognition to projects that incorporate materials reuse in their overall designs. An additional boost comes from occasional efforts to add value to recovered materials. Recently, RE Store sent pine school bleacher boards to a mill that planed them and added tongue and groove elements. RE Store sold the value-added wide plank flooring for a price five times greater than they would have otherwise received.

Inventory: Supply and Demand

The RE Stores' biggest sales categories are lumber, cabinets, doors, and windows. The inventory and demand differs somewhat between the Bellingham and Seattle stores. Wood sells very fast at the Bellingham store, and is often in short supply. Because the Seattle store is somewhat smaller, materials are necessarily a bit more selectively stocked. On any given day, a diverse base of materials is available—an array that the RE Store likes to describe as "what you would find in your hardware store, just used." Both stores have grown quickly, with storage and space issues emerging as the most significant barriers to their growth, and both generally have a quick turnover of materials. Demand for additional RE Stores is growing, with calls coming in from other parts of the state where government agencies and other organizations are hoping to attract enough support to build additional outlets.

The RE Store sees demand for its products primarily from homeowners and small scale contractors. Relationships with contractors, such as GreenLeaf Construction (see Case Study 3 in this section), facilitate the direct sale of lumber and have proven to be particularly beneficial. The RE Store is working to develop relationships with other contractors in the region given what appears to be a growing demand for used lumber. In addition to pursuing these relationships, the RE Store has more recently experienced an increased interest from architects and designers. This is attributed to the growing popularity of the LEED and Built Green certification programs.

Challenges to RE Store's Work

Building Codes

The RE Store has found that while programs such as LEED and Built Green, as well as the RE Store's own efforts, have improved awareness and acceptance of building material reuse, building codes often do not provide for reuse of these materials. This can make permitting difficult, since extra work, such as materials verification by a third party, may be required before a building that incorporates reused materials can pass inspection. Another factor that hinders project approval is re-grading lumber for reuse. Often after years of use in a building, lumber's original grade stamp is not accepted as valid for its second use, as the lumber may have lost strength, or degraded in other ways. It is therefore necessary to "re-grade" lumber if it is to be used structurally. To address this issue, the RE Store and other salvage organizations are looking to hire a person who would be responsible for grading used lumber that they stock.

Prevailing Wage

At present, workers in the deconstruction and salvage industry do not constitute a distinct labor category with a prevailing wage. They are classified as demolition workers. As a result, RE Store is required to pay the prevailing wage for demolition workers, which does not accurately reflect the work of deconstruction workers. The deconstruction work is often considered light duty work because no heavy machinery is employed and the work is therefore less dangerous than traditional demolition. Paying wages typical of demolition work is a burden that makes it impossible for RE Store to pay workers to salvage lower value and harder to obtain materials because of the added time required.

PROJECT HIGHLIGHTS

The RE Store meets and exceeds its goals of diverting usable materials from landfills, offering affordable used building materials to the public, and educating homeowners and contractors about materials reuse and recycling, while saving them money. The following points highlight its successes:

- The RE Store has turned building material waste into a viable sustainable business venture that diverts close to 3,000,000 pounds of waste per year.
- The RE Stores have seen an increase in profits, especially in the last three years. Of a total $74,000 profit in 2006, $25,000 will be reallocated into ReSources' educational programs and initiatives, and the remainder reinvested in equipment and operating reserves.
- The RE Store employs 40 people at its two locations.
- The largest deconstruction project conducted by RE Store was a 10,000 square foot commercial building.
- RE Store recently purchased and now occupies its own building for the Bellingham store.

Lessons Learned

Time and Place for Machinery

To better compete with demolition companies, and to salvage the most valuable materials through deconstruction, the RE Stores have modified their deconstruction practices to incorporate some usage of machinery. This hybrid method of combining hand deconstruction and machine demolition does not necessarily divert as much material from the landfill, but it speeds the process and allows for selection of the most reusable material, while still preventing far more landfilled waste than traditional demolition.

Improved Bidding

By using the hybrid method described above, RE Store has been able to improve its project bidding success, offering a service that is more comparable to traditional demolition in terms of both time requirements and price.

RE Store finds that deconstruction is often a hard sell because homeowners do not want to take the extra time that it requires over demolition. RE Store currently has about a 10 percent bidding success rate. Experience in the field has also improved RE Store's ability to assess which jobs will likely yield materials with valuable reuse potential.

Moratorium on Certain Materials

The RE Store has a "moratorium list" available on its website to help ensure that materials donated as drop-offs have resale value and are in demand. The list sometimes includes seasonal items like electric baseboard heaters, and always includes items that are not suitable for reuse, such as treated wood that may contain toxic chemicals, wood with nails in it, and items such as sinks and tubs in dated colors. This list helps limit the amount of time RE Store employees spend sorting through materials, and ensures that items for sale meet certain minimum quality standards. It also demonstrates that the RE Store has been able to identify products that are not in high demand for reuse.

Project Contacts

Robyn du Pre, Executive Director
RE Sources for Sustainable Communities
2309 Meridian Street
Bellingham, WA 98225
http://www.re-sources.org

Dean Fearing, Director
The RE Store (2 Stores—1 at above address, and one at Seattle address below)
1440 N.W. 52nd St
Seattle, WA 98107
http://www.re-store.org

Case Study Sources

Personal Communication with Robyn DuPre, Executive Director of RE Sources, on February 27, 2007; and Dean Fearing, Director of RE Store on March 12, 2007.

The RE Store website: www.re-store.org

SECTION 4

Design for Deconstruction

A New Approach to Building Design

As society continues to face significant waste and pollution impacts related to conventional building design, renovation, and removal practices, innovators are imagining a future where buildings are designed to consume fewer resources and generate less waste throughout their lifecycle. Building industry professionals are pioneering the concept of *Design for Deconstruction (DfD)*, sometimes referred to as Design for Disassembly, a technique whose goal is to consider a building's entire lifecycle in its original design. This includes the sustainable management of all resource flows associated with a building including design, manufacturing of construction materials, operation, renovation, and eventual deconstruction.[51]

The typical building lifecycle is a linear one, as illustrated in Figure 1. Resources are used and eventually discarded with minimal thought of re-cycling or reuse. The environmental impacts of this approach are sizeable. In terms of waste, if housing replacement rates remain unchanged, over the next 50 years 3.3 billion tons of material debris will be created from the demolition of 41 million housing units. Even more dramatic is the fact that, if trends in housing design continue, new homes built during this same time period will result in double the amount of demolition debris, or 6.6 billion tons, when they are eventually demolished. Beyond

extraction
↓
manufacturing
↓
design
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construction
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operation
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renovation
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disposal

Figure 1—Traditional linear material flow
(Source—DfD, 2006)

these waste issues, the energy consumed to produce building materials is having a huge effect globally. A 1999 United Nations study states that 11 percent of global CO_2 emissions come from the production of construction materials. These are the same materials that regularly end up in landfills.[52] The trend in construction practices since the 1950s has only exacerbated these impacts, as buildings progressively contain more complex systems, materials types, and connecting devices, making it more difficult technically, as well as economically, to recover building materials for reuse or recycling. Unless a sustainable lifecycle approach to building is adopted, most building components in the future will become increasingly more non-renewable, non-reuseable, and non-recyclable.[53, 54]

Incorporating Design for Deconstruction (DfD)

Design for deconstruction addresses waste and pollution issues associated with building design and demolition by creating a "closed-loop" building management option that goes against the traditional linear approach (Figure 2). By designing buildings to facilitate future renovations and eventual dismantlement, a building's systems, components, and materials will be easier to rearrange, recover, and reuse. It is estimated that the average U.S. family moves every 10 years. Over an average 50-year life span, a home may change hands five times and undergo structural changes to meet each occupant's needs. Thus, there is potential for multiple renovations over a building's lifetime, as well as complete building removal to make the land available for a newer building – as has been the trend most recently. DfD can proactively address future occupancy flow through a sensible approach that maximizes the economic value of a structure's materials, while working to reduce environmental impacts from their renovation and/or removal. DfD also creates adaptable structures that can be more readily reshaped to meet changing needs of owners.[55, 56]

Incorporating DfD into the design of a building comprises four major design goals. All of these goals combine to minimize the environmental footprint of a building.[57]

1) **Reusing existing buildings and materials**

   Architects and developers should, to the extent possible, incorporate reused materials in the construction of new buildings. Besides minimizing waste from disposal of materials from existing building, as well as decreasing resource use and pollution associated with the creation of new materials, incorporating reused materials will help preserve the materials embodied energy, which is the amount of energy consumed to produce the materials (see Section 3). Additionally, supporting the materials reuse market will also help create demand for more used materials.

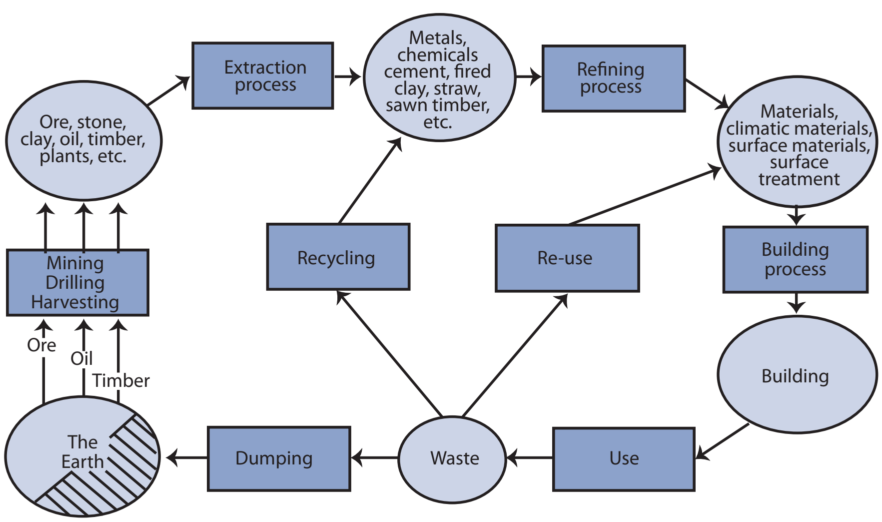

Figure 2—Closing the loop in the material lifecycle

(Source—Bjorn Berg, "The Ecology of Building Materials)

2) **Designing for durability and adaptability**

Designing a building for disassembly includes designing it for adaptability, which can reduce the generation of significant construction waste during building renovation.[58] This is shown in Case Study 5, one of the first residential construction DfD projects carried out in the U.S. Among other techniques, the case study home was created with repositionable interior walls that can be removed and relocated without creating any waste or compromising structural integrity. The wall sections can be reused as is, or "recombined" to create new configurations to meet the homeowner's needs. Already, the new owner of this building has taken advantage of this flexibility by remodeling to allow for a home business space. Because of the repositionable walls, this renovation could be completed without generating any waste.

3) **Designing for deconstruction by using less adhesives and sealant**

When assembling a building, DfD techniques stress the importance of connecting components and structures using simpler fittings, fasteners, adhesives, and sealants whenever possible. This will make it easier to disassemble the components quickly and minimize any damage to the materials to enable greater reuse. If chemical sealants or standard adhesives (i.e. glues, caulks, and foams) are used instead, more time and cost is needed to deconstruct components, and in some cases they cannot be properly recovered at all. On the other hand, when releasable adhesives and mechanical fasteners (i.e. screws, bolts, and connectors) are used, materials can be recovered expeditiously, without significantly affecting their quality and ultimate reusability. Reducing the amount of chemicals used in the building's construction also helps reduce the amount of toxic materials in a project. [59]

Since DfD is a new concept, current building codes typically do not yet support its techniques, nor do manufacturers' warranties. For instance, glues may be required by the manufacturer to assemble a product, and substitutions for glue would void the product's warranty. Until the present policies of buildings codes and manufacturers evolve, these restrictions may limit some, but not all, DfD techniques.

4) **Using less material to realize a design**

An important DfD principle is to "keep it simple." Lessening the amount of material and elements used makes a building's design less complicated, and requires less labor to deconstruct it in the future. Additionally, if construction professionals consider using the least amount of materials in the most efficient manner, they will help move the project towards the goal of generating near-zero waste.[60] Any amount of construction debris that cannot be minimized should be recycled when possible.

Other design techniques that help achieve DfD goals include:[61]

- Maximizing clarity and simplicity of the building design.
- Using building materials that are worth recovering.
- Minimizing the number of fasteners used when possible.

- Simplifying connections between parts, to enable easier deconstruction.
- Separating building layers and systems (i.e. mechanical, electrical)..
- Minimizing the number of components (i.e. use fewer larger elements).
- Using modular building components and assemblies.
- Disentangling utilities from the within the structure's walls, ceilings, and floors.
- Providing easy access to components and assemblies (windows, etc).
- Making connections between components and parts visible and accessible.

Lifecycle construction concepts are also being advocated by construction industry organizations, including the U.S. Green Building Council. Recently they announced that projects seeking certification under their LEED Green Building Rating System can earn "Innovation in Design" points by using the Cradle to Cradle (C2C)[62] program for building projects, as well as products certified under other established systems.[63] One of the main criteria that C2C uses to assess products is their design for material reuse and recycling. Although this applies only to the products within the building, this represents a shift towards awareness of the material flows that go into a building's construction. Expanding this to include an entire building's design is the objective of Design for Deconstruction.

Summary

In the United States, DfD is still in its conceptual stages in many respects. The idea of extended producer responsibility, materials conservation, and lifecycle construction are not well developed within the construction industry as a whole. Often, architects and builders do not design or construct buildings with the consideration that one day they will be taken down. The building's removal may not occur in their lifetime, or chances are those involved in the original project will not be part of its renovation or removal. In some regions, the financial incentive for speedy development drives quick assembly, rather than thoughts of incorporating disassembly. Changing the perception and practices within the construction industry, as well as among building owners may be DfD's largest barrier to overcome. However, as these issues are addressed through education and research the DfD concept can become a more widely accepted practice.

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CASE STUDY 5: 71 Boulevard House—A Residential Design for Deconstruction Project

Project Type	Design for Deconstruction
Location	71 Boulevard Atlanta, Georgia
Building Type	Single Family Residential Home
Size	2,166 ft^2
Owner	The Community Housing Resource Center
Completion Date	June 2006

Project Goal

This project was conducted as part of the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response (OSWER) Innovations Pilot Program. A joint venture between the U.S. Environmental Protection Agency (EPA), Community Housing Resource Center (CHRC) and Pennsylvania State University's Hamer Center, the 71 Boulevard Design for Deconstruction (DfD) house demonstrates that residential homes can be designed both for increased longevity, and for future disassembly and building material reuse. Such characteristics can help decrease the high amount of waste production and resource demands prevalent in the U.S. housing industry today. This is particularly relevant in cities such as Atlanta where high growth rates put pressure on land and material resources to accommodate burgeoning populations.

By incorporating techniques such as moveable walls, a disentangled heating and cooling system, and waste reduction, this project demonstrates not only that the environment can benefit from the incorporation of DfD techniques, but that the consumer can as well. Designing a house for near-zero waste means that the owner has increased flexibility and greater ease in reconstruction when carrying out additions and renovations. Funded in part by a $69,000 grant from the EPA, the project's partners plan to create educational materials around this project to promote the "cradle to cradle" approach for residential building design.

Building Description

The case study home is a two-story, 2,100-ft2 residential building constructed on a small 40 by 75 foot, previously undeveloped lot. Located approximately one mile from downtown in the dense urban setting of the historic Martin Luther King, Jr. District of Atlanta, Georgia, this house was designed within the District's strict design regulations. The nearby King Memorial, shops, and restaurants add to the sustainability of the project as a viable home site, and create the potential for a pedestrian friendly urban lifestyle. The site is zoned as live-work and could be used for a home office, a possibility made easier by the home's design for adaptability as well as disassembly.

Project Highlights: Residential Design, Repositionable Walls, and Disentangled Systems

By reducing its ecological footprint[64] during initial construction, future remodeling, and eventual deconstruction, this project comprises a best practice toolkit for DfD in residential construction.

Residential Design—A New Medium for Design for Deconstruction

DfD is not a typical process in residential construction; it occurs more commonly in rapidly changing commercial environments such as temporary offices or short-term retail facilities. As such, the 71 Boulevard project is unique to the industry, and had to utilize original approaches and creative thinking to achieve its goals.

As one of the first residential DfD projects, a range of adaptations had to be made to the more typical DfD commercial process in order for this project to succeed. For instance, standard DfD design incorporates a prefabrication strategy, using off-site labor and higher levels of technology. However, such high-tech conditions are not common in the residential construction industry, where the vast majority of homes are built on-site. Choosing to work within current residential construction DfD constraints in order to complete the project, project managers focused on building the homes first for *adaptability* (i.e. moveable walls), and second for future *disassembly*, rather than the typical primary emphasis on *disassembly*. Adaptability can be readily appreciated by everyday homeowners and effectively communicated to subcontractors on the project.

In addition to being on the forefront of incorporating DfD into residential home design, this pilot project was a successful learning tool for testing the viability of DfD in the market, both by working with a traditional construction company, and by selling the home on the open real estate market.

Repositionable Interior Walls

With its repositionable interior walls, the 71 Boulevard house incorporates a unique system of adaptability for residential construction. Repositionable walls are significantly different from the traditional stick framing home design, in which interior walls are necessary to hold up the roof. Any changes to wall arrangements in this traditional design not only destroy the wall materials, but create structural problems that often result in the generation of substantial waste materials through extensive re-framing or, in some cases, demolition because the home requires too much remodeling to meet new space needs.

In contrast, the repositionable interior walls in this home can be removed and relocated without creating any waste or compromising structural integrity. They are created using a light-gauge metal to frame the wall panels and reduce weight for portability, and a system of wood base plates and top and bottom trim pieces. When finished, each steel framed and drywall covered panel of the non-load-bearing wall can be removed individually. The wall sections can then be reused as is, or combined to create new configurations to meet the homeowner's needs. In fact, since 71 Boulevard was built, its current owner has already remodeled the downstairs to allow for a home business space, generating no waste in the process.

Disentangled Heating and Cooling Systems (HVAC)

Another successful DfD strategy in this project involved splitting the HVAC system by using two smaller heat pumps for air conditioning, one each for the first and second floor, rather than a single large pump. This approach has several benefits. First, it reduced the size of the units and the necessary ductwork. Second, by splitting the system, locating one in the basement crawlspace to control the first floor and one in the attic space to control the second floor, this approach eliminated the typical entanglement of ducts in the "core" of the structural zone of the second floor, where it would be sealed in by drywall finishes or sub-floor. Instead, both the crawlspace and attic allow for better system access. This design means that interior wall modifications are less invasive and more easily completed, as they will not involve maneuvering around or reconfiguring the systems. In addition, this HVAC strategy is a more energy efficient and affordable option.

Lessons Learned

This project was a success because of the practical lessons the project team learned—both positive and negative—that can be applied to future design for deconstruction projects.

Limitations of Residential Construction Practices

One of the major project lessons came from devising an approach to DfD that would be workable in real world residential construction. Project managers settled on a strategic approach that emphasized adaptability over maximum disassembly potential. Full disassembly was precluded by requirements of manufacturers warranties and building code. However, the project team remained conscious of DfD principles throughout, and identified achievable "levels" of disassembly. For example, aspects of the house most likely to be reconfigured in the future were designed to be the easiest to disassemble (interior walls, cabinetry), and those least likely to be reconfigured are less so (foundations, main stairwell, etc). Electrical and plumbing systems were bundled in central locations to avoid tangling them throughout the walls and creating an obstacle to simple disassembly. As noted above, all the ductwork was placed in the attic or the basement crawlspace to ensure that it too was untangled from the interior spatial arrangement.

Overall, project managers learned to work within the limitations of the residential market, which has deeply entrenched, slow changing practices geared towards constructing buildings with long lifespans and less adaptability. They were also able to construct the building using convenient materials, most obtained off-the-shelf from commercial hardware stores. This approach allows the DfD method used for 71 Boulevard to be easily replicated without depending on large-scale changes in residential construction methods.

Lack of DfD Awareness Among Residential Construction Professionals

Design for deconstruction is not a typical process in residential construction; therefore, residential construction professionals are often unacquainted with it and do not consider incorporating it into their projects. Consequently, a great deal of communication with suppliers and subcontractors was necessary to ensure that the ideas were understood and concepts carried through the entire construction process. For instance, skilled laborers are used to creating pieces that are not necessarily easy to take apart, and DfD asks them to turn against that core principle and think beyond the building's lifetime. Additionally, day laborers come on-site for only a short time and are likely unaware of the bigger picture goals for the project. As such, it was necessary for project managers at 71 Boulevard to remain vigilant in minimizing use of glues, caulks, foams, and other toxic agents that would have inhibited the ability to reconfigure or deconstruct the building. In the end, details were often worked out on the site in the presence of the craftsmen, to ensure that drawings were interpreted correctly.

The introduction of DfD practices into a typical construction process can often lead to cost and times issues. Because these techniques are uncommon at the moment, and in the early phases of industry adoption, projects make take longer, incurring higher labor costs, and increasing the overall project costs. Increasing the construction industry's familiarization of DfD techniques through education, and continuing with pilot projects such as the 71 Boulevard House to test more efficient DfD techniques, will help address these time issues.

Industry Collaboration

In preparation for this project, a collection of industry experts gathered in Atlanta for a two-day charette on DfD principals. The charette was organized around presentations describing both the DfD concept and the proposed design for the 71 Boulevard house. This gathering produced innovative ideas that were incorporated into the design and construction of the house, and the attendees left having gained valuable knowledge about the potential applications of DfD in residential settings. Such industry collaboration is extremely fruitful in advancing design for deconstruction work and techniques.

Project Contacts

Pam Swingle
U.S. EPA, Office of Solid Waste and Emergency Response
Innovations Work Group Program
Atlanta, GA
Tel: 404.562.8482
E-mail: swingle.pam@epa.gov

Andrea Korber
(Formerly of the Community Housing Resource Center)
Atlanta, GA
Tel: 404.272.5285
E-mail: akorber@gmail.com

Brad Guy
(Formerly of Pennsylvania State University)
410 Margaret Morrison Hall
School of Architecture
Carnegie Mellon University
Pittsburgh, PA 15213
Tel: 814.571.8659
E-mail: guy_brad@yahoo.com

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CASE STUDY 6: Chartwell School—Design for Deconstruction Project

Project Type	Design for Deconstruction
Location	25-acre site on the decommissioned Fort Ord military base in Seaside, California
Building Type	School
Size	12,955 ft^2 classroom building 8,272 ft^2 multipurpose building
Owner	Chartwell School
Completion Date	September 2006

Project Goal

In the late 1990s, the average public school building in the United States was 42 years old; over half of public schools reported plans for at least one major repair, renovation, or complete replacement of their facility. The scope of these modernizations or replacements will significantly affect school districts financially, and will also affect the environment by increasing construction material demands and waste generation. To minimize these ramifications, innovative projects such as the Chartwell School are building for durability, ease of maintenance, and adaptability—critical characteristics for a sustainable future.

Partially funded through a $29,400 grant from the U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Resource Conservation Fund, the Chartwell School was designed to help develop and promote simple, robust, and intelligent strategies for the construction industry to readily disassemble building materials and components for reuse or easy replacement. The Chartwell project team explored how a school structure can be created to allow for faster, easier, and low cost adaptation to natural changes and evolving demands, such as classroom size fluctuations, teaching pedagogy, and new technologies.

Building Description

As a kindergarten through eighth grade teaching facility, the Chartwell School educates children with dyslexia and related language learning disabilities. The school aims to be a model for development in the region by disseminating sustainable building practices that minimize ecological impacts while creating a healthy learning environment full of fresh air and natural light. To provide these services, administrators are building a new campus that will include four buildings developed on 5.7 acres of a 29-acre site on the decommissioned Fort Ord military base. The first phase of the project, and the focus of this case study, is a 12,955 square-foot classroom building and an 8,272 square-foot multipurpose building organized around a courtyard.[65] These two buildings were constructed for $9.2 million, or $344 per square foot, a cost according to its architects that is in line with typical school construction budgets.

Project Highlights: Utility Raceway, Modular Framing, and the Materials Lifecycle

In an effort to develop practical techniques that construction industry professionals can use in everyday projects, certain unique approaches were explored, including:

Visible Utility Connections via a Utility Raceway

To accommodate future changes and allow for easy maintenance of the existing systems, most utilities at Chartwell School were exposed to view by running a utility raceway the full length of the classroom building adjacent to the corridor. Teachers' cabinets were located along this wall, and the doors recessed in from the hallway, together forming a "shelf" to house the raceway. From a deconstruction and maintenance perspective, this provides several advantages in addition to allowing easy access to the wiring. First, it disentangles the utilities from the structure, making it simpler to recover the utility piping and cables and to take down wall sections. Second, by minimizing utility runs through the walls less drilling is needed, resulting in fewer holes in the wood framing that reduce its value for recovery. Lastly, making the systems visible also helps teach students how the building works, as well as the relationship between their classroom activities and the utilities that support them. Although the use of utility raceways is currently uncommon, they are a practical, feasible, and intelligent approach to building wiring.

Modular Framing

One of the key structural elements that allows for disassembly of the Chartwell School is the design of the building. Chartwell was designed in a modular fashion, a straightforward approach that incorporates simplified connections and fewer high capacity fasteners, and allows easy access for future removal. The floor plan was carefully laid out on this module, so that room sizes, window and door openings, and interior partitions typically land on the module layout. The simple frame also optimized material sizes, with the entire school designed on a 24" on-center (o.c.) module rather than the more conventional 16" o.c. Consequently, lumber needs decreased by 30 percent, which reduced the amount of labor needed on-site to handle lumber.

Awareness of the Material Lifecycles

One goal in designing for deconstruction is to reduce the lifecycle impacts of construction through materials reuse. Understanding the various material lifecycles is a helpful decision-making tool in this process, and one that was employed in the construction of the Chartwell School. The material lifecycles for all major components of the project were taken into consideration in the project's design. Project managers estimated the quantities of embodied carbon dioxide (CO2) emissions for many of the materials, considered the relative ease or difficulty of salvage, and explored the post-recovery value of that material. This analysis helped focus efforts toward wood structural and finish components, which have the greatest potential reuse value when balanced against their CO^2 footprints.

Lessons Learned

The Chartwell School project was a success for its innovative design, but also because of the practical lessons the project team learned—both positive and negative—that can be applied to future design for deconstruction projects.

Protecting Information for Future Disassembly

One of the key challenges in designing for deconstruction is ensuring that the buildings plans, specifications, and general instructions for disassembly are available for future use. Often these documents become misplaced or damaged over the years, so Chartwell School project managers worked to combat this problem in several ways:

- Final record drawings were bound with a sturdy cover to protect the paper, and include instructions to make reproductions rather than remove drawings from the bound original.
- Some building elements were directly labeled with critical information. For example, the roof trusses are labeled with their key structural properties, for use by structural engineers to determine if they are adequate for a future application.
- Permanent signage was installed in the school's utility and maintenance rooms identifying the architects and engineering design team for future reference.

Also, many of the school's systems are exposed to view, including utilities and the roof framing, making drawings less critical in these cases.

Recovered Wood and Seismic Requirements

One of the Chartwell School's major challenges was to constructing the building to allow for future disassembly and reuse of the wood framing. In California, extensive nailing and hardware is required to meet seismic requirements. Often plywood panels are nailed to the entire exterior of a wood frame building, which is a heavy level of fastening that will present major challenges for future disassembly. In an effort to avoid this, Chartwell's project managers analyzed a number of alternative fasteners, but no suitable substitutes could be found to achieve their goal. From this exercise, it is apparent that the detailing of wood frame walls in seismic zones to allow for design for deconstruction warrants further investigation.

Creativity with Salvaged Materials—Tongue and Groove Method

For the Chartwell School project, workers had to adapt their methods to allow for new, but not necessarily difficult, approaches for sustainable construction and material use. For instance, Douglas fir paneling, salvaged from demolition of the decommissioned Ft. Ord army barracks, was to be used in the project. However, project managers wanted to ensure that this valuable wood could be deconstructed for reuse in the future. The typical construction practice is to nail through the tongue in the wood, which makes it almost impossible to remove the paneling without breaking the tongue off. Chartwell project managers researched alternatives, and decided to employ the gentler "tongue and groove" method and apply the salvaged wood siding with aluminum extrusions instead of nails.

Indirect Benefits of Adopting Innovation

Doug Atkins, the Executive Director of the Chartwell School, has become an expert in communicating the advantages of green building, and design for deconstruction, techniques. Giving an average of two tours a week to members of the public, he has observed how Chartwell, by putting construction theory into practice, has influenced and inspired the community. Visitors have included municipal planners hoping to proactively rewrite their building codes; design firms, engineers, and consultants who want to learn from Chartwell's experience; and developers who recognize the growth of sustainable design and who hope to better understand the economics in order to properly position themselves in the market.

The attention that Chartwell has received for their innovative sustainable design has produced indirect financial benefits for the school as well. Although a final analysis has yet to be conducted, it is estimated that at least 25 percent more money has been raised through their fundraising campaign. According to Mr. Atkins, this result illustrates how their investment in sustainable school design increased interest in the school, and promoted their overall culture of inquiry as an educational organization.

Project Contacts

Timonie Hood
U.S EPA, Region 9
Office of Pollution Prevention and Solid Waste
San Francisco, CA
Tel: 415.972.3282, 415. 972.3285
E-mail: hood.timonie@epa.gov

Douglas Atkins
Executive Director
Chartwell School
Seaside, CA
Tel: 831.394.3468
E-mail: datkins@chartwell.org

Scott Shell
EHDD Architecture
San Francisco, CA
Tel: 415.825.9193
E-mail: scott.shell@ehdd.com

Brad Guy
(Formerly of Pennsylvania State University)
410 Margaret Morrison Hall
School of Architecture
Carnegie Mellon University
Pittsburgh, PA 15213
Tel: 814.571.8659
E-mail: guy_brad@yahoo.com

David Mar, Principal
Tipping Mar Structural Engineers
Berkley, CA
Tel: 510.549.1906
E-mail: david.mar@tippingmar.com

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SECTION 5

Lifecycle Construction Resources

This section lists a range of lifecycle construction resources. The list is not comprehensive, but does include a significant portion of available materials on the topic. Inclusion of a resource in this section does not connote endorsement by the U.S. Environmental Protection Agency.

EPA Websites

EPA Innovations Pilots
http://www.epa.gov/oswer/iwg/pilots/index.html

EPA Deconstruction and Reuse
http://www.epa.gov/epaoswer/non-hw/debris-new/reuse.htm

EPA Construction and Demolition Debris
http://www.epa.gov/epaoswer/non-hw/debris-new/index.htm

EPA Green Building
http://www.epa.gov/greenbuilding/

EPA Stewardship
http://www.epa.gov/stewardship/

EPA Lifecycle Building Challenge
http://www.lifecyclebuilding.org

Other Organizations

Please note: The Building Material Reuse Association (BMRA) maintains an online directory of building material reuse organizations, which can be accessed at http://www.ubma.org/directory/. Please refer to this ever-expanding and up-to-date source in addition to the list below.

2 Good 2 Toss—Reuseable Building Materials and Household Items (Online)
http://www.2good2toss.com

Acadia Services, LLC
Fairfield, CT
www.acadiademolition.com

American Institute of Architects
Washington, DC
http://www.aia.org

Architectural Salvage Warehouse of Detroit
Grosse Point, MI
www.aswdetroit.org

Beyond Waste Warehouse
Cotati, CA
www.beyondwaste.com

Boston Building Materials Reuse Center
Boston, MA
http://www.bostonbmrc.org/bostonbmrc/index.html

BRING Recycling
Eugene, OR
www.bringrecycling.org

Building Deconstruction Consortium (Online)
https://www.denix.osd.mil/denix/Public/Library/Sustain/BDC/bdc.html

Building Materials Reuse Association
State College, PA
http://www.ubma.org/

Building Resources
San Francisco, CA
http://www.buildingresources.org/

Building Value—Nonprofit Reuse Center
Walnut Hills, OH
http://www.buildingvalue-cincy.org/

Build It Green! NYC
Astoria, NY
http://www.bignyc.org/

Cabins, Cottages & Bungalows
Elfland, NC
http://cabinscottagesandbungalows.com/

Center for ReSource Conservation
Boulder, CO
http://www.conservationcenter.org/

Community Development Corporation of Utah
Salt Lake City, UT
http://www.slcdc.org/affordabilityproject.html

Community Environmental Center
Long Island City, NY
http://www.cecenter.org/

Construction Junction
Pittsburgh, PA
http://www.constructionjunction.org/

Crossroads Recycled Lumber
North Fork, CA
www.crossroadslumber.com

Dallas Contracting Co., Inc./
Restoration Materials Company
www.dallascontracting.com

Deconstruction Institute
Sarasota, FL
http://www.deconstructioninstitute.com/

Empire Services
Reading, PA
www.empireservicesberks.com

Garbage Reincarnation, Inc.
Santa Rosa, CA
www.garbage.org

Gorge Rebuild-It Center
Hood River, OR
http://www.rebuildit.org/

Green Demolitions
Greenwich, CT
www.greendemolitions.org

GreenGoat
Somerville, MA
http://www.greengoat.org/

Green Star Alaska Materials Exchange
Anchorage, AK
http://www.greenstarinc.org/ame/index.php

Habitat for Humanity RE Stores (Nationwide)
http://www.habitat.org/env/RE Stores.aspx

Historic Houston Salvage Warehouse
Houston, TX
http://www.historichouston.org/

Hobi International—Design for Disassembly Consulting
Batavia, IL
http://www.hobi.com/design.html

Home Resource
Missoula, MT
www.homeresource.org

Island Girl Salvage
Elk Grove Village, IL
www.islandgirlsalvage.com

Murco Recycling Enterprises
LaGrange, IL
www.murco.net

National Defense Center for Environmental Excellence (Online)
(Decon 2.0 Model)
http://www.ndcee.ctc.com

Northwest Building Salvage Network (Online)
http://www.nbsnonline.net/mission.htm

NY Wa$teMatch
New York, NY
http://www.wastematch.org/

Odom Reuse Co.
Grawn, MI
http://odomreuse.com/

Ohmega Salvage and Omega Too
Berkeley, CA
www.ohmegasalvage.com
www.omegatoo.com

Olde Good Things
Scranton, PA
www.oldegoodthings.com,
www.oldegoodwood.com

Old House Parts Company
Kennebunk, ME
http://www.oldhouseparts.com/

Recycle North
Burlington, VT
http://www.recyclenorth.org/

Rehab Resource
Indianapolis, IN
www.rehabresource.org/

ReHouse
Rochester, NY
http://www.rehouseny.com/

ReNew Building Materials & Salvage, Inc.
Brattleboro, VT
http://www.renewsalvage.org/

ReSource
Boulder, CO
www.resourceyard.org

RE Store Home Improvement Center
Springfield, MA
http://www.restoreonline.org/

Reuse Industries
Albany, OH
www.reuseindustries.org

ReUser Building Products
Gainesville, FL
http://www.thereuser.com/

ReUseIt Center
Batavia, IL
www.reuseitcenter.org

Second Use Building Materials, Inc.
Seattle, WA
http://www.seconduse.com/

Significant Elements
Ithaca, NY
http://www.significantelements.org/significant_elem.htm

Southface Energy Institute
Atlanta, GA
www.southface.org

Stardust Building Supplies
Mesa and Phoenix, AZ
www.stardustbuilding.org

TerraMai
McCloud, CA
www.terramai.com

The Community Forklift
Edmonston, MD
http://www.communityforklift.com/

The Green Institute
Minneapolis, MN
http://www.greeninstitute.org/

The Green Project
New Orleans, LA
http://www.thegreenproject.org/index.html

The RE Store
Bellingham and Seattle, WA
www.re-store.org

The Rebuilding Center of our United Villages
Portland, OR
http://www.rebuildingcenter.org/deconstruct/

The ReCONNstruction Center
New Britain, CT
http://www.reconnstructioncenter.org/

The Stock Pile
Canton, OH
http://www.thestockpile.org/

Umpqua Community Development Corporation
http://www.umpquacdc.org/

Urban Ore
Berkeley, CA
http://urbanore.citysearch.com/

U.S. Forest Service Forest Products Lab Articles and Resources
Madison, WI
http://www.fpl.fs.fed.us/staff/robert-falk.html#deconstruction

U.S. Green Building Council
Washington, DC
http://www.usgbc.org/

Whole House Building Supply
Palo Alto, CA
www.driftwoodsalvage.com

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[65] Phases two and three call for an additional classroom building and a library/administration building.