

# ISTC Reports

Illinois Sustainable Technology Center

## Overcoming Barriers to P2 and Recycling for Construction Waste

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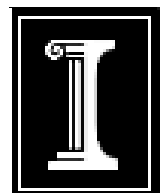
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TR-043

April 2010

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# Overcoming Barriers to P2 and Recycling for Construction Waste

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**April 2010**

Submitted to the  
Illinois Sustainable Technology Center  
Institute of Natural Resource Sustainability  
University of Illinois at Urbana-Champaign  
[www.istc.illinois.edu](http://www.istc.illinois.edu)

The report is available on-line at:  
[http://www.istc.illinois.edu/info/library\\_docs/TR/TR-043.pdf](http://www.istc.illinois.edu/info/library_docs/TR/TR-043.pdf)

Printed by the Authority of the State of Illinois  
Patrick J. Quinn, Governor

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This report is part of ISTC's Technical Report Series (ISTC was formerly known as WMRC, a division of IDNR). Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

## **Acknowledgments**

Funding was provided by the Illinois Sustainable Technology Center (ISTC), a division of the Institute of Natural Resource Sustainability at the University of Illinois at Urbana-Champaign (Contract No. HWR07209). ISTC was formerly known as the Waste Management and Research Center (WMRC). We are grateful to Ken Barnes, Nancy Holm, and staff members at the Illinois Sustainable Technology Center for helpful comments and advice. We are also indebted to our excellent research team at Illinois State University: Majid Farajpouredari, our research assistant; and Lucy Loftus, the McLean County project monitor. Many thanks go as well to the staff members of all the project partners who responded to our requests for information about their practices. Their cooperation and hard work was vital to the success of this project. All errors remain the responsibility of the authors.

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## Abstract

Estimates of construction and demolition (C&D) waste entering landfills range from 20 to 33% of the total waste stream volume. Although waste estimates are difficult to verify, it is clear that, even at the low end of this estimate range, there is significant potential for diverting C&D materials from landfills. A study by the California Environmental Protection Agency (2006) found that new residential construction comprised about 10% of the C&D waste stream. Although much of the construction waste that currently and typically goes to landfill can be recovered, effective waste management in the residential construction industry remains an elusive goal.

Guided by the ADOP2T™ model (Lindsey, 1998, 1999) for diffusion of innovation, this research project worked toward accelerating the adoption of waste minimization and pollution prevention (P2)/recycling practices by Illinois home builders. Major phases of the study included:

- a. establishing partnerships with home builders in two Illinois counties;
- b. identifying and quantifying typical waste streams from residential construction;
- c. identifying priority waste materials for P2/recycling, local best management practices, and barriers to P2/recycling faced by home builders;
- d. implementing P2/recycling demonstration projects in two counties;
- e. developing case study fact sheets to document the procedures and results; and
- f. disseminating the results of the demonstration projects.

Two very different demonstration projects were solicited and documented. In Normal, IL (McLean County), the demonstration site was a four-unit townhome in a new subdivision. The site had adequate room for multiple roll-off boxes to facilitate source-separation by trade partners. The Cook County demonstration project was a LEED-H<sup>1</sup> Platinum home in the City of Chicago on a very tight infill site with barely enough space for one 20 cubic yard roll-off box. The waste materials from this site were commingled and separated for recovery at a recycling center.

The source-separation at the McLean County site necessitated changes to production and management protocols. As a result, there were many barriers to the implementation of the waste management plan and the successful recycling that did occur required vigilant monitoring of the recycling roll-off boxes. As the demonstration project construction manager noted, “All material would go to landfill if not for effective (and subsidized) monitoring!” Haulers also complained

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<sup>1</sup> **Leadership in Energy and Environmental Design (LEED)** is a rating system developed by the U.S. Green Building Council (USGBC) to provide environmentally sustainable standards for the design, construction and operation of buildings and neighborhoods. LEED - H for Homes is a rating system that promotes the design and construction of high-performance green homes. Green homes use less energy, water and natural resources, create less waste, and are more durable and comfortable for occupants.

about multiple trips to various recycling service providers and the accompanying changes in routing that impacted productivity. Further, no recycling outlet was located in Illinois for gypsum wallboard, the material that contributes the greatest mass to the residential construction waste stream. In spite of these obstacles, most of the wood and about half of the cardboard waste was recycled, which diverted approximately 27% of the total waste from the landfill.

By comparison, the Cook County demonstration project commingled all construction waste into one roll-off box for sorting at a recycling center and did not require any procedural changes on the part of the builder or subcontractors. The only materials that needed to be separated were food waste. The simplest way to increase P2/recycling for builders is clearly the “no sort” option that yielded a landfill diversion ratio of almost 88% in this demonstration project. Given the fragmented nature of residential construction – small and scattered building sites, relatively small volume waste streams, and little consistency in trade labor from site to site – placing all construction waste into a single roll-off box with sorting at a recycling center may be the only viable long-term solution to accelerating recycling by single-family home builders.

Additionally, findings from the builder survey data and the demonstration projects indicated that:

- In spite of the increasing awareness of environmental impacts from construction wastes, residential builders are rational business persons and will adopt new means and methods when they are convinced that the benefits outweigh the risks.
- Both demonstration projects were cost-neutral to the builder, which indicated that recycling can be competitive with landfill pricing.
- Builders recognized the marketing value of being perceived as a “green” builder and reported their willingness to recycle if the process does not cost more than traditional landfill fees or create additional work on site.
- Residential construction waste volumes observed in the McLean County demonstration project and waste averages calculated from hauler invoice documentation from a sample of single-family homes in McLean County (8.63 pounds per square foot (PSF)) were considerably higher than the 3.0 to 6.0 PSF range reported in earlier waste studies.



## Introduction and Background

Construction and demolition (C&D) debris is a large portion of waste disposed in U.S. landfills. Estimates of actual volumes vary widely and range from 22 to 33% of the total landfill waste stream. The U.S. Environmental Protection Agency (U.S. EPA) (2009) estimated 2003 C&D waste volume at almost 170 million tons, based on statistical projections from 95 projects. Of this total, it was estimated that 39% came from residential sources and 61% from non-residential sources. A California EPA study (2004) reported that C&D waste comprised 22% of the waste stream. This waste volume is surprisingly consistent with a much earlier U.S. EPA study that estimated C&D waste at 24% of all municipal solid waste (Jones, 1993).

A much higher C&D waste volume is suggested by the Construction Materials Recycling Association (<http://www.cdrecycling.org/>, August 28, 2008). They calculate that approximately 325 million tons of recoverable C&D materials are generated each year in the United States and comprise about one-third of the U.S. solid waste stream. Although waste estimates vary widely and are difficult to verify, it is clear that, even at the low end of these estimates, there is significant potential for diverting C&D materials from landfills.

A waste characterization study commissioned by the California EPA (2006) indicated that new residential construction comprised about 10% of the C&D waste stream and that new non-residential (commercial) construction accounted for 8%. A more recent U.S. EPA report (2009) estimated that new single and multi-family construction produced 6% of the C&D waste versus 3% for non-residential new construction.

Waste recycling from commercial construction is more common than from residential construction because of the higher waste volumes, more space to site recycling boxes, contracting procedures that require waste separation, and consistent site supervision. Recycling in commercial construction is also driven by waste diversion mandates in many jurisdictions, such as California and the City of Chicago, and the voluntary pursuit of LEED<sup>2</sup> certification by owners.

By comparison, single-family residential construction is typically handicapped in recycling efforts by the very nature of the enterprise. Large numbers of independent builders construct homes on small scattered building sites, generate relatively low volumes of waste material, and utilize minimal on-site trade supervision. Further, single-family residential construction waste is usually exempt from jurisdictional recycling ordinances and mandates. The purpose of this study was to investigate ways to overcome barriers to pollution prevention (P2) and recycling in residential construction and thereby accelerate the acceptance and implementation of waste diversion practices.

Previous studies of waste from single-family home construction in the United States reported that between two and four tons of debris (50 cubic yards) were generated with each new

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2,000 square foot home (Jones, 1993; Laquatra and Pierce, 2004; and Yost and Lund, 1997). U.S. EPA (2009) calculated an average waste generation rate of 4.39 pounds per square foot (PSF), which is on the high side of these earlier estimates, but not inconsistent.

Home builders have long been concerned about the high cost of construction waste disposal (Austin, 1991) and these costs have continued to rise as waste volumes across the nation increase and the number of landfill sites decrease. Nationally, the average tipping fees paid to the landfill increased from \$4.90 per ton in 1976 to \$60.00 per ton in 2002 (Yost and Lund, 1995; Chartwell Information, 2008). However, total waste hauling fees include significant additional charges for roll-off box rental and transportation that increase the average cost to the builder in Central Illinois to approximately \$350 per haul for a 20 CY roll-off box.

Waste disposal costs impact the affordability of homes as well as a builder's bottom line. The good news for builders was that the robust housing market from 1991 through the mid 2000s allowed these costs to be passed along to the home buyer (Laquatra and Pierce, 2004). The National Association of Home Builders (NAHB) has demonstrated that builders pay twice for construction materials that could be recycled but end up in landfills. Payment is made when the materials are purchased and fees are assessed when the materials are dumped (Yost and Lund, 1995). These costs are then passed on to home buyers in the form of increased home prices. Aside from the costs of disposal and affordability, ethical questions related to material usage and declining availability of landfill space suggest that waste management be addressed systematically in all new construction and remodeling.

To assist the construction industry, private and governmental organizations have developed process guidelines and database tools to link waste producers with firms that recycle or reuse waste materials. The U.S. EPA's *Planning Guide for Construction and Development* (2005) and NAHB's *Residential Construction Waste Management* (Yost and Lund, 1997) identify ways for builders to reduce, recycle or reuse. Internet resources have been developed by many jurisdictions including California's Alameda County stop waste program (<http://www.stopwaste.org>) and California's state-wide Integrated Waste Management Program (<http://www.ciwmb.ca.gov>). The Partnership for Advancing Technology in Housing (PATH) and its information service for home builders, Toolbase (<http://www.toolbase.org/>), provide easily accessible resources related to waste minimization and descriptions of innovative programs from around the nation, such as a Minnesota project to recycle used asphalt shingles into hot mix asphalt.

Laquatra and Pierce (2004) noted that in spite of available resources, builders remain reluctant to pursue waste recycling, although up to 80% of construction waste has potential for diversion from landfills. Actual recycling practices are dependent upon the financial cost/benefit tradeoff associated with collection, separation, and transportation of waste materials and the return on investment. Further, existing programs, such as the one in Alameda County, are obviously area-specific and of little use to builders beyond an economical transportation distance. Summarizing previous research in diffusion of innovation among small businesses, Bierma and Waterstraat (2001) concluded that decision-makers are unlikely to adopt a new technology or practice unless it provides economic value either by: (a) reducing costs; (b) increasing customer base; or (c) solving headaches, such as simplifying production operations or easing regulatory compliance. For most builders, diversion of construction waste from landfills has not yet crossed one of these threshold criteria to yield a business advantage.

Home building requires considerable financial and marketing risks. Therefore, builders' avoidance of innovation, or at least slow adoption rates, may be rational behavior (Koebel, Papdakis, Hudson, and Cavell, 2004; Taylor and Björnsson, 2002). Given this background, what is needed to accelerate reuse and recycling in residential construction? Diffusion of innovation (DOI) theory is helpful in understanding the barriers to adoption and the means to overcome those barriers (Rogers, 1995). DOI models such as ADOP2T (Lindsey, 1999) accurately predict that simply advertising the advantages of pollution prevention in construction are not likely to lead to widespread adoption. Change agents need to provide opportunities for industry decision-makers to observe successful demonstrations of the innovation at the "how-to" level to reduce risk/uncertainty to a point where adoption can occur. As such, concepts from DOI formed the theoretical grounding for this project.

This project involved a systematic assessment of P2/recycling practices by selected Illinois home builders and the development of strategies for accelerating adoption of construction waste minimization practices. The study focused on two counties, McLean County and Cook County<sup>3</sup>. The research goals were to:

1. Identify waste material generated by Illinois home builders in the selected counties that have the greatest potential for P2/recycling.
2. Ascertain on a county and/or local area basis the Best Management Practices (BMP) for diverting priority waste for recycling or reuse.
3. Determine barriers to implementing BMPs for P2/recycling and methods to overcome these barriers.
4. Act as "change agents" per the ADOP2T™ model by facilitating demonstration projects and associated publicity events in the selected counties.

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<sup>3</sup> Appendix A lists Will County as the second case study site. However, the downturn in housing during late 2007 and 2008 necessitated the selection of a different location within the Chicago Metro Area.

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## Procedures

The research project was, in part, a market research study. We used many of the research techniques common to the field of market research as applied to organizational customers. The work was conducted in eight steps:

1. Identify and establish a partnership with home builders.
2. Identify and quantify typical waste generated by new home construction.
3. Identify the priority waste items with the greatest potential for P2/recycling.
4. Identify local Best Management Practices (BMPs) for diverting the priority waste material from the landfill.
5. Interview builder partners to identify barriers to P2/recycling for the priority wastes and identify methods to overcome the barriers.
6. Work with builder partners to implement the proposed plan with at least one demonstration project in each county.
7. Produce case studies that document the effectiveness of the demonstration project implementation.
8. Facilitate publicity events at each demonstration project site whereby other builders can see firsthand how the waste management plan is implemented.

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## Results and Discussion

The results will be presented and discussed using the procedural steps listed above.

### ***1. Establish partnerships with home builders.***

The faculty of the Illinois State University Construction Management program maintain positive relationships with many Illinois builders and active participation with professional organizations such as the Bloomington-Normal Area Home Builders Association, a local affiliate of the National Association of Home Builders, and the Chicago area Residential Construction Employers Council. In McLean and Cook Counties, a group of builders and waste haulers were identified and solicited to participate in the research project. The sample size was 16 and 10 individuals, respectively, in McLean County and the Chicago metropolitan area. Partner selection was based on the leadership roles in the construction community, willingness to adapt to new practices, and potential to host a demonstration project and act as mentors for other builders. Waste haulers were added as partners because of their service arrangements with specific builders and their pivotal role in diverting waste materials to recyclers. Recruitment materials are presented in Appendix A: Industry Partner Solicitation, and Appendix B: Script for Soliciting Builder Participation in P2/Recycling Demonstration Projects.

### ***2. Identify and quantify typical waste generated by new home construction.***

Two research-based studies were located that provided a baseline for the type and quantity of residential construction waste. Cornell University, in conjunction with the Home Builders Institute, compiled archival data from waste audits on six residential projects in various locations in the United States (Yost and Lund, 1995, 1997). One project was a 6-unit apartment building; the remaining five were single-family homes with an average size of 2350 square feet. To compare and validate the waste volumes, a waste audit was conducted by the Cornell research team on a bi-level home in Highland Mills, NY. It should be noted that the bi-level home audited in New York is a very efficient design and would be expected to generate lower waste material levels. Of the seven projects analyzed, waste volume ranged from 2.5 PSF to over 7.0 PSF, with both an average and median of approximately 4.5 PSF. By weight, the total waste was comprised of 5.4% cardboard, 29.0% gypsum board, 39.7% wood, and 25.9% all other materials. The findings showed that percentages of cardboard, wood, and gypsum waste were relatively consistent regardless of the size or style of the structure. More recent work by Laquatra and Pierce (2002, 2004) reported waste volumes consistent with earlier studies. It is of note that few construction waste audits have been conducted over the years and that a U.S. EPA (2009) estimate of residential C&D waste included the aforementioned audits in their statistical sample of 95 projects from eight sources.

In the present study, Illinois builders were asked to estimate the percentage of waste from common building materials. Although there was considerable variability in the percentage estimates (see Appendix C: Typical Waste Generated by New Home Construction), overall the major waste sources of cardboard, wood, and gypsum were within the ranges reported by the Cornell University study. However, two of the haulers interviewed indicated that the weight of waste should be double the amount reported in the earlier audits. To verify and quantify the perceived waste volumes, the research team requested and received from McLean County

haulers actual waste data for 12 single-family homes. The compiled results are presented in Table 1. Overall, the waste weights and quantities reported by the haulers are consistently higher than previous waste audit results. The McLean County demonstration project generated 8.30 PSF of waste, consistent with the data reported by McLean County haulers of 8.63 PSF. Data from the Cook County demonstration project home are not comparable to previous audits because of the unique nature of the structure (LEED-H Platinum and Net-Zero Energy Home) and the demolition of an existing home on the site that was included in the C&D waste totals.

As another comparative data point, the U.S. EPA (2009) reported waste generation rates of 2.41 to 11.30 PSF. At the higher end, these audit amounts are much closer to the McLean County data. In explaining this wide range in waste generation, the report noted variation in house types, local practices of the home builders, changes in materials and methods over time (early 1990s to 2000s), and the lack of standardized auditing practices for estimating waste volumes.

**3. Identify the priority waste items with the greatest potential for P2/recycling.**

As previously discussed, the review of literature and data collected from respondents confirmed that wood (solid and engineered), gypsum board, and cardboard are the priority materials for P2/recycling. Details are presented in Appendix D. Interviews with builders, haulers, and recyclers confirmed that these three materials comprise the highest percentage of the residential construction waste stream, typically about 75% of total waste, and have the greatest potential for recycling.

**4. Identify local Best Management Practices (BMPs) for diverting the priority waste material from the landfill.**

The deliverables for this step included: (a) a listing of agencies/firms willing to accept priority waste and the costs associated with material reuse/recycling, and (b) job-site practices that best facilitate waste minimization.

Table 1. Residential Waste Data from McLean County Haulers (2007).

New Construction SF	Construction Waste (Ton)	Roll-Off Box Volume (CY)	Waste per SF of Floor Area
2182	10.45	70	9.58
2326	7.70	70	6.62
2409	10.22	80	8.48
2456	11.39	80	9.28
2565	12.66	90	9.87
2700	15.71	100	11.64
2725	11.62	80	8.53
2874	18.56	120	12.92
2970	8.51	80	5.73
3027	15.50	90	10.24
3534	8.49	60	4.80
4256	12.48	100	5.86
Avg: 2835	11.94	85	8.63



Recycling Infrastructure. Waste diversion is highly dependent upon the local recycling infrastructure because transportation costs rapidly negate any P2 benefit of recycling. In many municipalities, cardboard can be readily recycled and generates a small positive cash flow for the builder or hauler. Wood recycling facilities are more limited; only one firm provides this service in Central Illinois.

For all practical purposes, gypsum cannot be recycled or diverted from landfill by home builders in Illinois. An exception exists in the Chicago area, where at least one recycler will provide a separate watertight box for storage and eventual recycling of source-separated, clean gypsum waste, which is hauled to a facility in Indiana. According to the recycler, gypsum recycling has only been utilized on commercial LEED projects that generate substantial quantities of waste. A Central Illinois hauler reported a similar gypsum recycling process for a commercial LEED project in Champaign, IL, where the gypsum waste was also trucked to Indiana. However, recycling gypsum in this way is cost prohibitive for relatively small waste volume projects, which are the norm for single-family residential construction.

Although not a priority recycling material for residential construction because of the small volume generated, a mature recycling infrastructure exists for metal and concrete/masonry in most areas. Trade contractors who work with metal, such as plumbers and electricians, typically take their scrap material with them at the end of the job. Similarly, trade contractors who work with concrete typically haul and recycle the waste material generated. This was the observed practice at the McLean County demonstration project.

Listings of agencies and firms that comprise the recycling infrastructure in McLean and Cook Counties are provided in Appendix E. Some cost data is also included. However, pricing information is often considered a competitive advantage and not divulged without a specific contract.

Best Management Practices (BMPs). Data gathered from builders and haulers in both counties, as well as a review of the literature, resulted in the following compilation of best job-site specific recycling implementation practices. The BMPs are biased toward a market solution where source-separation is required. If recycling centers exist in the area that will take commingled waste from the construction site and sort off-site, as is the case in Cook County, then the only consideration is cost because no additional management or supervision time is required to facilitate source-separation of waste. The researchers found that the BMPs identified in the partner interviews were very consistent with *Chicago's Guide to Construction & Demolition Cleanliness & Recycling* (2005) published by the City of Chicago and available online.

The compiled best management practices (BMPs) for source-separation of construction waste included:

- A. Identify materials that can be recycled. At a minimum, cardboard, wood, metals, and concrete have high potential for recycling. Before starting construction, review the project construction drawings to inventory the (a) specific types of materials utilized, (b) estimated material waste volumes, and (c) expected conditions of materials, i.e., are the materials reusable or only recyclable?

- B. Locate the recycler that will be accepting materials at the best price. Research whether the materials can be recycled locally. When discussing the types of materials with potential recyclers, talk about the (a) quality of materials, (b) handling considerations, (c) volumes of materials that the recycler can accommodate, and (d) cost of recycling services.
- C. Do your financial homework - is recycling/reuse feasible? Determine the economic benefits of recycling your C&D materials and compare it to the traditional fees for land-filling or disposal at a transfer station. It may be a moot point if permits require recycling and diversion of waste from landfill.
- D. Develop a waste management plan. Elements of an effective waste management plan include identification of appropriate recycler(s), waste hauling contracts and considerations, monitoring procedures, planning for on-site storage and source-separation of the construction waste (if possible), or utilization of a recycling center. Project storage space and ability to site multiple roll-off boxes is the key factor in the decision to separate on-site or commingle and have separation occur at a recycling center.
- E. Educate your employees and subcontractors. It is important to not only provide training on expected waste management practices, but to also involve employees and subcontractors in the establishment of site-specific procedures to gain their support and minimize the risk of contamination and non-compliance. Interestingly, the suggestion of using contractual remedies, such as specific contract language or withholding payments for non-compliance, was greeted with only mixed support from respondents.

***5. Interview builder partners to identify barriers to P2/recycling for the priority wastes and identify methods to overcome the barriers.***

Interviews were conducted with project partners to identify barriers to the implementation of effective P2/recycling practices and ways to overcome those barriers. The data collection formats included a combination of paper or email surveys, face-to-face or telephone interviews, and a focus group held as part of a local home builders' association meeting. The survey form and detailed results from interviews are documented in Appendix F.

The structured interview process based on the survey was the least useful method of identifying barriers to P2/recycling and ways to overcome barriers. This may have been the case because builders did not have experience with P2/recycling. The most useful information regarding barriers was acquired while working with builders and haulers to establish a demonstration project. Through all of these ways of engaging stakeholders, numerous barriers to P2/recycling were identified for builders of single-family homes attempting to implement an on-site source-separation recycling program. The lessons learned from this process were utilized to develop site-specific waste management plans for builders to evaluate and implement as demonstration projects.

Barriers and potential solutions are summarized below. However, it must be noted that almost all of these barriers disappear if construction waste can be commingled in one roll-off box on site and separated at a recycling center.

- A. Builders were willing to consider recycling options if the total cost of waste hauling did not increase. Although not a barrier from the builders' perspective, the relatively low cost of landfill fees in the Midwest makes it difficult for market-based recycling to provide economically viable alternatives.
- B. Inadequate site space is available for multiple roll-off boxes to facilitate source separation. One solution is to partition one roll-off box to accommodate multiple sorted waste materials (see item D below).
- C. New home construction generates approximately one pound of gypsum waste per square foot of floor area (Laquatra, 2004; U.S. EPA, 2009). Haulers and recyclers identified gypsum as the most important material to recycle in order to accelerate the recycling of C&D waste. Although legally and technically possible, recycling gypsum board in Illinois appears to be prohibited administratively by the Illinois Environmental Protection Agency (IEPA). The research team held discussions with IEPA representatives and U.S. EPA officers from Iowa, Michigan, and New York, and concluded that nothing in Federal or Illinois law prohibits the collection, grinding, land application, or recycling of drywall. Further, a member of the Illinois General Assembly legislation research unit (personal communication) who was seeking answers regarding regulatory statutes in Illinois that prohibit the reuse/recycling of gypsum wallboard also found no such statutes.

However, any recycling action that involves the land application of gypsum would require handling a waste and would, therefore, require a special use permit. Following discussions with IEPA and investigation of gypsum diversion alternatives in other states, the research team prepared and submitted a special use permit proposal by email to the IEPA in Springfield, IL. One of our waste hauler partners was willing to pay for the permit should it be granted. As of this final report date, there has not yet been a response from IEPA. Personal communication with haulers and recyclers suggest that IEPA has never approved such a permit. A concerted effort needs to be made by all stakeholders to find a workable solution to gypsum recycling options in Illinois. Other states have pursued gypsum recycling options. Appendix G presents an expanded discussion of issues related to gypsum recycling in Illinois together with example solutions from other states. Further, reports by Vermont Agency of Natural Resources Waste Management Division (2000) and Laquatra (2004) provide background to the scientific issues related to land application of gypsum.

- D. Builders work with specific haulers, not all of whom were willing to change practices or routes to accommodate recycling. The research team identified a hauler who was willing to partition a standard 20 cubic yard roll-off box to allow source-separation with only one box on site. The hauler would provide the modified roll-off box at the same fee and expected to recoup costs from reduced transportation and landfill fees.

The research team could not persuade a builder to switch haulers to facilitate this test project.

- E. Illegal dumping of non-construction refuse, such as garage sale remnants, furniture, and toxic materials, can quickly undermine builder enthusiasm for recycling. Most jurisdictions now require roll-off boxes to be covered with a tarp at the end of the work day. Some builders report that covering roll-off boxes with a tarp does discourage illegal dumping; others report that the non-construction materials are simply placed on top of the tarp. The solution to illegal dumping in commercial construction is gated and locked project sites, which is not feasible on scattered single-family housing sites.
- F. Source-separation requires significant supervision, trade education, and on-going monitoring. The McLean County demonstration project was successful in recycling wood and cardboard only because of subsidized and vigilant monitoring of roll-off boxes by ISU personnel. On almost every site monitoring visit, contaminating materials were removed from source-separated recyclable material. Some of these contaminating materials originated on-site, while others resulted from illegal dumping. Over time, with continuous commitment from management and implementation of procedures to prevent illegal dumping, a culture of source-separated recycling should evolve.

#### ***6. Implement P2/recycling plans as demonstration projects.***

Two demonstration projects were facilitated for this project: one in McLean County and the other in Cook County. Very different recycling procedures were utilized at each of these sites and, as a result, very different results were achieved.

McLean County. The McLean County demonstration project was a four-unit townhome of approximately 6,000 square feet (1,500 square feet per unit) in Normal, IL, undertaken in conjunction with Brady Homes. The project began in mid-November 2007 and was finished about May 27, 2008, when the last roll-off box was removed from the site.

Prior to framing stage, there were no roll-off boxes on-site because the foundation and site contractors recycled all concrete overage and removed their own waste materials, which were minimal. At the framing stage, two 20 cubic yard (CY) roll-off boxes were placed on site: one for wood and one for residual waste/trash. In February, coinciding with the application of vinyl siding that was delivered to the site in cardboard cartons, a 20 CY roll-off box for cardboard only was also placed on-site. The boxes were monitored and photographed by ISTC grant personnel about every second working day. Project signage was sponsored by a grant from State Farm Insurance. Recycling signage was ordered from WasteCap Wisconsin in late December with signs positioned as roll-off boxes were placed on-site.

The project generated 24.44 tons of waste that was hauled off the site in ten loads. The waste equaled 8.15 PSF. Two 20 CY boxes of wood and one 20 CY box of cardboard were recycled. Recycled material weighed 6.62 tons and resulted in 27% of the waste being diverted from the landfill. Unfortunately, another almost full 20 CY box of cardboard was contaminated

Table 2. Waste Material Tracking from McLean County Demonstration Project.

Load Date	Material Hauled (Wood, Cardboard, Trash)	Total Waste (Tons)	Recycled (Tons)	Volume (CY)	Recycling/ Reuse/ Landfill
1	1/25/08 Wood	3.00	3.00	20 CY	Recycle (Twin City Wood)
2	2/13/08 Trash	3.67			Landfill
3	3/7/08 Trash (contaminated cardboard)	1.85			Landfill
4	3/7/08 Trash	2.99			Landfill
5	3/11/08 Wood	3.00	3.00	20 CY	Recycle (Twin City Wood)
6	3/29/08 Trash (mostly gypsum)	3.49			Landfill
7	3/31/08 Trash (mostly gypsum)	2.64			Landfill
8	4/4/08 Trash (mostly gypsum)	1.43			Landfill
9	5/8/08 Cardboard	0.62	0.62		Recycle (Midwest Fiber)
10	5/27/08 Trash	1.75			Landfill
Total		24.44	6.62		27% Diverted

when a skid loader cleaning the project parking lot dumped mud and other refuse into the box. Failure to recycle this load of cardboard decreased the diverted waste by approximately 1,200 lbs. Table 2 provides tracking data for the McLean County (Normal, IL) project.

The three roll-off boxes of mostly gypsum board waste weighed 7.56 tons or 30% of the total project waste by weight. Estimating the gypsum waste ratio at 80% of the total weight yields approximately 12,000 pounds or 2 PSF. This amount is double the rule of thumb value of one pound per square foot of floor area for residential construction suggested by previous studies (Laquatra and Pierce, 2004; and Yost and Lund, 1995, 1997). The significant increase in gypsum board waste may be attributed to several factors at play in comparatively small multifamily units. First, relatively small room sizes generate more waste from window and door cutouts per floor area than larger units. Second, double layers of 5/8 inch Type X gypsum board and/or shaft wall are utilized for the fire-rated assemblies between the four units.

Overall, waste recycling and source-separation procedures were executed according to the waste management plan presented in Appendix H. Most subcontractors were cooperative and responsive. The percent diverted was lower than planned, 27% vs. 40%. Wood comprised most of diverted waste weight (40 CY with an approximate weight of 6 tons). Using previous research from single-family homes as guidance, wood should have contributed approximately 40% of the total waste. On this project, the lower volume of wood waste can likely be attributed to the panelized wall sections used for framing the structure. In spite of overall cooperation at source separation, contamination was a constant concern. Vendors, such as the gypsum supplier, put dunnage in the “cardboard only” box on several occasions. This lack of compliance did not

seem malicious. Rather, delivery personnel and trade contractors were likely just not used to working on residential projects with recycling requirements.

Examples of McLean County site monitor reports are presented in Appendix I. Monthly reports by supervisory personnel are included in Appendix J. Photo boards that document the waste management procedures during the months of January through March are presented in Appendix K. These boards were developed and utilized during the demonstration project publicity event on March 28, 2008. After that time, only cardboard was recycled and, therefore, additional photo boards were not created from the monitor reports.

Cook County. The Cook County demonstration project, the Yannell house, was a two-story 2675 square foot home seeking certifications for Leadership in Energy and Environmental Design for Homes (LEED-H) Platinum and Chicago's Zero Net Energy Homes (ZNEH). The LEED-H requirements for waste management were to divert 86% of the waste from the landfill, maintain weekly recycling reports, and limit wood framing waste. The home incorporated a variety of site-related green products including 100% pervious paving, two green roofs, solar panels, and a zero-turf landscape design. The Yannell home was a high profile project that generated significant attention in the green media. The following websites provide additional project details and photographs:

- <http://www.greenhomechicago.us/Site/Welcome.html>
- <http://www.theyannellhouse.com/>
- <http://www.greenbeanchicago.com/leed-for-homes-project-vies-for-zero-net-energy/>

The project started in December 2007 with the demolition of the old two-story house and was substantially completed at the end of March 2009. The wood framing started mid-March 2008 and it was at this stage that the research team became involved in the project to facilitate and document the waste management plan. Due to the site restriction, it was not possible to have more than one roll-off box on-site. As a result, the builder contracted with a recycling facility for hauling and recycling of commingled waste which, with the exception of food waste, could all be placed in a single roll-off box. The commingled construction waste was hauled to the recycling facility for material separation and recycling. The quantity and type of material recycled was estimated by an expert at the recycling facility at the time the waste was dumped for sorting. The steps in the sorting and recycling process are illustrated in Appendix L.

There are major advantages to placing all construction waste in the same roll-off box for sorting and recycling at an off-site facility. Commingled construction waste means that trade contractors do not need to alter their job-site practices, which in turn eliminates the need to monitor the roll-off box for content contamination. The recycling center provides the necessary data and waste separation. Unlike the McLean County project, where the waste was source-separated and a unique waste management plan was established, the waste management plan for the Yannell house was integrated with the LEED-H project and documentation provided by the recycling contractor (see Appendix M). Table 3 provides the material tracking and recycling report as of February 28, 2009, for each roll-off box hauled off site. At this point in the project, only some interior finish work remained to be completed. It was estimated that one more roll-off box will be hauled and recycled at final completion (April 15, 2009). This final roll-off box was

Table 3. Waste Material Tracking by Load from Cook County Demonstration Project.

Load	Date	Roll-off Box Vol (CY)	Wt Tons	Inert <sup>1</sup> Tons	Metal Tons	Wood Tons	OCC <sup>2</sup> Tons	Non- Recycled Materials Tons
1	12/14/2007	10	5.72	0.00	0.00	4.00	1.03	0.69
2	1/7/2008	20	4.22	0.00	0.21	3.17	0.42	0.42
3	3/11/2008	20	2.97	0.33	0.00	1.72	0.39	0.53
4	4/3/2008	20	2.74	0.00	0.00	1.34	0.85	0.55
5	4/30/2008	20	1.9	0.00	0.15	1.29	0.21	0.25
6	5/29/2008	20	2.23	0.25	0.00	1.52	0.33	0.13
7	6/23/2008	20	3.13	0.44	0.00	2.00	0.38	0.31
8	7/24/2008	20	2.21	0.35	0.00	1.37	0.20	0.29
9	10/02/2008	20	2.22	0.67	0.00	1.33	0.00	0.22
10	10/30/2008	20	3.08	1.08	0.15	1.39	0.31	0.15
11	12/22/2008	20	5.59	0.56	0.28	3.91	0.00	0.84
12	02/02/2009	20	2.91	0.58	0.15	1.75	0.00	0.44
Totals		230	38.92	4.26	0.94	24.79	4.12	4.82
%			100	10.95	2.42	63.69	10.59	12.38

Source: Recycling Systems Inc.

\*Table Notes:

1. Inert materials are soil and concrete/ concrete blocks. Anything with fine particles can be recycled as soil or alternate daily cover (ADC) for landfill. Waste is considered inert if the material:
  - a. Does not undergo any significant physical, chemical or biological transformations;
  - b. Does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and
  - c. Total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater.
2. OCC is Old Corrugated Cardboard.

not expected to alter the percentages of materials recycled. In total, 38.92 tons of construction waste was hauled from the home for sorting and recycling. All but 4.82 tons of waste was diverted from the landfill, which yielded a recycling ratio of 87.64%. Emphasizing the unique nature of the home, the waste generated was almost 29 PSF or about four to five times the average waste for a home of this square footage reported in previous studies. It must be noted, however, that this waste volume also included the demolition of an existing home on the site. Table 4 presents the typical use for the recycled construction materials.

Table 4. Typical Uses of Recycled Construction Materials from Cook County Demonstration Project.

	Material Type	Typical Recycling Use
Inert	Clean heavy debris including brick, concrete, soil, masonry, CMU, cinder block, asphalt, screened 1" and under debris.	Used for base and sub-base for roads and highways, land reclamation, embankments, and Alternative Daily Cover.
Wood	Includes non-hazardous painted, treated dimensional lumber; trim and sheet materials; railroad ties; telephone poles; and some tree cuts (not stumps).	Used for mulch (landscaping), boiler fuel, cover for wildlife habitat, compost bulking medium, feedstock for pulp mills, raw material for chipboard, and wood flour for plastic fiber.
Metal	All types of metal ferrous and non-ferrous recycled through local scrap metal processors.	Clean high quality material is sent to a mill for re-smelting; lower quality material is sent to a secondary market for further processing.
OCC	Old Cardboard containers, office papers, packing and shipping cartons, and papers.	Used for toilet and tissue paper, hand towels, napkins, cereal boxes, egg cartons, and newspapers.

**7. *Develop case studies that document the procedures and results of the demonstration projects.***

Case studies were developed for each demonstration project as two page back-to-back fact sheets that outline the P2/recycling results. The purpose of the fact sheets is to provide at a glance the waste management methods and results for the builder. The case studies will be used at dissemination events. The fact sheets are provided in Appendix N.

The direct financial benefits were minimal to the builders in either project. In McLean County, the builder paid the usual hauling fees per box even though the wood and cardboard were diverted from the landfill. The builder attributed the need for one less dumpster, a saving of \$325, to the recycling program. The hauler may have reduced transportation costs by dropping recycled materials at local recyclers and also received a credit for cardboard. These savings were not passed on to the builder, but rather accrued to the hauler to offset the additional overhead costs of having multiple roll-off boxes tied up on the site.

The Cook County situation was much different because the waste was commingled into a single box on a very tight building site and then hauled to a recycling center for material recovery. To be competitive, the recycler must keep fees in line with other waste firms that haul all material directly to the landfill. Although pricing is proprietary, the hauler provided the following estimates of recycling recovery costs and revenues. The costs displayed in Table 5 will vary based upon location, infrastructure, operating efficiency, and marketplace conditions.



Table 5. Recycling Costs or Revenues and Disposal Costs in Chicago Metro Area 2008.

Material	Recycling Cost or (Revenue)*	Disposal Cost
Inert Material	\$10 - \$14 per/ton	\$18 - \$50
Metal	(\$50 - \$250 per/ton)	\$ 0 - \$50
Wood	\$18 - \$ 35 per/ton	\$25 - \$50
Cardboard	\$10 - (\$40) per/ton	\$ 0 - \$50

\* Potential range of revenue indicated in parentheses.

Interpreting Table 5, inert material can be recycled at a cost of \$10 to \$14 per ton as opposed to a disposal cost of \$18 to \$50 per ton. The resulting savings by avoiding disposal costs range from \$4 to \$36 per ton. For items in parentheses, such as metal, the recycler can earn \$50 to \$250 per ton by selling the metal as opposed to paying disposal costs of \$0 to \$50 per ton. Revenue gains from material recovery for the Yannell project were estimated at about \$736, using the median recovery or disposal cost from Table 5. These cost savings were used to finance the operation of the recycling center and were not passed back to the builder. From the builder's perspective, recycling was cost-neutral, which makes waste recycling competitive with landfill pricing.

#### **8. Disseminate results from each demonstration project to builders.**

The results of P2/recycling efforts at each demonstration site were presented to stakeholder groups through demonstration events on-site and Internet links.

McLean County. A demonstration event was held on Friday, March 28, 2008. All of the project partners attended along with local media (WJBC, Cable 10 TV, and the Pantagraph), a representative from State Farm Insurance, and Ken Barnes of ISTC. The program lasted two hours and included (a) a site tour; (b) photo boards that charted weekly progress and documented waste management practices; (c) networking and informal conversation; (d) presentation with speakers from ISU, ISTC, Brady Homes, and Contractors Disposal; (e) question and answer session; and (f) media interviews with key representatives. Press releases and articles published or aired by the media are presented in Appendix O. The McLean County case study is available at: [http://www.istc.illinois.edu/info/library\\_docs/TN/Construction-and-demolition-case-study-Normal-IL.pdf](http://www.istc.illinois.edu/info/library_docs/TN/Construction-and-demolition-case-study-Normal-IL.pdf).

Cook County. The demonstration event in Chicago was held on April 8, 2009. Invitations were distributed by email to the listservs for major home building organizations in the Chicago area, the Home Builders Association of Greater Chicago (HBAGC) and the Residential Construction Employers Council (RCEC), as well as project partners and customers of the recycling service contractor. Follow-up emails were sent directly to all builder members of the HBAGC. The event announcement was also posted on the Illinois Sustainable Technology Center (ISTC) website. All email event notices included the Internet link to the demonstration project case studies housed on the ISTC website.

Approximately 15 individuals from a variety of construction disciplines attended the event which featured (a) a brief speaker program by project partners highlighting the keys to

success; (b) an opportunity to view photo boards and network informally with building partners; and (c) a tour of innovative LEED-H features of the home led by the project site manager. There were no press releases or photographs associated with this demonstration event because of an exclusive publicity agreement arranged by the architect. However, the Cook County project case study was distributed to all members of the HBAGC and RCEC and is readily available the ISTC website at: [http://www.istc.illinois.edu/info/library\\_docs/TN/Construction-and-demolition-case-study-Cook-county.pdf](http://www.istc.illinois.edu/info/library_docs/TN/Construction-and-demolition-case-study-Cook-county.pdf). In addition, Recycling Systems, Inc. maintains a link to the Yannell house case study at: <http://www.recyclingsystemsinc.com/index.php?p=studies>.

## Conclusions and Recommendations

Two very different demonstration projects were solicited and documented as a result of this study. In Normal, IL (McLean County), the demonstration site was a four-unit townhome in a new subdivision. The site had adequate room for multiple roll-off boxes in order to facilitate source-separation by trade partners. The Cook County demonstration was a LEED-H Platinum home in the Ravenswood area of the City of Chicago on a very tight infill site with barely enough space for one 20 cubic yard roll-off box. The waste materials from this project were commingled on site and separated for recovery at a recycling center.

Waste source-separation at the McLean County site necessitated changes to production and management protocols. As a result, there were many barriers to the implementation of the waste management plan and the successful recycling that did occur required vigilant monitoring of the recycling roll-off boxes. By comparison, the Cook County demonstration commingled all construction waste into one roll-off box for sorting at a recycling center and did not require any procedural changes on the part of the builder or subcontractors.

Given the fragmented nature of residential construction – small and scattered building sites, relatively small volume waste streams, and little consistency in trade labor from site to site – commingled waste deposited into a single roll-off box with sorting at a recycling center may be the only viable long-term solution to accelerating recycling by single-family home builders.

The findings of this study yielded the following conclusions and recommendations:

1. Residential construction waste volumes generated in the McLean County demonstration project of 8.15 PSF and waste averages calculated from hauler invoice documentation from a sample of single-family homes in McLean County (8.63 PSF) were considerably higher than the 3.0 to 6.0 PSF range reported in earlier waste studies. These higher values could occur for multiple reasons. Many of the previous audits were conducted on the East and West Coasts where landfill fees are considerably higher than in the Midwest and could promote more judicious waste management. Further, as noted by the U.S. EPA (2009), waste generation amounts can vary widely influenced by variations in home designs, local building practices, and changes in materials and methods over time. The U.S. EPA study reported waste volumes for specific projects ranged from 2.41 PSF to 11.30 PSF. Although at the higher end of the reported range, the McLean County waste findings are not inconsistent with the findings of that study.
2. In spite of the relatively long list of potential waste materials generated during new home construction, only three materials – cardboard, wood, and gypsum board – comprised about 75% of the waste. This volume ratio was confirmed by estimates from stakeholder partners, data from the McLean County demonstration project, and the review of literature. Facilities for recycling cardboard and wood exist in many locations; however, options for recycling gypsum board are in their infancy at best and need to be expanded.
3. Options for recycling of gypsum board in Illinois are very limited. Surrounding states typically allow options for recycling gypsum. New, clean, and dry gypsum wallboard scraps can be hauled to a manufacturer in Indiana for reprocessing and several haulers in the Chicago metro area can facilitate this option. Given the collection and transportation

costs, recycling gypsum in this way is typically limited to commercial construction LEED projects. However, no recycling options were found to exist in Illinois for reprocessing waste gypsum into new wallboard or land application as a soil amendment or composting bulking agent. Investigation indicated that there are no regulatory statutes in Illinois that prohibited the reprocessing or recycling of gypsum wallboard. The barrier to waste drywall recycling does not appear to be technical or economical, but rather administrative. Diverting a significant amount of scrap gypsum from landfills in Illinois will require collaborative action by all stakeholders to find a workable solution. See Appendix G for an expanded discussion and potential solutions.

4. Successful recycling of wood and cardboard only occurred at the demonstration site in McLean County because of vigilant waste monitoring and removal of contamination by the research team -- essentially subsidizing the recycling program. The builder for the McLean County demonstration project did not have the staff or budget to police the roll-off boxes for compliance with the source-separation recycling program. As the McLean County demonstration project construction manager noted, "All construction waste would go to landfill if it were not for effective monitoring!"

Source-separation requires substantial procedural changes for builder supervisors, trade partners, delivery personnel, and haulers. The trade partners need to sort waste into the appropriate roll-off box. The site superintendent must promote the recycling program and educate the trade partners. Haulers have to adjust disposal routes to accommodate trips to various recycling service providers, and locate recycling boxes for wood and cardboard on site for longer periods of time. These changes in practices impact productivity for all stakeholders and are a major source of resistance to any on-going recycling endeavors.

Solutions to these productivity issues are best managed by commingling all waste on the construction site and separating at a recycling facility, a service that is readily available in the Chicago metro area. Recycling centers typically divert as much as 85-90% of waste from landfill. This approach makes recycling immediate, effective, and does not change work practices. Waste at the Cook County demonstration home was commingled, which virtually eliminated on-site recycling concerns related to productivity. This may be the only viable long-term solution to accelerating recycling by single-family home builders.

However, recycling centers need significant volume to be financially feasible and no recycling centers currently operate downstate. Landfill waste is often trucked rather long distances. It seems logical that a regional recycling center could serve numerous smaller communities and not increase hauling distances. For example, a recycling center located centrally between the communities of Bloomington-Normal, Champaign, and Decatur could generate the waste volumes needed to be financially feasible. Recycling centers can also handle municipal waste. It may be time to stop discussing construction waste in isolation and begin looking at more comprehensive waste management policies for communities and/or counties, much like we do water treatment.

5. There is a high probability of illegal dumping into roll-off boxes at unfenced residential construction sites. Illegal dumping occurred at both demonstration sites, one in a relatively isolated new subdivision and the other at an urban infill site. And, although

illegal dumping is “illegal,” local jurisdictions do not actively enforcement the ordinance. On at least four occasions during the McLean project, illegally dumped materials were found to have contaminated the roll-off boxes reserved for separated recyclable materials. At the Chicago project, illegally dumped materials were not a source of contamination because all waste was commingled. However, the cost for illegal dumping was borne by the builder. Anecdotally, several builders reported that placing a tarp on the dumpster, as required by law, solved the illegal dumping problem. Other builders indicated that they had observed and dealt with illegally dumped material placed on top of the tarp or simply dumped beside the roll-off box. Illegal dumping is a significant problem at projects utilizing on-site material separation as an entire roll-off box can be easily contaminated and therefore rendered non-recyclable.

6. Finally, builders are rational business people who will adopt new means and methods when they are convinced the benefits outweigh the risks. Advantages for recycling may include cost reductions, perceived recognition as a green builder, or compliance with regulations. Builders in this study reported being willing to recycle if the process does not cost anymore than traditional landfill fees or create additional work on site. Both demonstration projects were cost-neutral to the builder, which indicated that recycling can be competitive with landfill pricing. The McLean County project may have generated a small saving to the builder because one less roll-off box was utilized than budgeted. The recycler in Cook County reported being cost-competitive with haulers who landfill all waste.

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## References

- Austin, T. (1991). Building green. *Civil Engineering*, August, 52-54.
- Bierma, T. and Waterstraat, F. (1995). Marketing pollution prevention. *Pollution Prevention Review*, Spring Issue, 63-72.
- Bierma, T. and Waterstraat, F. (2001). *Chemical management: Overcoming barriers to diffusion*. RR-087. Illinois Sustainable Technology Center (Formerly: Waste Management and Research Center), Champaign, IL.
- California Environmental Protection Agency. (2004). *Statewide waste characterization study*. December 2004. Accessed May 7, 2008. Retrieved from <http://www.calrecycle.ca.gov/WasteChar/WasteStudies.htm#2004>.
- California Environmental Protection Agency. (2006). *Targeted statewide waste characterization study: Detailed characterization of construction and demolition waste*. June 2006. Retrieved from <http://www.ciwmb.ca.gov/Publications/LocalAsst/Extracts/34106007/ExecSummary.pdf>
- Chartwell Information. (2008). *Solid waste market: data and research*. Environmental Business International, Inc. Retrieved from <http://www.wasteinfo.com/data.htm>.
- Chicago's Guide to Construction & Demolition Cleanliness & Recycling. (2005). Retrieved from [http://egov.cityofchicago.org/webportal/COCWebPortal/COC\\_ATTACH/ConstBestMgmtPractices2.pdf](http://egov.cityofchicago.org/webportal/COCWebPortal/COC_ATTACH/ConstBestMgmtPractices2.pdf).
- Jones, D.A. (1993). Dodging the dump. *Builder*, May, 246-249.
- Koebel, C., Papdakis, M., Hudson, E., and Cavell, M. (2004). The diffusion of innovation in the residential building industry. *Report for the Office of Policy Development and Research*. U.S. Department of Housing and Urban Development. Retrieved from [http://www.toolbase.org/PDF/CaseStudies/Diffusion\\_Reporta.pdf](http://www.toolbase.org/PDF/CaseStudies/Diffusion_Reporta.pdf).
- Laquatra, J. (2004). *Waste management at the construction site*. Retrieved from: [www.pathnet.org/si.asp?id=1069](http://www.pathnet.org/si.asp?id=1069). [Note: Although same title as the workshop materials of the same name by Laquatra and Pierce (2002), this is completely different material and includes extensive discussion of issues related to recycling gypsum.]
- Laquatra, J. and Pierce, M. (2002). *Waste management at the construction site*. Cornell, NY: Cornell Cooperative Extension. Retrieved from <http://ecommons.cornell.edu/handle/1813/64>.
- Laquatra, J. and Pierce, M. (2004). Waste management at the residential construction site. *Journal of Solid Waste Technology and Management*, 30(2), 67-74.
- Lindsey, T.C. (1998). Diffusion of P2 innovation. *Pollution Prevention Review*, Winter Issue, 1-14.

- Lindsey, T.C. (1999). Accelerated diffusion of pollution prevention technologies (ADOP2T). *Pollution Prevention Review*, 9(2), 33-37.
- Roger, E.M. (1995). *The diffusion of innovations*, (4th ed.). New York: Free Press.
- Taylor, J. and Björnsson, H. (2002). Identification and classification of value-drivers for a new homebuilding supply chain. *Proceedings of the Tenth Annual Conference of the International Group for Lean Construction IGLC-10*, 1-12. Gramado, Brazil.
- U.S. Environmental Protection Agency, Office of Enforcement and Compliance Assurance. (2005). *Managing your environmental responsibilities: Planning guide for construction and development*. April 2005. Washington, DC: Author. Retrieved from <http://www.epa.gov/compliance/resources/publications/assistance/sectors/constructmyer/myerguide.pdf>
- U.S. Environmental Protection Agency, Office of Resource Conservation and Recovery. (2009). *Estimating 2003 building-related construction and demolition materials amounts* (EPA530-R-09-002). Washington, DC: Author. Retrieved from <http://www.epa.gov/waste/consERVE/rrr/imr/cdm/pubs/cd-meas.pdf>
- Vermont Agency of Natural Resources, Waste Management Division. (2000). *Gypsum wallboard recycling and reuse opportunities in the state of Vermont*. Retrieved from <http://www.anr.state.vt.us/dec/wastediv/recycling/gypsum.pdf>.
- Yost, P. and Lund, E. (1995). *Residential construction waste management demonstration and evaluation*. Prepared for U.S. Environmental Protection Agency (Assistance Agreement Number: CX 822813-1-0) by the NAHB Research Center. Upper Marlboro, MD. Retrieved from [http://www.toolbase.org/PDF/CaseStudies/resi\\_constr\\_waste\\_manage\\_demo\\_eval.pdf](http://www.toolbase.org/PDF/CaseStudies/resi_constr_waste_manage_demo_eval.pdf).
- Yost, P. and Lund, E. (1997). *Residential construction waste management: A builder's field guide*. Upper Marlboro, MD: National Association of Home Builders Research Center. Retrieved from [http://www.toolbase.org/PDF/BestPractices/wastemngmnt\\_buildersguide.pdf](http://www.toolbase.org/PDF/BestPractices/wastemngmnt_buildersguide.pdf).



## Appendix A

### Industry Partner Solicitation

The Illinois State University Construction Management program has received a research grant from the Illinois Waste Management and Research Center (WMRC) to investigate ways to accelerate the adoption of waste minimization and pollution prevention best practices by Illinois home builders.

The major objectives of the project are to:

1. Document current waste minimization and pollution prevention practices.
2. Identify major barriers to more widespread adoption of waste minimization and pollution prevention practices.
3. Identify the Best Management Practices (BMP) to accelerate the adoption of practices design to minimize, substitute, reuse or recycle residential construction waste.
4. Facilitate demonstration projects and demonstration events to promote adoption of the BMPs in Will and McLean Counties.

In order to have the results be as practical as possible, our first task is to identify 10-20 influential members of the Illinois home building community to serve as partners/mentors in this project.

Partner/Mentors will be asked to commit to one or more of the following activities:

- Provide guidance on waste management and pollution prevention issues related to residential construction.
- Participate in an iterative interview to determine BMP related to waste management and pollution prevention issues related to residential construction.
- Provide information on specific waste management procedures and expenses, e.g., cost of waste hauling for a specific site/community.
- Possibly provide access to visit to a site/community.
- Consider being a demonstration site for a waste minimization and pollution prevention demonstration project.
- Review and comment on a draft BMP plan.
- Assist in disseminating the results by joining in presentations to professional builder groups.

#### What is in it for you?

- Free consulting on practical waste minimization and pollution prevention actions.
- Claim a marketing advantage as an environmentally friendly builder.
- Leadership position in residential waste minimization.
- Enhanced bottom line by diverting or minimizing construction waste.

We sincerely hope you are willing to participate in this research. Please RSVP to Rick Boser at Illinois State University by telephone, fax or email indicating whether your firm is interested in participating.

Name \_\_\_\_\_ Company \_\_\_\_\_ Phone \_\_\_\_\_ Email \_\_\_\_\_

Deadline for establishing our project partners is November 15, 2006. Thanks very much for considering participation in this project.

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## Appendix B

### Script for Solicitation of Demonstration Project Partners

Dear Participant,

Earlier this year we asked for your participation in a residential construction waste minimization and recycling program as part of a grant received by the Illinois State University Construction Management program from the Illinois Waste Management and Research Center (WMRC).

We are now ready to move into the demonstration project phase and are looking for several Bloomington-Normal area home builders to partner with us to minimize construction waste going to the landfill by locally recycling wood, cardboard, and hopefully gypsum board (still working out the details for gypsum board). We have made arrangements with two haulers to provide this service: XXXX & XXXXXX

If you are willing to participate, please contact one of these haulers directly and also let me know. Fees for waste hauling should be the same as you are currently paying. ISU staff will provide assistance with the waste management plan only. The business arrangements and payments will be between you and the waste haulers.

Our goal is monitor the waste and recycling from the construction of four new homes. We hope to start as soon as possible and follow the four homes from start to completion.

**What we ask of you?** We anticipate that the major challenge will be sorting the waste into the compartmentalized dumpsters. To this end, we ask the following of you, your superintendents, and subcontractors:

- Commit that their workers and subcontractors are willing (or contracted) to separate the waste. ISU staff is willing to provide training for your superintendent and workers as needed, and/or contract language and specs for subs.
- Grant ISU staff permission to audit the dumpsters as needed (daily/weekly).
- If there is contamination of separated waste, the responsible subcontractor will remedy.

**What's in it for you?**

- No change in waste hauling fees and the possible of cost reductions in the future.
- PR from participating in the recycling program.
- Marketing advantage for your participation in this green building project.
- Recognition as a leader in new ideas in residential construction.

We look forward to working with you on this waste minimization demonstration project. I'll follow-up with a phone call this week or please feel free to call me at 309.438.3696 to discuss this demonstration project further.

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## Appendix C

### Typical Waste Generated by New Home Construction

The literature regarding residential waste continues to reference the benchmark 1993 NAHB Research Center waste audit published by Yost and Lund (1995) for identifying and quantifying the typical waste generated in single-family home building. More recent work by Laquatra and Pierce (2004) confirmed that these waste volumes were still generally valid. Yost and Lund compiled data from waste audits on six homes in various locations in the United States, as well as conducting a waste audit for a bi-level home in Highland Mills, NY. It should be noted that the bi-level home audited in New York is a very efficient design and would be expected to generate lower waste material levels. The results of the audit are summarized in Table C-1.

Interviews with builders in McLean County suggested that the waste quantities reported by the Yost and Lund (1995) are still relatively accurate. However, two of the haulers interviewed indicated that the weight of drywall waste should be double what was reported in their study. The research team requested and received actual data from a McLean County haulers to quantify the perceived waste quantities. The results are presented in Table 2 of the narrative of this report. Overall, the waste weights and quantities reported by the McLean County hauler are consistently higher than previous waste audit results.

Table C-1. National Waste Audit Summaries.

	NAHB Oregon 3,000 SF	NAHB Maryland 2,200 SF	NAHB Michigan 2,600 SF	NAHB Maryland 2,450 SF	Illinois 2,060 SF	Illinois 9,000 SF 6 unit Apt	Cornell N.Y. 1,894 SF	Avg.
Total Pounds of Waste	13,684lb	10,210lb	12,182lb	9,378lb	14,860lb	33,560lb	4,656lb	
Waste per square floor of floor area	4.56 lb	4.64 lb	4.68 lb	3.84 lb	7.2 lb	3.73 lb	2.46 lb	4.44 lbs.
Cardboard Waste%/ Total Weight.	2%	4.2%	10.3%	5.1%	5%	6%	5.9%	5.4%
Gypsum Waste%/ Total Weight.	27.8%	27%	24.1%	31.4%	25%	25%	38.4%	29%
Wood Waste %/ Total Weight.	46.2%	41.1%	40.9%	33.9%	46.0%	44%	30.1%	39.7%
Subtotal Cardboard, Wood & Gypsum Waste%/Total Weight.	76%	72.3%	75.3%	70.4%	76%	75%	74.4%	74.1%

(Source [http://www.toolbase.org/PDF/CaseStudies/resi\\_constr\\_waste\\_manage\\_demo\\_eval.pdf](http://www.toolbase.org/PDF/CaseStudies/resi_constr_waste_manage_demo_eval.pdf))

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## Appendix D

### Priority Waste Items with the Greatest Potential for P2/Recycling

Laquatra and Pierce (2004) as well as Yost and Lund (1995) indicated that the combined amounts of waste wood, gypsum, and cardboard remain relatively constant regardless of a structure's size or style. Figure D-1 presents the overall percentage of residential construction waste attributed to wood, gypsum board, and cardboard. Figure D-2 presents the percentage of each of the priority materials. Wood and cardboard have at least some existing markets for recycling in McLean County; however, alternate uses for drywall are problematic in Illinois.

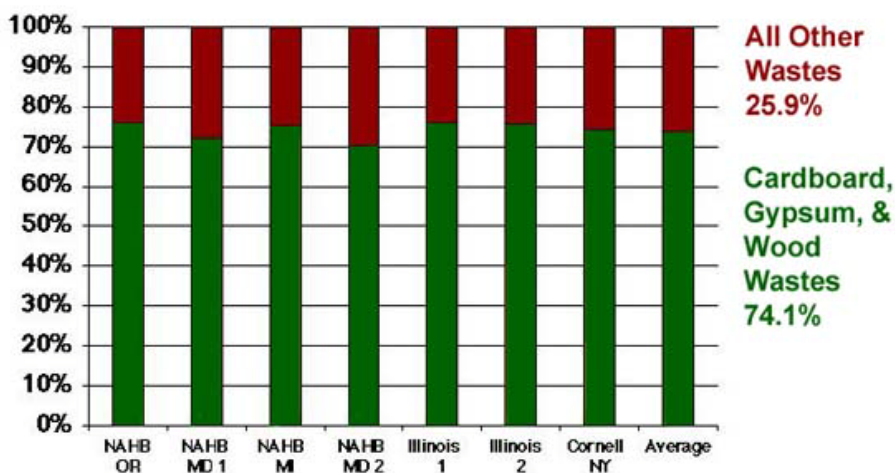


Figure D-1. Percentages of Combined Wood, Gypsum, and Cardboard Waste by Weight.

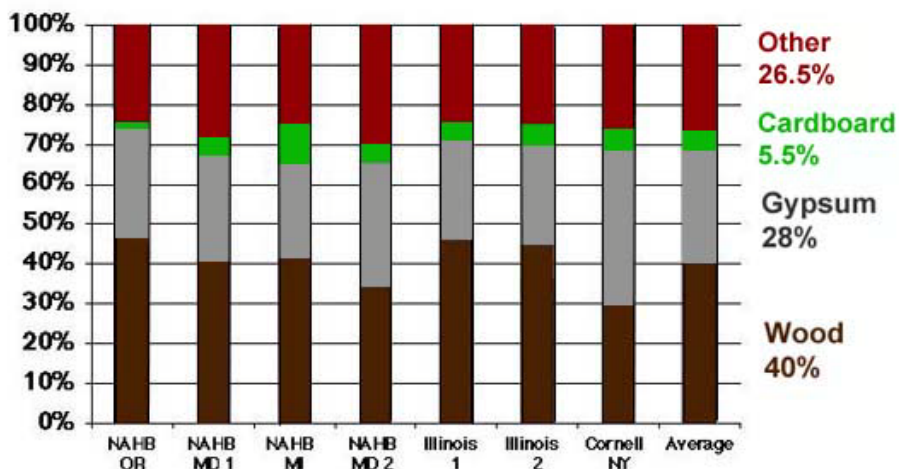


Figure D-2. Percentages of Wood, Gypsum, and Cardboard by Weight.  
(Sources: Laquatra and Pierce, 2004; Yost and Lund, 1995)

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**Appendix E**  
**Listings of Recycling Agencies and Firms in**  
**McLean and Cook Counties**

**Table E-1. Material Destination List for Typical C & D Waste in McLean County.**

	<b>Material Description</b>	<b>Destination Facility</b>	<b>Address</b>
1	Construction wood	Twin City Wood Recycling	1606 W. Oakland Ave Bloomington, IL
2	Construction wood	Kirk Wood Products	10424 E. 1400 North Rd. Bloomington, IL
3	Cardboard	Midwest Fiber Inc.	422 S. White Oak Rd Normal, IL

**Table E-2. Material Destination List for Typical C & D Waste in Cook County.**

	<b>Material Description</b>	<b>Destination Facility</b>	<b>Address</b>
1	Old Corrugated Cardboard Containers/ Mixed papers	Recycling Services, Inc	3301 W. 48th Place, Chicago
2	Metal, White Goods, Computer components	Acme Refining	3357 S. Justine, Chicago
3	Metal	General Iron	1910 N. Clifton, Chicago
4	Landscape Debris	Land and Lakes	Romeoville, IL
5	Landscape Debris	CDT landfill compost facility	Joliet, IL
6	Concrete	Lindahl Brothers, Inc	3301 S. California, Chicago
7	Asphalt and Concrete	Reliable Asphalt	3741 S. Pulaski, Chicago
8	Inert Material	Bluff City Material	2252 Southwind Blvd., Bartlett, IL
9	Inert Material	Land Reclamation Services	1127 S. Chicago St., Joliet, IL
10	Wood	Chicago Wood Waste	3020 E. 104th St., Chicago, IL
11	Wood	Homer Industries, LLC	14000 S. Archer, Lockport, IL
12	Plywood & Structural Timber	Building Salvage& Construction	2422 S. Halstead, Chicago
13	Drywall	US Gypsum	East Chicago, IN
14	Plastics	Antek Madison Plastics USA ltd	8822 S. Dobson Ave., Chicago
15	Glass Container	Recycling Alliance	10330 S. Woodlawn, Chicago

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## **Appendix F**

### **Waste Minimization Survey of Selected Home Builders in Illinois**

#### **Interview Schedule/Survey (Part A)**

#### **McLean and Will County Results (Part B)**

#### **Cook County Results (Part C)**



7. Does your company currently *recycle* any of the wastes generated at your site?

Yes                       No

If you answered "yes," please explain what and how: \_\_\_\_\_

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8. Does your company currently *reuse* any of the wastes generated at your site?

Yes                       No

If you answered "yes," please explain what and how: \_\_\_\_\_

---



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9. In the past two years, has your company tried any of the following techniques to reduce construction waste?

- a.  Use standard dimensions in the building design.
- b.  Use computer-assisted design techniques to minimize construction waste.
- c.  Make subcontractors handle own waste (no dumpster at site).
- d.  Include requirements for waste minimization, reuse, or recycling in bid documents and subcontracts.
- e.  Offer incentives to subcontractors/employees for waste minimization, reuse, or recycling.
- f.  Use alternate construction techniques (e.g., wall panelization, ICFs or SIPs, etc.)
- g.  Burn waste on site.
- h.  Grind waste on site.

10. Do any of your subcontractors typically haul their own waste?  Yes                       No

If "yes," please circle the appropriate subcontractor:

Cabinets	Electrician	Flooring/Carpet	Plumber	Roofing	Trim
HVAC	Framing	Drywall	Painter	Other	

11. If you do recycle or would in the future, what motivational reason(s) apply?

- a.  Immediate cost savings
- b.  Long-term cost savings (recycling may cost the same or a little more now, but I believe it will save me money in the near future)
- c.  Makes sense (if materials can be reprocessed, they shouldn't be buried in a landfill.)
- d.  Some homebuyers would prefer that construction wastes were recycled.
- e.  Personal/company responsibility to society/environment.
- f.  Other: \_\_\_\_\_

12. How much would your company be willing to pay to include recycling in your waste hauling contract?

\_\_\_\_\_ 5-10% over what we currently pay.

\_\_\_\_\_ no more than what we currently pay.

\_\_\_\_\_ up to 5% over what we currently pay

\_\_\_\_\_ recycling would have to cost less than what we currently pay

**Optional**

Company Name: \_\_\_\_\_

Your Name: \_\_\_\_\_

Thank you for taking the time share you knowledge and experience with us.

## Appendix F – Part B

### Results from Waste Minimization in Surveys

#### McLean and Will County

	McLean County					Will County	
Builder ID	B1	B2	B3	B4	B5	B6	B7
1. No. of Homes 2006	32	40	6	22	65	6	20
2. Average SF	1800-2400	2400-3000	3600-4200	2400-3000	1800-2400	3000-3600	2400-3000
3. Home Type (Prod/Spec/Custom)	30/40/30	0/50/50	0/25/75	0/50/50	33/33/34	0/33/66	0/20/80
4. Building Method (Primary)	Stick Framing w/ roof Trusses	Stick Framing w/ roof Trusses	Stick Framing w/ roof Trusses	Stick Framing w/ roof Trusses	Stick Frame Single-Family, Panelized Multi-family, w/ roof trusses	Stick Framing w/ roof Trusses	Stick Framing w/ roof Trusses
5. Waste Hauling Cost	\$1000-1500	\$1500-2000	\$200-500	\$1500-2000	\$500-1000	\$500-1000	\$1000-1500
6. SEE BELOW							
7. Currently Recycling Waste	No	No	Cardboard & wood	No	Concrete by foundation and site contractor; masonry cuts buried under porch	Sort wood & grind or reuse	No
8. Currently Reuse Waste Materials	No	Lumber	Return extra materials	No	No	No	No
9. Waste Reduction techniques	Standard Dimensions	Standard Dimension	- Standard Dimension - CAD design - Panelize	No reply	- Standard Dimension - CAD design - Panelize	- Standard Dimension - CAD design	Standard Dimension
10. Subs haul own waste? SEE NOTES							

6. Construction Waste Estimate Percent by Volume as Provided by Builders	McLean County					Will County	
	Builder ID	B1	B2	B3	B4	B5	B6
Long wood (lumber & molding >= 3 FT	10	40	10	20	35	1	60
Short wood (lumber & molding < 3 FT	10		25	15		60	
EWP (engineered wood products)	10		10	5		4	
Treated wood (decking, etc.)	5		10	3		1	
Masonry (brick, block, concrete, etc.)	10	10	2	4	5	5	5
Metals (copper, aluminum, steel, etc.)	5	5	1	1	2	1	0
Roofing (asphalt shingles, tar paper)	10		2	4	10	5	1
PVC (pipe, cutoffs, etc.)	5		2	1	2	3	1
Corrugated cardboard & boxes	10	20	0	20	5	10	10
Drywall scrap	24	20	20	20	35	6	20
Insulation waste (fiberglass, cellulose, etc.)	1	5	0	1	1	2	3
All other			16	6	5	2	
*Total	100%	100%	100%	100%	100%	100%	100%



Recycling Motivation & Acceptable Extra Cost:	McLean County					Will County		
	Builder ID	B1	B2	B3	B4	B5	B6	B7
11. If you do recycle or would in the future, what motivational reason(s) apply								
a. Immediate cost savings		X					X	X
b. Long-term cost savings	X	X						X
c. Makes sense	X		X			X	X	
d. Some homebuyers would prefer construction wastes were recycled	X				X			
e. Personal/company responsibility to society/environment	X		X	X	X	X	X	
f. Other:								
12. How much are you willing to pay to include recycling in your waste hauling contract?								
• 5-10% over current cost								
• up to 5% over current cost	X				X			
• No more than over current cost	X	X	X			X	X	X
• Recycling would have to cost less							X	

\*Note: Percentages as provided by builders

Comments and Notes:

1. B3: Custom Home builder who does not use roll-off dumpster boxes. Puts waste directly in dump truck during framing and drywall. Through the remainder of job, waste is stacked on site and trucked back to shop to sort and recycle. Short wood is used to provide customers with firewood. Has taken wood to Twin City Wood Recycling when quantities are sufficient. Uses CAD for framing minimization (reduce cuts). Reuses roof panel off-cuts (flip for opposite corner).
2. B2 & BC3 indicated that some sub trades hauled their own waste; typically mechanical, electrical and plumbing contractors.
3. B3 uses spray applied cellulose insulation. The contractor sweeps up and reuses all waste material.
4. B4 is participating in a cardboard recycling demonstration to reduce waste costs. They are a custom home builder and reported that they often haul two 25 CY dumpsters of cardboard from a single home because the cardboard boxes are not broken down. The builder estimates one 10 CY box would be adequate. The hauler has agreed to provide the builder a credit for any payment from the recycler.
5. Two other McLean County builders who did not participate in the full interview reported that they do not use roll-off dumpster boxes. All waste is put directly in a dump truck that is left on-site during the phases that generate high volumes of waste, primarily framing and drywall. One of these builders recycled cardboard. Trade contractors were required to break down boxes and stack in garage. Periodically, the builder would pick up and recycle at Midwest Fiber.

## Appendix F – Part C

### Results from Waste Minimization in Surveys

#### Cook County

Cook County	Builder B1	Builder B2	Builder B3	Builder B4	Builder B5
1. No. of Homes ( 2006)	13	0	6	4	12
2. Average SF	Over 2400	2400-3000	Over 2400	3000-3600	Over 2400
3. Home Type (Prod/Spec/Custom)	0/50/50	100/0/0	0/50/50	0/33/66	0/50/50
4. Building Method	Stick Framing/ Roof Truss	Panelized Wall Framing/ Roof Truss	Stick Framing/ Roof Truss	Stick Framing/ Roof Truss	Stick Framing/ Roof Truss
5. Waste Hauling Cost	\$1500-2000	Over \$2000	Over \$2000	Over \$2000	Over \$2000
6. See Below					
7. Currently Recycling waste	Separate dumpster for conc. & wood	No	wood	Sort wood and grind or reuse	No
8. Currently Re-using waste materials	No	No	Return extra materials	No	No
9. Waste Reduction techniques	Standardized dimensions, Computer Aided-Design, Alternative construction methods	Alternate. construction methods, i.e., panelized. walls)	Standardized dimensions, Computer Aided-Design, Alternative construction methods	Standardized dimensions, Computer Aided-Design,	n/a
10. Subs Haul Their Own Waste	No	No	No	No	No

6. Construction Waste Estimate Percent by Volume	Cook County				
	Builder ID	B1 <sup>1</sup>	B2	B3	B4
Long wood (lumber & molding over 3' long)	8	20	0	10	50
Short wood (lumber & molding under 3' long)	8	25	15	15	
EWP (engineered wood products)	0	5	2	5	
Treated wood (decking, etc.)	0	5	2	10	
Masonry (brick, block, concrete, etc.)	5	2	15	5	6
Metals (copper, aluminum, steel, etc.)	2	1	0	5	0
Roofing (asphalt shingles, tar paper)	5	1	2	5	3
PVC (pipe, cutoffs, etc.)	5	10	0	5	3
Corrugated cardboard (including boxes)	0	5	10	15	15
Drywall scrap	10	5	40	24	20
Insulation waste (fiberglass, cellulose, etc.)	0	1	0	1	3
All other	--	20	14	---	
<b>Totals</b>	<b>40</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Notes:

<sup>1</sup>B1 totals as provided by builder.

**11. If you do recycle or would in the future, what motivational reason(s) apply**

Builder ID	B1	B2	B3	B4	B5
Immediate cost savings		X	X		
Long-term cost savings		X	X	X	X
Makes sense	X	X	X		X
Some homebuyers would prefer that			X	X	X
Construction wastes were recycled.	X		X		X
Personal/company responsibility to					X
Society/environment.					
Other:					

12. How much are you willing to pay to include recycling in your waste hauling contract?

Builder ID	B1	B2	B3	B4	B5 <sup>1</sup>
5-10% over what we currently pay.					X
to 5% over what we currently pay					X
No more than what we currently pay.	X	X	X	X	X
recycling would have to cost less					

Notes:

<sup>1</sup>Builder B5 entered three responses. Upon follow-up, it was stated that additional cost in the 0-10% range would be acceptable for an effective recycling program.

## Appendix G

### Recycling of Gypsum Board in Illinois: Comments and Resources

As part of this study, the investigators sought to identify safe, acceptable, and cost-effective methods for recycling gypsum wallboard, which is a significant contributor to the C&D waste stream. New, clean, and dry gypsum wallboard scraps can be hauled to a processor in Indiana. However, no gypsum recycling options were found to exist in Illinois. The research team also investigated regulatory statutes in Illinois that prohibit the reuse/recycling of gypsum wallboard and no such prohibition statutes were located. Diverting a significant amount of scrap gypsum from the landfill in Illinois will require collaborative action by all stakeholders to find a workable solution. See additional details and discussion in the narrative of this report under barriers to recycling.

#### Possible Gypsum Recycling Options

1. A collaborative group of stakeholders should work with IEPA to identify safe and acceptable standardized practices (or a close as possible to standardized) under which a special use permit may be issued for utilizing gypsum as a soil amendment or composting agent. Having a model application available to builders and haulers would alleviate much uncertainty in the permitting process and reduce the time and cost involved in preparing an application. A brochure prepared by the University of Georgia and presented at the end of Appendix G titled, "Guidelines for On-Site Use of New Scrap Wallboard in Georgia Residential Construction" might provide a simple and useful starting point for discussion.
2. Based on a model special use permit application for gypsum as a soil amendment or composting agent, conduct several pilot tests in Illinois to monitor the recycling success and known concerns related to land applications of gypsum. Reports by Vermont Agency of Natural Resources Waste Management Division (2000) and Laquatra (2004) provide background to the scientific issues related to land applications of gypsum as well as offer potential solutions that could be piloted in Illinois.

#### *Issues Related to Decomposition of Gypsum*

(Excerpt from Vermont (2000) report cited above)

The moist anaerobic conditions of landfills allow bacteria to reduce the sulfate component of gypsum to hydrogen sulfide gas, carbon dioxide, and water. Hydrogen sulfide gas at low concentrations is noxious, and at higher concentrations can be dangerous. Regardless of H<sub>2</sub>S generation, the 1.7 million tons of gypsum drywall waste generated nationally every year consumes a significant amount of landfill volume.

Composting gypsum drywall presents two challenges. The first challenge is that the temperature, moisture, and oxygen within the compost mixture must be monitored to avoid anaerobic decomposition. The second challenge is that the final product should be monitored for the presence of paper pieces from the

wallboard due to consumer concerns. However, the Clean Washington Center has found that the pieces of paper are unnoticeable in compost mixtures containing less than 30% gypsum drywall. (Original Source: *Composting of Clean Gypsum Wallboard Scraps*, Clean Washington Center, 1999) (N.B: 20% as mentioned in the US composting council)

3. Incentives may be needed for gypsum recycling collection points in Illinois. Gypsum is a heavy material and long transportation distances would quickly negate any financial advantages to the construction industry as well as increase the carbon footprint related to hauling, resulting in a net environmental loss.

### Case Studies and Accepted Procedures in Other States

Although there are many studies and pilot projects related to recycling gypsum wallboard in other states, the following three are most closely related in proximity or purpose to the residential construction waste reduction initiative in Illinois.

**The Bruce Company, Middleton, WI** (Contact person: James Altwies, 608-836-7041, x. 344, jaltwies@bruceco.com). The Bruce Company is one of three recyclers in Dane County, WI, that will recycle clean scrap drywall. The charge in July 2008 was \$15/ton. ([http://www.co.dane.wi.us/pwht/recycle/public\\_locations.aspx?type=31](http://www.co.dane.wi.us/pwht/recycle/public_locations.aspx?type=31)). The Drywall Scrap Company in Madison, WI, also recycles clean dry scrap drywall at a fee of \$15/ton.

**Okaloosa County Florida** This project evaluated the effectiveness of composting gypsum drywall and yard waste in both windrows and vessels. The compost being generated was by local peanut farmers. (Reference: Cochran, K. and Townsend, T. (2004). Opportunities and Constraints for the Implementation of Drywall Recycling in Florida. *Proceedings of the Nineteenth International Conference on Solid Waste Technology and Management*, Philadelphia, PA, 600-609.)

Abstract: Construction and demolition (C&D) debris continues to be a waste stream of concern to many solid waste facility operators. As recycling rates for municipal solid waste (MSW) materials plateau, many solid waste managers wanting to increase recycling rates are beginning to view C&D debris as an untapped arena for recycling. Drywall is one of the larger components of C&D debris. Drywall has been targeted for recycling not only because of the volume that is disposed, but also in response to the odors produced at C&D debris landfills blamed on the decomposition of drywall. Factors that must be considered when developing a drywall recycling program include separating the drywall from the other components of C&D debris, assessing which markets are available, and how the recovered drywall must be processed. Collection and separation can be challenging; it can be performed at the point of generation or at the location where the mixed C&D debris is disposed or recycled. Markets include use in Portland cement manufacture, application as an agricultural amendment, and use in new drywall production. Processing techniques should adequately separate the gypsum from the paper, size reduce the gypsum, and address concerns over dust generation. Gypsum drywall recycling is currently being practiced in several areas of North America, but not to any large extent in Florida.

In recognition of the need to develop drywall recycling in the state, the Florida Department of Environmental Protection sponsored several research and demonstration projects to examine the feasibility of initiating drywall recycling programs in Florida. Results suggested that drywall recycling was technically feasible, and that sufficient market capacity exists in Florida as a whole. The markets, however, are not always located where the material is recovered. Several economic barriers need to be overcome: low landfill tipping fees for C&D debris, the low cost of virgin material, and high transportation costs. In certain regions of the state where large amounts of scrap drywall are generated and where markets are relatively close, these economic barriers can most likely be overcome.

**Cooperative Extension Service of The University of Georgia, College of Agricultural and Environmental Sciences (2002, October).** *Guidelines for On-Site Use of Scrap Wallboard in Georgia Residential Construction (Circular 857)*, written by Gaskin, J. Waltz, C., Garber, M., and Wade, G. This publication provides specific information regarding the land application of scrap gypsum in Georgia. Retrieved from <http://pubs.caes.uga.edu/caespubs/pubs/PDF/C857.pdf> and [http://www.gasustainability.org/files\\_pdf/wbguide\\_1.pdf](http://www.gasustainability.org/files_pdf/wbguide_1.pdf).

# Guidelines for On-Site Use of New Scrap Wallboard in Georgia Residential Construction

## Guidelines for Use

When you are planning to apply ground scrap wallboard on your building site, you should follow the steps listed below.

### 1. Determine the application rate.

First, have the soil tested. You should have a routine soil test performed on soil where ground scrap wallboard will be applied. Your County Extension Agent can supply you with bags for soil sample collection and detailed information on how to take a proper soil sample. A routine analysis will tell you the soil pH, and the amounts of phosphorus, calcium, potassium, magnesium, and zinc available for plants to use.

The application rate for the ground scrap wallboard is based on the amount of silt and clay that is typically present in the soil surface. Soils in the Piedmont, Mountains, and Ridge and Valley have more silt and clay than those in the Coastal Plain; consequently, higher rates of ground wallboard gypsum can be applied (**Table 1**). Research has shown that nutrient imbalances due to gypsum application do not generally develop in soils high in silt and clay. High rates of gypsum application can sometimes cause a problem with magnesium in sandy soils.

**Table 1.** Recommended rates of ground scrap wallboard application. *Note: These weights are for dry ground wallboard.*

Region	Recommended Rates
Piedmont, Mountains, and Ridge and Valley	250 lbs/1000 ft <sup>2</sup>
Coastal Plain	50 lbs/1000 ft <sup>2</sup>

### 2. Determine if there is enough land at the site to apply all the wallboard.

To *calculate* the actual amount of land needed.

To determine if you have enough land available to apply wallboard for each project, multiply the number of square feet in the house by 1.5 lbs. Divide this number by the appropriate number of pounds for your region in **Table 1** and multiply by 1000 (*See the worksheet on Page 2 for assistance*). This is the number of square feet you need to apply all your ground wallboard. Then, compare this number to the area you have for application (lawns, plant beds, and gardens). Be sure not to include the footprint of the house and impervious areas such as the driveway in your area for application.

#### Example:

A 2,500 square-foot house is being built on a three-quarter acre lot (32,670 ft<sup>2</sup>). Approximately 5,000 ft<sup>2</sup> of the lot will be occupied by the house and impervious areas. This means 27,670 ft<sup>2</sup> of land is available for ground scrap wallboard application. Using 1.5 lbs per square foot, construction will generate about 3,750 lbs of wallboard. Using a typical application rate (Table 1) of 250 lbs/ 1000 ft<sup>2</sup>, you will need 15,000 ft<sup>2</sup> of land for application. Because 27,670 ft<sup>2</sup> is available for application, all of the scrap wallboard generated can be land applied.

*Proceed with the following steps, if you have enough land to apply the wallboard from a specific site.*

### 3. Segregate scrap wallboard.

Place all the clean scrap wallboard in one location that will be accessible to the grinder. Moisture resistant or fire retardant wallboard should not be used because guidelines for land application of these products are not





## Worksheet to calculate the amount of land needed to apply ground wallboard from a building site.

### Step 1: Area needed to apply wallboard.

Formula: [Size of the house (ft<sup>2</sup>) x 1.5 lbs/ft<sup>2</sup>] ÷ [Recommended application rate (lbs/ft<sup>2</sup>) (Table 1)] \* 1000

Your Numbers: [ \_\_\_\_\_ ft<sup>2</sup> x 1.5 lbs/ft<sup>2</sup> ] ÷ [ \_\_\_\_\_ lbs/ft<sup>2</sup> ] \* 1000 = \_\_\_\_\_ ft<sup>2</sup>

### Step 2: Existing area to apply wallboard.

Formula: Size of the lot (ft<sup>2</sup>) - Size of impervious area (ft<sup>2</sup>) (Driveways, etc.)

Your Numbers: \_\_\_\_\_ ft<sup>2</sup> - \_\_\_\_\_ ft<sup>2</sup> = \_\_\_\_\_ ft<sup>2</sup>

**Step 3: Compare.** The number in Step 1 is the amount of area needed to apply ground wallboard from a site. If the number calculated in Step 1 is less than or equal to the number from Step 2, you have enough land to apply all the ground wallboard from your building site.

available at this time. Wallboard from demolition or that has been painted or wallpapered should not be used.

### 4. Grind the wallboard scraps.

Clean wallboard scraps should be ground with equipment that has a two-inch screen to make sure the paper is shredded and there are no large chunks of wallboard. Controlling dust during grinding is important. If ground wallboard will be stored before application, cover the pile with a tarp to keep the material dry and easy to handle.

### 5. Apply the ground wallboard.

Apply fertilizer and high magnesium dolomitic lime to the soil according to the recommendations from your soil test results. The ground wallboard should be evenly spread over the soil at or less than the recommended rate. Photographs at the right illustrate an even application at the recommended rate. The ground wallboard should be tilled or mixed into four to 12 inches of soil. **Beneficial reuse does not include digging holes and burying the wallboard.**

## Useful Facts

- ♦ A skid loader bucket will hold about 1 yd<sup>3</sup>.
- ♦ A front end loader will hold 2-3 yd<sup>3</sup>.
- ♦ Dry ground scrap wallboard weighs about 400 lbs/yd<sup>3</sup>.
- ♦ At a rate of 250 lbs/1000 ft<sup>2</sup>, one skid loader bucket would cover 1,600 ft<sup>2</sup> (40ft x 40ft). This is an area slightly smaller than a volleyball court.
- ♦ At a rate of 250 lbs/1000 ft<sup>2</sup>, about one-third of a skid loader bucket would cover the goal box on a soccer field.

## Application Rates



♦ 250 lbs/1000 ft<sup>2</sup>



♦ 50 lbs/1000 ft<sup>2</sup>

This document was supported by the University of Georgia, College of Agricultural and Environmental Sciences, Cooperative Extension Service, and the Engineering Outreach Service along with the Pollution Prevention Assistance Division. This publication was written by:

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Circular # 857

December 2002

The University of Georgia and Fort Valley State University, the U.S. Department of Agriculture and counties of the state cooperating. The Cooperative Extension Service offers educational programs and materials to all people without regard to race, color, national origin, age, sex or disability. An EQUAL OPPORTUNITY affirmative action organization committed to a diverse Work Force. Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, The University of Georgia and the U.S. Department of Agriculture cooperating. Dr. Gale A. Buchanan, Dean and Director.

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**Appendix H**  
**McLean County Waste Management Planning Documents**

# MCLEAN COUNTY WASTE MANAGEMENT PLAN

Project Name: Brady Homes Construction Waste Recycling Demonstration Project

Contractor: Brady Homes

Construction Waste Management Plan Manager (Contractor's Rep): Randy Timm and Jim Hayes

Project Location: Corner of Sheppard & Airport Roads, Normal, IL

Estimated Construction Dates: December 1, 2007 to April 30, 2008

**Project Scope** – The 4-unit townhouse in Vineyards subdivision, Normal, IL. Each townhome is approximately 1500 SF and priced at \$150,000. Ample site space to house 3 roll-off boxes. Framing panelized to minimize wood waste.

**Recycling Goal** - To recycle **50%** of waste generated on the site by weight if wood, cardboard, and gypsum can be recycled. (Minimum goal of **30%** if gypsum cannot be recycled.)

## Goals and Intent:

**Reduce:** The Project shall generate the least amount of waste and methods shall be used that minimize waste due to error, poor planning, breakage, mishandling, contamination, or similar factors. Promote the resourceful use of materials to the greatest extent possible.

**Reuse:** The Contractor and Subcontractors shall reuse materials to the greatest extent possible. Reuse includes the following:

1. Salvage reusable materials for resale or reuse on this Project, or for storage for use on future projects.
2. Return reusable items (e.g., pallets or unused products) to the material suppliers.

**Recycle:** As many of the waste materials not able to be eliminated in the first place or salvaged for reuse shall be recycled. Waste disposal in landfills shall be minimized to greatest extent possible.

## Analysis of Estimated Construction Waste to be Generated:

Projected waste materials

- Cardboard
- Gypsum board (**if possible**)
- Wood

## Recycling Service Providers and Targeted Materials (Service Provider Agreements in Place)

**Company #1** Contractor Disposal, Inc. (Waste Hauler)

**Company #2** Midwest Fiber Inc. (Cardboard recycler)

**Company #3** Twin City Wood Recycling, Inc.

## MATERIALS-HANDLING PROCEDURES

Contractors and Subcontractors will separate and handle materials as stated below.

**Cardboard:** Separate and flatten clean cardboard and boxboard and place in designated containers on the job site. Do not include waxed cardboard, tissue, paper plates or towels, pizza boxes or any item that is not paper. Separate plastic, Styrofoam and other items which may be stuck to the cardboard boxes. Staples may be left in cardboard. Cardboard that is over 50% covered in mud, paint, or other contaminants should be disposed of as trash. The cardboard will be sorted, sold, and made into new paper products.

**Wood:** No treated lumber (Green or Brown wood)

### Recycling Operations

<u>Action</u>	<u>Accountable</u>
Order dumpsters - oversee delivery	xxx xxxx, Brady Field Manager
Educate job site personnel on recycling requirements	xxx xxxx and xxx xxxx
Order signs for dumpsters and other recycling bins	Richard Boser, ISU
Schedule dumpster pickups/drop offs	xxx xxxx
Monitor dumpsters for contamination	xxx xxxx
Document recycling results	Richard Boser

## EDUCATIONAL AND MOTIVATIONAL PLAN

Check all items intended to be used

- Complete Construction Waste Management Plan
- Hold Orientation/Kick Off Meeting
- Update & Progress in Monthly Job-Site Meetings
- Post Targeted Materials (signage)
- Post goals/progress (signage)
- Require those who contaminate dumpsters to re-sort
- Provide stickers, t-shirts, hats or other incentives
- Public recognition of participating subs
- Take photos to document progress and share
- At site visits, discuss waste management with job-site personnel
- Conduct periodic presentations for job-site personnel on waste issues
- \_\_\_\_\_

## WASTE AUDITING PROCEDURES

Describe how the recycling program will be monitored so that recycling and trash containers are kept free of contamination. Include frequency of monitoring.

Dumpsters will be checked and photographed at least twice a week by ISU personnel. Contaminating materials will be documented and transferred to the "Trash Only" box if it is possible to easily and safely remove the materials. If the quantity or type of contaminant makes this impractical or unsafe, the monitoring personnel will contact \_\_\_\_\_ at xxx xxxx or xxx xxxx to determine a solution. \_\_\_\_\_ is on site almost daily and will also monitor the dumpsters and take the appropriate action as needed, including notification of \_\_\_\_\_ so that the contamination can be documented.

# SITE MONITORING CHECKLIST

Material being recycled: **Wood – Cardboard- Drywall (if legal)**

Project Name: **Brady Homes Construction Waste Recycling Demonstration Project**

Date/Time: \_\_\_\_\_

Monitor Name: \_\_\_\_\_

1. Are all dumpster signs in place?  Yes  No
  
2. Is access to the container adequate?  Yes  No
  
3. Check container
  - A. Material Level:  Empty  ½ or less  ½ or more  Full (needs emptying)
  - B. Contamination: (List common contaminants on a master form. Make copies from master form as needed.)
    - Food Waste
    - Materials not sorted
    - House Hold Garbage
    - Other:-----
  - C. Does this container need to be cleaned?  Yes  No
  - D. Comments: \_\_\_\_\_

# RECYCLING SUPERVISOR MONITORING CHECKLIST

*Instructions: Monthly, talk to all stakeholders about the progress/ barriers of the recycling project.*

## **A. Brady Homes:**

1. Are there any problems with the waste and recycling program?  Yes  No
2. Does material move from the work areas where it is generated to the dumpsters safely and efficiently?  Yes  No

Comment/Notes:

3. For the next month, what would you like to change?

## **B. Contractor Disposal**

1. Are there any problems with the waste and recycling programs?  Yes  No
2. Are there areas that the hauler would like to see improved?  Yes  No

Comment/Notes:

## **C. Subcontractors and/or others**

1. Are there any problems with the waste and recycling programs?  Yes  No
2. Are there areas they would like to see improved?  Yes  No

Comment/Notes



# Tracking Form for Materials Taken Off-Site

## Brady Homes Construction Waste Recycling Demonstration Project

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Company Name: \_\_\_\_\_

<b>Date</b>	<b>Material Taken Off Site</b>	<b>Weight (Ton)</b>	<b>Volume (CY)</b>	<b>Recycling/ Reuse/ Landfill</b>

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## Appendix I

### McLean County Demonstration Project Site Monitor Report - Examples

#### SITE MONITORING CHECKLIST

Material being recycled: **Wood**

Project Name: **Brady Homes Construction Waste Recycling Pilot Project**

Date/Time: January 15, 2008 @ 1:30P

Monitor Name: Rick Boser

1. Are all dumpster signs in place? X Yes  No
2. Is access to the container adequate? X Yes  No
3. Check container
  - A. Material Level:  Empty x  $\frac{1}{2}$  or less   $\frac{1}{2}$  or more  Full (needs emptying)
  - B. Contamination: (List common contaminants on a master form. Make copies from master form as needed.)
    - Food Waste in Wood Only box: one soda can.
    - Materials not sorted: dunnage from shaft wall delivery (3 pieces about 4' long) and waste tyvek.
    - House Hold Garbage: None
    - Other: None
  - C. Does this container need to be cleaned?  Yes x No
  - D. Comments:

I arrived when the shaft wall was being delivered. The driver was tossing the dunnage into the Wood Only box (may have not noticed or cared). When I asked him to please put the waste in the Trash Only he was very cooperative. I climbed into the box and removed 2 pieces of dunnage, one approximately 4' x 8' piece of scrape Tyvek, and one soda can. As I lifted them out of the Wood box, the driver put them into the Trash box.

Site progress: Roof trusses in place, about 60% of sheathing complete. Shaft wall being installed between units on second floor and roof.

Lesson Learned: Delivery personnel and other occasional site visitors need to be informed of recycling expectations.

## SITE MONITORING CHECKLIST

Material being recycled: **Wood**

Project Name: **Brady Homes Construction Waste Recycling Pilot Project**

Date/Time: January 28, 2008, 12:00PM

Monitor Name: Lucy Loftus

1. Are all dumpster signs in place? X Yes    No
  
2. Is access to the container adequate? X Yes    No
  
3. Check container
  - A. Material Level:    Empty    ½ or less    ½ or more    Full (needs emptying)
  
  - B. Contamination: (List common contaminants on a master form. Make copies from master form as needed.)
    - X Food Waste in Wood Only box: pizza slice box, candy wrappers, coffee and soda containers
    - Materials not sorted
    - X House Hold Garbage: Both Wood Only and Trash Only containers (see comments)
    - X Other: paper waste, empty concrete bag, glove
  
  - C. Does this container need to be cleaned?  Yes   X No
  
  - D. Comments
    - Household waste in Wood Only box: wood door and frame, wood chair, vinyl siding.
    - All contamination removed by monitor and placed in Trash Only container.
    - Household waste in Trash Only box included garbage bags, toys, metal shelves, and carpet underlayment.
    - New project sign was in place facing Airport Road.

## **Appendix J**

### **McLean County Demonstration Project Monthly Monitor Reports**

## RECYCLING SUPERVISOR MONTHLY MONITORING CHECKLIST

**Date:** March 4, 2008

**Purpose:** Discuss recycling project progress/ barriers with all stakeholders.

**Builder:** Brady Homes

1. Are there any problems with the waste and recycling program?  Yes  No

*Comment/Notes:* Program appears to be working well. Superintendent reminds/informs trade partners of the required recycling processes at each weekly meeting. There has been continual contamination in the boxes; however, amounts are minimal and the site monitor has been removing as needed.

2. Does material move from the work areas where it is generated to the dumpsters safely and efficiently?  Yes  No

*Comment/Notes:* The framing contractor reported that sorting the material for placement in designated dumpsters added an extra 10-15 minutes periodically – but not daily. Framers were asked where they wanted the wood only box placed for ease of depositing waste material.

3. For the next month, what would you like to change?

Moving to drywall stage within the next two weeks. Although gypsum recycling and/or diversion is not part of the pilot project, the team will make one more attempt to locate a local source to take/dispose of the drywall.

**Hauler: Contractor Disposal**

4. Are there any problems with the waste and recycling programs?  Yes  No

5. Are there areas that the hauler would like to see improved?  Yes  No

*Comment/Notes:* Even though the project is a four unit townhome, space is still limited for placing dumpsters.

**Subcontractors or others**

6. Are there any problems with the waste and recycling programs?  Yes  No

7. Are there areas they would like to see improved?  Yes  No

*Comment/Notes:* Have not yet talked directly with the subcontractors. Builder indicates that here have not been any complaints or suggestions for improvement. As indicated above, subcontractors have noted that it does take additional time to separate the waste streams.

## RECYCLING SUPERVISOR MONTHLY MONITORING CHECKLIST

**Date:** March 28, 2008 at demonstration event

**Purpose:** Discuss recycling project progress/ barriers with all stakeholders.

**Builder:** Brady Homes

1. Are there any problems with the waste and recycling program?  Yes  No

*Comment/Notes:* Overall, source separation is going well. Some continual contamination remains and is removed by monitor. Most workers appear cooperative. Recycling program reminders at weekly subtrade meetings. One box of cardboard contaminated when skid loader dumped a bucket of mud in the cardboard only box.

2. Does material move from the work areas where it is generated to the dumpsters safely and efficiently?  Yes  No

*Comment/Notes:* As noted in earlier report, source separation does add some additional time for framing personnel – estimated at 10-15 minutes periodically – but not daily. Vinyl siding contractor didn't report any problems as they carry waste around the building to the box anyway. Gypsum waste was consistently placed in trash.

3. For the next month, what would you like to change?

No source for drywall waste. All gypsum waste trashed and sent to landfill.

**Hauler:** Contractor Disposal

4. Are there any problems with the waste and recycling programs?  Yes  No

5. Are there areas that the hauler would like to see improved?  Yes  No

*Comment/Notes:* None

**Subcontractors or others**

6. Are there any problems with the waste and recycling programs?  Yes  No

7. Are there areas they would like to see improved?  Yes  No

*Comment/Notes:* ISU recycling team did not talk directly to trade contractors. Informal site meetings were positive and indicated awareness of recycling program.

## RECYCLING SUPERVISOR MONTHLY MONITORING CHECKLIST

**Date:** May, 9 2008

**Purpose:** Lessons learned at project end

**Builder:** Brady Homes

1. Are there any problems with the waste and recycling program?  Yes  No

*Comment/Notes:* Overall, waste recycling and source separation went as planned. Most subcontractors were cooperative and responsive. Percent diverted was lower than planned, 29% vs. 40%, which is somewhat surprising given that two boxes of wood were recycled (40 CY with an approximate weight of 6 tons). Previous project data for detached single family homes indicated that wood should comprise about 40% of the waste. The fact that the project utilized panelized walls likely reduced the volume of wood waste by about 10%.

In spite of overall cooperation at source separation, contamination was a constant concern. Vendors, such as the gypsum supplier, put dunnage in the cardboard only box on several occasions. Did not seem malicious, they were just not used to recycling job sites and/or didn't read the signs. And an almost full 20 CY cardboard only box was contaminated by a skid loader bucket (or two) full of mud, which likely decreased the diverted waste by approximately 1,200 lbs.

2. Does material move from the work areas where it is generated to the dumpsters safely and efficiently?  Yes  No

*Comment/Notes:* Boxes placed in consultation with subcontractors and superintendent. Framer estimated that waste separation add 10-15 minutes periodically – but not daily. Roll-off box placement and work flow appeared acceptable as gypsum and roofing waste was consistently placed correctly in the trash box. Similarly, cardboard from vinyl siding boxes was consistently placed in the cardboard only box.

3. For the next month, what would you like to change? n/a – project complete

**Hauler: Contractor Disposal**

4. Are there any problems with the waste and recycling programs?  Yes  No
5. Are there areas that the hauler would like to see improved?  Yes  No

*Comment/Notes:* No new problems to report. Using source-separated dumpsters likely increased the number of roll-off boxes used on the project, as compared to similar sized project.

**Subcontractors or Others** – (Based on conversations with site superintendent)

6. Are there any problems with the waste and recycling programs?  Yes  No
7. Are there areas they would like to see improved?  Yes  No



**Appendix K**  
**McLean County Demonstration Project Photo Boards**

# ISU - Brady Homes Construction Waste Recycling Pilot Project

January 18, 2008, 930 AM



Overview



Contamination

- Comments**
- New monitor trained
  - Wood Only sign was lying  $\leq$  20 feet from container, possibly windblown. Sign was replaced.
  - Contamination removed from Wood Only box and placed in Trash Only container.



Wood Only



Trash Only

# ISU - Brady Homes Construction Waste Recycling Pilot Project

January 24, 2008

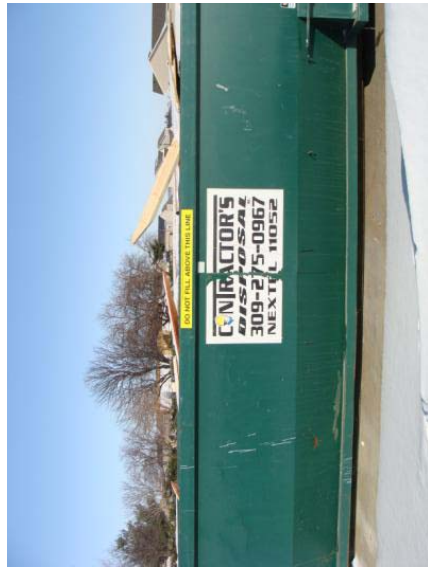


Overview



Contamination

- Comments**
- Most contamination found in two ends where signs are located.
  - Contamination removed and placed into Trash Only container by monitor.
  - Wood Only container is filled over yellow fill line. Combined with snow cover, this situation makes it difficult to ascertain whether all contamination has been removed.



Wood Only



Trash Only



# ISU - Brady Homes Construction Waste Recycling Pilot Project

February 4, 2008



Overview



Contamination

- Comments**
- Contamination was removed from Wood Only container and placed in Trash Only container by monitor.
  - Wet, heavy snow cover was considerable; monitor moved pieces around in order to search for potential contamination. Due to snow cover, complete contamination removal cannot be guaranteed.



Wood Only



Trash Only

# ISU - Brady Homes Construction Waste Recycling Pilot Project

February 11, 2008



Overview



Contamination

- Comments**
- Contamination removed from Cardboard Only and Wood Only containers and placed into Trash Only container by monitor.
  - Cardboard found in both Wood Only and Trash Only containers; it is possible that on-site workers are not clear about separation.



Wood Only



Cardboard Only



Trash Only



# ISU - Brady Homes Construction Waste Recycling Pilot Project

February 15, 2008



Overview



Contamination

**Comments**

- Contamination removed from Cardboard Only container and placed into Trash Only container by monitor

- Beer cans listed as household waste, due to unlikely situation that alcohol would be

- consumed on a work site.
- Beer cans were located under very large flat cardboard boxes that had been stacked by monitor during previous visit.



Wood Only



Cardboard Only



Trash Only

# ISU - Brady Homes Construction Waste Recycling Pilot Project

February 19, 2008



Overview



Wood Contamination



Cardboard Contamination

## Comments

- Broken glass inside Wood Only container from shattered picture frame. This may be a safety issue for collector.
- Much digging was required to get to picture frames. Last picture frame only noticed from glint off glass; more may be deeper in the pile.
- Contamination removed from both boxes and placed into correct containers by monitor.



Wood Only



Cardboard Only



Trash Only



# ISU - Brady Homes Construction Waste Recycling Pilot Project

March 6, 2008



Overview



Cardboard Contamination



Cardboard Contamination



Wood Contamination



Wood Only



Cardboard Only



Trash Only

## Comments

- Contamination removed by monitor and placed into correct containers.
- Given the variety of contamination, amount of mixing, and heavy mud caking, it is likely that the work site had been cleaned up using a skid loader (or like equipment) and contents dumped into Cardboard Only. Most of the very heavy material was located in the container directly behind the "Cardboard Only" sign.



# ISU - Brady Homes Construction Waste Recycling Pilot Project

March 14, 2008



Overview



Cardboard Contamination



Cardboard Only



Trash Only

## Comments

- Contamination removed and placed into Trash Only container by monitor
- Worker carrying large bag of waste (from masonry or brickwork crew) to the Cardboard Only Container was stopped by monitor and informed of recycling effort. Worker was directed to the Trash Only container. Worker was friendly, did not seem aware of recycling project. It is possible that the Recycling signage on the containers may not be noticeable (washed out) due to the number of other signs affixed to the containers.
- Wood no longer being recycled (this information passed on during site visit on March 20).

# ISU - Brady Homes Construction Waste Recycling Pilot Project

March 22, 2008



Overview

## Comments

- No contamination found



Cardboard Only



Trash Only

## Appendix L

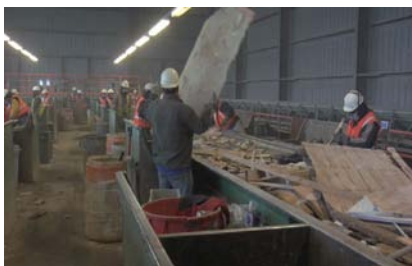
### Recycling Systems Processes

Our experienced driver will pick up the fully loaded dumpster from your jobsite and bringing it to our transfer facility where it is weighed in by our Scale Master.



The load is dumped in the designated area in the transfer station where it is "graded". That information is then input into our database.

Material is transferred to an excavator with a grapple bucket onto an Action vibratory screen.



Laborers sort material as it comes across the conveyor. Each laborer is designated a specific material that they pick from the line. This laborer shown is pulling wood boards and dropping them in the designated shoot.

Sorted Materials Include:  
INERT: Clean Heavies  
METAL: All Types Ferrous & Non-ferrous  
WOOD: Lumber, trim, and sheet  
OCC: Old Cardboard, Office paper, etc.  
PLASTICS: Buckets, Crates, etc.



Bulk wood separation: Uses include alternative power plant fuel and mulch.

Sorted recyclables are consolidated in large trailer loads for the most efficient and least carbon impact mode of trucking transportation available in our industry.



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## Appendix M

### Cook County Waste Management Documents

Michael Yannell  
4895 N. Ravenswood  
Chicago, Illinois

October 29<sup>th</sup>, 2007

LEED-H Action Plan

Re: Waste Management Program

Michael,

In regards to our waste management plan, [REDACTED] will provide a refuse dumpster onsite from Recycling Systems at the 4895 N. Ravenswood site. The dumpster will be on site from the commencement of the construction period, November 12, 2007 thru the completion (approximately one year). All refuse coming from this site will be recycled through this yard.

GGC Inc, as the general contractor, will make every effort to meet the LEED-H requirements to manage waste, specifically meeting a goal of 88% recyclable diversion rate, a weekly recycling report rate, and limiting the framing waste factor. All subcontractors working at this site will be educated as to the sensitivity regarding excessive waster and refuse coming from this construction site.

All parties will be constantly reminded that material take-offs and material ordering need to be as tight as possible in an effort to reduce unnecessary waste. Also, all subcontractors will be encouraged to recycle any and all extra materials that do end up being used at this jobsite.

Thank you,



Jeffrey Berry  
[REDACTED]

[REDACTED]  
[REDACTED]



Thank you for calling on [REDACTED], Inc. to quote on construction waste recovery services for your project. We are proud to participate and partner with your team to complete your next new Project.

[REDACTED], Inc. is the growing extension of a family owned trucking firm that has been serving GC's in the Chicago Land area for over 25 years. Since its inception in 2000, RSI has operated three IEPA certified Construction and Demolition debris processing and transfer facilities. Certification is achieved by passing an initial site inspection, gaining the issuance of a site ID number and periodic inspections and monitoring by the IEPA. One of the requirements of the IEPA is that 75% of the debris which is processed at the facility is diverted from landfills. We have successfully met this requirement for the last five years.

We are currently operating the largest and only "state-of-the-art" construction waste recovery facility inside the city limits of Chicago, permitted by the City of Chicago and certified by the IEPA.

City of Chicago Department of Environment, Permit # [REDACTED] IEPA Site # [REDACTED]

All of the waste materials from your project will be processed at this facility and with your help we expect to achieve at least the 75% diversion from landfill level required to achieve two LEED MR credits. We have successfully completed 8 LEED projects (all have achieved 2 MR credit points) and we are currently working with GC's on 12 new USGBC - LEED certification projects.

Examples of the types of materials we can recover are:

Soil, Landscape Waste	Wood, including non-haz painted, treated and coated wood	
Masonry and CMU	Wood Trim	Metals (Any Type)
Asphalt	Wood Sheet Materials	Drywall (Clean trims, source-separated)
Concrete and bricks	OCC (Old Cardboard)	Packing & Shipping
Electrical Conduit, Piping	Railroad Ties	Office Paper
Carpet and Ceiling Tiles (Source-separated, shipping to manufacturer at customer's expense)		

We grade and weigh each load from your project and provide a monthly cumulative report on your progress toward the two LEED certification points available. Additionally we are available to consult with your staff on your construction waste management plan. I am attaching a sample of a LEED report which we produce for our customers seeking the U.S. Green Building Council's Leadership in Energy & Environmental Design certification credits for Construction Waste Management.

We will be pleased to have the opportunity to serve your projects, your company and our environment in the future. If I can be of assistance, please call me at [REDACTED].

Sincerely,



[REDACTED]

**Appendix N**  
**Case Study Fact Sheets for Demonstration Projects**



# ISTC *Illinois Sustainable Technology Center*

Illinois Sustainable  
Technology Center  
University of Illinois

Formerly Waste Management and Research Center (WMRC)

## Construction and Demolition Waste Reduction

### Summary

#### Project:

Multifamily townhome project in Normal, IL.

#### Work Site:

New mixed density residential community.

#### Construction:

Panelized walls, roof trusses, and shaft wall between units.

#### Cost Savings:

Cost neutral. Project goal was to not exceed typical waste hauling fees. May have saved \$325 for one less dumpster than originally estimated.

#### Total Waste Reduction 27%

6.62 tons of wood and cardboard were recycled. 17.82 tons were hauled to landfill.

#### Completion:

May 2008

This case study is one in a series developed by the Illinois Sustainable Technology Center at the University of Illinois to highlight techniques for saving money and protecting the environment through reuse and recycling of construction and demolition debris.

### Project Description: Four-Unit Townhome Building, Normal, IL

The McLean County pilot project was a four-unit townhome of approximately 6,000 square feet (1,500 square feet per unit) in Normal, IL undertaken in conjunction with Brady Homes. The project began in mid-November 2007 and finished at the end

May 2008. The project generated 24.44 tons of

waste that was hauled off the site in 10 loads. The waste equaled 8.15 pounds per square foot. Two 20 CY boxes of wood (6 tons) and one 20 CY box of cardboard (0.62 tons) were recycled. The wall sections were panelized, which resulted in reduced wood waste. Recycled material resulted in 27% of the project waste being diverted from the landfill. Project signage was sponsored by a grant from State Farm Insurance. Dumpster signage was ordered from WasteCap Wisconsin.



Project Sign Sponsored By State Farm



Cardboard Recycling Bin

### Spotlight: Source Separation

Roll-off boxes (dumpster) were not placed on site until the framing stage in early January. Prior to this time, the foundation and site contractors recycled all concrete overage and removed their own waste materials, which were minimal. When the framing began, two 20 cubic yard (CY) boxes were placed on site: one for **wood waste only** and one for non-recyclable waste. In February,



## Challenges

Illegal dumping occurred on several occasions and contamination had to be removed from the recycle boxes.

Creating a culture of recycling takes time. Don't expect total compliance from the start of the project.

Space for source separation would be very difficult on a typical single-family home site.

coinciding with the application of vinyl siding that was delivered to the site in cardboard cartons, a 20 CY roll-off box for “**cardboard only**” was also placed on-site. Trade contractors were consulted as to the preferred location of the wood, cardboard, and waste boxes. In spite of overall cooperation at source separation from trade partners, contamination was a constant concern. Vendors, such as the gypsum supplier, put dunnage in the “cardboard only” box on several occasions. This lack of compliance did not seem malicious; rather delivery personnel and trade contractors were just not used to working on residential projects with recycling requirements. The boxes were monitored and photographed by ISTC, formerly WMRC, grant personnel at least twice a week.

## Keys to Success: Source Separation

- Discuss waste handling requirements with crew and subcontractors before beginning a project and re-emphasize their importance at weekly meetings as work progresses.
- Seek trade contractor input in the location of waste and recycling boxes. As the space allows, waste and recycling bins were placed close to each other and as close to the work as possible.
- Clearly designate and monitor the recycling bins to prevent contamination.
- Post lists of what is and is not recyclable on the recycling boxes.
- Post recycling requirements at various locations on the site.
- Boxes were hauled only when full.



**Wood Only Recycling Bin**

## Project Team

**Building Owner and Builder:** Brady Homes, Bloomington, IL. (309) 663-5301.

**Hauling Contractor:** Contractors Disposal, Bloomington, IL. (309) 451-3867.

### Recycling Services:

Midwest Fiber, Bloomington, IL (309) 452-0064

Twin City Wood Recycling, Bloomington, IL. (309) 827-9663

**Research Team:** Illinois State University, Department of Technology, Normal, IL 61790-5100; Contact: Richard Boser, Principal Investigator, (309) 438-3661.



**Finished Townhomes**

*This research was funded by Grant No. HWR07209 awarded to Illinois State University from the Illinois Sustainable Technology Center, a division of the Institute of Natural Resource Sustainability at the University of Illinois at Urbana-Champaign.*



# ISTC *Illinois Sustainable Technology Center*

Illinois Sustainable  
Technology Center  
University of Illinois

Formerly Waste Management and Research Center (WMRC)

## Residential Construction Waste Recycling Demonstration Project in Cook County, IL

### Summary

**Cost Savings:** \$736

**Project:** Residential two-story LEED-H home (2,675 sq. ft.)

### Waste Reduction:

- 87.64 % at substantial completion.
- 34.10 tons of inert, wood, metal, and cardboard reused or recycled.
- 4.82 tons hauled to landfill.

**Work Site:** Urban

**Completion:**  
March 2009

### Construction and Demolition Waste Reduction

This case study is one in a series developed by Illinois Sustainable Technology Center at the University of Illinois to highlight techniques for saving money and protecting the environment through reuse and recycling of construction and demolition debris.

### Project Description: Yannell Residence, Chicago, IL

Goldberg General Contracting was the lead contractor for the two-story 2,675 square foot home that was built to LEED-H Platinum requirements. The home incorporated a variety of site-related green products including 100% pervious paving, two green roofs, solar panels, and a zero-turf landscape design. Goldberg General Contracting recycled or reused 34.10 tons of the 38.92 tons of mixed



**Yannell House - Cook County**

construction and demolition waste generated for a waste reduction of 87.64%. Only 4.82 tons of waste material was hauled for landfill --the equivalent of one of the 12 roll-off boxes hauled from the site. Reuse and recycling volumes included the demolition of an existing two-story home on the site that dated from 1908.

### Spotlight: Advantages of Commingling Construction Waste

Due to the site restriction, it was not possible to have more than one roll-off box on site. As a result, the builder contracted with a recycling facility for hauling and recycling of commingled waste, which, with the exception of food waste, could all be placed in a single roll-off box. The commingled construction waste was hauled to the recycling facility for material sorting and recycling. The major advantages to commingling construction waste are that trade contractors do not need to alter their job-site practices, which in turn eliminates the need for (a) recycling signage and associated costs, (b) training trade contractors and delivery personnel as to site recycling practices, and (c) monitoring the roll-off box for content contamination.

### Cost Savings Accrued to Through Recycling

Material	Tons	Recycling Cost/ton	Avoided Disposal Cost*/ton	Savings
Inert	4.26	\$10 - \$14	\$18 - \$50	\$133
Metal	0.94	(\$50 - \$250)	\$ 0 - \$50	\$165
Wood	24.79	\$18 - \$ 35	\$25 - \$50	\$273
O.C.C.	4.12	\$10 - (\$40)	\$ 0 - \$50	\$165
<b>Total Saving</b>				<b>\$736</b>

\*Costs that would have been paid if material were landfilled. Savings calculated on the average disposal cost for material based on local rates in 2008. Savings accrued to the Recycling Service and not the builder.

### Keys to Success for Commingled Construction Waste

As opposed to source separation of construction waste, contracting with a recycling service provider to haul commingled waste off-site for sorting is relatively problem-free. Still there are a number of steps the builder can take to assure success.

- In the planning phase, inform all trade partners of the recycling goals and procedures, and their responsibilities in making recycling and waste reduction successful.
- Recycling procedures should be reiterate periodically as work progresses.
- Food waste cannot be commingled with construction waste. Place a garbage can on-site specifically marked for food waste.
- Place the roll-off box as conveniently as possible to work, but out of the traffic pattern.
- If not already required by the jurisdiction, consider tarping the roll-off box at the end of the work day to minimize illegal dumping of household trash.
- Contract with haulers for larger hauls of full containers “on-demand” rather than regularly scheduled pickups when containers might not be full.

### Project Team

**Architect:** Farr Associates, 53 W. Jackson Blvd., Suite 650, Chicago, IL 60604; Contact: April Hughes, Project Manager, (312) 408-1661

**General contractor:** Goldberg General Contracting; 3510 N. Elston Ave. Chicago, IL 60618, contact: Jeff Berry, Vice President, (773) 279-9600

**Recycler:** Recycling Systems Inc, 3152 S California Ave, Chicago, IL 60608, contact: Cal King, Manager, (773) 579-1999

**Research Team:** Illinois State University, Department of Technology, Normal, IL 61790-5100; Contact: Richard Boser, Principal Investigator, (309) 438-3661.

*This research was funded by Grant No. HWR07209 awarded to Illinois State University from the Illinois Sustainable Technology Center, a division of the Institute of Natural Resource Sustainability at the University of Illinois at Urbana-Champaign.*

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## Appendix O

### Project Dissemination and Media Materials

1. *A diffusion of innovation perspective for construction waste management* Abstract of Presentation at the Associated Schools of Construction Regional Conference, Downers Grove, IL. October 20, 2006.
2. *Waste minimization in residential construction: a diffusion of innovation approach.* National Association of Industrial Technology 2007 Annual Conference. Panama City, FL. October 23, 2007.
3. *Less waste heading to landfill from pilot construction project.* Pantagraph, Bloomington, IL. Friday, March 28, 2008 8:38 PM CDT. Newspaper coverage of dissemination event for McLean County demonstration project.
4. *Research project results on overcoming barriers to P2 and recycling for construction waste.* Solid Waste Association of North America. Bloomington, IL. May 13, 2008.
5. *Results of a Demonstration Project in Residential Construction Waste Minimization.* National Association of Industrial Technology 2008 Annual Conference Nashville, TN November 18-22, 2008.

**Abstract of Presentation at the Associated Schools of Construction  
Regional Conference  
October 20, 2006**

**A DIFFUSION OF INNOVATION PERSPECTIVE FOR CONSTRUCTION WASTE  
MANAGEMENT**

<b>Mohamed El-Gafy, Ph.D. , M.A.I</b> <i>Email: <a href="mailto:mgafy@ilstu.edu">mgafy@ilstu.edu</a></i> <i>Department of Technology</i> <i>Illinois State University</i> <i>Campus Box 5100,</i> <i>Normal, IL 61790</i>	<b>Richard Boser, Ph.D. , CPC</b> <i>Email: <a href="mailto:raboser@ilstu.edu">raboser@ilstu.edu</a></i> <i>Department of Technology</i> <i>Illinois State University</i> <i>Campus Box 5100,</i> <i>Normal, IL 61790</i>
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**Abstracts:** Waste generated in construction and demolition sites are disposed away in landfill sites, increasing the burden on landfill loading and operation. Waste management is getting more importance in construction industry and a warning signal has been released because of the environmental problems. Reduction, recycling and waste reuse are considered as the only methods to recover waste; however, implementation still has room for improvement. Based on the diffusion of innovation theory, this papers examines the diffusion of the construction waste management concept and innovations within the construction industry and explores factors that drive or impede the diffusion process.

**Keywords:** Construction, Waste Management, Diffusion of Innovation, Drivers, Barriers

# Waste Minimization in Residential Construction: A Diffusion of Innovation Approach

Richard Boser  
 Illinois State University  
 &  
 Mohamed El-Gafy  
 Michigan State University



NAIT 2007



NAIT 2007 - Minimization of Residential Construction Waste

1

## Presentation Outline

- Construction Waste Status
- Drivers of Waste Minimization
- Diffusion of Innovation
- ADOP<sup>2</sup>T
- Preliminary Results & Barriers
- Lessons Learned

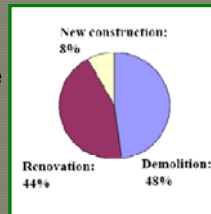


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## Overall Construction Waste

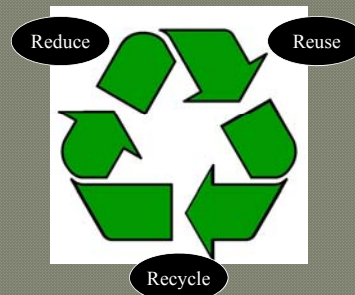
- 136 million tons/year of construction waste (EPA)
- 24% municipal solid waste from construction
- Nearly 3-5 pounds of construction waste per person per day



NAIT 2007 - Minimization of Residential Construction Waste

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## Ways to Minimize Waste



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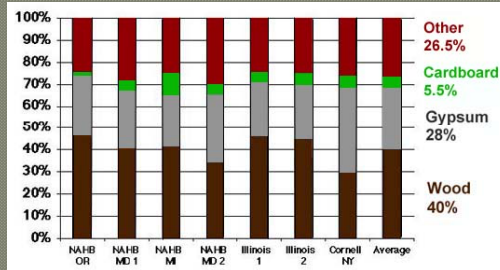
## Residential Waste



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## Types of Waste by Weight



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## Waste Audit Data

Table 1: National Waste Audit Summaries

	NAHB Oregon 3,000 sf	NAHB Maryland 2,200 sf	NAHB Michigan 2,600 sf	NAHB Maryland 2,450 sf	Illinois* 2,060 sf	Illinois 9,000 sf 6 unit Apt.	Cornell New York 1,894 sf	Averages
Total Pounds of Waste	13,684 lbs.	10,210 lbs.	12,182 lbs.	9,378 lbs.	14,860 lbs.	33,500 lbs.	4,656 lbs.	
Waste per square foot of floor area	4.56 lbs.	4.64 lbs.	4.68 lbs.	3.82 lbs.	7.2 lbs.	3.73 lbs.	2.46 lbs.	4.44 lbs
Cardboard Waste %/ Total Wght.	2%	4%	10.3%	5.1%	5%	6%	5.9%	5.4%
Gypsum Waste %/ Total Wght.	27.8%	27%	24.1%	31.4%	25%	25%	38.4%	29%
Wood Waste %/ Total Wght.	46.2%	41.1%	40.9%	33.9%	46.0%	44%	30.1%	39.7%
Sub-Total Cardboard, Wood & Gypsum Waste %/ Total Wght.	76%	72.3%	75.3%	70.4%	76%	75%	74.4%	74.1%

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## Drivers of Waste Minimization

- Increasing landfill tipping fees
- Increasing energy costs
- U.S. Green Building Council (USGBC) "LEED for Homes"
- C&D regulations
  - Massachusetts Waste Ban 2005
  - Chicago C&D Ordinance

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## Why Change?

1. Save money, improve bottom line
2. Generate new customers
3. Reduce regulatory problems



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## Diffusion of Innovation

### Stages of adoption



Awareness



Interest



Evaluation



Trial



Adoption

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## ADOP2T - Accelerated Diffusion of Pollution Prevention Technology

- Identify Construction Waste Management (CWM) opportunities
- Identify construction leaders
- Recruit partner contractors
- Establish demonstration sites
- Promote demo sites & available technology
- Adopt Best Management Practices (BMPs) at multiple sites or facilities

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## Market Based Solutions

### Wood

- Grind on-site for landscape mulch
- Truck to Wood Recycling Center



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## Market Based Solutions



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## Market Based Solution

### Gypsum Board (if allowed):

- Land application
- Livestock bedding
- Athletic field marker
- Others



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## Market Based Solution

### Cardboard

- Easiest to recycle
- Recyclers pay for cardboard



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## Barriers & Lessons Learned

Residential CWM significantly different from waste management on commercial projects

- Limited space available
- Limited budget
- Relatively small quantities

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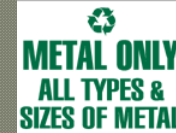
## Barriers & Lessons Learned

- Stakeholders have different goals
  - Builders vs. Haulers vs. Recycling Centers
- Differing views of recycling realities
  - Waste separation? Benefits?
- Need existing recycling infrastructure
- Diverting heavy materials (gypsum) is necessary for success

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## QUESTIONS?



Source of Signage: WasteCap Wisconsin

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## Less waste heading to landfill from pilot construction project

Friday, March 28, 2008 8:38 PM CDT

By Mary Ann Ford  
[mford@pantagraph.com](mailto:mford@pantagraph.com)

NORMAL — Three large construction trash bins sit outside a four-unit complex under construction at the Vineyards subdivision in northeast Normal.

Big signs specify the purpose of each: wood, cardboard, trash. Only items in the trash bin will end up at a landfill. The rest will be recycled.

It's all part of a pilot construction waste recycling project organizers hope will soon be used at all residential construction sites.



Jordan Raffety, left, Kevin Dailey, center, Diane Forman, right, and Tory Moews, all with Chillis Drywall pitch pieces of drywall into a trash only dumpster Friday (March 28, 2008) at the Vineyards subdivision in Normal. (Pantagraph/CARLOS T. MIRANDA)

“Our industry likes to be self-regulated,” said Ed Brady, president of Brady Homes, and the developer of the Vineyards. “Hopefully this (pilot project) will prove to our industry that you can do this.”

Brady Homes partnered with Illinois State University’s Department of Technology, Contractors Disposal and the Waste Management and Research Center for the project. It was funded through a \$70,000 grant from the Illinois Department of Natural Resources Waste Management and Research Center.

“After we compile the data, hopefully we can make more builders aware that this is possible,” said Ken Barnes, environmental engineer for DNR’s pollution prevention program. “We can say someone tried it and whether the cost zeroed out or was in the hole.”

The cost of recycling is a key, Brady said, because it could affect the cost of the house.

“It has to be affordable,” he said.

Barnes said that’s one of the problems in the state now. “Our tipping fees are so low in Illinois, it’s cheaper to take things to the landfill.”

Rick Boser, chairman of ISU’s technology department and organizer of the two-year project, said another problem facing the construction industry is finding places to recycle construction waste.

Boser couldn’t find anyplace that would recycle drywall — among the heaviest of materials a

construction site has to recycle.

Barnes said some materials are banned from recycling because they contain hazardous materials. But, he said, only 1 percent of the material actually has hazardous wastes like asbestos or lead-based paint.

For instance, he said, concrete used in a parking lot can't be recycled because the yellow paint used to delineate spaces is hazardous. But, he argues, not all the concrete has yellow paint on it.

Barnes said some small steps are being made to change the hard-and-fast Illinois Environmental Protection Agency rules. Old roofing shingles, which often contain asbestos, will be ground up and used on the shoulders of tollway roads as part of one pilot project, while another project is grinding drywall for use in landscape material.

Boser said when the Brady Homes site project is completed in May, the results of the recycling project will be compiled and given to Barnes. Barnes said he will pass them onto the U.S. Environmental Protection Agency with hopes that it could change policies at the state level.

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## Research Project Results on Overcoming Barriers to P2 and Recycling for Construction Waste



**SWANA**  
SOLID WASTE ASSOCIATION  
of North America

**Richard Boser**  
Illinois State University

Solid Waste Association  
C & D Waste Workshop  
May 13, 2008



### Presentation Outline

- Residential construction waste
- Commercial vs. residential construction
- Barriers to P2 and recycling
- Pilot project in Normal, IL
  - Overview & results

### Residential Waste



**2000-3000 SF House  
3 – 5 Tons**

Wood

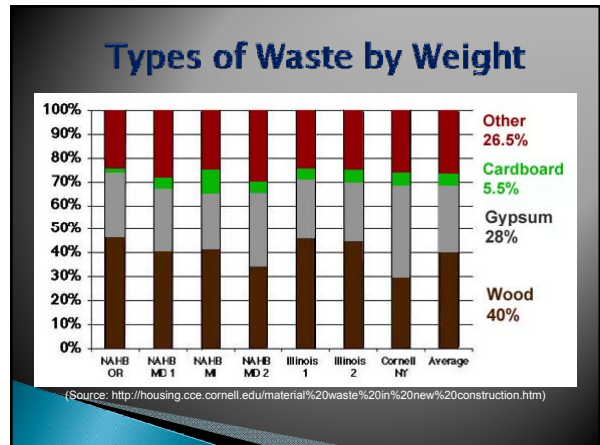
Shingles

Cardboard

Metal

Drywall

Block/ Brick



### Commercial vs. Residential

<p><b>Commercial</b></p> <ul style="list-style-type: none"> <li>➤ Larger waste volumes</li> <li>➤ Fenced site</li> <li>➤ Multiple roll-offs</li> <li>➤ Defined location</li> <li>➤ Written contracts</li> <li>➤ Better control of work force</li> </ul>	<p><b>Residential</b></p> <ul style="list-style-type: none"> <li>➤ Small waste volumes</li> <li>➤ Open sites</li> <li>➤ Limited roll-off space</li> <li>➤ Scattered sites</li> <li>➤ Minimal contracts</li> <li>➤ Minimum control of work force</li> </ul>
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### Barriers to Construction Waste Recycling

- Management Issues**
  - Senior management commitment
  - Site management - Implementation of plan?
- Cost**
  - Start up costs are perceived as too expensive
- Space**
  - Size of sites - space at a premium
- Sub Contractors**
  - Difficult to motivate sub-contractors
  - Training - What exactly is waste?
- Spoilage and Contamination**
  - Contamination of separated waste



### Still More Barriers



- Recycling infrastructure
- Stakeholders goals differ
  - Builders vs. Haulers vs. Recycling Centers
- Views of recycling realities & waste separation
  - Management vs. Supervisors vs. Trades
- Diverting heavy materials (gypsum) is necessary for economic success

### Why Change Practices?

1. Save money – improve bottom line
2. Generate new customers
3. Reduce regulatory problems



### ADOP2T Approach

- Identify construction leaders
- Recruit partner contractors
- Establish demonstration sites
- Promote demo sites & available technology
- Identify construction waste management opportunities
- Adopt BEST MANAGEMENT PRACTICES (BMPs) at multiple sites or facilities

### Goal = Market Solutions

#### Wood

- Grind on-site for mulch
- Truck to recycling center



### Market Solutions

#### Cardboard

- Easiest to recycle
- Recyclers pay for cardboard



### Market Solutions

#### Gypsum Board (if allowed):

- Land application – soil amendment
- Livestock bedding
- Athletic field marking
- New gypsum board





### Potential Management Solutions

- ▶ Training for site supervisors and trade contractors
- ▶ Contractor selection based on sustainability policy
- ▶ Incentives and/or penalties for improper separation or contamination
- ▶ Bid lists only open to waste minimization practitioners

Source: [www.envirowise.gov.uk](http://www.envirowise.gov.uk) (2004)

### Planning Solutions

- ▶ Panelized walls
- ▶ Prefab components
- ▶ Modular sizes



### Pilot Project in Normal, IL

- November 2007 – May 2008
- Funded by WMRC
- No financial sponsorship of builder or hauler
- 4 Unit Townhomes @ 1,500 SF/unit
- ADOP2T approach = ACCELERATED DIFFUSION OF POLLUTION PREVENTION TECHNOLOGY



SIWANA C&D Workshop – May 13, 2008

### ISU –Brady Homes Construction Waste Recycling Pilot Project January 4, 2008



### ISU –Brady Homes Construction Waste Recycling Pilot Project January 12, 2008



### ISU –Brady Homes Construction Waste Recycling Pilot Project March 27, 2008





### Pilot Project Results – Numbers

- ▶ 9 – 20 CY roll-off boxes to date
- ▶ Landfill – 6 boxes – 16.07 Tons (32,140 LBS)
- ▶ Recycled
  - 2 – 20 CY boxes of wood (12,000 LBS)
  - 1 – 20 CY of cardboard (1,240 LBS)
  - 1 box of cardboard was contaminated @ 90% full
- ▶ Waste generated = 45,380 LBS (7.56 LBS/SF)
- ▶ Waste diverted = 13,240 LBS (29%)
- ▶ Project goal for diversion = 40% minimum

### Pilot Project – Lessons Learned

- ▶ Recycling required vigilant monitoring
  - Contamination removed on almost every visit
- ▶ Material separation a marginal success
- ▶ Difficult to expand program without recyclers for gypsum (and maybe asphalt shingles)
- ▶ Costs more to recycle wood than haul to landfill
- ▶ Recycling transfer center would make the process easier for all!

## Successes?

- ▶ 2 builders are recycling cardboard
- ▶ 1 scattered site builder planning to implement recycling during 2008
- ▶ 1 builder/developer investigating recycling requirements for new subdivision



## Questions?



**Richard Boser**  
**Illinois State University**  
Solid Waste Association  
C & D Waste Workshop  
May 13, 2008





## **Construction Division Presentation Proposal**

**NAIT Annual Conference Nashville, TN  
November 18-22, 2008**

Title: Results of a Demonstration Project in Residential Construction Waste Minimization

Presenters:	Dr. Richard Boser Department of Technology Illinois State University Normal, IL 61790-5100 Tel: 309.438.2609 Fax: 309.438.8626 email: raboser@ilstu.edu	Dr. Mohamed El-Gafy School of Planning, Design and Construction Michigan State University East Lansing, MI 48824 Tel: (517) 432-6512 Fax: (517) 432-6512 email: elgafy@msu.edu
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### Statement of Need

New home construction is one of the largest sources of landfill-destined waste. The construction of a new single-family home in the United States typically results in waste production of three to five pounds per square foot. With the average new home size now exceeding 2200 square feet, between three to five tons of waste is generated per home. Builders' decision to send all waste to landfill as opposed to recycle or reuse is driven by economics and the complexities of diverting the waste stream materials. The presentation will illustrate the results of a funded demonstration project into means and methods of waste minimization on a townhouse venture in the Midwest. The results and lessons learned from the research should be beneficial to construction faculty and home builders interested in sustainable development or coping with local recycling mandates.

### Overview

Results will be presented from a funded demonstration project showcasing waste management practices by a Midwest home builder. The purpose of the project was to (a) analyze the effectiveness of recommended Best Management Practices to minimize, substitute, reuse or recycle waste materials and accelerating the adoption these practices, (b) determine the volume of waste diverted from the landfills, and (c) ascertain the level of monitoring and/or supervision required to minimize the contamination of recyclable waste (wood and cardboard).

### Major Points

1. Overview of Best Management Practices related to waste minimization in residential construction.
2. Results of a funded demonstration project including management and monitoring procedures, and data on waste diverted from the landfill.
3. Discussion of a model waste management plan for residential construction.

### Summary

Results will be presented from a funded demonstration project showcasing waste management practices on a Midwest townhome development. Discussion will include Best Management Practices, project results, and example documentation for a waste management plan.


## Results of a Demonstration Project in Residential Construction Waste Minimization

Richard Boser, Illinois State University  
Mohamed El-Gafy, Michigan State University

NAIT Annual Conference, Nashville, TN  
November 20, 2008

### Presentation Outline


- Project background
- Barriers to P2 and recycling
- Overcoming barriers
- Best management practices
- Pilot project in Normal, IL



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### Residential Construction Waste

- C&D debris estimated 20–33% of MSW
- New residential 10% of C&D or 2% of all MSW
- Historically: 2–4 tons of waste per new home or about 4.5 psf (4 studies 1993 – 2004)
- Hauler data from 12 new homes in McLean County (2008)
  - Size 2182 – 4256 SF (avg. 2835)
  - Avg – 11.94 tons per home
  - Avg – 8.3 psf
  - Normal pilot: 8.15 psf



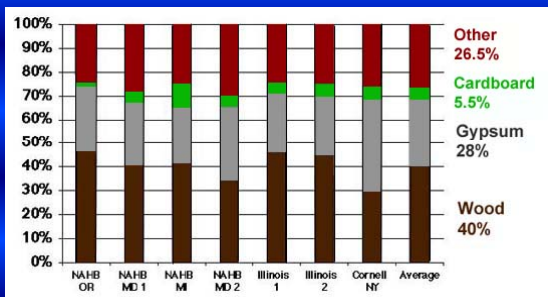
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### Priority Waste to Recycle



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### Types of Waste by Weight



Waste Type	Percentage
Wood	40%
Gypsum	28%
Cardboard	5.5%
Other	26.5%

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### Barriers to Recycling Residential Construction Waste

#### Management

- Commitment to waste plan
- Increased cost
- Site supervision
- Loyalty to hauler

#### Job Site

- Change job-site practices
- Training – What exactly is waste?
- Contamination of separated waste
- Illegal dumping



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### Fundamental Barriers



- Recycling infrastructure
- Stakeholders goals differ
- Builders vs. Haulers
- Views of recycling realities & waste separation
- Management vs. Supervisors vs. Trades
- Diverting heavy materials (gypsum) necessary for economic success
- Space – small lot with limited space for dumpsters

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### Local Best Management Practices

- Identify recycling infrastructure
  - Normal – Wood and cardboard
  - Chicago – Everything except gypsum
- Management practices
  - Waste management plan
  - Commitment
  - Maximize P2 with fabricated assemblies
- Job-site practices
  - Training for source separation
  - Supervision

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### Overcoming Barriers: P2 Planning

- Panelized walls
- Prefab components
- Modular sizes
- Accurate material take-off & ordering



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### Management Solutions

- Contractor selection based on sustainability policy
- Bid lists only open to waste minimization practitioners
- Incentives and/or penalties for improper separation or contamination

Source: [www.envirowise.gov.uk](http://www.envirowise.gov.uk) (2004)



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### Goal = Market Driven Solutions

#### Wood

- Grind on-site
- Truck to recycling center



#### Cardboard

- Easiest to recycle
- Recyclers pay for cardboard



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### Market Solutions – Gypsum Board

- New gypsum board
- Portland cement Ingredient
- Livestock bedding

#### (if allowed):

- Land application
- Soil amendment
- Compost



NAT Annual Conference 2008

### Pilot Project in Normal, IL

- November 2007 – May 2008
- Funded by ISTC
- No financial sponsorship of builder or hauler
- 4 Unit Townhomes @ 1,500 SF/unit




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### ISU –Brady Homes Construction Waste Recycling Pilot Project January 4, 2008






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### ISU –Brady Homes Construction Waste Recycling Pilot Project January 12, 2008







Roll Off Boxes On-Site Contamination

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### ISU –Brady Homes Construction Waste Recycling Pilot Project March 27, 2008





Cardboard Only Contamination

NAT Annual Conference 2008 16

### ISU –Brady Homes Construction Waste Recycling Pilot Project April 9, 2008






Cardboard Only Trash Only Contamination

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### ISU -Brady Homes Construction Waste Recycling Pilot Project April 24, 2008





80 LB bag of cement

Cardboard Only Trash Only Contamination

NAT Annual Conference 2008 18



### ISU –Brady Homes Construction Waste Recycling Pilot Project May 1, 2008

**Cardboard**      **Trash Only**      **Contamination**

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### Last Photo of Last Trash Dumpster Still On Site May 9, 2008

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### Normal Pilot Project Results

- ▶ 10 – 20 CY roll-off boxes – Total 24.44 tons
- ▶ Landfill – 7 boxes – 17.82 Tons (35,640 LBS)
- ▶ Recycled 6.62 tons
  - 2 @ 20 CY boxes of wood (12,000 LBS)
  - 1 @ 20 CY of cardboard (1,240 LBS)
  - 1 box of cardboard was contaminated @ 90% full
- ▶ Waste generated = 48,880 LBS (8.15 psf)
- ▶ Waste diverted = 13,240 LBS (27%)
- ▶ Project goal for diversion = 40% minimum
- ▶ Cost neutral for builder – maybe one less box

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### Normal Pilot – Lessons Learned

- ▶ Material source separation a marginal success
  - Recycling required vigilant monitoring
  - Contamination removed on almost every visit
- ▶ Difficult to expand program without recyclers for gypsum
- ▶ Costs more to recycle wood than haul to landfill (\$5.00/CY or \$33 ton)
- ▶ Recycling transfer center would make the process more doable for all!

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### Conclusions

1. Cardboard, wood, and gypsum board comprise 75% of the waste.
2. Recycling of gypsum board in Illinois remains an obstacle.
3. Source separation requires:
  - a. Substantial procedural changes for all stakeholders.
  - b. Vigilant waste monitoring.
4. Illegal dumping is problematic for source separation.
5. Builders will recycle if it doesn't cost anymore.
6. Recycling may provide some "green" marketing value.

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### Questions?

#### Results of a Demonstration Project in Residential Construction Waste Minimization

Richard Boser, Illinois State University  
Mohamed El-Gafy, Michigan State University

NAIT Annual Conference, Nashville, TN  
November 20, 2008

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